A PRACTICE BASED LEARNING ENVIRONMENT FOR ENGINEERING STUDENTS

Acquiring Competences for Working in Advanced Manufacturing Engineering

Dissertation submitted for the Award of Doctor of Philosophy

Felix Schmid

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ABSTRACT

In this thesis the author describes the design and operation of a learning environment aimed at imparting technical, technological and managerial knowledge, developing understanding of the underlying issues and enhancing team work skills for an advanced technology future. He offers an analysis of learning, education and training and compares group work with individual tasks, presents a major case study and illustrates the features which distinguish the approach from role play, simulation and experiential learning.

When staff at Brunel University were faced with the problem of teaching Computer Integrated Manufacturing (CIM) to engineering students on thin sandwich type undergraduate degree programmes the writer suggested the use of an approach he would later describe as 'practice based learning' or 'real life simulation'. The fourth year course in CIM is designed as a double option for the complementary undergraduate courses, Brunel Manufacturing Engineering (BME) and Special Engineering Programmes (SEP). It is an extension of the Manufacturing Design and Practice course in years one to three of the BME course and of the Design strand on SEP, both of which restrict students' work to the use of individual machine tools and stand alone computing facilities.

A wide range of teaching methods is used on the CIM course, including lectures by course staff, presentations by experts and, as the major element, a large group project involving all the students on the course, organised in a management matrix, coordinated by the students and supported by the staff acting as experts. The students also undertake assignment work alongside the technical tasks, to focus their thinking and to improve written communication skills. While the course described cannot replace more than a small proportion of the more conventional lecture, laboratory and tutorial teaching on an engineering programme, it provides a setting where students can experiment and learn about their own strengths and weaknesses in a realistic situation and in the context of teamwork. It also offers a space where they can make quite serious mistakes without direct consequences to their careers.

The experience of seven years leads the author to believe that advanced manufacturing technologies and the associated management techniques should be taught in a project based environment with clear and real targets and realistic constraints, offering students challenges to which they can only rise through close and creative team work. The management of task execution must be left largely in the students' own hands. A high level of "consultant" type support is essential though, allied to an assessment scheme which promises and ensures fair treatment of the individual.

The different parts of the thesis will be relevant to readers depending on their interest and background. Chapter 1 sets the scene and outlines the approach taken. Following this broad outline of the scope of the dissertation the author places Computer Integrated Manufacturing in a wider context in chapter 2, by providing an introduction to the underlying issues of computer integration and human factors. He puts forward a case for new approaches to the education and training of engineers and managers who will be working in Computer Integrated Manufacturing and Advanced Manufacturing Environments in general. Chapter 3 is devoted to the management of projects while chapter 4 is used to question the role of the engineer. Chapters 5 and 6 provide an introduction to theories of knowledge, teaching, learning and motivation. Chapters 7 and 8 are devoted to particular aspects of engineering education, while chapter 9 reviews the approach used at Brunel University. The topical issues of competence and its relevance to engineering education is discussed in chapter 10, leading into chapters 11 and 12 which deal with aspects of the CIM course. Chapters 13 and 14 are devoted to case-studies and particular tools. The key question of assessment of a practice oriented and team based course is addressed in chapter 15, followed by an evaluation of the CIM process and its application to engineering education of a full time nature which is included in chapters 17 and 18.

I. Dedication

The former general manager of a factory in Royton (near Oldham, Lancashire), in charge of producing electronic control systems for machine tools, defined manufacturing as the industrial equivalent of cooking: the transformation of a number of ingredients into a palatable whole, on a limited budget - and even though chaos may reign in the 'kitchen'.

The manufacturing engineer is the person who must ensure that we do not end up with a great sticky mess at the end of the process. In Advanced Manufacturing Environments the potential for chaos and mess is perhaps greater than elsewhere. So, let us educate young manufacturing engineers to work with people and machines and to create great things. In this thesis the author tries to present his own approach and to illustrate its advantages and drawbacks in the light of seven years of experimentation and experience.

The people who have supported the author in this venture all happen to be rather fine cooks, both male and female. Is this a coincidence? Probably not, teaching is, after all, a transformation process not too dissimilar from cooking or manufacturing. What was special about the general manager from Oldham? She belonged to an earlier generation of engineers but was happy to discuss the present and the future. Thus this thesis is dedicated to good cooks and engineers, men and women, in alphabetical order!

II. Acknowledgments

It is a most enjoyable duty to thank the many people who helped in the preparation of this thesis. The author would like to record first and foremost his great appreciation of Chris Ellis' support as his loyal friend, supervisor and sports partner and of Ray Wild who turned him into a manufacturing and human factors person and who (almost) always supported his whims. A great many thanks are due to my mother Emilie and my brother Thomas who never failed to listen to my stories and to believe in me! June Phillips' help was invaluable in keeping CIM on course and without Bob Grieve and Peter Broomhead the CIM approach would not have existed. Without Jean-Noël Ézingeard it would not have continued to exist. Their efforts were greatly appreciated.

I am grateful to Regula Schmid, Dietrich Brandt and Tania Hancke for devoting a great deal of time and effort to discussions and to keeping me motivated. My colleagues at the Swiss Federal Office of Transport allowed me to re-acquire the habit of thinking and to have evenings and weekends off - precious writing time. Tony Medland deserves thanks for suggesting the theme for the dissertation. The author was greatly assisted by Robert Bear and Roger Hull in taming software and hardware and in the preparation of diagrams while Lynne Duriç was always ready to help out when organisational problems seemed to become insurmountable!

Thanks are due to Sylvianne Wignacourt and Jean Claude Gentina of École Centrale Lille, for the sabbatical within a sabbatical, and to GEC for the financial support through the funding of The General Electric Company Prize 1993: Manufacturing Systems Engineering, one of the Partnership Awards for excellence in teaching innovation. This had been awarded to the Department of Manufacturing and Engineering Systems at Brunel University for the development of the CIM course.

The students involved in Brunel's CIM course were, of course, the stars of the show and their hard work, dedication and motivation and friendship must be acknowledged here. Without them there could be no thesis.

III. Table of Contents

IV. List of Figures

V. List of Tables

VI. List of Text Boxes

1 Introduction and Scope of the Thesis

The author of this dissertation presents a teaching approach which was developed to assist in satisfying a perceived need for mature engineers who would be ready to take on responsibilities in advanced manufacturing environments. The approach developed out of a particular constellation of staff and students against a backdrop of well established 'thin sandwich'[1)] type degree programmes. In this first chapter of the thesis the author sets out to circumscribe the scope of the report and to provide a rationale for his enterprise. Of necessity, the reader is referred to later sections for a more detailed analysis of particular issues.

1.1 Hypothesis

In the past, and in many instances even today, company structures, both in manufacturing and service industries, were designed to resemble pyramids where physical production was carried out at the lowest and broadest level and where decisions were taken at the highest level [Semler, 1993]. Raw data generated at the lowest level would be successively transformed and refined into more and more meaningful (that is, less detailed) 'management' information, for example, into five or six figures (turnover per employee, stock turns per annum, etc.) for a profit centre which would then be submitted each month to a chief executive. He or she would take all business decisions concerning the subsidiaries on the basis of these figures, often described as performance indicators.

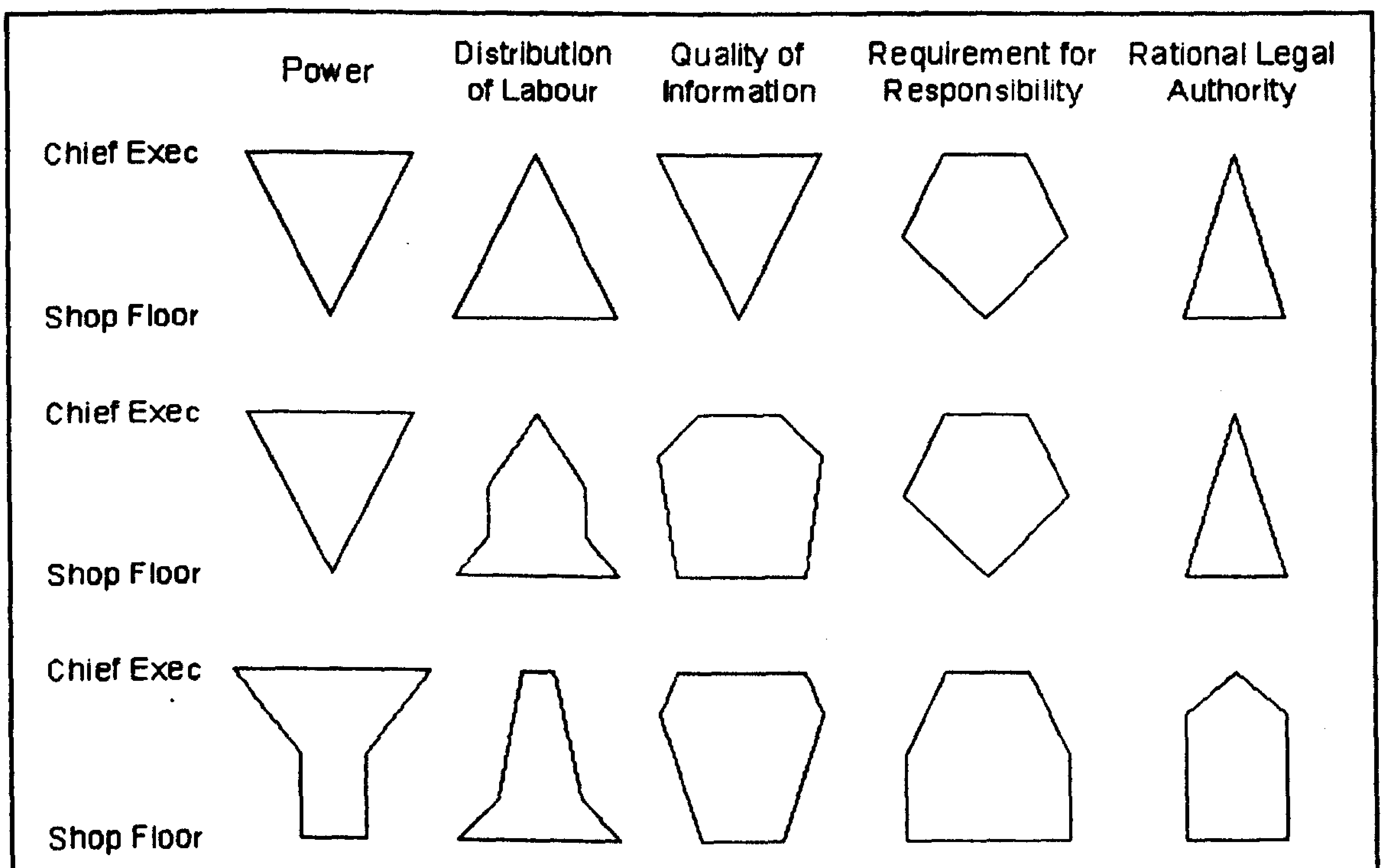

Figure 1 Characteristics of Company Structures

The first row of symbols of Figure 1 shows the patterns which resulted from such hierarchical structures for a number of key dimensions related to successful company management. Both the pyramid illustrating the quality of information provided to different levels of the organisation and that showing the distribution of hierarchical power were widest at the top

1) an arrangement whereby academic study at a university type institution alternates with practical training in an industrial company. A thin sandwich is characterised by several periods of industry based work while a thick sandwich features, in general, a single industrial period of one year's duration.

and, in a truly taylorised factory (see below), of width zero at the base. The requirement for responsibility, defined as the obligation to act in a manner which is in the best interest of the company, the individual and society, has always tended to be greatest for middle managers [Semler, 1993]. The distribution of authority, defined as power legitimated by the consent of those subject to it, may appear at odds with that of hierarchical power but it shows that within the lower levels of an organisation leadership had to be linked to professional respect.

The above patterns were typical of the large organisations which started to appear once machines, power operated at low cost, had become available and once an industrial labour force had been established, prepared to execute instructions unquestioningly. As markets and technologies changed though, the above patterns (perhaps with the exception of the distribution of labour) failed to follow substantially the transformation which was occurring in the area of information (refer to the second row of Figure 1): computers and software tools (e.g., databases and spreadsheets) made high quality information available for anybody who was able to apply the technology.

As a result of these developments, knowledge is no longer the prerogative of the holders of power. Decision taking should no longer be vested in the top echelons of a company. In order to adapt the patterns shown in rows 1 and 2 of Figure 1 to the new needs, organisational structures must be changed [after Schmid, 1986]. The third row of Figure 1 shows a set of patterns which is more in line with the possibilities offered by modern (information) technology.

Company structures and employees' capabilities are no longer in line with the needs of companies. Change is necessary to adapt to new environments.

1.2 Analysis and Orientation

The move towards computer integration of manufacturing operations is only one of many changes which have affected the production of artefacts since the early times of human evolution. However, its impact is viewed as much more significant than even the industrial revolution. This adoption of CIM as the key to a successful future for manufacturing in highly developed (and thus high cost) countries is not necessarily based on facts or experience but may well be a preconception, an expression of hope or simply the quest for an old fashioned panacea.

Bowers [1984] believes that educators are responsible to some extent for improving people's communicative competence, thus obviating the need for some of the technological non-solutions [Gill, 1994]. More likely than not, the move towards the use of CIM might well be simply a reflection of the helplessness and unease with which modern societies react to the ever increasing rate of innovation[2)] and the associated growth in knowledge and information[3)]. The race for CIM may also reflect the ever shortening 'window of time' allowed to deliberate the 'right' decision.

High level managers believed for a long time that CIM would return to them the control over their fiefdoms which they were sure to have held before the 'information revolution'. Computers, 'objective machines' were expected to replace value dominated people. This has been

2) from Bowers [1984] philosophical viewpoint: "The continual onslaught of technological innovation in both consumer and work sectors represents further examples of fundamental issues being settled in a one-sided manner rather than through the negotiation of meanings involving participants who represent diverse points of view ... the development of a theory of education that leads to the fostering of the student's ability to participate in the negotiation process is one of the primary aims ..."

3) according to Cooley [1993], the latter has grown by a factor of 10^7 in one century but this statement must be seen in the context of the comments in section 5.1.

shown to be a deficient analysis of the situation, resulting from a lack of understanding of the development of industry:

> **The belief in the saviour role of CIM is founded on a misinterpretation of the capabilities of machines and the failings of people and thus on a lack of education of the decision makers.**

It may be possible to remedy this unsatisfactory situation gradually through the transformation and enhancement of engineers' and managers' formation[4], a view which motivated the work reported in this thesis. A number of authors have commented on the need for educational approaches which will produce a new kind of engineer and manager, able to analyse problems and decide solutions, lead and motivate people [Brummett, 1985; Clark, 1985(1); Cooley, 1993; Corfield, 1983; Finniston, 1985 & 1989; Sparkes, 1993; Ursprung, 1991]. The Council for Industry and Higher Education (CIHE) affirmed 1993 in a response to the Engineering Professors' Council that Industry requires people who are trained for life long learning (note the use of train and learn). Industry sources have also stated that engineers' formation must be both theory and practice based.

However, many institutions still accept the classical lecture as the key medium to transmit scientific knowledge and to teach engineering skills. The department of Engineering and Management Systems (E&MS) was created under the leadership of Professor Ray Wild to provide high quality engineering education following the 'thin sandwich' route. It later became the department of Manufacturing and Engineering Systems (M&ES) as a result of the amalgamation with the Production Technology Department.

1.3 Synthesis and Praxis

The writer reports on an analysis of the new needs influencing the formation of manufacturing engineers, placing these in the context of education in general and that of engineering education in particular. The thesis is not intended to be solely a theoretical study of concepts and educational methods but a report on a practical experiment involving, in all, 254 students belonging to seven student generations.

The author has developed a method for the integration of the teaching of a wide range of engineering knowledge and skills into a single advanced course dealing with aspects of Computer Integrated Manufacture or CIM. In this course CIM is the "vehicle" which allows this teaching process to take place without recourse to conventional play-acting and simulation, both of which do not reflect real life in engineering environments. The methods used include practical work, group and team development activities, lectures and management tasks of the nature found in progressive industrial organisations.

The link between real life engineering practice and the students' experience on the course is established in two ways: the teams work in a laboratory which is equipped to industrial standards both in terms of the computing equipment with its associated software and the machine tools and automated inspection equipment. This technological foundation gives the students a feel for 'real' industrial systems type problems but there is also a second, even more significant element of 'praxis': the time limit for the achievement of a pre-defined set of objectives is given by an 'open day' for visitors from sponsoring industry. This provides an immoveable deadline which is tougher than most deadlines existing in industry.

The application of the concepts in the context of Brunel University's Manufacturing and General Engineering degree programmes has yielded a substantial amount of experience and

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4) in the sense of the French word 'formation' which encompasses both education and training.

statistical material which supports the claims for validity of some of the educational methods adopted for this CIM course. The course is being run as a final year option satisfying about 20 % of the study requirement. The success of the approach is tested by a variety of approaches including a comparison of the assessment results with those of the students' performance on the programmes as a whole. Its suitability for engineering students following a 'standard', full time, three or four year degree programme is discussed briefly. The approach is also reviewed in the light of a survey of former students of the course who are now working in industry.

The writer's interest in people issues has resulted in a course which is intended to increase students' interest in human factors and appropriate work design. On the course, this aspect does not appear under a heading of its own, with the exception of a lecture on the principles of human centred design and another lecture on applications software designed for better person-machine interaction. The human centred approach is encouraged by lecturers and should develop naturally.

1.4 Evaluation and Review

During the literature review undertaken for this dissertation the writer came across the text 'Teaching Achievement Motivation' by Alschuler et al., discussed in section 6.3. Although this text dates back to 1970 it proved to be of significance: the authors set out to change the teaching environment in ordinary schools to develop students' need for high achievement. Alschuler was a strong proponent of McClelland's ideas and theories. As will be explained in chapter 17, in which the CIM course is evaluated, it is not their aim to enhance the performance of just a few top students but to motivate all the students to become high achievers within their natural limitations.

On reading this text the writer of the present thesis realised that he had been involved in growing an environment similar to that conceptualised by Alschuler et al and used successfully in the USA in the 1970s. While Alschuler et al place their concept in the context of the Psychological Education movement, the writer started from his own needs for a teaching situation which would allow him, as well as his students, to explore an emerging range of technologies and their management in an environment rich in scope for achievement, possibilities for affiliation and the sensitive handling of power issues[5)].

1.5 Limitations

The reader will fail to find a self contained formal literature review in this dissertation. The writer felt that the subject was too wide and ramified to lend itself to such a treatment. However, in each chapter there are many linked references to texts which deal with particular aspects in great detail. Where appropriate these have been reviewed in a critical manner. The text is intended to serve as a guide to running a project of this nature, suggesting useful tools and offering advice on particular approaches whose effectiveness is described in some of the case studies of chapter 13.

As described in chapter 9, the CIM course forms an integrated part of the engineering programmes taught in the Department of Manufacturing and Engineering Systems at Brunel University. It has been developed and shaped in line with the Department's philosophies on engineering education.

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5) all these terms are explained more fully in the chapter on evaluation (17) of the CIM course.

2 Manufacturing and Computer Integration in Manufacturing: Industrial Background, Human Centred Approaches and Educational Needs

2.1 Introduction

'Productivity and the Future of Work', a symposium on the changing face of industry, provided a panoramic view of all the issues, both well known and emerging, which affected people's relationship with their work in the mid-1980s [Munich, 14-16 October 1986]. The symposium very much reflected the interests and views at a time when there seemed to be no limits to the capabilities of technology.

The participants in the symposium, both from industry and academe, addressed the questions of whether there was and whether there should be a future for human work. The starting point for this discussion was the original 'job of work' carried out by an individual in a fixed time frame and following more or less detailed instructions according to the worker's abilities and qualifications. At the time, in 1986, it appeared that both in manufacturing and service industries most of these 'simple' jobs would disappear, people being replaced by advanced technology solutions which would offer better all round performance.

Much of what the contributors predicted has happened: computers and computer controlled machines and systems have replaced people in many roles at most levels of a wide range of organisations. However, only some of the jobs have simply disappeared, many have been changed to adapt to the new environment. This process has resulted in the development of the theory and practice of Human Centred Computer Integration starting in the early 1980s. Depending on the sector of human activity concerned, approaches have ranged from ergonomics to complete socio-technical systems solutions, some of which are very significant. The following discussion will be confined to the problems arising in manufacturing industry although most approaches can be transferred to other areas of human activity.

2.2 Industrial Revolution and the Use of Computers

2.2.1 Background

The changes brought about by the emergence of powerful computer technologies are often compared to the changes which resulted from the industrial revolution: many authors have described this transition from craft work to factory production, the move from individual skill to the division of labour with its emphasis on dexterity and speed rather than an awareness of the process as a whole. Bowers [1984]: "The sense of time and human activities became intertwined in such a way that change came to be seen as the expression of progress. The rapid development of technological innovation during the latter part of the eighteenth century and the industrial revolution of the nineteenth century strengthened the idea of unlimited abundance." Similar feelings were at the heart of the economic optimism of the 1960s, e.g., the 'Deutsches Wirtschaftswunder'.

The 'first' Industrial Revolution progressed in two stages, a beginning in the last quarter of the 18th century with the mechanisation of the cotton and woollen industries of Lancashire, Central Scotland and West Yorkshire and the continuation with the mechanisation of the iron and steel industries from ca 1830 [Crystal, 1990]. The transformation meant that instead of small quantities of expensive goods, industry could supply standard products of repeatable quality, with vastly improved productivity [Rembold, 1993]. While these changes led to entirely different working conditions in the production of artefacts, the creation of markets for mass produced goods also meant that industry had to recruit workers whose background lacked any prior involvement with manufacturing.

This development was very welcome in a period where: "The continual rise in the population made it indeed impossible to provide work for everyone in the English village. Agriculture had absorbed all the hands it required. Great national industries, like cloth, were migrating back out of the country districts to which they had moved in the later Middle Ages..." [P.486, Trevelyan 1942]. However, at the same time a great many craft based businesses, such as hand loom weavers, disappeared, with their skilled workers ending in abject poverty.

But "An important group had even accepted, indeed welcomed, industry, science and progress (though not capitalism). These were the 'artisans' or 'mechanics', the men of skill, expertise, independence and education, who saw no great distinction between themselves and those of similar social standing who chose to become entrepreneurs..." [P.90, Hobsbawm 1968]. Although this group of 'engineers' was not very large it created its own myths, including that of the superiority of machines over people. Very often the men became successful businessmen (gender specific labels intended) in their own right.

In general, however, the situation in the cities was barely better than that in the countryside. Between 1800 and 1840 entrepreneurs had to employ workers on subsistence wages because much of the value added was not reinvested in the system by their backers. The new markets were only being established and workers were not yet perceived as potential customers. Naturally, people changed a great deal as a result of all the pressures and experiences, as observed by Robert Owen: "The general diffusion of manufactures throughout a country generates a new character in its inhabitants; ... it will produce the most lamentable and permanent evils ... The manufacturing system has already so far extended its influence over the British Empire as to effect an essential change in the general character of the mass of the people." [Owen 1815]

Not only Owen but also a number of other 'modern' industrialists, such as Titus Salt in Bradford, developed models of industrial communities which showed the way towards creating a better environment for workers.

"Some time in the 1840s all this began to change, and to change rapidly,... the readiness to accept legal supervision of working conditions - as by the admirable Factory Inspectors - increased... British industrialists now felt rich and confident enough to be able to afford such changes." [pp.123-4, Hobsbawm 1968] For a while Britain had become, to use a cliche, the 'workshop of the world'. New hierarchies and new opportunities for training, education and personal development for the masses emerged. Working hours became regulated and salaries rose to levels where most people could live without constant fear of the future - apart from the Great Depression of the 1930s.

2.2.2 Recent Developments in Industrial Production

The industrial society whose social patterns persisted in Europe until the mid 1980s, the type of society to which many 'threshold countries' aspire, thus existed only since the late 19th century. Major cracks in the system appeared around the time of the first oil crisis of 1973/74. However, the seeds for a new revolution had been sown before and during World War II: the new levels of mass production necessary for the war machine led to the development of mechanically programmable machine tools. After the war, rising standards of living meant that the increased productivity could be absorbed without leading to overcapacity [Finniston, 1989]. The advent of NC (numerically controlled) machines, invented at the MIT in 1947 initially had an impact only on the feasibility of more and more complex components. Once the new manufacturing processes and computer controlled systems of the late 1970s and early 1980s had arrived, productivity and quality of output could grow at rates not even imagined before, thus providing the foundation on which 'megacorporations' could be built with scant regard to overhead costs but still employing relatively large work-forces.

By the mid 1980s, though, the process of industrial concentration and the move to ever larger and more complex manufacturing facilities ceased as low cost producers emerged in the 'third world'. Changing markets threatened industrial stability and with it the social fabric. European industry had to change. As stated earlier, this process was and is compared to the industrial revolution of the 19th century:

- the introduction of new technologies with advanced capabilities[6],
- the modern understanding of systems behaviour can be compared to the early understanding of the behaviour of rigid bodies,
- the replacement of human organising power by that of computers (similar to the substitution of water and steam power for human muscle),
- the introduction of new materials to all sectors of the industrial economy,
- the development in data communications with new levels of speed and accuracy parallels that of the emergence of steel ships and of railways in the 1st industrial revolution[7],
- new markets are developing in China and the Pacific Rim in general.

However, there are also some key differences between the two 'revolutions' [see, e.g., Finniston, 1989]:

- the capabilities of modern technology are far more advanced, by orders of magnitude, than those which replaced craft based industries[8],
- the cost involved in acquiring and maintaining advanced technology is very high and investors are far more risk averse than in the past.
- today, the needs of a large population can often be satisfied by a proportionally very small workforce,
- first world markets are generally not expanding in volume terms but qualitatively, with increased product diversity in some sectors and very much reduced variety in others[9],
- improved communications and better transport links have rendered competition worldwide and therefore unpredictable,
- the emerging new markets are often poor, volatile and very price-sensitive,
- productivity in most sectors of the economy has risen dramatically and the productive capacity far outstrips demand[10],

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6) 'lithographic' pattern making for casting, direct from the solid model, for example, is potentially similar in impact to the development of accurate machine tools during the first industrial revolution.

7) forty percent of personal computers used in US industry are networked and all the computer workstations used by Ford's design studios throughout the world are linked in this manner [OU CIM Video, 1985; Tenbrock, 1994].

8) the production cycle for individual tractor parts at Caterpillar has been reduced from 25 days to 6 days. The production cycle for producing one tonne of steel has reduced in the US from 13 to 5.3 hours. The complete development cycle from concept to production is now only 31 months, seventy five percent of the figure a few years ago [Tenbrock, 1994].

9) standardised body shells and engines of motor vehicles, for example, contrast with innumerable fit- and trim options: Volkswagen reduced their range of so called 'platforms', that is self supporting car substructures, from 16 to 4 (Guardian, 1994-08-19). The variety of body care products burgeons while the number of white goods brands diminishes.

10) even if the international demand for capital and other goods increased at 2-5% per annum, real productivity rises would continue to outpace this by far [after Finniston, 1989]. Tenbrock [1994] gives the US steel industry as an example where the labour force has reduced from 400,000 to 160,000.

People, displaced by technological or economic developments in one industry, can no longer expect to be re-employed quickly elsewhere. The skill levels required to operate and manage the new technologies in their pure forms are very different from those available amongst existing workforces. Computer Integration is only one of the many applications of advanced technologies to manufacturing. It has received more attention than many others though, not just because of the fascination with its 'pseudo-intelligent behaviour', but because of its scope for displacing human workers at all levels of an organisation, rather than simply replacing manual workers. It is also believed to have further long term implications which cannot yet be predicted.

2.3 Computer Integrated Manufacturing

2.3.1 Defining Computer Integrated Manufacturing

Computer Integrated Manufacturing (CIM) has been described as 'the un-interrupted flow of electronic information throughout an enterprise' [OU CIM video, ca. 1985]. In this relatively early quotation CIM is viewed not so much as the creation of a synergy between the traditional strengths of manufacturing organisations on one side and the data and information handling capabilities of computers on the other, but rather as an add-on to businesses' existing structures. Spur [quoted in Schultz-Wild, 1989] goes a step further in that he describes a CIM system as: "an information system oriented to manufacturing technology". Somlo [1989] provides perhaps the most extreme definition of CIM as: "the integrated processing of materials and information", while Meyer [1988] suggests that: "CIM in its final state integrates all levels and functions [of a company, ed.] into a coherent system supported by computers". Further definitions may be found in appendix L.2.

It may be useful to define CIM in the context of some of the other key concepts involved in the advancement of industrial production: in this section and throughout most of this dissertation the terms Manufacturing Systems Engineering, Computer Integrated Manufacturing, Concurrent Engineering and Integrated Manufacturing will be used relatively loosely although a clear distinction could be made. Integrated Manufacturing (IM) stresses the key business importance of the manufacturing function; concurrent engineering (CE) refers to the paralleling of processes which in the past were carried out sequentially; computer integrated manufacturing (CIM) describes the result of introducing computers into manufacturing using the concepts of IM and CE as part of a manufacturing systems engineering (MSE) project.

2.3.2 The Emergence and Development of CIM

Very basic programmable mechanisms, in the shape of the NC machine tools mentioned above using paper tape as an input medium, first made their appearance in the world of manufacturing in 1947. The division into a hardware and a software component, the latter being adaptable to new needs with relative ease, represented a very significant departure from more traditional approaches to manufacturing automation. Ever since it has been possible to make a distinction between computers used as programmable controllers, process control computers and business management systems [Rembold, 1993], which could also be described as the three hierarchical levels of the application of computers in manufacturing.

Although it was widely expected that computers would one day have a major impact on manufacturing as a whole, until the early 1980s most organisations became more and more vertically and horizontally structured in an attempt to cope with the increasingly complex manufacturing tasks of the time (e.g., producing Concorde). Computer systems were tailored to these situations rather than simplifying the organisations to ease the introduction of computer oriented approaches. The move from 'computers in manufacturing' to CIM thus had to progress in stages:

After early experimental work, from the mid 1960s onwards, computers played an increasingly important role in manufacturing industry although, in a first phase (1960 to around 1970), only in the shape of programmable controllers for machine tools and process oriented systems such as payroll management and bill of materials production. In parallel they were used to solve complex mathematical and modelling problems. Such applications were ideally suited either to mini-computers with limited capabilities or to mainframe computers operating in 'batch' mode with very significant support from data processing departments. In fact, this amounted to the invention of the concept of vertical and horizontal 'islands of automation'[11) which brought significant improvements in the areas where the systems were installed but which had little or no impact on the manufacturing organisation as a whole. As the capabilities of computer systems were enhanced, the scope of their use could be extended, for example, to include drafting and design.[12)]

Reviewing this phase, Dan Elder of Honeywell, quoted by Wedeking [1991], states "... we were able to learn from other companies' experiences and avoid many of the pitfalls associated with 'islands of automation' ... Our charter is to develop an integrated environment that will help us fully implement a concurrent engineering or team approach to product development. We want to reduce our development cycle from an average of two to three years to a year and a half or less. At the same time we want to ensure that we are achieving the highest possible product quality and delivering cost-effective systems to our customers."

Once it was shown that the performance of computer systems in one functional area or at one hierarchical level of a plant could be improved by using data from another system directly, rather than through the intermediary of paper based systems or people, the myth of the dichotomy between 'reliable computers' and 'unreliable people' was born. Any information which could be transferred by a keyboard stroke or, better still, automatically, was perceived to be 'good information' whereas any process involving people was expected to lead to 'corrupted data'. Because people's attention span will always be limited, it is inevitable that they make mistakes, sooner or later. The relatively basic computers of the period though were well suited to such simple tasks as the forwarding of information between two points. In this second phase (from about 1975 to 1985) of the computerisation of manufacturing the emphasis was thus on communication between stand-alone applications but still only within confined subsystems. DNC (direct numerical control) systems were developed but there were a great number of problems in translating CAD data into the data required by machine tools.

During the third phase (starting around 1985) of the computer integration of manufacturing most of the efforts were concentrated on using computers, arranged in networks, as automatic decision and control devices for whole manufacturing plants or particular subsystems. Computers, on the one hand, were seen to be objective and accurate, 'able to take impartial decisions'. People, on the other hand, be they managers or shop floor staff, were viewed as 'subjective and easily influenced'. Because manufacturing operations require a constant stream of decisions, most of which are time-critical since they concern the loading of manufacturing equipment, computers were adopted as the ideal tools. Very quickly though

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11) traditionally, the term 'islands of automation' has been used to describe applications of computer based automation in different areas of one level of a hierarchical organisation, but without linking the systems in the different areas. The author of this thesis defines these as horizontal islands of automation. Vertical islands exist where, e.g., machine tool controllers are not linked to a production planning systems which is in the level above, process computing.

12) Seed [1993] describes the introduction of computer based systems to manufacturing at Mercedes Benz: the company introduced the first large and inflexible information system in 1962. A Mercedes production planning system was introduced in the 1970s but was not linked up between sites.

it became apparent that the amount of data required and the need for absolute accuracy during initial acquisition of data made the move to "intelligent" computer systems excessively expensive.

The complexity of early integrated factory management systems was such that their performance could be assessed only once completed products started to emerge from the process. Systems operation was non-intuitive and could only be described in mathematical terms [d'Iribarne, 1990]. Any interference with the automatic operation of the system, made necessary, for example, by a customer's change of plans or equipment problems, could trigger major disruption and an overall failure to achieve scheduled deliveries.

2.3.3 Technological and Computing Euphoria

At the same time (around 1985), microprocessor based systems started to emerge, offering automation possibilities beyond engineers' and managers' wildest dreams. High speed data networks became available, together with the necessary central information storage devices. The concept of the "lightless factory", often described as a Japanese invention, was the result of these technological advances, a concept promising high productivity, flexibility, top quality and very low labour costs due to the almost automated design of products and the development of the corresponding automatically controlled means of production, the automatic handling of goods at all stages of manufacture and the reduction in labour costs to nearly zero.

This scenario did not materialise, however, since it became apparent very soon that the investments required to achieve such performances were beyond the resources of even the biggest and most powerful manufacturing organisations. A prominent victim was General Motors of the USA, where the company management spent large funds, a sum equivalent to the price of acquiring one of its Japanese competitors, on developing a fully automated car factory, an enterprise resulting in a failure which brought the company close to collapse [Gannon, 1988].

What went wrong? Some critics maintain to this day that the systems used were simply not powerful enough, that software and hardware were still flawed. As technological optimists they are convinced that better systems will fulfil the early promises. Technological pessimists though argue that any system whose complexity exceeds a level at which it could still be operated by a human being will ultimately be doomed to failure. Both groups tend to overlook one of the factors which was mentioned in section 2.2.2: even though productivity of the industrial workforce had risen to very high levels in the 1960s and 1970s, direct labour costs, expressed as a proportion of product cost, remained more or less constant, partly due to the higher skill levels required by new technology [Boer, 1994]. Its complete removal could therefore not be achieved in a cost-effective manner.

The relatively indiscriminate use of computer based systems was aimed at displacing the "lower" levels of industrial workforces but, at the same time, created many new support and management functions elsewhere in the companies. Rather than being able to establish a lightless factory run by a few experts from home, industrialists were faced with top-heavy organisations with high wage bills and under-qualified machine minders and cleaners on the shop floor. This was clearly an undesirable outcome and other routes towards higher industrial effectiveness were sought.

Alain d'Iribarne [1990] writes about the study of national and socio-cultural characteristics at company level, that is, where their impact is felt: "The importance of such an approach is that it leads to the recommendation of a radical change in perspective concerning the relationship between technology, social systems and industrial efficiency. It emerges in fact from this work that it is in a way the very unifying vision of advanced technologies (particularly in the industrial context where it is introduced and adjusted for large companies and designed to be very 'closed off') that gives people very little leeway in its use and very limited prospects of it widening out. Any productive group whose characteristics are not close to the view of the designer must therefore have a hard fight to enter the relatively narrow margins left open for this, even if it seeks in the main to loosen the constraints. The results support the design and development of completely open ended advanced technologies, that is to say those which leave room for organisation, for very diversified use and take into account the relevant social and marketing perspectives."

2.3.4 Finding an Alternative

While it would be easy to side simply with either the technological optimists or the pessimists, choosing one or other of the extreme positions, we would run the risk of denying manufacturing the use of powerful tools which can enhance its effectiveness and thus profitability. The data and information handling capability of computer systems must be used if manufacturing is to continue to provide a contribution to Gross National Product (GNP) and to offer challenging and reasonably paid work to a proportion of a country's population. The contribution of people, individuals and groups, can also have a major impact.

New systems must be designed by engineers who have a thorough knowledge of the needs of users and who are willing to adapt the concepts to the size of manufacturing entity for which they are intended. Companies must choose technologies which fit in with the status of technological work in the respective society, the relative status of the technologies evaluated, the level of training of personnel and the professional backgrounds of the future users [d'Iribarne, 1986]. It is thus necessary to develop new paradigms for the computer integration of manufacturing, paradigms based on people and computers as partners.

2.4 People, Organisations and Technology

Recently, such a new vision has been promoted under the heading of POT (people, organisation and technology), as part of the Manufacturing, Organisation, People and Systems (MOPS) programme, supported by the UK Department of Trade and Industry [Evans, 1994]. This vision is founded on the principle of using organisation, people and technology 'as equals' to develop a manufacturing strategy that will enable companies to respond to the dynamic markets of the 1990s. It emerged as one of the products of the human-centred systems debate of the 1980s. This section is used to provide a background and to reflect on some of the aspects of the debate.

2.4.1 Human Centred Computer Integrated Manufacturing

2.4.1.1 The Meaning of Human-Centredness

The concept of 'Human-Centredness' and the ideas that underlie the approaches were first developed and formulated by Howard Rosenbrock in the early 1980s [Rosenbrock, 1983] but are to some extent enhancements of theories first defined by the more progressive members of the ergonomics community such as Branton. The concept of human centred[13)] design goes along with and includes many principles well known in the field of 'human work design': personality promotion, skill-based manufacturing and complementary design of man-machine

13) the phrase 'human centred' is sometimes replaced by the term 'anthropocentric'.

systems [Schmid, 1993]. Support from the European Community worried about the decline of European competitiveness, and from the research funds of a number of countries led to the 'invention' of HCCIM or Human Centred Computer Integrated Manufacturing.

In general, a human-centred technology is one which extends human skill and its application to real life situations. The technology itself must be designed so as to optimise the synergy between human skill and computer power. The work within the factory must be organised such that in all areas people are able to apply a substantial range of their skills rather than just a small 'useful' part thereof. Individual skill and competence should be increased through a balanced combination of learning by doing and formal training and education. An example of such an approach is given in section 13.5.3.

A short quote from the preface to 'Person Centred Ergonomics ...' [Oborne, 1993] may serve to highlight some of the reasons for retaining human beings in systems: "... far from being sources of error in a system, people at work bring unique characteristics to the system which no machine would ever hope to match. They have a sense of responsibility in their work, a quality of flexibility and adaptability and the ability to predict events and courses of action for the future."

2.4.1.2 Background to Human Centred Systems Design

In a human-centred system traditional design and manufacturing skills are used to their fullest extent. The range of activities for which each operator is responsible is maximised, to include, for example, production work as well as quality and planning related duties. As a result, each person will develop a general knowledge of the whole production process and must be given the freedom and opportunity to comment on any aspect of it. Cherns [1975] developed ten principles of socio-technical design, four of which are at the heart of human centred systems design:

- compatibility: the way in which a job or system is designed should be compatible with the objectives of the design, e.g., a system requiring participation for its operation must be designed in a participative manner,
- minimal critical specification: the specification of a job or system should identify and specify no more than is absolutely essential,
- information flow: information for action should be directed first to those whose task it is to act,
- power and authority: those who need resources to carry out their responsibilities should have the power and authority to command those resources (cf . Figure 1).

The concept of human-centred manufacturing relies on skill enhancement rather than skill replacement. The German Industriegewerkschaft Metall (IG Metall, a trade union) realised the need for this in 1976 and lobbied for new approaches to the training of workers and a change in attitude in industrial relations in the 'old industries' (steel, textiles etc). The Lucas shop stewards committee took up the theme in their campaign to replace arms production with socially useful products.

There are many ways of increasing human-centred working within as well as outside manufacturing industry through the application of computers. True interactive computer-based systems are needed and are being designed for a variety of human work situations, perhaps more so in areas such as banking and air-traffic control than in manufacture. The reason for these positive developments is that the introduction of the computer has forced people to think deeply, perhaps for the first time, about the fundamentals of processes, both qualitatively and quantitatively. This need for reflection on the key issues in manufacturing is not limited to management; the integration of computers involves everyone engaged in the production process.

2.4.1.3 The Person-Centred Ergonomics Angle

Human Computer Integration in manufacturing and elsewhere is, in essence, no more than the application of the fundamental concept of ergonomics to computer supported systems, that is, "designing the 'machine' (or any aspect of the environment with which the person has to interact) to match the operator's abilities" [Oborne, 1993]. The operator is part of one or several feedback loops maintaining a system in the desired state or near to it. This traditional view of the ergonomic approach has been expanded in recent years to include the person's story in the analysis, where 'story' refers to an individual's social and cultural background. Person-centred ergonomics view the interaction between human and machine as one which must be controlled and dominated by the operator(s) in the system.

Human beings have special abilities and dimensions of flexibility which must be taken into account when designing a system. A primary feature which humans can bring to systems is a sense of purpose. Since this differs from person to person the system must be designed to cope with the general thrust of the intentions or purposes. This purposeful behaviour (see also appendix D) is not predetermined but evolves from continuous 'computation' of information provided by the environment. According to Branton, the performing of such computations, that is, the existence of 'un*self*conscious intentions' may help explain skilled activity. The writer of this thesis would contend that this is one of the factors which affects the design of experiential learning environments where predictions of motivation, learning and leadership performance are difficult and unreliable.

Operators, people, bring to a system a collection of inherent strengths and weaknesses which interact with the system to change it. In Branton's opinion [Oborne, 1993], operators in any system invariably turn it from being a closed loop entity, in which information flows between components with (theoretically) maximum efficiency for correcting deviations, to an open-loop system. The deviation corrections are effected by the operator on the basis of his or her mental model of the system and its operation. Thus system design must be defined by the abilities and backgrounds of the operators who inject human factors into their work such as autonomy, responsibility and creativity.

2.4.1.4 People interacting with Computers

Computer systems, if they are to be subservient to human beings, must be designed in a human centred way, to paraphrase a statement by Rosenbrock quoted below. Design efforts must not be limited, as a matter of course, to interface improvements such as the use of mice, windows and graphics. The efforts must be aimed at sharing meaningful tasks between person and machine, for example, allowing a human operator to decide on the rate of injection of plastic into a mould, based on her experience, while providing, as a backup, a number of proven time profiles stored in the computer. Since computer based technology is still relatively new, there is a chance for cross-disciplinary teams to work together not only in establishing the new technology but also in getting this technology accepted by the users. Even though changes in working procedures may be radical, properly managed process innovation and skill development can open opportunities for new, more satisfying and thus more human-centred ways of working.

In the past, and to some extent even today, computers have been used often to de-skill jobs. A typical example of such an approach were the computer controlled human workplaces for parts insertion into printed circuit boards (PCBs) which had been developed in the early eighties: parts were automatically presented in a carousel to the operator while a light point indicated the insertion position. The only contribution demanded from the human being was the dexterity involved in pushing two or three 'legs' of a component through a set of holes!

The development of human-centred computer based tools provides people with assistance in the management of complex situations. The combination of human skills, such as fast and adaptive decision making, with computer capabilities, such as quick storing, processing and retrieval of information, offers a good approach to dealing with highly dynamic problems. The computer based tools either simply provide information to the user in a structured form or they help by offering options for approaching the solution of problems. Thus they can be viewed as elements of a decision support system. Algorithms for decision making can either exist in the system or can be added by users as and when required. It is important that the user can check the method of operation of the algorithm at any moment. In some instances it may be necessary to limit the level of automation provided by the computer systems so as to leave sufficient scope for the work of the human[14)].

Various projects have been set up to design alternative methods of implementing technology in the form of "flexible manufacturing systems in which the operator is not subservient to the machine" [Rosenbrock, 1983]. The European Community project on 'Human Centred CIM Systems', described by Ainger [1990], was one of the key projects concerned with human centredness in manufacturing. The objective of the project was to produce human-centred CIM components, in which human skill and its application are optimised, in harmony with leading-edge computerised manufacturing technology.

Appendix D offers some additional insights into the human being versus/with computer debate including a discussion of 'purpose' as a key differentiator.

2.4.2 Transforming Companies and Organisations

To remain competitive in world markets, manufacturing enterprises must take full advantage of the potential for increases in productivity, better quality and greater flexibility provided by more responsive organisational structures, better utilisation of human skills and experience and the power of modern computer-aided technologies. To achieve these goals a skilled, cooperative and motivated workforce is required. Traditional management hierarchies and forms of control must be modernised. More participation by employees is needed at all levels, in planning, designing and implementing new technologies and systems. Technical systems must be designed not just to meet economic and technical goals, but also to satisfy organisational and human requirements.

Experience suggests that manufacturing systems do not operate effectively and do not yield the expected benefits unless attention is also paid to the organisation and people issues during design and implementation. There is now an increased recognition that organisation and people issues are important, but most companies adopt a fairly narrow approach as to how these issues should be addressed. Managements attempt to find ways of overcoming the resistance to change and the reluctance of people to accept new technology but fail to provide an entirely new environment and philosophy. Lang [1990] discusses this reluctance of companies to move from interfacing to integration because it requires more change than quick and easy projects.

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14) this is an important consideration in situations where operators' principal responsibility is one of monitoring the system. As a low frequency but high impact (e.g., risks in a power station) environment it is potentially stress inducing. The introduction of relatively artificial tasks can enhance the working environment. In theoretical terms this could be described as a low technical interdependence high technical uncertainty intervention situation which lends itself to enriched jobs, maintaining worker knowledge at a high level [Cummings and Blumberg, in Wall, 1987]

Some companies have started to change the way they use technology and have begun to consider organisation and people issues in some depth. The changes needed are, at times, quite simple but must be structured well. Organisation and people issues should be considered at all stages, from business strategy right through to manufacturing systems design and implementation. Instead of looking for the technological fix, companies need a broader and more balanced approach that addresses manufacturing organisation, people and technological systems. It is necessary to overcome the belief that technology provides the answers to all problems. Managers must develop a new and broader vision of the 'Factory of the Future'.

2.4.3 Organisations and Strategy

The oft stated demand for flexibility, adaptability and improved responsiveness to customers' requirements, combined with the need to motivate people and to make use of their skills, judgement and experience, mandate change in organisations, work practices and technology. These facets of an enterprise must be developed in a way that will allow highly trained people, at all levels of the company, to adapt their work strategies to the variety of situations which they will have to face. There is a need, therefore, to move away from an organisational model characterised by:

- large number of hierarchical strata,
- centralised and cumbersome decision taking,
- under-qualified, single skilled operatives with little competence or authority,
- complex information handling and management processes,
- static structures and reactive handling of markets.

Such a company structure and, as an example, its order management process, are illustrated in Figure 2 [after Creux, 1993], based on a real company analysed as part of a UK Department of Trade and Industry (DTI) supported Manufacturing Organisation, People and Systems (MOPS) project. Instead of the still common multi-layered organisation trees with their complex and cumbersome decision processes, companies are today advised to create organisational models based on:

- flat organisational hierarchies,
- decentralisation of decision making and control[15],
- increased competence and authority for shop floor staff,
- multi-skilled employees and team working,
- skill supporting technologies,
- simplified handling and use of information,
- continuous improvement involving all employees.

Other benefits of such a balanced manufacturing strategy are reported to include: shorter throughput times, reduced inventory, improved product quality, streamlined material flows, easier production planning and control, put simply, more economic operating conditions and improved job satisfaction which can lead to better motivated people [e.g., Skinner, 1992;

15) the cell-based reorganisation of factories provides one of the solutions for achieving decentralisation and devolvement of responsibility and authority. Fundamentally, this approach is based on dividing up a large plant into many semi-autonomous units which have all the resources, in terms of people, organisation and technology, to carry out the tasks involved in performing all the operations involved in transforming a number of inputs into a significant whole.

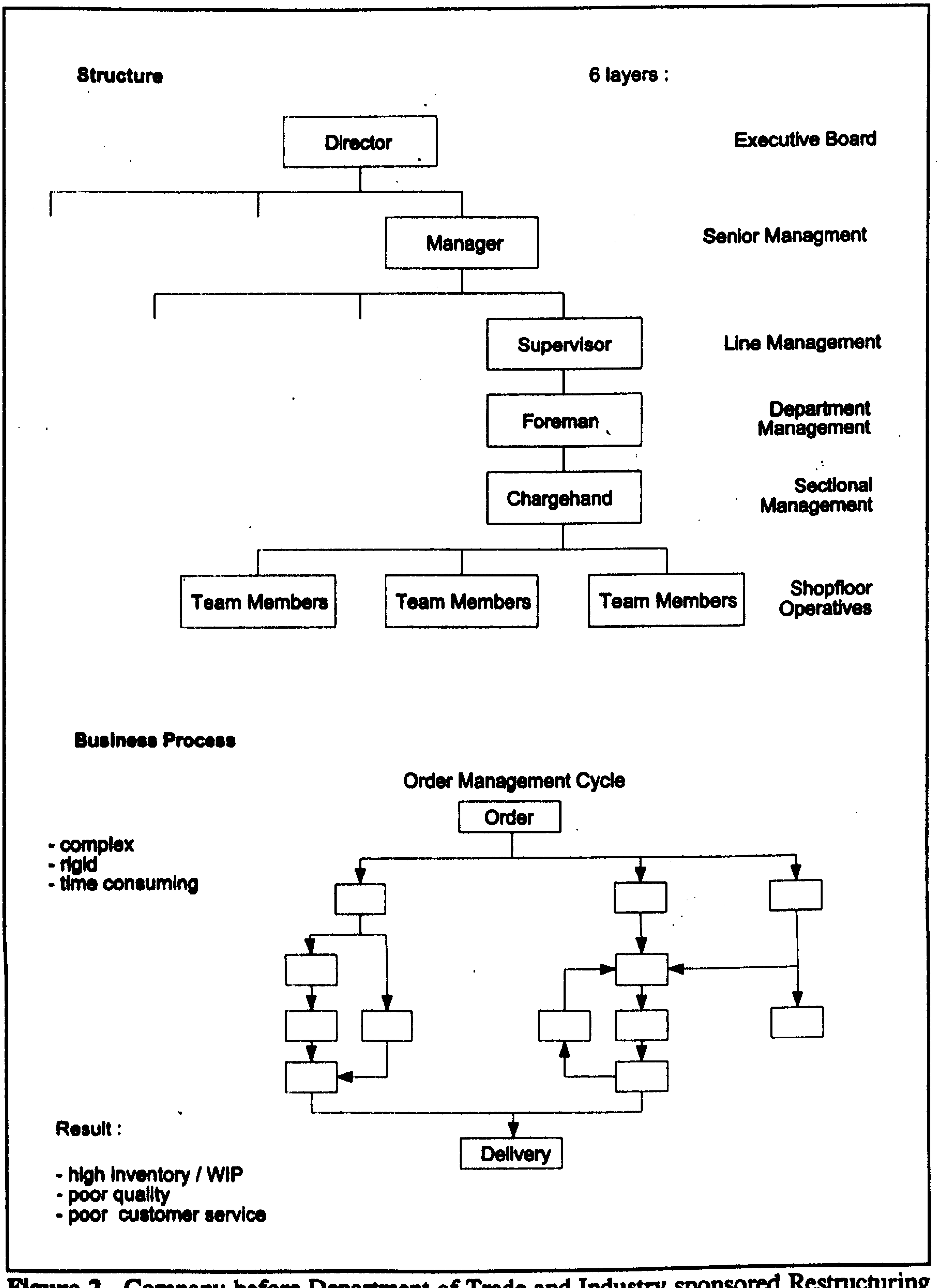

Figure 2 Company before Department of Trade and Industry sponsored Restructuring

Hill, 1989; Slack, 1991]. Figure 3 shows the result of the transformation of the structure of the company mentioned above which was undertaken with the help of the DTI.

The appropriate starting point for the development of a human-centred computer integrated manufacturing system is thus the consideration of strategy. Two strategic components must be considered here:

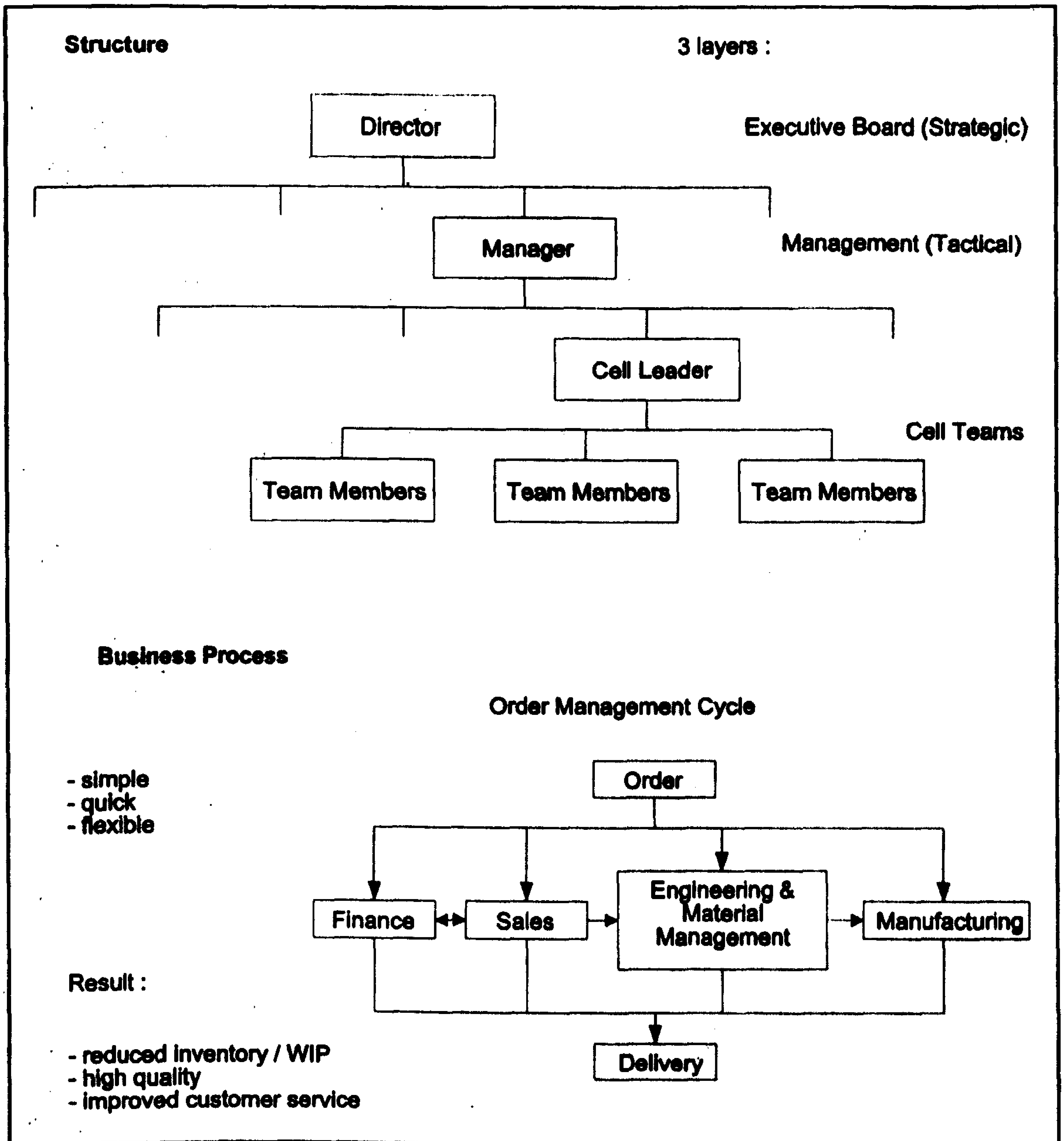

Figure 3 Company after Department of Trade and Industry Sponsored Restructuring

- the corporate strategy and, associated with this, how computers can help realise business objectives
- the method and priorities adopted by the organisation in the development of its computer systems.

Although a number of methodologies[16)] exist and others are being developed to reflect new approaches to systems development, evidence seems to suggest that no one methodology can guarantee successful systems development on its own. As a general rule it can be stated that usable methodologies must be flexible and adaptable to almost any given situation. It may be better to have a set of guiding principles which cover the key issues and to allow system developers to use these as tools in a manner which is appropriate to a particular organisation rather than prescribing a flawed all-purpose methodology.

16) for example, the dual design approach advocated by Brandt [in Schmid, 1993], the DIN guidelines [ibid.].

Users are often disappointed in a system once it is delivered. This statement is particularly true of computer based systems. One reason given for this is an inaccurate specification of users' requirements. It is often wrong to imply that this is all the users' own fault as it is frequently the case that the people for whom the system is intended are left out at critical stages of the development process and, even when they are asked to participate, they are often not adequately briefed or guided when stating their requirements. This problem is described in J. Rachel's case study of the design of a new customer-oriented software system in a water company. Users were theoretically involved in the process of designing the system but, in fact, they were ignored [Rachel, 1994]. This situation could potentially be improved through the adoption of changed patterns of training and education for young managers.

2.4.4 The Process of Change, Education and Training

The change process involved in moving from an existing mix of organisational methods and technical tools needs to be planned in a way which is appropriate to humans. Possible patterns for changing business environments and company structures are shown in Figure 4 [adapted from Ainger, 1990]. For the example it has been assumed that the company needs to be transformed to reach a new stable modus operandi by changing both its organisation and the technologies used to run its systems. The main part of the diagram is used to illustrate three possible migration paths from one structure to another. The two structures differ in terms of the level and complexity of the organisational methods and technological tools applied. The two subsidiary figures indicate the respective rates of change as a function of time. For example, in all three diagrams, Path 3 refers to a transformation dominated by organisation oriented approaches.

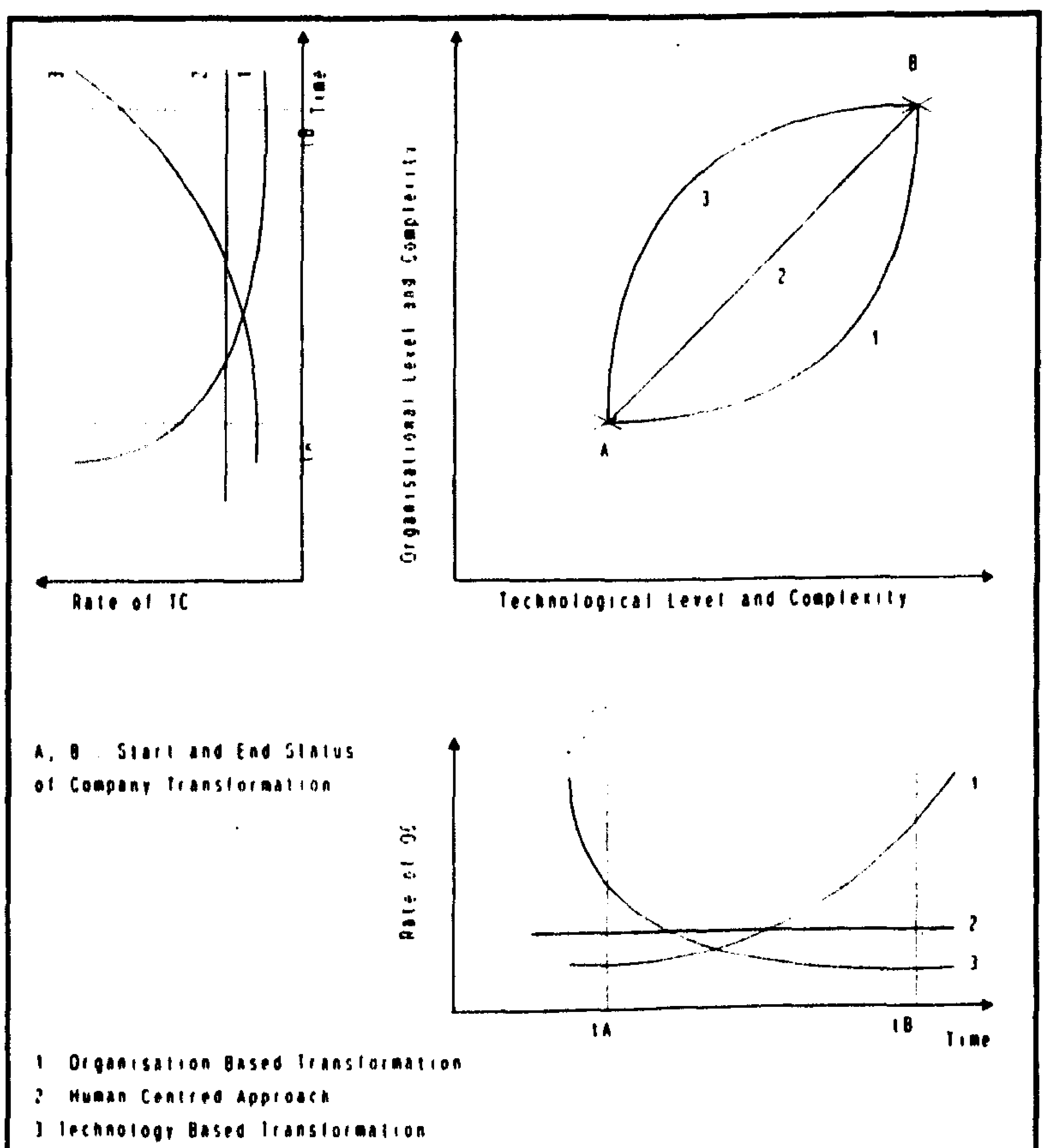

Figure 4 The Different Routes for Organisational Change

Most people are disinclined to handle rapidly varying rates of change with high peaks [Clegg, in Wall, 1987], although they do not object to change as such. Indeed, most people positively relish change in their private lives - as long as they are the prime movers. Company transformations should therefore follow the approach identified as path 2 in Figure 4 and involve the people concerned with the outcomes. The diagram illustrates the need for a balanced process of organisational and technological transformation where humans are able to adapt in an incremental fashion to a changing work environment. The third axis of the main graph would show the rate of change in training and attitude required of the humans involved in the process.

This third axis forms the context for the work reported in this thesis. As described elsewhere, the course team to which the author belongs had originally intended to teach CIM in a way which is represented by a path very similar to (1) in Figure 4. They soon realised though that the most important skills they had to teach[17)] students were the ability to change and the associated ability to manage change. The students also had to be taught how to specify their own needs and requirements in terms of systems and organisation. Out of this developed the interest in human centred CIM and in the principles of POT.

2.4.5 A Cautionary Remark

It is to be expected, unfortunately, that the human centred approaches postulated will only be applicable to some areas of manufacturing, particularly to 'leading edge' production, where competition is not purely on cost but includes factors such as timeliness. While it would be theoretically interesting to eliminate competitive pressures as threats to human oriented work designs by means of trade barriers, McKinsey & Co [1993] state in a recent study that global competition is essential if productivity, measured as value added per hour worked, is to increase and thus create conditions ensuring company survival.

It must be accepted that this free international trade will militate against human oriented work designs as long as there are no internationally binding agreements or consumer pressures which guarantee comparable levels of industrial employees' welfare in all markets. Such a levelling of the 'competitive playing field', although desirable from the human work angle, will also result in a levelling of living standards between newly industrialised and developed nations. There is, clearly, a built-in conflict between different goals. However, this must not be used as an excuse not to teach the skills required for the successful development and implementation of Human Centred Systems.

2.5 Educational Needs in Advanced Manufacturing Environments

Many managers are promoted from the ranks of engineers who often lack some of the skills and qualifications[18)] necessary to perform well as managers. One author [Stevens, 1985] suggests that the majority of engineers become managers at an early stage of their careers. Other authors use the terms engineer and manager interchangeably in the context of modern manufacturing [e.g., Skinner, 1985]. Between 1985 and 1995 awareness of these issues has grown, leading to the trialling of continuous professional development (CPD) in the shape of voluntary schemes administered by the Engineering Institutions. The Engineering Council [1995] has addressed the issues in its guidelines for the professional development of engineers which includes clear recommendations for postgraduate education of all professional engineers.

Since managers play such key roles in operating complex systems of the type encountered in advanced manufacturing and, in particular, in CIM installations, it would appear appropriate to ensure the best possible preparation of engineers, the future managers. In the past, the vast majority of engineering courses have been characterised by the transfer, from teachers to students, of great quantities of information, from the fields of mathematics, the natural sciences, technology and applied engineering. Unfortunately this approach is not in line with the requirements of either the individuals or industry.

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17) the use of the word 'teach' in this context is deliberate. The writer could have used a phrase like 'assist students to acquire skills'. The definition of teaching must include this helper function

18) for the present, terms such as 'skill', 'qualification' and 'capability' will be used more or less colloquially. They will be defined later

2.5.1 Manufacturing and Education for Manufacturing Engineering - Aspects of a Problem

"Historically, companies met the need for manufacturing engineers by promotions from the ranks of machine operators" [MSB, 1985] who would have possessed some of the key skills required for the new role as a result of their shop-floor experience. By 1980 in the USA, for example, there were fewer than half a dozen universities offering specific Manufacturing Engineering programmes [MSB, 1985].

The situation in the United Kingdom in the early 1980s was similar to that in the United States, if not worse, in the sense that the political environment was not supportive of manufacturing industry as a main contributor to the GNP and that industry was no longer seen as a creator of wealth. But while the UK government promoted the growth of service industries there were other views such as that of Sir Kenneth Corfield, Chairman of STC, who wrote in 1983: "Increasingly it is being seen that Britain has the knowledge and inventiveness to spur innovation but that this is not translated into production. ... Inadequate attention is given to the huge problem of funding and resourcing the resultant product for production." [Corfield, 1983] Comments like these had an impact since, around 1987, the UK government funded the Manufacturing Systems Engineering Initiative which led to the emergence of a number of new manufacturing courses in higher education.

Later, in 1989, Finniston looked back and declared: "Britain's main wealth creating activity is manufacturing. Although a vigorous service sector is very important, only 18% of its activity is tradeable internationally compared with 80% in manufacturing. ... It is necessary ... to increase the speed of response of .... advanced technology manufacturing" [Finniston, 1989].

By that time Parnaby at Lucas had already derived from a similar realisation the idea of creating a new discipline, Manufacturing Systems Engineering or MSE, to encourage the development of a new breed of engineer capable of specifying, designing, implementing and managing production operations. Although this term of Manufacturing Systems is now part of the industrial vocabulary (and the 'jargon' of this thesis) it is a term which requires definition, best perhaps in Parnaby's own words: a manufacturing system is

> **"an integrated combination of processes, machine systems, people, organizational structures, information flows, control systems and computers whose purpose is to achieve economic product manufacture and internationally competitive performance."** [Parnaby, 1987]

Parnaby had first introduced the concept in Lucas owned businesses from where it spread, partly as a result of the quality of his key dissemination tool, the Lucas Mini-Guides. The initiative was hugely successful in that it created in the UK and internationally a new and respected profession virtually overnight. The provision of a near scientific base for the design, introduction and management of production operations was one reason for the pervasiveness of the MSE approach.

At the educational level this was translated by Finniston et al. into: "To design and operate modern manufacturing or process systems requires engineers with multidisciplinary skills who can apply them wherever automated design, manufacture and test are used for one-off, batch, or continuous production, across the spectrum of product and process types." Commenting on the rate of technological change Finniston et al. state that education and training must become a continuous process, that engineering courses must be broader based, more flexible and more responsive to the changing technologies. They draw the conclusion that the formation of more and better manufacturing systems engineers is essential. The necessary skills have to be made available to students learning something about the manufacturing world in which they live. They should develop and extend their awareness of engineering through both specialised (technology based) and integrated (broad based) engineering applications. To design and operate the modern manufacturing or process system requires, in their view, engineers with multidisciplinary skills:

> **"The design of the artefact must be related to its production, ultimate performance and use - and this desirable goal cannot be achieved without people who are educated, trained and have the attitude to adopt change at the right time and in the right way."** [Finniston, 1989]
>
> **"Graduate engineers are needed who have received an appropriate education to enable them to appreciate and work across traditional engineering disciplines, combining and integrating appropriate engineering concepts, systems designs and the business of engineering."** [ibid.]

Unfortunately though, some of the features which had militated against engineering at the time of writing of the Finniston report in 1980, status and pay, still obtained in 1989 (and, to some extent, still do so today). However, Finniston et al. also conceded that engineering courses had changed a great deal and had broadened their scope [Finniston, 1989]. Naturally, this development process has continued until today, perhaps tempered by the requirement for mass higher education.

"Every effort is necessary to ensure the availability of an effective training and support environment, the right sort of corporate attitudes, the attitudes of individuals and acceptance that education and training is a continuous process ... engineering courses must be ... responsive to the changing technologies." [Finniston, 1989]

From much of the available literature on the subject and based on the author's own experience it would appear that one of the key difficulties in forming manufacturing engineers is the issue of defining a 'body of knowledge' which encompasses all an engineer needs to design, implement and run complex manufacturing systems [see Shea, 1985; Brummett, 1985]. In most cases the Manufacturing Systems engineer is described in terms of the objectives he or she has to achieve rather than in terms of skills and knowledge. For example: "A Manufacturing Systems Engineer should be capable of coordinating endeavour on a broad front, whilst maintaining a clear perspective of ultimate business goals and managing technology in the appropriate fields." [Finniston, 1989]

A discussion of the issue can be found in sections 4.3.1, 4.3.2 and 4.5.2. However, this move from a content-defined to a process and objective-defined 'job description' is a phenomenon more and more common in the professional world, since much of the factual knowledge which was important in the past can now be retrieved from computer databases and knowledge based systems whenever necessary. Since 1989 the profession of manufacturing systems engineer has become well established, despite the problematic definition, and systems engineers trained with a manufacturing focus have made a substantial impact on manufacturing industry. Discussion has now moved to issues concerning engineering education in general [EPC1-6], in particular as a consequence of the impact of mass higher education.

2.5.2 Summarising the Problem and Attempting a Solution

For convenience and so as to reflect common industrial practice, it may be acceptable to use the expressions 'engineer and manager for advanced manufacturing technologies and systems', 'engineer for CIM' and 'manufacturing systems engineer' as approximate synonyms even though different companies and institutions of higher education might wish to make clear distinction. The problem facing an educator wishing to prepare engineers for a career in Manufacturing Systems Engineering and, by dint of argument, in Manufacturing Management, is multifaceted: there are a number of valid definitions for the scope of the professional involvement but there is no clearly defined body of knowledge, although there is a demand for a broad base in classical engineering subjects; in addition, there is a long list of skills and personal characteristics[19] which such an engineer should possess but there are few, if any, guidelines covering which of these are important and how they can be imparted.

Conventional classroom teaching, even if enlivened by video presentations and industrial guest-lectures, may be well suited to the transfer of factual knowledge and method based approaches, e.g., systems analysis using Laplace transform, but it should not be applied to the teaching of management and social interaction skills. Most of these can only be enhanced through personal experience of situations where such skills can be applied. A method adopted at Brunel University to formalise the acquisition of such skills is the Brunel Diploma of Professional Development (BDPD) which gives recognition for the learning derived from professional work accomplished during industrial training periods.

It has become the conviction of this author that the skills needed by future manufacturing engineers can be taught and developed by using project work of a novel nature as a teaching platform. While this project work cannot replace more than a small proportion of the conventional lecture, laboratory and tutorial based teaching on an engineering course, it provides a space where students can experiment and learn about their own strengths and weaknesses in a near professional work and team environment. Moreover, the project approach presents the opportunity for integrating the knowledge and skills, gained from studying individual subjects over the whole duration of an academic programme, into a cohesive framework tailored to the tasks facing the professional manufacturing engineer.

Within an individual module, rather than on the scale of a complete programme of study, the author and his team created a course offering such an integrated approach, which follows the precept on the need for integration stated by Finniston: "integrated engineering, which derives from the ubiquity of the computer, is industrial treatment of the artefact as a whole and not just the final assembly of its parts. It is not CAD or CAM or CIM... the final artefact must be designed with final economy not just of cost, but ease of production, assembly, maintenance, final quality." [Finniston, 1989].

The teaching environment created for this course is based on the Parnaby approach to Manufacturing Systems Engineering which can be restated as:

Products made by Processes operated by

Machines which have to be adaptively

Controlled by

People to meet

Market and Business Systems Targets

The opportunities to integrate existing knowledge and capabilities and to adopt the additional skills to work competently in this new engineering context are made available through a range of different activities and tasks which result naturally from the project approach based on cooperation in a large group. The description and analysis of this approach form the subject of the present thesis. It will be demonstrated that the course described goes some way towards satisfying the profile of the engineer given by Hernaut [1993], the deputy director

19) for a discussion of these refer to sections 4.6, 8.2 and 10.4.2.3 of the dissertation

for human resources of Siemens: "Knowledge of system functions in the field in question and an appreciation of technological possibilities (hardware and software) is needed... In light of the growing complexity of modern devices, equipment and systems, the ability to see things as a whole, to think in terms of systems and to communicate at a systems level with all Ingenieurs[20)] working on the project gains in importance."

2.6 Looking Ahead

The education of people and the development of methodologies and techniques are only part of a larger consideration: the question of tangible returns must be resolved if industry is to continue to put effort into supporting the design of computer integrated systems, in particular those involving a human-centred approach. Developers, users and, perhaps more importantly, stake holders[21)] must be able to derive clear benefits from the major investments required. The criteria for determining benefit is usually based on financial and functional issues and may not include consideration of what is best for the people involved.

We have to assume that the economic imperative, also mentioned in 2.4.5, can be satisfied by solutions which go beyond the technology dominated patterns being advocated today. Extended studies of the philosophical, societal and ergonomic issues surrounding human work, "tools" and automation should point the way towards a more optimal integration of people, systems and computers. In this pursuit researchers must be mindful of all aspects which make up the acronym COWPATES[22)], but particularly those referring to human needs and economic prerogatives. At some future time, tasks involving the cooperation of people and computers may well be viewed as "jobs of work" rather than complex sociotechnical problems, in the tradition of skill and craft based occupations so prized in times past. Before entering discussions of a number of issues involved in the professional development and education of engineers it may be appropriate to provide a brief overview of the CIM course whose development prompted this dissertation.

2.7 Brief Introduction to the CIM Approach to Engineering Education

The need for a course in Computer Integrated Manufacturing (CIM) at Brunel University arose from the conversion of an existing Production Technology degree programme into the Brunel Manufacturing Programme (BME). CIM was perceived as the key to future success in manufacturing industry and a team of academics was assembled to develop the course. Very soon though, the members of the team realised that the major issues in improving the competitiveness of manufacturing industry related not so much to the implementation of new technological approaches but to the development of skills which would facilitate the process. A decision was therefore taken to develop a new educational approach, henceforth described as the CIM approach which would open up a range of opportunities for students to develop their skill and knowledge in a team based situation, working on a practical task rather than being given information in lectures and tutorials.

An existing laboratory area was cleared and the members of the team defined an overall task, the development of a computer integrated manufacturing facility, as well as a range of sub-tasks related to computer hardware and software, robotics, Direct Numerical Control (DNC)

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20) deliberately not translated by Hernaut and Macleod to differentiate between A-grade and B grade engineers

21) a general category of all the potential beneficiaries of new systems, including share-holders, workers, the community

22) Customer(s), Ownership, Weltanschauung (or world image), Purpose(s), Actor(s), Transformation(s), Environment(s) and Social issue(s), after Ainger (1995) and Checkland (1981)

of machine tools, Computer Aided Design (CAD) and manufacturing cell design. Up-to-date computing equipment, donated by IBM, was made available to the students who had to form an organisational structure modelled on a business enterprise. The students were given a free hand and a small budget to manage the development process themselves. At first, it was expected that each iteration of the course, lasting eight months, would be self-contained. However, once the magnitude of the overall task became apparent, a decision was taken to develop the manufacturing facility and all its support function over a number of years, mirroring the process of continuous improvement which should characterise any well run manufacturing operation. Each year, the team responsible for the course, together with the students involved, deliberated ways in which the complexity of both the manufacturing plant and the equipment used could be developed to mirror ever more exactly an industrial situation. Practice based learning was born. A fuller description of the approach will be found in chapter 9 (section 9.5) and in chapters 11 and 12.

As will be discussed further in section 4.2.4, there exists today a marked move away from stable company management structures, founded on the principles of line responsibility, formal working groups, strong hierarchies and specialised competence of staff resulting from routine. In their place or, more often, in parallel, companies institute small, flexible units charged with particular tasks, limited in time rather than scope. On completion of a project the working unit is either dissolved or modified to suit another task. The discussions in this section are based on a number of sources, most important of which is Gregor and Hansel [1993].

3.1 Line Management and Project Management

3.1.1 Rationale for a Move to Project Management

"The management of engineering projects has become a much discussed subject and we are, perhaps, only on the fringe of learning the techniques by which large teams of engineers can be brought together to work not in series but in parallel to reduce the time-span of complex projects" [Corfield, 1983]. This statement, made by a leading industrialist at a time when companies still had substantial 'fat' and when the economies of the Western World were booming, was an expression of admirable foresight in its anticipation of concurrent engineering and lean systems. Today industry must respond quickly to complex and large scale changes if it is to survive in the highly competitive global business environment.

Similar pressures are also identified by D. Jones of Cardiff Business School in 'The Lean Enterprise Benchmarking Project' carried out with Cambridge University and Andersen Consulting[23)]. A result of the study which is of particular interest in the context of this thesis is the need for continuous improvement and change rather than the more conventional demand for consistency, in terms of quality and price, postulated by many managers.

3.1.2 Features of the Line Management Approach

Figure 1 on page 1 summarised some of the changes in factors indicative of company identity and internal structures. Some of these are directly relevant to the discussion and should be borne in mind while reading this sub-section. In hierarchical or line management the distribution of power and responsibility tends to be as shown in row one of Figure 1 while rows two and three correspond more or less to project management, showing both poor (row two) and appropriate (row three) forms of organisation.

A line management approach requires clear structures for command and information flows in a company or other organisation and thus helps establish responsibility and accountability at all levels. It relies on guidelines to ensure the observance of procedures and due diligence as well as the practice of good housekeeping. Line management is thus necessary for the long term operational effectiveness of a business and mandatory for financial and legal reasons. Individuals' tasks tend to be clearly delimited in all directions and wherever possible they are externally sequenced and controlled through the use of Laufzettel[24)] or more sophisticated computer tools (sometimes wrongly referred to as group ware). Very often it provides the

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23) as quoted in the 'Independent on Sunday' (1993-01-24). "the three elements that make the difference getting the human side right by working in teams and pushing responsibility downwards; fixing the factory process so that parts flow through it with the smoothness of syrup; and installing a lean supply chain that is tightly integrated and has a properly working just-in-time delivery system."

24) an appropriate German expression for the use of a routing sheet for office based jobs of work

company's long term memory. A useful source for more information on this topic is Handy and his review of Max Weber [Handy, 1985].

3.1.3 Features of the Project Management Approach

Gregor and Hansel (see also section 4.6) give a number of reasons for the passage from a long term stable form of organisation to a dynamic and rapidly adapting set of sub-systems: the management of technical, organisational and social innovation often requires the creation of interdisciplinary teams; taylorisation is difficult in situations where individuals are more expert in large domains than their managers; successful innovation requires the development of discussion, motivation and a sense of purpose; flexibility must be maintained.

They highlight six reasons for the adoption of project management, a less hierarchy oriented approach than line management. It is adopted by many businesses despite the inherent risk of losing some control when introducing innovation and change in companies:

1) advanced forms of information and communication technologies require specialised personnel, often better qualified than their managers. Such people tend to work in networks rather than on their own,
2) due to the increasing rate of change in both internal and external environments the need for qualification and re-qualification is substantial,
3) lean organisations require flexible and multi-skilled work forces,
4) the new contents require more cognitive learning and specialisation as well emotional and social learning,
5) the change in the standards and values of society demands the encouragement of discussion rather than its suppression, the support of more individuality and a more flexible working life,
6) work should provide a sense of purpose and belonging, as well as being motivating. The company environment must ensure a good context for work.

For all the people involved this change from stability to flexibility of roles has resulted in great intellectual and affective challenges. Engineers are no longer simply asked to accomplish a number of tasks corresponding to their function, they have to assume responsible roles in organisations and must often cope with tasks from outside their normal sphere of competence.

3.2 Engineers and Engineering Projects

Capable engineers tend to be moved very quickly into project management roles, out of both necessity and the wish to assess their suitability for line management. At Turner & Newall, the car component manufacturers, for instance, the whole programme of engineering recruitment is founded on a two year involvement in task forces. This transition from an engineering role to a management role at a relatively early stage of the career[25)] is one of the reasons for the significant changes to the range and dominance of functions occurring in work situations and therefore to the range of faculties and qualities demanded. Since more and more engineering work relates to projects and their management, the author has chosen the engineering functions exercised at different stages of projects to illustrate the powers which make for capable engineers.

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25) see chapter 3 1 3 for a comment on this issue, which is of special relevance in the UK

Daenzer & Huber define a number of dimensions of project management:

1. Functional Dimension (WHAT)

   Project Start-Up (Preparation Tasks)
   Project Continuation (Support Tasks)
   Project Conclusion (Completion Tasks)

   These activities apply to all of sequential, simultaneous and concurrent engineering - only the timing differs; and thus the complexity of the management process.

2. Institutional Dimension (WHERE)

   The project organisation and its links with the business organisation as a whole.

3. Staffing Dimension (WHO)

   The organisation by itself cannot carry out a project. It is therefore essential to define correctly the task and personal profiles of the project manager, team members and other personnel associated with the project

4. Psychological Dimension

   Primarily a people factor but closely linked to organisational matters. The aims, approaches, methods and processes must be accepted, supported and enhanced by the people working in the organisation.

5. Instrumental Dimension (HOW - TOOLS)

   This concerns the 'crafts' aspects of the project. The choice of the right tools to manage the processes, e.g., planning and control tools (graphs etc), moderation techniques, management of meetings, defining of aims, assessment, presentation, deciding, structuring and many others.

In real life the dimensions are closely interwoven: the project manager, for instance, is both a person and an institution, she satisfies functions and should use appropriate tools and techniques. The formal structure given is thus only useful for analytical purposes. A complete version of this table can be found in Appendix B.

Table 1 Summary of Project Activities [after Daenzer, 1992]

Table 1 gives a comprehensive summary overview of the activities occurring over the duration of a general engineering project. It goes almost without saying that some of the project activities may need to take place concurrently, to minimise time from conception to completion. Table 2, appearing in section 4.2.4, uses a similar but smaller set of activities and relates these to three phases of an engineer's professional development.

With the following list the writer offers his overview of the skills and powers needed to carry out the tasks involved in completing projects and developing products:

(1) identifying and describing needs: analysis[26)]

(2) knowledge of the capabilities of technology

(3) exploring limits and daring to try (entrepreneur)

The early engineers were able to create mental images of their own or of other people's ideas and to transform them into real objects without the tools available today to almost any engin-

26) analysis: statement of the result of resolving a problem into simpler elements so as to facilitate the solution. Perhaps the most difficult task faced by engineers because it requires qualities, faculties and knowledge.

eer, that is, codified technical drawings and computer models (be these CAD solid models or flow simulations) [Pitou, 1984]. However, even 'modern' engineers should have this essential ability of

(4) creating mental images: synthesis[27]

also the first key step in engineering design[28]. Good engineers will not be content with a single solution, they will seek at least an alternative or, better, a whole range of options! They must thus be adept at

(5) assessing the options and making the optimal choice

From the mental image of a potential solution to a problem the engineer must develop the detailed route to the implementation of the solution, which demands some or all of the following activities depending on the product or project:

(6) planning tasks

(7) selecting tools and methods

(8) building prototypes

(9) testing prototypes

Once the project or the product design or the service has reached a sufficiently mature state, engineers are called to ensure its continued production or operation:

(10) managing a workforce

(11) assuring quality of output to satisfy customers

(12) engaging in a process of continuous improvement

As shown in Table 2, in section 4.2.4, engineers involved in some or all of the stages of projects are faced with a wide range of job-functions in performing their roles. To be successful, they require natural or personal qualities and faculties acquired through education and training.

3.3 Task Culture, Control and Authority: Leadership Styles and their Suitability for Project Management

Project management is part of the task culture [Gregor, 1993, Handy, 1985] where the emphasis is placed on "getting the job done". It is generally applied in rapidly changing environments and where the introduction of innovation is required. Tasks are often complex and not easily delimited. Results are not clearly definable but are described in statements of objectives which are not always given 'from above' but developed interactively[29], as accurately as possible. Planners seek to bring together the appropriate resources, be this the right equipment or the right people at the right level of the organisation. From then on it is the project team which has to move forward. The relatively short term nature of individual projects prevents both the codification of acquired knowledge and the specialisation of individuals. Control is more difficult due to the net of processes taking place simultaneously,

27) synthesis: combination of facts, concepts and ideas into a whole which should have the elements of a solution contained within

28) for the present discussion the term 'design' is used to encompass the whole conceptual process from the original identification of a need through to the planning of the production of its solution. It is thus only marginally less comprehensive than the engineering process as a whole. Occasionally the word 'design' may also be used to describe only the creative phase or the development of the physical characteristics of a product.

29) a process sometimes described as procedural objective agreement [Gregor, 1993].

preventing effective control of individual work places and sub-tasks. It is only possible by combining the cognitive level of management with an intuitive "distributed" activity.

The issue of authority (in the meaning of recognised and accepted power or legitimised power) is one of the aspects where line management supports individuals charged with leadership tasks far better than a project structure. The latter often involves the management of peers or of people who were peers recently. As will be seen below, influence in a project will be based more on expert power than on status or personal power.

According to Handy[30)], authority (that is, legitimised power) can be derived from one or a combination of legitimacy (AL), of position or status (AS), of competence (AC) and of personality (AP). Gregor and Hansel do not attempt to distinguish between authority and power, because either can be used to exert influence in organisations and teams regardless of their legitimacy. They list three possible forms of leadership:

1) the presence of natural leadership qualities in the dominant person (born as a member of the elite...);

2) a social influence process flowing from the exercise of,
   - (a) the power over rewards (salary, promotion)[31)],
   - (b) the power from coercion (threat of redundancy)[32)],
   - (c) the power derived from the person's qualities,
   - (d) the power resulting from knowledge and skills,
   - (e) the acceptance of a person's legitimacy,
   - (f) the power derived from information;

3) a controlling influence based on responsibility for the actions to organise and manage the activities necessary for the project (maintaining agenda, preparing meetings) which is largely independent of a person's qualities[33)].

Although Gregor and Hansel's classification is very similar to that of Handy, it provides a contrast because of their strong rejection of (1), Handy's AP and their support for (3) which Handy has not listed. (2c) is not substantially based on (1) but deals with learnt and adopted qualities. Crawford [1984] has observed that, amongst engineers, AL or (2e) are of great significance since the legitimacy of the leader is expected to ensure access to tangible resources, an aspect which tends to rate highly with people whose work is rooted in the physical world.

Gregor differentiates between two leadership types, directive (elsewhere: 'authoritarian') and interactive (elsewhere: 'co-operative' or 'democratic'). The former is based on instruction, delegation and control. Counter to public perception it includes the famed 'management by objectives'. The latter type is founded on team decision processes and the acceptance of aims and methods. The two types are shown in Figure 5 top left and top right, while the mixed or real life type is shown at the bottom (the writer's contribution to the debate). In this version, collaborators (or workers) receive aims and associated objectives from the management level and negotiate scope and scale of their own contribution with managers and colleagues based on a joint understanding of the needs. It is, in essence, a team based

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30) in a reference to Peabody

31) results in loss of motivation if promised and then withheld

32) leads to immediate loss of motivation.

33) the provision of the right tools is therefore a very powerful way of supporting an individual in his or her leadership role.

management approach. On the Special Engineering Programme run by the Department of M&ES, management based on negotiation of this type is encouraged through the 'tasks' course (see section 9.4.1).

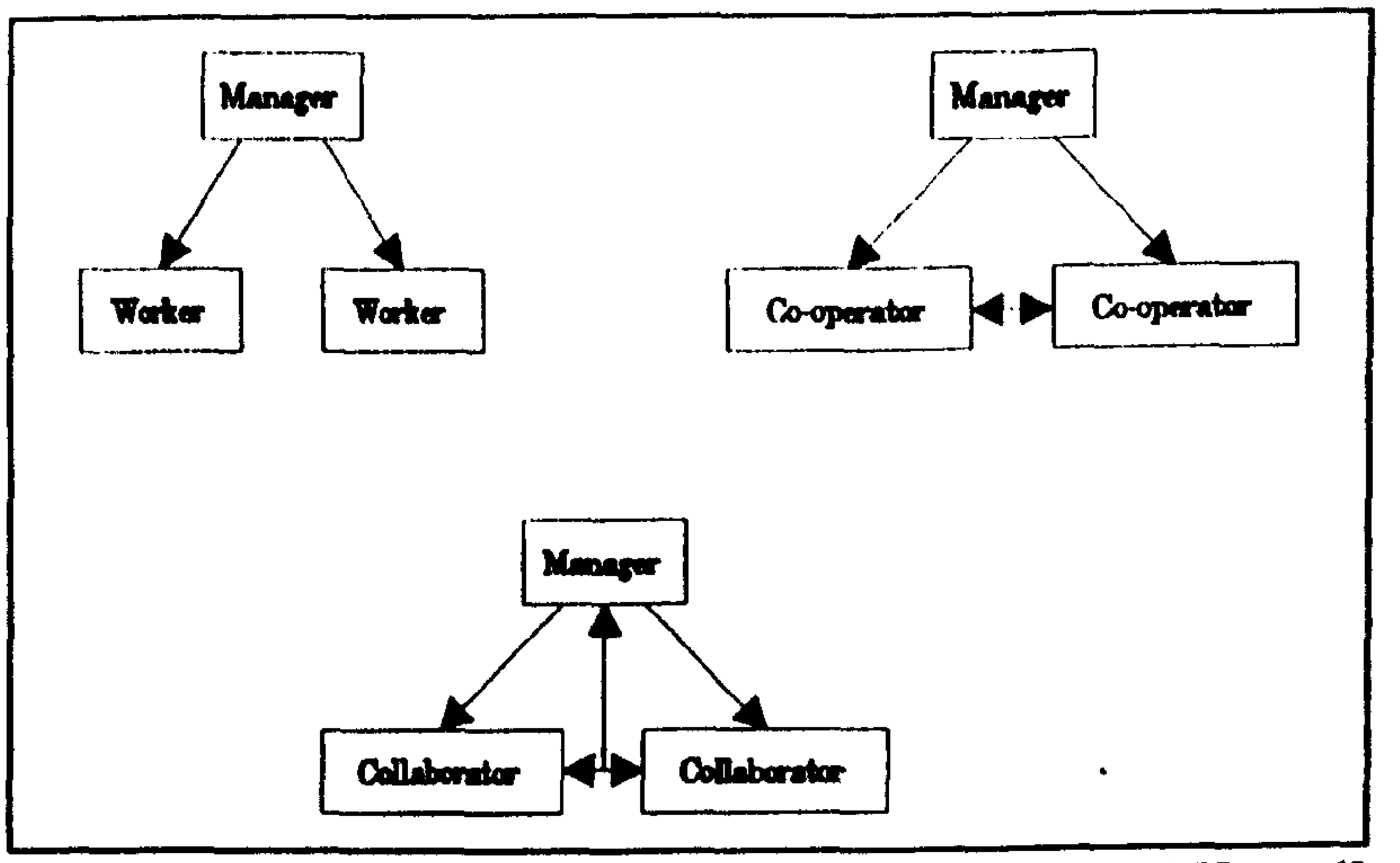

Figure 5 Models of Leadership [after Gregor and Hansel]

Directive leadership needs clear demarcation of tasks; results must be controllable and, if possible, also the process; the task structure and task interactions must be transparent; and external interactions must not be too intensive to prevent confusion of roles and lines of command. The 'boss' must know at least as much as the best of the workers[34]. It is adapted to the patterns of responsibility inherent in line management.

Interactive leadership is unavoidable in situations where a manager's knowledge and faculties are inferior to or different[35] from those of staff. The leader has to create a client centred and group work oriented culture based on consensus and must forge multiple perspectives into a single vision for the group or team. Creating and maintaining motivation is allied to the need for using team members according to their skills - the manager or leader assumes the role of coach and adviser.

Neither directive nor interactive leadership ever exist in a pure form: the way in which the two are mixed depends on the situation, which can exhibit aspects of line management and project management and on the type of authority or power conferred on the leader by the organisation and the members of the workforce. The nature of the CIM course tended to favour a real life approach with elements of directive intervention.

The following, more detailed, considerations apply to non-hierarchically structured groups, although some of the observations are relevant to groups of any type.

3.4 Defining an Optimal Choice of Team Size

At a very fundamental level, team size is an economic question. Too small a group will deliver results proportionately smaller than the reduction in resources while too large a group will produce output whose quality is only marginally better than that of the optimum size group. Wilhelm Hill [1994] discusses this issue with reference to the size of boards of management of industrial companies but his reasoning is based on a more general theoretical and practical appreciation. He is drawing on the large body of results of empirical group research. His observations form the basis of the following paragraphs.

In departing from the optimum size of working groups the balance between the quality of performance and resource utilisation tends to deteriorate. In their EPC paper Holcombe and

34) for many authors [Cooley, Rosenbrock] the 'Meister' is the linchpin of German industry's success. He or she knows all there is to know and is better at all the tasks than all the subordinates: the concept of the directive leader personified.

35) the author has observed many times, particularly in the UK, how people with the necessary 'generic management abilities' but little domain specific expertise or experience are placed in positions requiring a directive management style. They tend to be ridiculed and ignored by their subaltern staff.

Lafferty [1993] argue that teams should number between four and five students because, in their own words, "fewer than that limits the scale of the projects that can be tackled and reduces the amount of group dynamics to a level where some of the main communications and management issues do not necessarily appear. Larger groups soon fall apart irretrievably." The case made by the two authors is reviewed in some more detail in section 11.5 of the dissertation. Broadly, the writer concurs with their estimate which is based on experience with group members which are new to each other. He feels though that slightly larger groups can work well if they are based on prior relationships.

3.5 Structuring Groups

While a group, as a collective entity, can delegate some responsibilities to its members and other groups, it retains responsibility for its own key tasks. In the case of management boards[36)] this would be the definition of strategy as well as acquisitions and mergers. In general, the group will retain responsibility for complex and poorly structured problems, often linked to other problems and problem areas. If neither the information requirements nor the options for solving the problem are very clear then groups tend to perform much better than individuals. Every single member of the group contributes his or her motives, attitudes, knowledge and capabilities thus enlarging the horizon of the group. Interaction uncovers errors, preconceptions and inaccurate assessments.

For a group to be successful in achieving its objectives it must be structured appropriately: based on their attitudes, knowledge and capabilities, its members must be in a position to analyse the problem(s) as individuals and to arrive at an informed opinion before contributing this to the group as either a suggestion or the critique of another member's suggestion. The more heterogenous and thus more complementary its composition, the better will be the performance of the group. The group structure must be open: differing views and opposing views must be accepted and should not be subjugated by pressure to conform. Every member must explicitly participate in taking the decision(s).

The ideal size of a hierarchically non-structured group is thus five to eight people, particularly if there is a need to secure commitment. A significantly smaller number endangers diversity (and thus complementarity) reducing the quality of decisions. A substantially increased group size prevents explicit position taking by each member due to time constraints. If such position taking is still deemed necessary, it will result in repetition and confirmatory statements. Individual opinions are no longer discussed in detail and members can safely neglect their duty of being informed with respect to every problem.

3.6 Conclusion

In engineering, the change from line management, as the preferred approach for organising research, design and production, to team oriented management, centred on projects, has led to more responsive structures with simplified communications which can be adapted to changing needs with relative ease. However, the demands on engineers faced with the new management roles are substantial. They require new skills to deal with the organisational aspects and handle the opportunities offered by technical developments. The role of senior management has also become more complex since the size and composition of project teams has a significant impact on their success and, more importantly, since the provision of

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36) This discussion is of topical importance since the CIM company has its own board of management with both executive and non-executive members. Its effectiveness will be assessed in section 17.4.5

management information is no longer an automatic hierarchical process. The distribution of power and authority must be analysed and redefined as indicated in the third row of Figure 1.

The education and training of engineers must take into account the new demands to a limited extent. While it would be neither desirable nor effective to change the complete pattern of the process of engineering formation, the integration of an element of team based project work may provide the opportunity for students to acquire some of the competencies applicable to advanced manufacturing environments. Before discussing the educational issues it may be appropriate to investigate the role definition of engineers.

"My own conclusion is that engineering is an art rather than a science and by saying this I imply a higher, not a lower status." H.H. Rosenbrock

4.1 The 'Professional Engineer': Roles and Characteristics

The Oxford dictionary specifically lists the meanings of the word 'engineer' as "maker of engines" and "one who works in a branch of engineering, esp. as a qualified professional". What is interesting about these definitions is that they both hinge on the activity rather than the personal qualities of the individual and that no background information is given. It is thus necessary to derive, for the purpose of this thesis, definitions of the engineer which go beyond the choices given by the dictionary. Opinion on the characteristics of engineers and on what makes an engineer a good engineer has developed over the 200 to 250 years since the emergence of the disciplines of civil, mining and mechanical engineering[37].

Before attempting some modern definitions of the term engineer it may be useful to undertake a historic excursion, concentrating on Britain, where engineering found its most vital expression, and France, where it found its codification and strongest recognition.

4.2 Facets contributing Definitions[38]

4.2.1 The Early History of Engineering

Work we would describe today as engineering existed from the earliest of times, but it was invariably ascribed to craftspeople or builders, from the invention of the throwing wheel to Archimedes, from the Roman builders of aqueducts to shipwrights, to the master-builders of the great cathedrals. Filippo Brunelleschi (1377-1446) and Michelangelo Buonarotti[39] (1475-1564) deserve a mention, the former because he scandalised his contemporaries by building the giant cupola of the Duomo in Florence without a supporting framework, made of wood, as was the convention at the time[40]. On the basis of his erudition and wide range of interests Brunelleschi must have been the renaissance engineer incarnate (see also section 5.1). Leonardo da Vinci, as a matter of course, should be mentioned too, but his achievements (and his plagiarising of the ideas of the 12th Century) would fill a book... While the great architects had a high profile, there was little awareness of the future importance of the role of people like the eminent Gutenberg, "the prototype of the entrepreneurial and innovating engineer" [Noblet, 1984], who appeared on the scene as early as the 15th century.

The job-title 'engineer' is old. In the 2nd century A.D. the word 'ingenieurs' was used by Pliny the Younger [book 10, letter 40] although he referred to it as a vernacular expression. In the 11th and 12th centuries it appeared in the form 'engegneres' and referred to the designers of war machines. The first 'officially designated' engineer was English, "Waldivius

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37) although the author has refrained from making a clear statement on whether he prefers the French approach (on which were modelled the German, Austrian and Swiss systems) or the British approach, a bias towards the former should be discernible. However, in either case the historic development has led to situations which have both positive and negative aspects. The two resulting systems are briefly compared in section 4.4.3.

38) the definitions appearing below have been written by the author in an attempt to crystallise the results of a discourse.

39) in his capacity of architect of the cupola of the Duomo San Pietro in Rome.

40) Brunelleschi used rows of bricks which were tapered slightly inwards so that each row would offer to the next the surface of an inverted conical ring. The bricks were arranged in a fishbone pattern to provide spiral stiffening. Since the cupola had both an inner and an outer skin, linked by a honeycomb-like, structure he achieved great strength and a low mass. Not only was he a great technical innovator, he was also the first manager to apply the Taylorist principle of minutely instructing unqualified workers whom he used to replace his sacked skilled workers. The division between conceptual and practical work, not familiar to the medieval architect-engineer had thus been established, made possible by the discovery of the 'perspectiva artificialis'. Poitou [1984] is well worth reading in this context.

Ingeniator", King William I's Royal consulting engineer, advising on the state of the fortifications. The first managing engineer, "Magister Ingeniator", was English too, a monk who was overseeing a group of what must have been the first 'technician engineers', each in charge of a specific aspect of a big building project. The French, however, were not far behind with the creation of the "Corps du génie" in the late 13th and early 14th century [Isnard, 1984]. For some time to come, the title of Engineer was to remain in the preserve of the military. Nevertheless the knowledge required was clearly spelt out and included mathematics and geometry at an advanced level.

An early definition could have been phrased thus:

> the engineer is a man who designs and operates war machines, a task for which he or she uses knowledge of mathematics and geometry combining scientific methods with a natural curiosity and ingenuity.

Clearly, this is not the positive image of the engineer which today's professional engineering groups would like to foster although many of the great advance in engineering of today have been spawned by the demands of the 'defence' sector.

4.2.2 Modern Times and Recognition

In France, the meaning of the word 'ingénieur' started to change around the year 1600 [Vérin, 1984] with the establishment of the 'Corps des Ingénieurs des Ponts et Chaussées', such that Furetière could say in 1727 "Se dit aussi par rapport à l'architecture civile, d'un homme, qui par les machines qu'il invente augmente les forces mouvantes, autant pour traîner et enlever les fardeaux, que pour conduire et élever les eaux"[41]. Diderot [1772] could refer to a third (non-military) class of engineers who 'improved the great roads, built bridges, beautified streets and repaired the canals'. Diderot and Furetière both had observed, at the beginning of the 18th century, the emergence of the criteria for judging the modern engineer which applied to France as well as England: timeliness, soundness and economic production [Vérin, 1984].

In as far as its formal recognition was concerned, the transformation from the Royal Engineers, Ingénieur de l'Armement and the Ingénieur-Architecte to the civil(ian) engineer had to wait until the late 18th century, the time of the invention of the steam pumping engine in Britain and the establishment of the Corps des Mines in France, an élite body of, originally, 57 engineers charged with supervising the mining industry. Interestingly, in England the early professional engineers were described as 'mechanics' and were usually recruited from the ranks of millwrights. This was not meant as a derogatory term but was praise in that it signified that they understood the complexity of mechanical systems (the word mécanicien in French was even modelled on mathématicien, that is, a true scientist). Of course, schools of engineering existed only in a moral sense: most 'graduates' were practitioners who had learnt their trade from their employer, see Figure 6. Only the two Brunels were exceptions to the rule - but Brunel Senior was of French origin and had trained in France [Poitou, 1984].

In France, the large scale breakthrough for the profession of ingénieur came as late as the beginning of the 19th century when the first purpose-educated engineers shaped the second phase of the industrial revolution. This process was started by Napoleon with the creation of the École Polytechnique in 1794 which was allowed to recruit a small number of students

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41) this passage translates as: "In the context of non military architecture the term 'ingénieur' refers to a person who, by the means of the machines he (or she) invents, amplifies forces both to lift heavy loads and to transfer and raise quantities of water."

destined for non-military careers [Noblet et al., 1984].

In Britain the establishment of engineering as a codified profession with its own high calibre training had to wait even longer, until the end of the 19th century [Guagnini, 1984]. At first, until about 1880, professional engineers in England were trained at night school, e.g., the Manchester Technical School (now UMIST), whereas scientists were educated at University - even though Owens College in Manchester (now Manchester Victoria University) had as its mission the support of local industry.

Factory owners and managers were at that time still suspicious of highly educated engineers and preferred to train well qualified skilled people so that they could take on more complex tasks, such as maintaining and improving machines, in particular the big steam engines whose failure would paralyse the whole mill. The attitude towards engineers in Britain is to this day influenced by this early mistrust of professionalism.

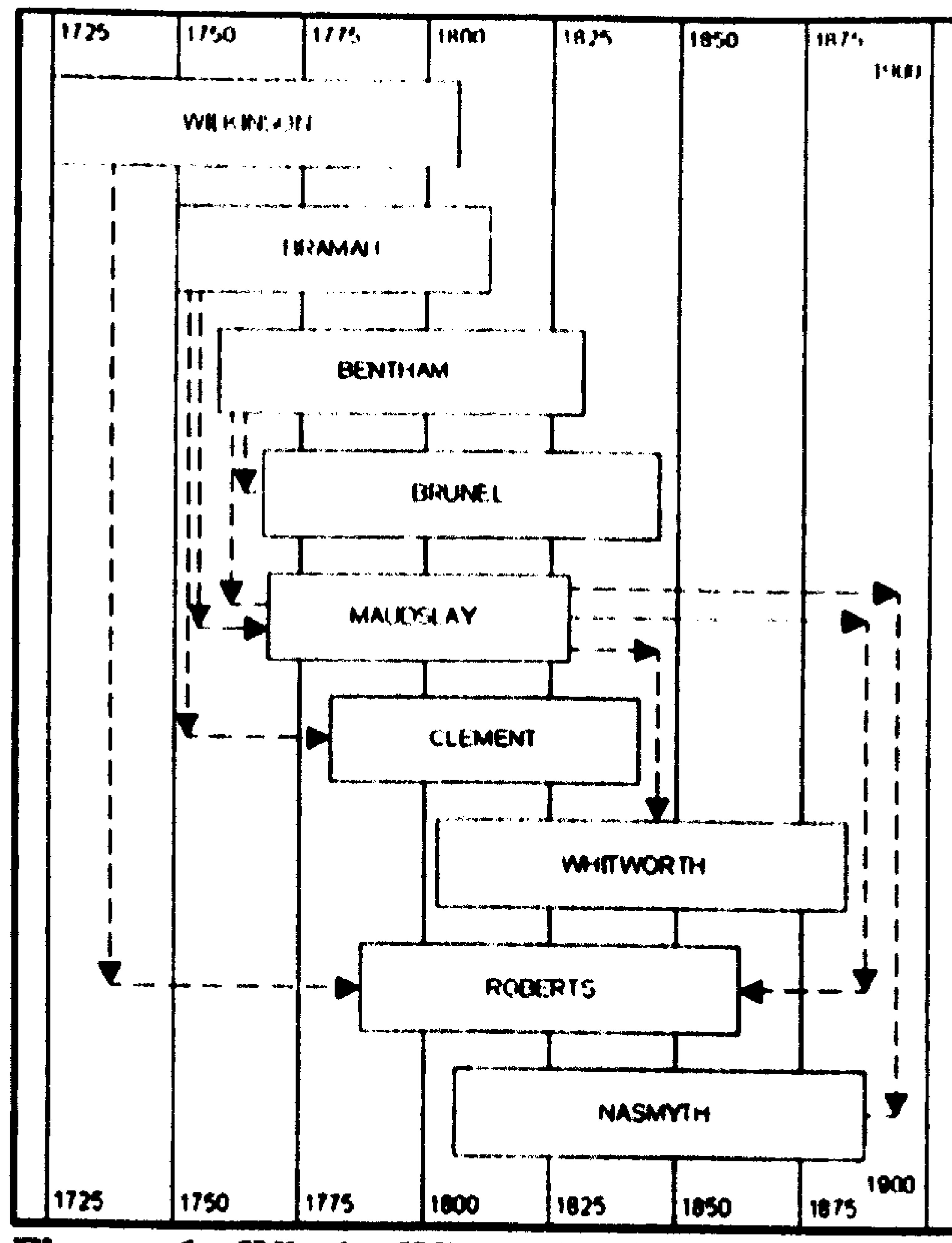

Figure 6 Who's Who: the 'School' of the Great English Engineers

Since the beginning of the 20th century 'engineers' have been accepted as equal partners of the scientist and, subsequently, their role has expanded, to include areas such as cybernetics and ecotechnology. However, nothing changes and genetic engineering (carried out by biochemists and biologists) attracts some of the opprobrium which was attached to the word ingenium in medieval times...

Outside Britain engineers were the heroes of the 19th and of the 20th centuries even though authors like Alain and Phillippe. d'Iribarne [d'Iribarne, 1987] have detected great differences between the status and background of engineers in France, Germany, the USA and Japan. Names like Eifel, Edison, Riggenbach, Picard, Giesl, Siemens, Tupolev and Marconi spring to mind. This was true right up to the early 1970s when the prestige of engineers came to be questioned as a result of the more and more apparent collapse of the world's ecology, for which they were held to be partly responsible. A "heroic" definition in this context would have been:

> the engineer is the person who can solve any technical problem, no matter what it is and no matter how difficult it might be.

English literature does not feature many engineer heroes, with the exception of hagiographies of the 19th century engineers and of authors like Neville Shute [1954], who related his own experience as a site engineer involved in airship development.

4.2.3 A 'European' Definition

For the purpose of this thesis the definition of the engineer will be crafted as a composite of the British Chartered Engineer, the French 'ingénieur diplômé' and the German 'Diplomingenieur'. One of the published definitions we find is "An *ingénieur* is defined as an engineer who uses creative ability over a wide range of problem-solving situations, particularly at a conceptual level" [Macleod, 1992]. This definition may well be applicable in some circumstances. In its generality though it does not help us distinguish the 'modern' engineer from the 'historic' engineer, especially so since it uses the word 'engineer' as part of the definition! It is, as a matter of fact, a carbon copy of the definition of the French engineer, as put forward by the d'Iribarnes [1987], a conceptual designer who sets out to make the most "beautiful technical object", regardless of cost or function. According to the same authors, in Germany and Holland the status of empirical knowledge, of technological and administrative work is very different from the situation in France. German engineers tend to be less ambitious in their use of automation but implement more reliable and cost effective automated systems.

Three terms might be of assistance in finding a more up-to-date definition, all originating from the quality debate of the late 1980s and going beyond the 'timeliness, soundness and economic production', quoted above in section 4.2.2. They are: predictability, reliability and repeatability. The difference between craft engineers who were, in essence, experimenting on the basis of experience, and what we might call professional engineers can be defined by the results of their activities.

A modern engineering product, created as the result of an engineering project or as the output of an industrial process must be predictable in terms of performance, time of delivery and cost. It must be reliable and safe. If it is one of many products to an identical specification then it also needs to be repeatable in terms of functionality, performance and appearance. In order to achieve such an end-result the engineer must use a scientific approach. Since her or his work is normally undertaken in a commercial environment there is also a need for an economic perspective. A tentative formal definition for the purpose of this discussion could thus be:

> an engineer is a professional person who uses knowledge, conceptual and creative ability to solve, subject to time constraints, the problems involved in developing, producing and maintaining goods or services which perform predictably and reliably in line with the specification agreed with a customer while working within clear financial limits.

The earliest engineers satisfying this definition, Watt, Stephenson and Whitworth (inventor of the standard screw thread), were practical people who could identify problems which were amenable to solution with the available technologies or further developments thereof. An example of this was Brunel's realisation that future marine transport needs could only be satisfied by the construction of steel hulled ships. In the view of one of the most important British historians the engineers "were better paid than their fellow-workmen, they were on the average more intelligent, and they took the lead in educational movements ... They were in the forefront of progress and invention..." [Trevelyan, 1942]. Times have changed: some of today's engineers seem to feel that they have to be given a task which they can solve without looking left or right, simply using the tools and methods suggested by their leaders or the company's project handbook [Bisang, 1994; Willi, 1994]. This is a description of passable technicians, very useful people, but not that of engineers. Engineers should not be blamed for this attitude though: it is a consequence of the much greater pressures and fears resulting from legal requirements (e.g., product liability) and companies' promotion rules.

4.2.4 A Role and Function based Definition

Engineers fulfil a range of functions and roles, related to their tasks, in each phase of their career, ranging from scientific inquiry through to negotiation with members of the workforce and with senior management and investors. Before we can discuss these and the mixture of qualities required for successful performance we need to provide a definition of the terms 'task', 'function' and 'role' for the purpose of this dissertation, since the dictionary definitions are circular!

task: job of work with a beginning and an end and with a defined set of objectives

function: duty to perform a set of similar tasks or a range of tasks requiring similar activities and capabilities for their completion

role: group of functions and behaviours required for satisfactory execution of task(s), based on capabilities.

Each professional function demands a different set of qualities, faculties and knowledge[42)] of the capable engineer. In the past, the pattern of work tended to vary slowly over the professional life of an engineer, but today the mix of these functions and thus the role often changes dramatically between the early and later stages of an engineer's career [EPC 1, 1989; EPC 3, 1991; EPC 5, 1992; EPC 6, 1993]. In most cases though a number of common characteristics determining the set of qualities and faculties can be identified.

Position of Engineer > Project Stage	Project Engineer (Junior Engineer)	Project Manager (Senior Engineer)	Engineering Manager
Problem Identification	No Role	Minor Role	Key Role
Problem Analysis	Minor Role	Key Role	Major Role
Project Definition	Minor Role	Key Role	Major Role
Project Specification	Major Role	Key Role	Minor Role
Design Process	Key Role	Major Role	Supervision
Process Development	Key Role	Major Role	Supervision
Production	Key Role	Minor Role	No Role
Improvement	Major role	Major Role	Supervision
Project Review	Minor Role	Major Role	Key Role

Table 2 Engineering Roles in Projects

One of the important transformations taking place in industry and administration, in both the private and public sectors of the economy, has been described in chapter 3: it concerns the change from the use of line management to control the activities of groups of people at all organisational levels, to the adoption of project management approaches for supporting teams involved in 'change processes' or charged with duties expected to be of limited duration [Gregor, 1993].

In defining an engineer on the basis of the function oriented powers or capabilities required, we can show in Table 2 that engineers involved in some or all of the stages of projects are faced with a wide range of job-functions in performing their roles. The table also indicates that the functions to be satisfied by the engineers involved depend on their hierarchical role. The choice of hierarchical descriptions used in the table is more or less arbitrary[43)]. To be

42) see chapter 5.5 and the glossary for explanations of the terms 'quality', 'faculty' and 'knowledge'.

43) Macleod provides such a classification in his [1992(1)] paper, but based on the vocational levels of Graduate, Chartered and Fellow (member of an engineering institution).

successful, engineers require natural or personal qualities, faculties and knowledge[44] acquired through education and training:

> an engineer is a person who is able to perform competently all the functions involved in project work in the domains of fundamental research, process research and development, product design and manufacture, service design and delivery, moving between technical and managerial roles and using either a concurrent or sequential approach to the scheduling of tasks, or a mixture of the two. He or she is able to develop professionally and socially in the course of an engineering career.

According to Macleod [1992] there are three components of competence which give an engineer the ability to work within and to cope with such a demanding job definition: Cognis, Technis and Intuis. These are discussed in some detail in chapter 5, suffice it to mention here that they are all ways of dealing with knowledge. Although Macleod does not specifically mention this, the engineer must also be able to supervise and manage other people. The issues of abilities, skill and knowledge will also be discussed in section 5.5 while some of the knowledge and powers required for successful project work in industry will reappear in section 8.1.1, in the context of individual study and design projects.

4.2.5 An Education based Definition of Engineers

Sir Kenneth Corfield, also quoted in section 2.5.1 and elsewhere, wrote in 1983 that the making of an engineer is foremost the making of a man or woman: "How can technology, management and finance find a common language in a society in which they scarcely have a common meeting ground?" "The critical decisions for Britain in taking stock of the technology revolution are in education and in investment."

The Engineering Professors' Conference [EPC 3, 1991] expect that the (academic) education of the engineer of the future will lie somewhere between the extremes of:

(A) graduates who are well grounded in basic engineering skills and concepts, but who may require further education and training before they can apply themselves to any particular engineering task;

(B) graduates who are highly specialised and prepared for particular specialist jobs in engineering with only a little further training.

While most 'standard' engineering courses are currently placed somewhere between the two extremes it is difficult to define exactly the position of sandwich programmes in these terms. 'Thin sandwich' programmes in particular provide a broad base of engineering knowledge and understanding combined with practical experience and some substantial specialist skills. By sharing the effort and cost of sandwich students' education industry obtains the best of both worlds... The stated longer term objective of the EPC is the development of four year MEng courses to cater for 'A-grade' engineers. This is also an objective of the Engineering Council whose policy paper [1994] postulates that the award of chartered status for engineers should be dependent on education to MSc level or equivalent. For a long time there have been moves in Britain to award the title and status of ingénieur, or professional engineer, only to those people having studied at a university or a comparable institution. Although the writer does not agree with this approach he would put forward the following education oriented definition of the engineer:

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44) in line with the definitions to be found in section 5.5.2. The personal qualities mentioned here are sometimes referred to as inherent qualities. There is a debate of whether they are amenable to modification through education and training.

an engineer is a professional person with a university education who has a broad base of knowledge in mathematics, the different branches of physics (mechanics, electricity, waves and radiation), in chemistry, as well as specialist knowledge in one or several domains of engineering and who has developed the qualities to use and apply this knowledge in a responsible manner.

Even at a superficial level we find a great variety of ways in which we can define the role and characteristics of an engineer although it is interesting to realise that there is little conflict between these.

4.2.6 An Attempt at a Formal Definition

Grouping many of the elements discussed, we can try to derive a formal definition to capture the essence of the engineer.

> Professional engineers are people, aware of their history, who are able to solve technical and sociotechnical problems either by themselves or in teams within clear financial and temporal constraints while acting in a responsible, sound and ethical manner, developed as the result of a course of study at a university or through another recognised development programme, drawing on a reliable knowledge base of both generalist and specialist information.

An awareness of the history of the profession and of the effect this has had on present patterns of thought and methods of working is essential if engineers are to be creative, effective and responsible, yet weary of repeating the mistakes of the past. The other criteria listed refer more closely to the preceding discussion and are therefore not mentioned again. As a matter of course, even this definition is only one of several tentative steps towards defining the goals of an engineering education.

4.3 Defining the 'Good Engineer'

What now is the difference between an engineer and a good engineer? At the most simplistic level it would be possible to state that a good engineer is better at dealing with more of the functional responsibilities than an average engineer, making fewer mistakes. For the engineering institutions a good engineer is one who satisfies the conditions for becoming a chartered engineer, that is, a clearly defined educational background, experience and proof of responsible work as well as the sponsorship by existing members. The working group of the Engineering Professors' Council believes:

> "that professional engineers should be equipped to deal with new and challenging problems which demand insight and understanding. This creative ability is at the heart of professional engineering capability. This is why we emphasise understanding and fundamental principles..." [EPC 3, 1991]

It would also be possible and appropriate to define the good engineer by his or her scope, that is, the ability to 'grow' from one role into another. Macleod's theory is that "most top *ingénieurs*[20)] had the fortune to be involved in activities during their formative years which stimulated their creative faculties. Such activities would seldom be associated with education..." [1992].

Ursprung[45], the director of the Swiss Science Agency, views engineers as people who do, realise and implement instead of being concerned with understanding and explaining, the approach taken by the sciences and humanities. Society expects engineers to solve problems which extend far beyond their conventional tasks. A central task of engineers is that of technology assessment - which they can only do well if they have adopted some of the approaches used in the humanities and social sciences. [Ursprung, 1991]

Author	Tasks of Engineers	Approaches	Capabilities	Education
J. Bordogna [1993]	service to society applying intelligence and cognitive expertise analysis and integration	scientific liberal environmental	multi-disciplined functionally literate proactive leadership	integrate curricula across years, separate research and practice orientation
F.D. Brummett [1985]	concurrent engineering	change orientation	communication problem solving	multidisciplinary teaching
K. Corfield [1983]	wealth creation	liberal profession	parallel working in large teams	education is the key to the future
M. Finniston [1980, 85, 89]	manufacturing in Britain is wealth creation	good engineers are integration oriented people	multidisciplinary skills for automated design etc. used	education and training must become a continuous process
Gregor and Hansel [1993]	multi-dimensional management	change oriented	diagnostic and analytic, people skills	
R.H. Hayes [1984]	render the manufacturing function externally supportive, involved in whole product development process		awareness of company strategy, human resource management skills	entrepreneurial, reduce content
K. Hernaut [1993]	conception, design, realisation, diffusion and operation: innovation	holistic views required to cope with complexity	knowledge ability	
A. d'Iribarne [1990]	cooperation with the future users of systems			
R.E. Klein [1991]	team work	seek and confront truth	visual, geometrical reasoning, practical	open ended courses
I.A. Macleod [1992]	handling of different types of information		problem solving at conceptual level	
G. Morgunov	satisfaction of social needs	productive engineering activity	broad natural science, humanistic outlook on world, comprehensive system of knowledge	
J.F Shea [1985]	vision of what factories can become and zeal and knowledge to make it happen		data processing, employee utilisation, systems engineering	give universities opportunities for applied research, continuing educat'n
W. Skinner [1985]	attention to the demands of the market .		breadth of approach and conceptual skills	new curricula for engineers are essential
H. Ursprung [1991]	do, realise, implement technology transfer	analytic rational liberal	multi-dimensional problem solving, up to date knowledge	reduce undergraduate study time, postgraduate education should be industry based

Table 3 Prominent Views on Engineers

An overview of different authors' views is given in Table 3. Of particular interest are the strong emphases placed on team work, problem solving and change oriented skills.

45) although he does not expressly state this, Ursprung is discussing the education of engineers for the manufacturing industries of Switzerland.

4.3.1 Industrial Views of Engineers

The industrialist Hernaut [1993] demands that "young Ingenieurs ... must have high professional mobility and flexibility, i.e., the ability to adjust quickly to new problems ... that they are able to master efficiently the transition to workplace demands. This presupposes, however, that graduates have already been exposed to practice-oriented problems during their studies." He also requires young engineers to have a broad but relatively shallow spectrum of mathematical, scientific and technical knowledge, laying the foundation for subsequent professional mobility. Good engineers have the ability to acquire independently the additional knowledge they need for their jobs.

Corfield states clearly that not everything that characterises a good engineer can be taught: "Natural qualities also play their part and the character of a person, as well as his or her learning, will affect his or her career prospects." He also insists that the engineer should not be seen as a creator of knowledge but a creator of wealth [Corfield, 1983].

> Key features of the 'good engineer' are therefore the broad knowledge base; the ability to acquire in-depth knowledge independently and quickly; creativity; understanding concepts and the ability to apply these; the flexibility to adapt to changing roles; natural, but not necessarily innate qualities, such as leadership and communication skills; intuition for the needs of others and of the environment; a responsible and ethical attitude and principled stance.

Hernaut, the head of continuing technical education at Siemens AG, goes on to state that every engineering task requires a different combination of theoretical and practical approaches, that is, a different methodology. Individuals' aptitudes, inclinations, abilities and skills differ widely and engineers will therefore be suited to tasks corresponding to a particular domain of the continuum from the practical-concrete (manufacturing management) to the theoretical-abstract (research). The education of engineers must take into account these characteristics of people if it is to get the most from an individual.

4.3.2 The Good Manufacturing Engineer

When manufacturing (systems) engineering courses were first developed in the UK and USA in response to the perceived decay in the competitiveness of Western industry their creators had to identify what differentiated a manufacturing engineer from a production engineer, from an industrial engineer and from the physicist-cum-engineer who develops a novel process for the production of Large Scale Integrated (LSI) devices. The industrial engineer is principally concerned with ensuring that procedures are appropriate, that the workforce follows the instructions given and that it is properly utilised (the time study scenario). Normally, the tasks of the industrial engineer will be defined in close detail. The production engineer expects to receive the complete specification of a product (plans, materials, quality parameters) from the team(s) responsible for its design. He or she will be conversant with all the production processes available in the plant and with the logistics involved in outshopping goods on time, to the right quality and at the calculated cost. The physicist will drive the process development from the angle of capability, often regardless of cost: the process must be made capable of achieving particular tolerances and yields.

One of the key characteristics which differentiates good manufacturing engineers from physicists, from production and industrial engineers, should be a keen awareness of available technologies, company strategy, cost and profit[46]. The term 'awareness' reflects a somewhat more superficial knowledge backed up by the ability to handle details at a later stage. Rather than having to be told which method to use to produce an artefact, the manufacturing engineer is involved in the design and development process from the beginning and will be able to advise on modifications, the use of different materials and production processes to reduce production costs[47]. The scope of the manufacturing engineer extends beyond the company in that she or he will have the objective of making the manufacturing function externally supportive of company strategy [Hayes, 1984].

For Wickham Skinner manufacturing managers require breadth and conceptual skills because corporate attitudes at top levels often reflect technological illiteracy. He accuses the present curricula for both engineers and managers of not only failing to identify and solve these problems but of contributing to them [Skinner, 1985]. The issues have also been addressed in the Harvard Business Review (Post Industrial Manufacturing, November-December 1986): "the availability of Computer Integrated Systems and Flexible Manufacturing Systems leads to the need for:

- 'a sharp focus on intellectual assets as the basis for a company's distinctive competence...'
- 'a close attention to the market and to the special competence of manufacturing engineers.'"

The problem of the education of engineers for the manufacturing environment of the future has been raised by Joseph F. Shea of Raytheon Company, a defence contractor, in the following words: "In the short run, the obvious route is for industry to encourage changes in university curricula and to supplement those changes with applied research support related to the specifics of individual industries... The tougher question is how - and, frankly, whether - to teach manufacturing as a system. The traditional industrial engineering programs are not, in general, held in high esteem by either industrial or academic peer groups... The seeds of a manufacturing systems curriculum may lie in providing courses which apply the principles of data processing, information systems, data base feedback and control, employee utilization and motivation and systems engineering methodology to the management of a manufacturing system... some of it may be better learned if it is deferred to continuing education. At the least, the MSE student should take away a vision of what factories can become, some tools with which he or she can begin to contribute, and the zeal to make the vision a reality." [Shea, 1985]

4.4 The Teaching and Training of Good Engineers

4.4.1 History and Diversity

"Adult education received its first impetus from the Industrial Revolution in the desire of mechanics[48] for general scientific knowledge... From 1823 onwards mechanics' institutes, begun in Scotland by Dr. Birkbeck, spread through industrial England... from 800 to 900 clean respectable-looking mechanics paying most marked attention to a lecture on chemistry"

46) the reader will be able to appreciate later, in chapter 11, that the awareness of available technologies and strategy are of great importance on the CIM course while cost is addressed as far as possible through the process of acquiring new equipment and software for the installation. The issue of profit could only be considered properly in a context such as that given by the environment of the Mondragon Polytechnic in Northern Spain where students undertake commercial work as part of their education and training.

47) "A well known rule of thumb among Japanese companies is that once a product specification has been developed over 80% of costs are fixed." [Kato, 1993]

48) in the meaning explained in section 4.2.2.

[Trevelyan, 1942]. "Technical education emerged from the middle of the 19th century as a revolt against the use of genesis without analysis" [Mcleod, 1992(1)].

Environments for the successful acquisition of engineering knowledge and skill, the formation of good engineers, can be created in many different ways. They range from the early engineering apprenticeships of Watt's times to personal computer based learning systems. However, depending on the aspect of the engineer's role which is to be developed, e.g., analytical ability or synthetic thought, one environment may prove more suitable than another. Each environment though requires its own range of methods for teaching and forming the aspiring engineer. Apprenticeships would use learning by imitation and correction, supported by much practice, while the most modern systems might use virtual reality to let the learner 'experience' and resolve problem situations.

A key aspect of designing learning environments has always been the question of reality, of providing a situation for the advanced learner which is as close to real life[49)] as possible while the actions of the learner must endanger neither people nor systems, directly or indirectly. There is usually a continuum between the two extremes of this dichotomy but the choice of solution is also strongly influenced by cost considerations[50)].

4.4.2 The Academic Route to Engineering

For the purpose of this thesis it will be necessary to focus on the academic route to the profession of engineer and, in particular, the models existing in the Department of Manufacturing and Engineering Systems (M&ES). However, it may be useful to illustrate some aspects of the wider debate on the best approach to the university education of engineers which has been current since the 1970s. In doing this we should be mindful of the words of Corfield in which he paints a very positive image of the rounded engineer:

"the treatment of engineering as a liberal profession and the claim that engineering offers, with the humanities, an excellent basis for living one's life as contrasted with earning one's living may fall less easily on the ear, lie less easily on the mind" and "... engineering as a way of life and whose values ... are contributing to the creation of wealth from which, in turn, the other values, so highly prized in older societies, are themselves derived." ... "let me, therefore, make quite clear that education is the key to future wealth creation and that the world belongs to those who understand this and act upon it." [Corfield, 1983]

In his paper 'The Bicycle Project Approach' [Klein, 1991] Klein states "A vital part of the university experience is confronting with truth and, moreover, the process of seeking truth. As such a central reason for the existence of a university is to promote the search for truth and teaching the students the critical skills and methods needed to carry out this process ... a significant number of students in engineering curricula arrive with deficiencies in visual, practical and geometric reasoning. Moreover there is little to suggest that textbook and lecture mode course exposure, being inherently sequential, serial and memorization oriented, provide any needed redemptive values to address these deficiencies" ... "it is hard to motivate any student to learn anything if the student believes:

- that the answer is known and/or is simple and needs only to be memorized;

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49) this is of major importance to the writer and is discussed in section 11.4.5, with reference to the CIM Course.

50) the development of realistic simulators for the cabs of locomotives and heavy goods vehicles and for control systems of process and manufacturing plants has been a relatively recent phenomenon, dictated not by the high risk involved but by the much increased potential cost of an accident due to a wrong manipulation.

- that the student can spend an 'all nighter' just prior to an exam or report and 'get their usual A'; and
- that they can dry lab or otherwise bluff their way to a grade based on the usual university propensity to give generous partial credit for even wrong answers."

He translates these observations into the design of an open ended course where students work in groups on a bicycle related design problem concurrent with the lecture course. His observation "the usual trend reveals academically superior students with good grade averages based upon memorization to be uncomfortable and insecure, whereas a considerable fraction of the generally more average students ... come into their own and excel because they have a meaningful and concrete challenge." It is perhaps worth noting that two of the three students in Klein's best group were co-op or sandwich students.

Klein does not explicitly discuss the problem of how to deal with very low achieving students although it is possible to infer from his comments that he worked with mixed ability groups: teams entirely composed of poor students tended to produce repetitive work, usually based on well known concepts while intelligent groups would come up with new ideas. He accepts this drawback of the approach. As will be shown later, with the CIM approach each student is involved in several different groups or teams such that she or he must work in an number of roles and functions.

Figure 7 is a slightly modified version of a qualification model for workers in advanced technology industries developed by A. Bitzer et al. at the Technical University of Aachen, FRG, in 1991. The approach is team oriented and is intended to design the work place concurrently with the workforce qualification process. This model could be adapted further to serve as a structure for both the initial education of engineers and their continuous professional development. It places much emphasis on a multi-facet, multi-stage process allowing members of a workforce to understand the changes and to adapt their skill and attitudes as the transformations occur. It could also be used to integrate engineers formally into the work design process for other jobs in a computing intensive environment.

It is at this point perhaps sensible to review (briefly) the approaches used in different European countries to satisfy the wide range of requirements just stated.

4.4.3 Patterns of Engineering Education in Europe

In Europe there exist four fundamentally different approaches to engineering education: the Anglo-Saxon model, the French model and the German model with its Swiss variant[51)]. The four basic approaches are depicted and compared schematically in Figure 8 (with notes listed in Text Box 1), the time scale being given for men. The only difference for women is in the absence of periods of military service. The figure reveals the existence in each model of a second strand of engineering education which either leads to a sub-degree qualification (France, United Kingdom and, at present, Switzerland) or a more practically oriented engineering diploma (Germany and, in future, Switzerland). It must be emphasised that the diagram can only represent standard or average programmes of study.

The main differences can be identified clearly in the diagram: most obvious are the wide disparity in course durations, the different methods for controlling "student quality"[52)], the decreed comparability levels and the variety in postgraduate paths.

51) Austria uses the German model, although with shorter study times, and (Northern) Italy follows the Swiss model but with a slightly extended period of study.

52) which can happen at or before the point of access to higher education or during the first or second year thereof.

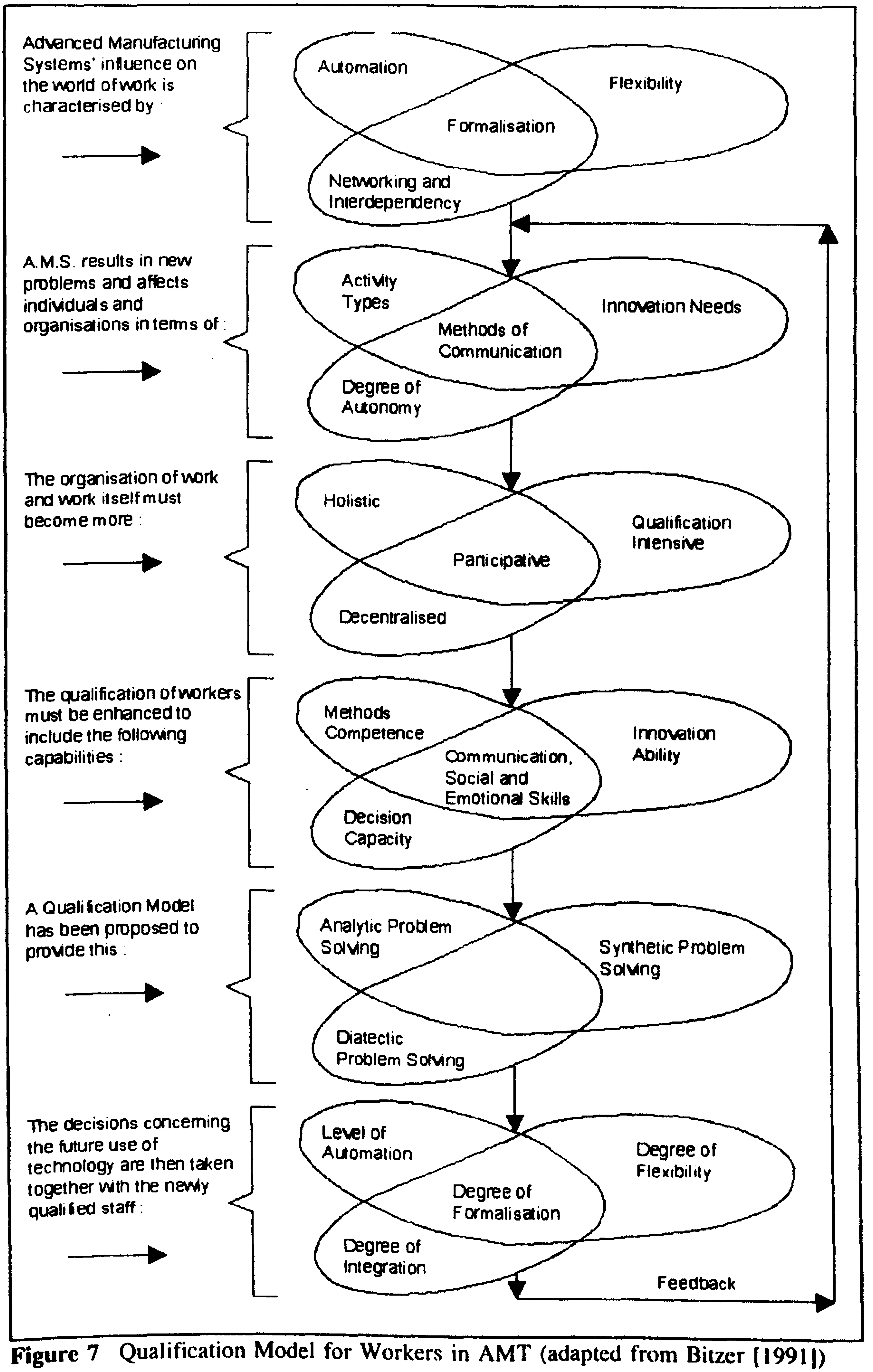

Figure 7 Qualification Model for Workers in AMT (adapted from Bitzer [1991])

Of particular interest for the present is, as a matter of course, the pattern shown for the

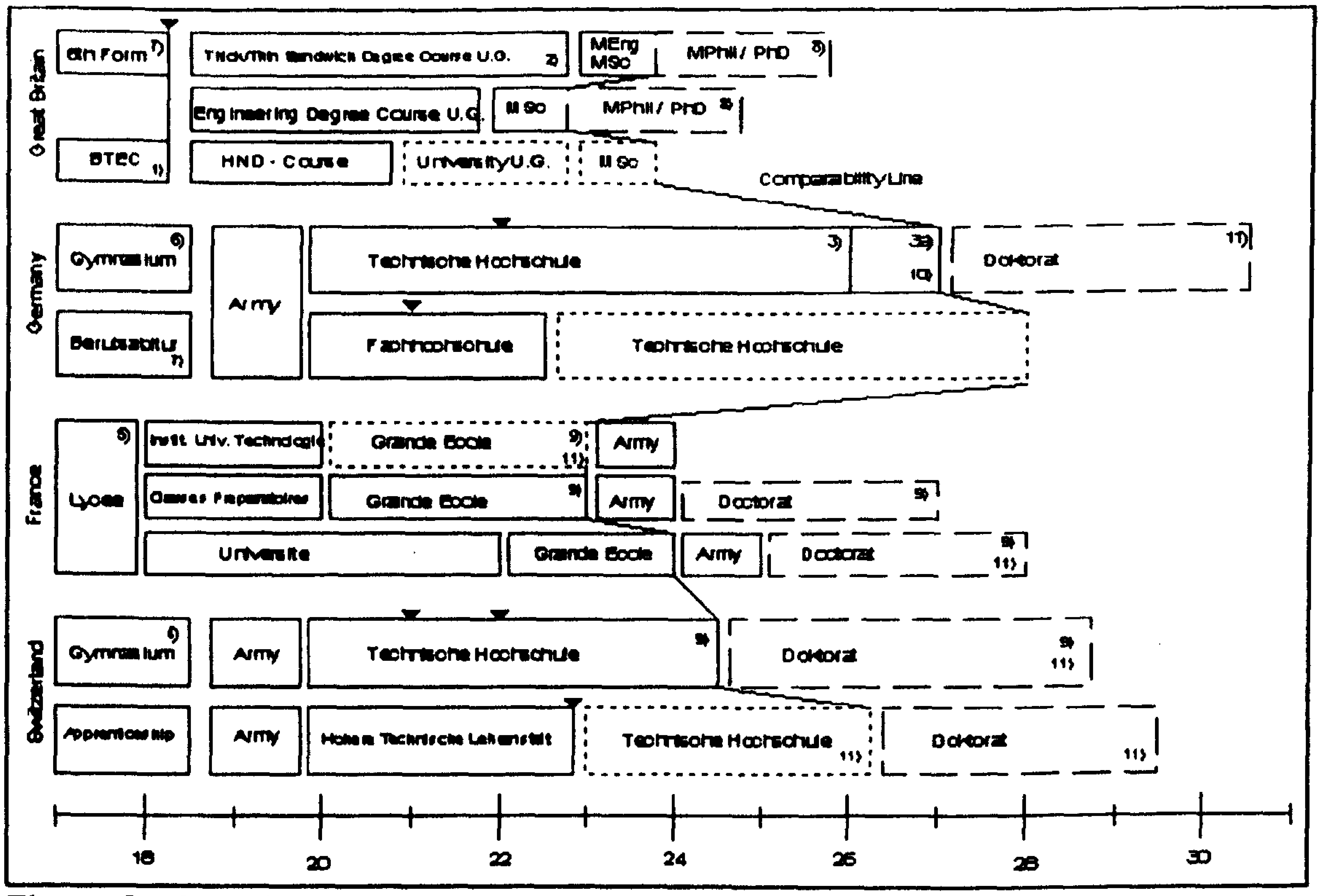

Figure 8 Overview of the Main European Patterns of Engineering Education

1)	Many students complete this one year behind their cohort.
2)	Courses incorporating industrial training periods.
3)	Minimal duration.
3a)	Mean duration.
4)	Matura (university access certificate).
5)	Baccalauréat (university access certificate).
6)	Abitur (university access certificate).
7)	A-Levels and International Baccalaureate.
8)	Standard duration.
9)	May be reduced by one year if military service is integrated.
10)	May vary by -1 to +3 years.
11)	Very rare transition.
▾	Elimination points (interim exams etc).

In France, Germany and Switzerland women can finish their studies one year earlier than men since they are not subject to compulsory national (army) service.

Text Box 1 Notes for Figure 8.

United Kingdom which differs from all other models both in terms of the range of higher degrees and the attempt to provide a formalised quality grading at degree level which is intended as a method for selecting engineers suited to work in research and product or systems development, that is, in innovation[53]. While it could be assumed, based on this diagram, that UK graduates would tend to be less mature than their peers from other cultures, there are two factors which mitigate against this: most UK students leave home at eighteen years of age and thus have to cope with independence much earlier. Students on so-called "thin sandwich" and "thick sandwich" courses (admittedly only about 5% of all engineering students) spend between twelve and eighteen months in industry before graduating - a formative experience!

The writer has accumulated most of his relevant experience teaching students on thin sandwich type degree courses but feels competent to make a reasonably accurate assessment of comparative maturity. In his view, the line of academic comparability drawn in Figure 8, defined by institutions, indicates also an equivalence of maturity. In terms of specialist engin-

53) the number of graduates entering such professions is but a small proportion of the cohorts.

eering oriented qualities[54], faculties[54] and knowledge[54] UK students are also broadly comparable to their European peers since they start their engineering career, in effect, already at age sixteen as a consequence of the specialised narrow range of A-level subjects or the technical nature of a BTEC course. Some universities have chosen to offer enhanced degrees, that is, four year full-time programmes offering further specialisation and resulting in the award of a degree of Master of Engineering (MEng.).

The one domain which can be assumed to be less well developed in students following the UK pattern of education is the area of relations and links[54] which requires for its development much experience founded on 'real life' projects, undertaken as both individual and team work. This is perhaps the single most significant strength of the German Technische Hochschule system where most students carry out so-called "grosse Studienarbeiten" which involve them in the solving of real problems. In the UK this acquisition process relies on a period of "directed objective training" which takes place in industry, usually post graduation, and which culminates in "chartered engineering" status or, at the European level, Eur. Ing. status. For some graduates a university based MSc with a substantial project may well prove attractive, whereas for others industrial work, potentially leading to a Master of Technology (MTech) or, in some universities, Engineering (MEng), may be more attractive.

Unfortunately, many senior managers in industry are no longer willing or able to make the very substantial investment in training necessary for success. They find it difficult to quantify the cost of workplace based training and, more importantly, the benefits which can derive from such investments. A complaint which is heard frequently concerns the high cost of developing promising engineers who then move on to other jobs - what is, in reality, a two way traffic is often described as a great loss to one party. Both managers and government representatives are therefore asking universities to bridge the capability gap which could otherwise cause problems for industry. This observation was not one of the reasons for designing the CIM course as a deep learning (see section 5.8.1) experience but, in retrospect, it proved to be a step in the right direction.

Elsewhere in Europe, moves are also afoot to enhance engineering education. Ursprung [1991], for example, wants to shorten the study time and make problem solving the cornerstone of undergraduate engineering education in an interdisciplinary context. At postgraduate level he envisages a shorter doctoral programme which gives people research skills without turning them into researchers. In industry engineers would then be able to use these skills to solve multi-dimensional problems and to bring, even into small companies, the latest advances of science and technology. The Eng.D. programme offered by, amongst others, the Department of M&ES at Brunel University, is a high level postgraduate course which is industrially relevant. The doctoral programme of four years' duration consists of taught components and a number of projects of different size and scope. Another example is provided by the curriculum development efforts at École Centrale Lille where a staff group was set up to promote team and project based learning at this Grande École, thus fulfilling a pioneering role in French academe (see case study 13.4.4).

4.5 Professional Opinion on Engineering Education

4.5.1 J. Bordogna

J. Bordogna, head of the Directorate of Engineering of the USA National Science Foundation, quotes and paraphrases Benjamin Franklin thus: "... educating young people in the developing colonies of North America should include the teaching of *mechanicks ... to*

54) see section 5.5.2 for definitions.

be informed of the Principles of that Art by which weak Men perform such Wonders, Labour is saved, Manufactures expedited... He also urged that learning be pursued so as to balance useful knowledge with the liberal arts, and with the specific intent of serving mankind *the Aim and End of all Learning*" [Bordogna, 1993]. According to 18th century colonial belief, engineering was to include a blend of the arts, the creation of artefacts and systems in service to society, that is, a liberality in the undergraduate programs taken up again in the latter half of the 20th century.

"The traditional demands on manufacturing were to make a product well, quickly and inexpensively, while today we also insist on this being done safely and in an environmentally benign fashion. Today, engineers' decisions have to be value laden! The engineering process happens in an environment where scientific inquiry, engineering activity, available technology, economic context and public policy have to be integrated concurrently. The education of engineers must move from a 'bottom up' approach to a lateral depth approach where a number of areas are investigated in depth but where the connections between these are sought at the same time." [Bordogna, 1993]

Bordogna's summary shows, in the left column of Table 4, the features of most curricula developed as a result of the strong emphasis on the science base of engineering, curricula which have tended to exclude the elements listed on the right. In future, these must be included in the educational enterprise for intellectual and functional completeness. Lateral depth or functional literacy must be achieved for the whole of the table with emphases depending on the particular engineering discipline being studied. He draws the conclusion that curricula must be integrated across the years of study and that their focus must shift from content to a development of human resources and to a broader educational experience. Courses should develop the capabilities of integration, analysis, innovation and synthesis and contextual understanding.

Vertical (in-depth) thinking Develop Order Solve Problems Develop Ideas Understand Certainty	Lateral (functional) thinking Correlate Chaos Formulate Problems Implement Ideas Handle Ambiguity
Abstract Learning	Experiential Learning
Reductionism	Integration
Analysis	Synthesis
Research	Design/Process/Manufacture
Independence	Teamwork
Technology/Scientific Base	Societal Context
Engineering Science	Functional Core of Engineering

Table 4 Bordogna's Comparison of Engineering Approaches

Bordogna's views on the ways to achieve this are similar to those of Ursprung, that is, (1) an integrative program leading to a practice-oriented technology-based Master's degree; and (2) a research-oriented, discovery-based Doctoral degree. On the whole, Bordogna seems to be rather superficial in his approach, perhaps a function of the contribution expected from him in the publication quoted.

4.5.2 F.D. Brummett

Forrest D. Brummett of Detroit Diesel-Allison states: "Based on an education that provides the ability to adapt to changing requirements, both organizational and technological, manufacturing engineers of the future must seek change and be willing to learn throughout their 35-45 year working life. Skills of the twenty-first century factory professional must include communication and problem solving[55] as well as scientific technological grounding and superior personal skills for team problem identification and resolution... the profession of manufacturing engineering ... still differs from the established engineering disciplines, such as mechanical and electrical engineering, which are defined traditionally in terms of both educational degree and specific expertise."

"Manufacturing engineering is, in contrast, more defined by function and demands

Present Organisation: Off-line Management	Future Organisation: .Real-time Management
Manual Outdated policies, systems and procedures supplemented by informal organisation	Computer-aided systems CAD, CAM, FMS, text processing,electronic mail, data bases, etc., supported by flexible policies, systems, procedures
Divisive Overly divided into work tasks and between functions and layers	Integrative Integrating information network relying on some functional expertise, but in more open, cooperative context
Disengaging Hierarchical approach which narrows and restricts effective problem solving, causing people to retreat into own worlds	Interactive Interaction both internally and externally with vendor base and client system - internationally
Declarative Top-down commands with little listening or feedback	Interrogative Active use of "what if" scenarios, with heavy graphic support

Table 5 Preparing for the Factory of the Future (Modern Machine Shop, 1983)

multidisciplinary capabilities in mechanical, materials, industrial, and systems engineering. As the basic concepts of technology, applications, and management merge, the discipline of manufacturing engineering becomes better defined." He goes on to write: "Under the heading of 'concurrent engineering', manufacturing engineers work as a team to coordinate product design between the product engineer and the manufacturing support groups and to evaluate the feasibility and producibility of the product. Once the product has been reviewed and approved by each group, it is released to production. The team approach to solving manufacturing problems and planning manufacturing operations is widespread in industry today. To work well, team members must have well-developed interpersonal skills. The importance of these skills may increase with further integration of manufacturing operations."

"A manufacturing team will include many different titles, job descriptions, and technical backgrounds, depending on the industry. However, three general personnel categories make up most manufacturing teams: production personnel, technical personnel, and managers. Production personnel and technical personnel, designers, and managers are all required to understand the total system. Increased automation will affect manufacturing personnel at three levels of production: (1) the element level, which involves the process mechanization and the informational component, (2) the cell level, which is composed of a combination of

55) problem solving is a term used widely in the literature but is rarely defined. Sometimes it is equated with design, sometimes with creativity and innovation. Further discussion can be found in sections 5.7.2, 10 and Table 15.

automation elements, and (3) the plant level, which includes multiple cells. Computer-integrated manufacturing ties these levels together with common data bases." [Brummett, 1985]

Brummett's line of argument is founded on the juxtaposition of present and future as presented in Table 5, reproduced here, which he quotes from Modern Machine Shop, October 1983. The table is used to make a comparison between two different organisational environments: off-line management and real-time management. In the latter products are designed with careful consideration of cost and producibility and this requires the involvement of the entire manufacturing organisation, A project, the upgrading of an existing product, for example, can no longer be handled in self-contained stages (design, process engineering, work study, production...) but must be considered as a multidisciplinary integrated task. Brummett defined, as a matter of fact, what later became known as concurrent engineering.

4.6 Engineers and Education for Project Leadership

As discussed in some detail in section 4.2.4, many engineers have to take on project management roles early on in their careers. Gregor and Hansel [1993] have defined five dimensions of project management as illustrated in Figure 9. The dimensions place different demands on the manager and her or his education and training:

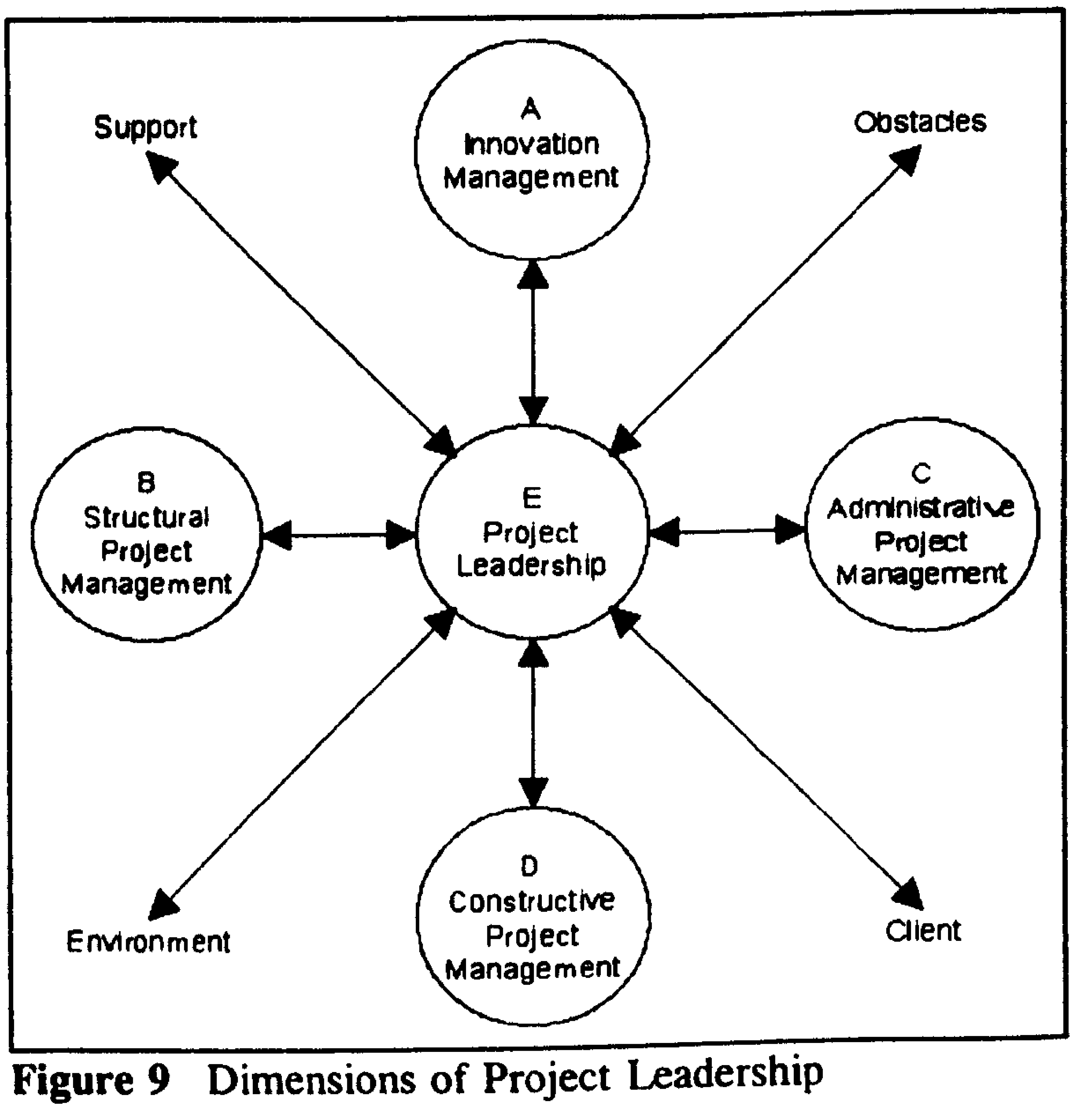

Figure 9 Dimensions of Project Leadership

(A) Managing Innovation: be aware of and able to manage change processes and their consequences for people. Managers must learn to cope with uncertainty, insecurity and resistance to change.

(B) Structural Project Management: managers must be able to develop and interpret project manuals and project tools, such as creativity enhancing methods.

(C) Administrative Project Management: handling and controlling resources (time, human, funds), estimating project stages and durations, negotiation with line management.

(D) Constructive Project Management: assuring the quality of both the process and the deliverables, as well as the latter's functionality. Negotiation of intermediate and final objectives with clients and the people affected by the process.

(E) Generic Project Management: managing people requires an awareness of such issues as power and authority, being able to assess one's own attitude to these and the influence exerted by others. The future managers must also gain an awareness of their own staying power.

The education and training process should help managers to cope with the sometimes conflicting demands resulting from working in all five dimensions concurrently. As a first step, still according to Gregor and Hansel, managers must learn to elaborate, together with top management, a diagnosis of the company (structure, culture and objectives) and of the project situated in its context. The second step is the creation of a vision or strategy for the company and the project. The third step consists in the definition of a path for implementing the vision. A university engineering education should not necessarily be designed to provide all the training needed to develop the ability to work in the above five dimensions but it should develop in students an awareness of the problems which they will encounter.

Drobek et al. [1994] have studied the performance of managers in a medium sized company and have developed a method for profiling the staff motivation aspects of the generic (project) leadership role, that is, dimension E from Figure 9. They assess each manager's capability on a number of subsidiary dimensions, some of which also relate to dimensions A-D of Gregor and Hansel, as shown in brackets in the following list.

Team Orientation	(A)
Capability in Managing Conflicts	
Ability to Criticise Constructively	(D)
Career Planning for Subordinates	(C)
Delegation Capability	(C)
Ability to Brave Challenges	(A)
Transparent Leadership	(E)
Ability to Empathise	(C)

The pattern emerging from the analysis of a manager's performance can be used to help her or him develop the areas where their leadership skills might be lacking. Drobek et al. perceive the integrating role of managers as the key element in successful team based work. The engineer-manager is no longer simply a technical expert who manages individuals one-to-one but a team promoter who is continuously being requalified.

4.7 Conclusion to the Role Definition of Engineers

In the discussion up to this point we have studied the environment in which engineers work and we have developed a range of definitions of the engineer's role in industry and society. We have also identified some of the demands which this places on engineering education. The education process should be designed to form engineers who have a broad knowledge base, the faculties to use this and the qualities to relate well to other people and to act ethically and responsibly.

Although the writer would have enjoyed the challenge of developing a complete engineering course satisfying these demands he was fortunate in working in a university department whose staff had managed to create such an environment and where one of the few elements lacking was a course which would pull together all the strands and which offered the students a final opportunity to test their performance in a situation as near to real life as possible, but with the benefit of tutorial support and without the risk of losing a job... The course concept was briefly outlined in section 2.7 while the following chapters provide some of the theoretical foundations for its development. In the following chapter we shall look in some detail at the issues determining the design of learning situations, an essential precursor to describing the CIM approach, a Practice Based Learning environment.

5 Knowledge and Theories of Learning

"The process as well as the context of formal education should be designed to prepare students to live mature, effective, adult lives." [Alschuler, 1970]

Only through poor usage has the word teaching come to mean those things teachers do while getting paid for being in a classroom [after Pittenger and Gooding, 1971]. This conventional image of teaching is not very old, dating back to the renaissance for children of the middle class and to the early 19th century for all children (the 'ragged schools' leading to universal instruction [Crystal, 1990]). Rather than being a 'broadcaster', the traditional view, a teacher must be a designer of effective learning situations taking account of students cognitive abilities and developmental stages. Wherever possible teachers should be 'narrowcasters', using the teaching and learning approach most suited to a particular situation and student. Tradition though can be very strong, especially so in the case of schooling since the pervasiveness of the experience in our society favours a virtually unchanging transfer of dogma from one generation to the next, often in cycles of fashion. While educational reformers battle to introduce more appropriate forms of interaction economic pressures continue to favour classroom based learning and schooling, in effect, the broadcasting of knowledge.

At the most basic level, university teachers of engineering could simply follow the EPC's approach which is described in detail in their publications [EPC 1, 3, 5, 6]. Unfortunately though there are no simple and conflict free definitions in the field of teaching and learning, even the word 'knowledge' is used at different levels of the discussion in different ways, depending on the context. In the present chapter the author discusses first this issue of knowledge from a philosophical point of view and then provides a framework of qualities, faculties and knowledge in which an engineer's, or indeed any human being's, problem solving ability can be analysed. This is followed by a section on learning theories and issues of practical implementation.

5.1 The Traditional Concept of Knowledge

Human activity is based on knowledge and its application to particular situations and objectives. Epistemologists have found many ways of describing and classifying knowledge and there are different opinions as to the way knowledge has developed throughout the history of mankind and as to what is its current state. In philosophy, there is the distinction between 'Wissen' and 'Erkenntnis' where the former can be translated as all embracing knowledge in the sense used in section 5.5.2.1 while the latter could be described as rational knowledge (a dictionary translation does not exist). For the purpose of this thesis, 'cognis'[56)] is defined as circumscribing the world of rational knowledge and 'gnosis'[56)] the spiritual realm while 'knowledge' contains both. Education in general and universities in particular, can be said to be concerned predominantly with the transfer and appreciation of cognis which, unlike the realm of gnosis, can be codified.

In the context of engineering Rosenbrock [1989] distinguishes two domains of 'knowledge', on the one hand that of 'explicit knowledge' and on the other that of skill and 'tacit knowledge'[57)]. People in general, not just engineers, can function as professionals in their environments by accessing both. Rosenbrock postulates that, in future, both domains must continue to expand while remaining approximately in proportion to each other. Such a development is necessary to maintain a good quality of working life, according to Rosenbrock.

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56) this use of 'cognis' conflicts with Macleod's terminology (section 10.2.1) while the suggested use of 'gnosis' is reasonably well aligned with the spiritual context of the 'gnostics' of early Christendom (γνωση).

57) he does not, however, introduce a differentiation between the rational and spiritual realms, cognis and gnosis.

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J.S. Brown [1989] uses the term 'implicit knowledge' for the domain of skill and 'tacit knowledge' and distinguishes between two types of learning: Formal Training and Informal Learning. It may be pertinent to add here that Brown's distinction between learning and training is probably polemic rather than necessary. The writer will therefore be using the terms **formal** and **informal learning**. Brown asserts that 'explicit knowledge' can be codified and transmitted in a highly structured manner, formal learning; while 'tacit knowledge' and skill tend to be adopted as the result of practice and experience, informal learning. Although this clear separation of domains of knowledge and associated types of learning may be valid at a very elementary level, it does not take into account that 'explicit knowledge' can be acquired through informal learning, followed by a phase of reflection. Conversely, in the opinion of the author, 'implicit knowledge' can be formally learnt and then internalised through practice.

Inferring from the contexts in which the authors discuss knowledge, it can be assumed that they deal exclusively with the realm of cognis although some of their approaches could be extended to the realm of gnosis, opening up interesting opportunities for a debate on the way in which gnosis is adopted. This debate could also include issues such as tangibility, for which there is no space here.

5.2 Other Philosophical Approaches to Knowledge

Beyond the classifications of knowledge offered in section 5.1, there are many others indeed, suffice it to mention, as an illustration, Macleod's [1992(1)]: operational knowledge is required to carry out vocational tasks, broad knowledge goes beyond what is directly relevant to vocational tasks while deep knowledge concerns basic assumptions and fundamental principles which can only be used through understanding.

Branton argues that "much 'non-conceptual mental work' must be involved in skilful pursuit of purpose. Consciousness is something which some of our colleagues in that most recent branch, cognitive ergonomics, seem to by-pass. They concern themselves mainly with human functions that are verbalisable and computational, overlooking vast areas of non-linguistic, non-conceptual, mental activity ... while the problems of explaining such basic functions as selective attention or directed awareness still remain with us. The largest part of our knowledge is still 'tacit knowledge' ..." [quoted in Oborne,1993].

Bowers [1984] attacks the dominance of codified theories and abstract thought and argues for a teaching approach integrating commonsense experiences and tacit forms of knowledge (accepting that the teacher has acquired these in a specific cultural context). He argues that the oft demanded freedom from cultural values is bought at the price of a new dependency on technicisms. He deplores the exclusive recognition of measurable reality. Mapping Bowers' views on the taxonomy of capability the writer of this thesis interprets his views as favouring complex skills over measurable skills and understanding over recall and know-how (see also 5.5.2.3).

5.3 Development of Knowledge and Ways of Learning

While it is generally accepted that the cognis or rational knowledge available to societies and individuals has expanded, even exploded, throughout the development of humankind and its history [Bowers, 1984, p.IX; Rosenbrock, 1990] the distribution between the explicit and

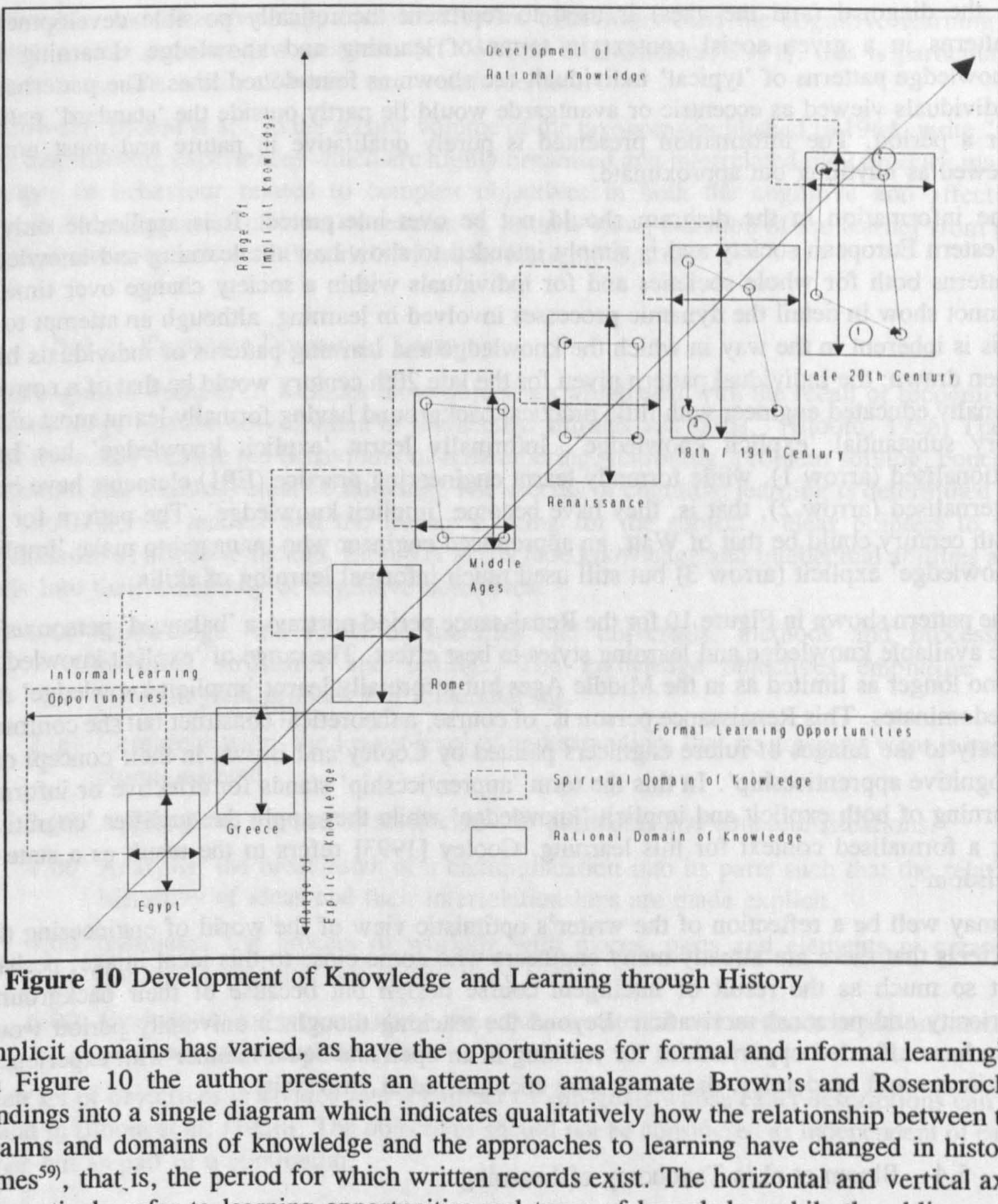

Figure 10 Development of Knowledge and Learning through History

implicit domains has varied, as have the opportunities for formal and informal learning[58]. In Figure 10 the author presents an attempt to amalgamate Brown's and Rosenbrock's findings into a single diagram which indicates qualitatively how the relationship between the realms and domains of knowledge and the approaches to learning have changed in historic times[59], that is, the period for which written records exist. The horizontal and vertical axes respectively refer to learning opportunities and types of knowledge while the oblique axis refers to time and 'progress'.

The following should be kept in mind with respect to the content and purpose of the diagram: implicit rational knowledge is shown as part of 'cognis' even though it equally well be shown as part of gnosis - the difference is in the application, that is, rational knowledge tends to be used for practical purposes rather than philosophical or academic discussion. The relative sizes of the rectangles of 'cognis' and 'gnosis' indicated the significance of the two domains over the whole of a society at different times in history. The gain of 'cognis' indicates the increasing respect for rational thinking. The position of the rectangle of cognis with respect

58) by definition, reference is being made here only to the rational world - the development of cognis has been accompanied by a decline of the gnosis available to the human.

59) the diagram includes the development of gnosis which runs counter to that of rational thought.

to the diagonal (and the axes) is used to represent theoretically possible developmental patterns in a given social context in terms of learning and knowledge. Learning and knowledge patterns of 'typical' individuals are shown as feint dotted lines. The patterns for individuals viewed as eccentric or avantgarde would lie partly outside the 'standard' pattern for a period. The information presented is purely qualitative in nature and must not be viewed as anything but approximate.

The information in the diagram should not be over-interpreted. It is applicable only to Western European society and is simply intended to show how the learning and knowledge patterns both for whole societies and for individuals within a society change over time. It cannot show in detail the dynamic processes involved in learning, although an attempt to do this is inherent in the way in which the knowledge and learning patterns of individuals have been drawn: the individual pattern given for the late 20th century would be that of a conventionally educated engineer with little practical background having formally learnt most of the very substantial 'explicit knowledge'. Informally learnt 'explicit knowledge' has been rationalised (arrow 1), while formally learnt engineering practice (EP1) elements have been internalised (arrow 2), that is, they have become 'implicit knowledge'. The pattern for the 18th century could be that of Watt, an apprenticed engineer who managed to make 'implicit knowledge' explicit (arrow 3) but still used much informal learning of skills.

The pattern shown in Figure 10 for the Renaissance period portrays a 'balanced' person using the available knowledge and learning styles to best effect. The range of 'explicit knowledge' is no longer as limited as in the Middle Ages but informally learnt 'implicit knowledge' still predominates. This Renaissance person is, of course, a theoretical construct but she conforms nicely to the images of future engineers painted by Cooley and Brown in their concept of a 'cognitive apprenticeship'. In this the term 'apprenticeship' stands for affective or informal learning of both explicit and implicit 'knowledge' while they apply the qualifier 'cognitive' for a formalised context for this learning. Cooley [1993] refers to the result as a state of 'wisdom'.

It may well be a reflection of the writer's optimistic view of the world of engineering that he feels that there are already many engineers who come close to this ideal image, perhaps not so much as the result of intelligent course design but because of their background, curiosity and personal motivation. Beyond the teaching though, a university period would also have afforded opportunities for working in an open and equal manner with experienced engineers and academics, the tutors they encountered at University.

5.4 Bloom et al.'s Taxonomy of Learning

A group of American educationalists published in 1956 a 'Taxonomy of Educational Objectives' with the aim of helping teachers better to understand learning processes and thus to improve course design [Bloom, 1956]. This was not intended to be a Dewey-style classification based on an analysis of terminology but a taxonomy aimed at identifying the inner logic of learning situations. Learning objectives were defined in behavioural terms, that is, they were used to circumscribe the intended scope of the modification of the learners' behaviour. Bloom et al. divided the set of potential learning objectives into the cognitive, affective and psychomotor domains of learning. They did not attempt to analyse the psychomotor domain, concerned with manipulative and motor skills, since it is relevant to apprenticeships rather than to class room teaching. In all domains complex behaviour is built on simpler behaviour and the awareness of the individual increases with the complexity of the behaviour. Bloom et al. contrast simple objectives, such as rote recall or remembering of knowledge, with complex objectives, such as understanding, insight, really knowing and true knowledge. In practice, a complete separation of the cognitive and affective aspects of learning is impossible, indeed, where appropriate affective behaviours exist the cognitive learning of subject matter presents few problems [cf. Weiner in Dienstbier, 1991], this is particularly true of situations which allow for peer reinforcement.

Krathwohl, Bloom et al., in the second volume of the taxonomy published in 1964, write "we find that learning experiences which are highly organised and interrelated may produce major changes in behaviour related to complex objectives in both the cognitive and affective domain." An important element of success is, in their view, isolation of the learner from the 'normal environment' (cf. Guthrie's views in section 5.6.2.6).

5.4.1 Cognitive Domain of Learning

"The cognitive domain ... includes those objectives which deal with the recall or recognition of knowledge and the development of intellectual abilities and skills." [Bloom, 1956] These objectives thus include the behaviours of remembering, reasoning, problem solving, concept formation and (limited) creative thinking. The success of cognitive learning is determined by the situation, the interest and the learner's liking for the subject - clear pointers to the significance of affective factors. Bloom et al. include knowledge and intellectual abilities and skills into their taxonomy of cognitive objectives:

1.00 Knowledge: the recall of specifics and universals, methods and processes, patterns, structures and settings. The knowledge objectives emphasise the psychological processes of remembering.

2.00 Comprehension: the lowest level of understanding, that is, grasping what is being communicated.

3.00 Application: the use of abstractions in particular and concrete situations.

4.00 Analysis: the breakdown of a communication into its parts such that the relative hierarchy of ideas and their interrelationships are made explicit.

5.00 Synthesis: the process of working with pieces, parts and elements to create a pattern or structure not clearly there before.

6.00 Evaluation: judgements about the value of material and methods based on internal evidence and external criteria.

Each set of objectives is divided into a number of sub-goals whose exact descriptions can be found in Bloom et al. [1956]. The objectives should not be considered as independent of each other but as part of a continuum.

5.4.2 Affective Domain of Learning

The affective domain of learning "includes objectives which describe changes in interest, attitudes, and values, and the development of appreciation and adequate adjustment." [Bloom, 1956] The development of the cognitive domain is, unfortunately, not a sufficient condition for the achievement of objectives in the affective domain although Krathwohl and Bloom acknowledge the possibility of using cognitive objectives for facilitating affective goals. The continuum of goals in the objective domain consists of:

1.0 Receiving or Attending: the learner must become sensitised to certain phenomena and stimuli.

2.0 Responding: the learner is not just willing to attend but is actively attending, displaying 'interest' and gaining satisfaction.

3.0 Valuing: the learners show through their behaviour that they attach 'worth' to the thing or phenomenon being addressed and that they are committed.

4.0 Organisation: the learner encounters situations for which more than one value is relevant and has to build up a value system.

5.0 Characterisation by a Value or Value Complex: the individual acts consistently in accordance with the values internalised through having attained lower level goals.

The highest achievement in the affective domain is the development of an individual Weltanschauung or world view, a value system having as its object the whole of what is known or knowable. It is possible to establish relations between the categories of the two domains. In such an analysis Knowledge corresponds to Receiving and Attending, Comprehension to Responding, Application to Valuing, Analysis and Synthesis to Conceptualisation and Evaluation to Organisation. Krathwohl et al. give the following example for Receiving: "listens to music with some discrimination as to its mood and meaning and with some recognition of the contributions of various musical elements and instruments to the total effect." The corresponding objectives in the cognitive domain are Comprehension, Application and Analysis.

		Classification Methods >>	Affective Components (Krathwohl's Range)					EPC and Schmid Categories							
								Qualities		Faculties				Content	
Domain	Category	Sub-Category	Receiving	Adjustment	Values & Attitudes	Appreciation	Interest	Aptitudes	Attitudes	Recall	Skill	Knowledge	Understanding	Atoms 2 and 1	Relations & Links
Psychomotor															
Cognitive	1 Knowledge							x		x				x	
	2 Comprehension		x					x		x				x	
	3 Application		x					x			x				x
	4 Analysis		x								x	x			x
	5 Synthesis		x									x			x
	6 Evaluation								x			x			x
Affective	1 Receiving	1.1 Awareness					x		x			x	x	x	
		1.2 Willingness to Receive					x		x				x	x	
		1.3 Controlled or Selected Attention				x	x		x				x		
	2 Responding	2.1 Acquiescence in Responding			x	x	x		x				x		x
		2.2 Willingness to Respond		x	x	x	x		x				x		x
		2.3 Satisfaction in Response		x	x	x	x		x				x		x
	3 Valuing	3.1 Acceptance of a Value		x	x	x	x		x				x		x
		3.2 Preference for a Value		x	x	x	x		x				x		x
		3.3 Commitment to a Value		x	x				x				x		
	4 Organisation	4.1 Conceptualisation of a Value		x	x								x		
		4.2 Organisation of a Value System		x	x								x		
	5 Characterisation	5.1 Generalised Set		x									x		
		5.2 Characterisation											x		

Table 6 Commonly used Affective Terms and the Taxonomies

Table 6, based on Krathwohl et al. [1964], but expanded significantly by the writer, is included here to demonstrate the accuracy of the taxonomy when it is compared with the everyday usage of terms which refer to behaviour forming part of the affective continuum. The writer has mapped the terms concerned with the affective domain onto the cognitive domain, as suggested by Krathwohl et al. The resulting diagram is also used to illustrate the relationship between the writer's categorisation of capabilities and Bloom's as well as Krathwohl's analysis.

Nearly all cognitive objectives have an affective component. The interest objective, for example, can be the affective component of all or most cognitive objectives of a course. As Krathwohl et al. [1964] observed though, many course managers start out with objectives rooted in the affective domain of learning but are content for these to move into the cognitive domain in order to facilitate testing. They describe this phenomenon as 'shift of intent'.

5.5 A Taxonomy of Capability

In the introduction to their taxonomy of learning, Bloom et al. express the fear "that the availability of the taxonomy might tend to abort the thinking and planning of teachers with regard to curriculum, particularly if teachers merely selected what they believed to be desirable objectives." This caution is very germane to the following section since many of the recommendations made by the EPC and by the author of this thesis can be viewed as substantially prescriptive and may therefore be taken on board unthinkingly. Bloom et al. also stated that "each theory of learning accounts for some phenomena very well but is less adequate in accounting for others.

5.5.1 Critique of the EPC Taxonomy

"Tools" selected for teaching purposes should always be assessed in terms of their contribution to the aims of the education process. In engineering (and elsewhere) the development of a professional capability is probably the most important aim. The study of the contribution of the CIM course must not neglect this.

When the writer embarked on his background studies to provide a theoretical framework for the assembly of learning methods forming the CIM approach, his research very quickly led him to the Engineering Professors' Conference (EPC, expanded from 1.1.1994 into the Engineering Professors' Council) and its working groups. Over a period of five years the members of this body carried out an in-depth investigation of best practice in engineering education putting forward a number of new approaches to curriculum design. Their conclusions and recommendations must be rated very highly in an international comparison. At first the writer was hopeful that he would be able to transfer the results of the EPC's work on teaching methods and their classification without any modification. However, he soon found that he disagreed in several important respects with the findings of the sub-committees of the EPC. Even though these disagreements are mostly concerned with terminology they lead to a different structure and some new definitions.

In their publications the working groups of the EPC addressed the issues of content, quality and assessment in first degree engineering courses with a view to improving the capability of future engineers. They undertook an analysis of the current situation and then embarked on a very thorough process of definition of the terminology used in teaching and learning and the approaches advocated by experts in the field. In their first contribution on the issues they wrote [EPC 1, 1989]: "... distinguishing between (i) *skills* (either manual or intellectual) which are learnt mainly through practice; (ii) knowledge, which is simply information committed to memory, and (iii) the deeper learning variously described as understanding, conceptual learning, or meaningful learning."

Based on the very valuable efforts of the EPC the writer has developed his own taxonomy of learning which, he hopes, is slightly more robust and rigorous than their approach. As shown below he defines three categories within the domain of capability and learning: qualities, faculties and knowledge. All of these can pertain to individuals, teams and groups (cf. the concepts of the learning organisation and learning society). The taxonomy differs most markedly in its replacement of the term 'knowledge' by the term 'recall', which he uses to describe a memory based *faculty* and in using the word 'knowledge', for the *content* of learning, instead. This is, in fact, in line with one of the dictionary definitions of knowledge: "the sum of what is known". The writer uses the term 'capability' in a meaning which is even wider than that postulated by the EPC Working Group on Quality in Engineering Education [EPC 1, 1989; EPC 6, 1993], in that he also includes in his requirements personal qualities, in addition to faculties and knowledge (or content). It may be useful to refer back to some of the comments made in chapter 4.2.4 about the definition of the engineer.

5.5.2 Components of Capability

Engineers can be described as capable with respect to the execution of their duties if they have adopted and acquired the qualities and faculties needed to gain and use knowledge and if they possess the knowledge requisite for solving engineering problems, management tasks and for attending to related duties. The writer is of the opinion that there is a relevant difference between 'acquire' and 'adopt' which are both used, quite indiscriminately in general parlance, to describe the behaviour of the student during learning. He applies the term 'adopt' to more active learning in formal situations while he uses 'acquire' for relatively passive learning in substantially informal situations. These usages are in line with the dictionary definitions[60)].

5.5.2.1 Knowledge (Content)

As discussed in section 5.1, at a philosophical level and in relative detail, cognis, or rational knowledge, exists in two forms, explicit and implicit. Here these two terms are used to structure 'classical' descriptions or terminologies of knowledge[61)] (see section 5.3). The term 'content' will at times be used interchangeably with cognis when discussing qualities and faculties. Table 7 provides an overview of the definitions and attributions.

An example of 'data' as a basis for inference is 'knowledge' about the pin allocations of different RS232 connectors. It is only useful in conjunction with facts. Facts are here taken to be meaningful associations of data while information is defined as the result of processing data and facts, possibly attaching a 'quality rating'. An example of 'schemata' would be the learnt moves a football player can access in milliseconds.

Terminology of Knowledge	explicit	implicit
atoms of knowledge -		
data	x	
fact, formulae	x	
information	x	(x)
fiction	x	x
sources[a)]	x	x
ideas	(x)	x
relations and links -		
schemata[66)]		x
rules	x	x
principles	x	(x)
concepts	x	x
intuitions		x

Notes: a) the awareness of resources which can help overcome a lack of memorised information.

Table 7 Classification of Knowledge

Knowledge is transmitted through teaching and training, it is adapted to a person's needs through reflection and unconscious modification and retained either directly or as a consequence of practice. Together[62)], knowledge and the faculty of recall help pass exams, but not much more. In professional contexts, knowledge is only of use in combination with faculties and qualities which permit its application to real problems. Students must therefore not only

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60) 'acquire': 1 gain by and for oneself; obtain. 2 *come into possession of.* 'adopt': 1 take (a person) into a relationship... 2 *choose to follow (a course of action etc). 3 take over (an idea etc.) from another person.*. 4 ... [The Concise Oxford Dictionary, 1990].

61) In the following discussion no distinction will be made between cognis, gnosis and the combination, knowledge. Although this would be possible it would complicate the issue and would not add significant interest.

62) which corresponds to the Engineering Professors' definition of 'knowledge'.

be guided in the acquisition of knowledge but must also be helped to enhance their faculties and to develop their set of personal qualities. An 'official' review of these issues is attached in Appendix A.1 which presents Table 2 from [Sparkes, 1989].

Content is adopted and acquired by learning activity in both the cognitive and affective domains, the latter being dominated by acquisition (see section 5.4).

5.5.2.2 Qualities

For the purpose of this dissertation human qualities are classified, in a relatively arbitrary manner, as follows:

- aptitudes: predispositions facilitating the acquisition of manual and mental faculties, of the natural or acquired kind; e.g.: dexterity with numbers;
- attitudes: settled behaviour; e.g.: confidence, enthusiasm, motivation [EPC 1], ethical behaviour, reliability [Macleod, 1992(2)], openness for new ideas;
- values: principles, standards; e.g.: truthfulness [Macleod, ibid], honesty, fairness;
- emotions: instinctive feelings; e.g.: likes and dislikes;

Qualities (sometimes quoted as natural, innate, intrinsic) cannot be taught formally, they are acquired or modified through processes in the affective domain of learning (see section 5.4.2 and ?).

5.5.2.3 Faculties

In the following enumeration no differentiation is attempted between so-called 'manual' and 'mental' faculties[63]. Both require the intervention of intellect in their acquisition and application.

- recall: ability of memorising, storing and retrieving data and information accurately; e.g.: 'knowing the pin-out of an RS232 interface connector'. Recall can be directly useful in passing exams but is only a prerequisite for success in acquiring and using other faculties[64].
- skill: ability to do specific things without necessarily being able to understand the processes by which one does them, such as speaking, writing, designing, playing tennis etc. Skills can be further subdivided into manual and mental skills and both of these again into measurable and complex skills. The correct execution of skill dependent actions is controlled mainly by automatic processors, on the basis of unconscious schemata[65)+66)].
- know-how: expertise acquired and adopted by accumulating experience of successful problem-solving in a well defined field, which may require substantial recall effort and the use of a number of skills; e.g.: the activities involved in repairing a television set. It can be adopted through the classic appren-

63) the writer is of the persuasion that human beings have no pronounced natural predisposition in either of these directions: conditioning and education tend to push people one way or the other.

64) Bartlett, paraphrased by Reason [1990], found in 1932 that "odd or uncommon features of the to-be-remembered material were 'banalized' to render them more in keeping with the person's expectations and habits of thought... that people were unconsciously attempting to relate the new material to established knowledge structures or *schemata*." This observation would indicate that the faculty of recall in an engineer requires special consideration and schooling.

65) Bartlett [1932] defines a schema as "an active organisation of past reactions, or of past experiences which must always be supposed to be operating in any well-adapted organic response." Schemata and long term memory reliance on active knowledge structures rather than passive images result in "the tendency to interpret presented material in accordance with the general character of earlier experience."

ticeship. The correct execution of know-how based task activity is controlled mainly by stored rules[66].

understanding[67]: intellect, reasoning power. The ability of grasping concepts and using them creatively, the basis of (logical) thinking. Essential to cope with novel situations requiring planning and conscious analytical processes, such as designing new artefacts or explaining not yet encountered phenomena. The power to work with intuitions.

Table 8 is included here to show a possible set of relationships between knowledge, qualities and faculties. It is intended to illustrate the complexity of the issues and their classification rather than to present a definitive picture of the component parts of the different faculties. The structure is evolutive in that it moves from the simple to the complex [Bloom, 1956].

Analysis and Synthesis[68], two key elements of the engineering approach, require a mix of all the faculties listed, although analysis is perhaps biased more towards the first three while synthesis relies more on skill, know-how and understanding. Faculties can be taught using different methods belonging to processes in both the cognitive and the affective domains of learning (section 5.4.2), depending on their complexity.

faculties > function of:	recall	skill	know-how	under-standing
aptitudes	x	x	x	
attitudes	x	x	x	x
values		x	x	x
emotions				x
data		x		
fact, formulae		x	x	
information		x	x	x
fiction		x		x
sources			x	x
ideas		x	x	x
schemata		x	x	x
rules		x	x	x
principles			x	x
concepts			x	x
intuitions				x

Table 8 Faculties as a Function of Qualities and Content

The components of 'qualities' and 'faculties' are, at times, taken together under the joint heading of 'powers' by the writer.

5.5.3 Analytical and Synthetic Faculties vs Knowledge Acquisition

Traditional engineering education stresses the importance of a knowledge of the science and technology base of engineering. Students can adopt factual[69] and procedural[69] knowledge in lectures and tutorials, by recording information and applying paradigmata to examples. Only very rarely though will this force students to question assumptions and preconceptions. They tend to learn factual content and methods, for the reason given above, an approach which can appear, on the surface, very successful, especially so since it is resource efficient. It pre-supposes, however, that on graduation engineers will not immediately take up positions of responsibility since they first have to develop a 'feel' and understanding for engineering.

66) based on an interpretation of Reason's [1990] work on human error. The writer would contend that Reason's definition of rule-based activity can be equated to know-how, in an analogy to the linking of schemata and skill.

67) "the ability to go beyond the information given". [Bruner, 1974]

68) the usage of these two terms is that defined in section 4.2.4 rather than the slightly different meanings of 5.4.1.

69) factual knowledge = atoms of knowledge, procedural knowledge = relations and links (see Table 7).

The acquisition of both analytical and synthetic faculties is essential for students who are expected to undertake placements in industry at an early stage of their careers. The ability to analyse a problem and to develop reasonable hypotheses about its essence and genesis cannot be taught in an abstract manner, students have to experience the underlying gnostic processes. While such an experience may be provided in carefully designed, game based environments, these would not reflect the reality of engineering where uncertainty is high both as regards the process of problem solving and the kind of solution which may be achieved. The intellectual development of the student should never be measured in terms of the correct application of well rehearsed methods but in her or his ability to try a number of different approaches and to assess their relative performances.

Teaching and learning is thus no longer a simple question of 'talk and chalk' but rather a complex process of formation and long term motivation. The issue of learning is therefore addressed in more detail in the following sections. As will be seen later, the formation of engineers in the Department of Manufacturing and Engineering Systems at Brunel is firmly based on the development of analytical and synthetic powers, as well as personal qualities.

5.6 A Review of Learning Theory

5.6.1 Early Theories of Learning

A whole string of philosophers and psychologists leading up to Branton [Oborne, 1993] have tried to uncover the physical and metaphysical principles determining human behaviours and rational action (or reasonable conduct). Of particular interest were always the principles underlying the acquisition of skills and of decision making ability. The author bases his discussion of these issues largely on Hergenhahn who provides a useful step by step analysis of the different theories of learning. Where no references are given in the text in section 5.6, the information presented may be assumed to originate in Hergenhahn [1988].

There exists a great plethora of theories of learning, of how we acquire qualities, faculties and knowledge, some of which are purely mechanistic, relying on genetic structures and programming; others which assume that most components of capability are present at birth, as a result of reincarnation and simply need to be 'switched on' (Theosophy, Anthroposophy, Buddhism) while yet others are firmly based on learning processes which allow any individual who so desires to acquire any ability whatsoever. Plato stated that knowledge was gained by reflecting on the contents of one's own mind, that knowledge was reminiscence and, as such, innate. As will be seen, the writer's beliefs draw on both the mechanistic and learning paradigms. Therefore, the theory of reincarnation as a source of capability will not be pursued.

The Greek philosopher Aristotle can be viewed as the precursor of almost all modern theorists of learning in that he was an empiricist who related learning to sensory experiences. He formulated the law of association: the experience or recall of an object[70)] will lead to the recall of things which are similar (law of similarity), opposite (law of contrast) or which have originally been experienced at the same time (law of contiguity). A high frequency of joint experience of two objects leads to a strengthening of the bond between the two, the definition of associationism. Thomas Hobbes took up Aristotle's ideas in the early 17th century and was the first to describe stimuli (he perceived a pleasure orientation, a principle also espoused by Jeremy Bentham) and aversive feelings. He developed a reinforcement theory which was taken up by Locke and Hume. The latter went very much further in locating all knowledge, including the laws of nature, in the human imagination where it is created from sensory

70) this may be a real object, a thought or a concept or any other entity whose description can be stored.

experiences: even a statement of causality is but an association of two contiguous observations.

Kant reacted strongly to the pure empiricists and rationalists (the latter based on Plato) and postulated innate patterns of thought which help structure sensory experience, amongst which are causality and unity, concepts which we do not experience. The faculties of the mind must thus be taken into account. John Stuart Mill agreed with the concept of complex ideas being an amalgam of simple ideas but stated that the whole was more than the sum of the parts. Both Kant and Mill's views are reflected by the proponents of the Gestalt movement. Darwin's contribution was the removal of the dichotomy of 'animal and instinct' versus 'human and rational behaviour'.

The Engineering Professors' Conference distinguishes between a cognitive and an affective[71] domain of learning. As criticised already in section 5.5.1, the analysis lacks rigour even though it is very useful: the process of learning and the content transferred in the process are not differentiated. In their taxonomy, reproduced in appendix A.1, cognitive learning is equated with knowledge, skills and understanding, while the affective domain is concerned with attitudes, values and personal qualities. The process characteristics of cognitive and affective learning are not defined. This representation though only re-enforces the impression that a division between cognitive and affective learning is not useful. A more detailed review of learning theory is thus necessary.

Early experimental work on learning was undertaken by Ebbinghaus, at the end of the 19th century, who turned to the concept of reinforcement through practice and who is often regarded as the father of psychology as an entity separate from philosophy. His work led eventually, during the first half of the 20th century, to that of John B. Watson who was to become the founder of behaviourism.

5.6.2 Behaviourist Approaches

Watson noted that consciousness could only be studied through introspection, in his view an unreliable research tool. He advocated instead the study of the behaviour of organisms as a subject which was amenable to scientific investigation. Behaviour can be observed, quantified and its relationship to experience can thus be established. All superstition can be removed from human existence; this was his firm belief!

5.6.2.1 Edward Lee Thorndike

Thorndike worked at the same time as Watson and established the theory of connectionism, based on the bonds between sensory events and behaviour. His work with animals led him to believe that unsuccessful responses would eventually be discontinued and that only those which resulted in a reward would subsist. He noted that learning was incremental and not insightful, that it was not mediated by ideas. He developed two versions of a Law of Exercise. The first version had two elements, the Law of Use and the Law of Disuse:

- connections between a stimulus and a response are strengthened as they are used,.
- connections between situations and responses are weakened when practice is discontinued or if the neural bond is not used.

The second version, written after 1930, stated that reinforcement increases the strength of a connection whereas punishment does nothing to the strength of a connection. The latter observation is of the greatest significance in education. His law of effect, which stated that

71) the reader is referred to Bloom et al.'s taxonomy (section 5.4) and Weiner's affective theory of motivation, (section 6.2.4).

the consequences of a response are important in strengthening the bond between the stimulus and the response, was attacked since it appeared to imply that the effect could strengthen a neural connection which predated it in time. However, later work showed the criticisms to be invalid. Thorndike also developed the identical elements theory of the transfer of training. To this is related the theory of associative shifting which allows the transfer of a response to a stimulus or set of stimuli totally dissimilar to the original stimuli.

Thorndike viewed the control of human learning as the avenue for advancing humankind, indeed as its salvation. Since everything was based on eliciting responses to stimuli it was in his view a relatively simple matter to improve people. "For strange as it may sound man is free only in a world whose every event he can understand and foresee. Only so can he guide it. We are captains of our own souls only in so far as they act in perfect law so that we can understand and foresee every response which we will make to every situation." This expression of his credo of 1949 seems to give absolute power to educators. He has the following advice for teachers: good teachers know what they want to teach and can thus choose the right material, they know what responses to look for and when to apply satisfiers. A modern view! In 1922 he formulated seven rules for the teaching of arithmetic which can be applied to teaching in general:

(1) consider the situation the pupil faces.

(2) consider the response you wish to connect with it.

(3) form the bond, do not expect it to come by a miracle.

(4) other things being equal, form no bond that will have to be broken.

(5) other things being equal, do not form two or three bonds when one will serve.

(6) other things being equal, form bonds in the way that they are required later to act.

(7) favour, therefore, the situations which life itself will offer and the responses which life itself will demand.

These thoughts, which were to develop into Skinner's attitude towards education, are highly significant for the design of the CIM course since they expressly require the use of real life oriented learning. Also relevant is Thorndike's assertion that learning is enhanced if the effects produced by the response satisfy needs of the organism (see chapter 6 for a reference to theories of motivation and a summary of the key approaches).

It is perhaps interesting to note, in passing, that Thorndike did not have a high opinion of lectures and demonstrations as teaching tools because "they ask of him [the student] only that he attend to, and do his best to understand, questions which he did not himself frame and answers which he did not himself work out. They try to give him an educational fortune as one bequeaths property by will." (1912, quoted from Hergenhahn [1988])

5.6.2.2 Stimulus - Response (Skinner)

Much of the work on learning theory which grew from the seeds planted by Thorndike can be traced back to B.F. Skinner. Most of it involved more and more complex theories of the stimulus (S) response (R) relationship. Skinner himself distinguished between respondent behaviour (to a known stimulus) and operant behaviour (simply emitted by the organism). He also defined respondent conditioning (Type S), or classical stimulus based behaviour and operant conditioning (Type R). Type R is assessed by measuring the response rate while in Type S the strength of conditioning is usually determined by the magnitude of the conditioned response. Skinner is more interested in the effect of reinforcement on the rate of response in operant conditioning than in the time to solution. Whether or not something is a reinforcer can only be ascertained by its effect on behaviour.

To modify behaviour, one merely has to wait for the desired behaviour and then to apply a reinforcer which has been found to have an effect on the individual. Skinner is of the opinion that the environment shapes the personality and that people are totally interchangeable at birth. He carried out many experiments to study animal behaviour (the Skinner box) and used more and more complex chains of events. A relatively simple example is that of the discriminative stimulus:

$$S^D \rightarrow R \rightarrow S^R$$

where R is the desired response, S^R the reinforcing stimulus and S^D the discriminative stimulus which is present during the time during which a response to a situation is going to be rewarded, but not otherwise. This is, in fact, a variation of respondent conditioning according to Thorndike. S^R represents the feedback given to a student. A potential implication for the creation of alternative learning situations can be construed from the above relationship: if students are to behave differently in a new learning situation then there must be a clear discriminative stimulus to open up the possibility of modified behaviour. In the case of the CIM course such a stimulus is provided by the timetable which identifies the learning structure or environment as different from the "normal" lecture mode (see section 12.2.1 for some more detail).

5.6.2.3 Punishment, Reward and Education

Skinner shares Thorndike's view that punishment does not engender modification of behaviour although subjects will avoid aversive stimuli. However, punishment generates many unfortunate by-products, including the replacement of one undesirable response with another, an observation which applies particularly to universities' disciplinary procedures (pages 97 and 98 of Hergenhahn [1988] provide worthwhile material on this). The award of marks for a performance though can be viewed as a generalised reinforcer, acting in a similar way as does money. Very important considerations which can affect performance, according to Skinner, are the frequency and timing of reinforcers:

- partial reinforcement, where the subject receives a reinforcer after a variable number of responses (but at a fixed average rate), is more effective than immediate and complete reinforcement (or: constant praise corrupts)[72].
- in general, small immediate reinforcers are preferred over large delayed ones. This has to be taken into account when designing complex learning environments where rewards may not be linked directly to responses.

One method to encourage appropriate behaviour, advocated by Skinner, consists in creating an early commitment when offering longer term but larger rewards. This will be shown to be one of the elements of managing the early stages of starting any new iteration of the CIM course. A learning situation which involves early commitment can result in contingency contracting, that is, a modification of a person's environment which will help him or her change a behaviour.

Skinner also provided guidelines for applying his theory of learning to the process of education: learning proceeds most effectively if:

- the information to be learnt is presented in small steps;
- learners are given rapid feedback concerning the accuracy of their learning (i.e., they are shown immediately after a learning experience whether they have learned the

72) Abram Amsel's observed that total reinforcement fails to teach students how to handle frustration. This is an important skill in professional life where rewards do no automatically follow every correct action (or response).

information correctly or incorrectly - refer to section 14.5 concerning task reviews); and

- learners are able to learn at their own pace.

Skinner became a strong supporter of programmed learning (discussed in section 5.6.2.6) using teaching machines whose success he put down to constant interchange between student and program, progression in small steps with instant verification, etc. He was of the opinion that the development of complex theories of learning was wasteful. Like Watson and Thorndike before him though, Skinner believed in the salvation of mankind from itself through scientific modification of behaviour.

Premack views all responses as potential reinforcers and stresses that the choice of appropriate reinforcers depends on the subject (organism) under study.

5.6.2.4 From One Stimulus to Many

With the Brelands instinctive patterns and evolutionary history were allowed back onto the scene of psychology; new experiments showed that particular patterns of behaviour bore no relationship to stimuli. Bolles took the position that subjects adopt innate responses appropriate to the circumstances and learn to bond these to the most vivid stimuli present in the environment. C.L. Hull realised that a great number of different stimuli will be present in any situation. These are acted upon by non-observable processes within the subject and result in the responses which the experimenter can observe. While not all the elements of Hull's theories were accepted he spawned a whole generation of researchers who put behaviourist psychology on a mathematical footing. This and further work, such as Pavlov's, will not be discussed here even though it is of some interest. Suffice it to mention that the role of genetic determination in terms of preparedness for associations and particular response characteristics gradually became accepted.

5.6.2.5 Guthrie's Model of Learning

In the opinion of the writer, Edwin Ray Guthrie's model of learning is more relevant to his own approach than the models of the other psychologists and philosophers discussed by Hergenhahn. Guthrie was interested in human learning rather than in that of animals. He was convinced that by applying the law of parsimony carefully one could explain all learning phenomena by using only one principle. In 1952 he proposed his single law of learning, that of contiguity: "A combination of stimuli which has accompanied a movement will on its recurrence tend to be followed by that movement." He modified the law in 1959 to read: "What is being noticed becomes a signal for what is being done."

Guthrie thus was an associationist following in Aristotle's footsteps although he differed from the other associationists in that he postulated one-trial learning as opposed to conditioning through frequent repetition of stimulus response situations. Guthrie based his law on the observation that in any given situation there exist a multitude of different stimuli. Even situations which are supposed to be identical will differ in a number of ways. The theory of one trial learning can be adopted once the recency principle has been accepted. This states: that which was done last in the presence of a set of stimuli will be that which will be done when that stimulus combination next occurs. What others view as learning through reinforcement in a number of trials, can thus be seen as establishing bonds with a number of different but similar sets of stimuli. Guthrie links his theory to movement at either micro or macro level. Many movements together form an act which can then be observed as a response. Depending on the situation a large number of different movements will be necessary to complete what is perceived as one act.

Guthrie is able to describe the development of skills in terms of his theory: a skill is made up of many acts. Learning a skill such as riding a bicycle or playing volleyball consists of learning thousands of associations between specific sets of stimuli and specific movements. In Guthrie's own words [quoted from Hergenhahn, 1988]: "Learning occurs normally in one associative episode. The reason that long practice and many repetitions are required to establish certain skills is that these really require many specific movements to be attached to many different stimulus situations. A skill is not simple habit, but a large collection of habits that achieve a certain result in many and varied circumstances." Reinforcement is a mechanical arrangement that prevents unlearning. According to Guthrie punishment, the presentation of an aversive stimulus to modify behaviour, can be effective if it produces behaviour which is incompatible with the undesired response and if it is applied in the presence of the set of stimuli which lead to the undesired response.

5.6.2.6 Applying Guthrie's Theory

The writer has tried to interpret Guthrie's theory to explain a number of phenomena encountered in education: many teachers complain about the difficulty of teaching "today's kids" who appear to be permanently distracted. This accords well with theory in that stimuli multiply while, as a direct result, the recurrence of similar sets of stimuli is becoming less and less frequent. Therefore, the opportunities for collecting from similar (but not identical) situations the different movements to form acts and, by extension, skills, become more widely spaced. From the outside this is viewed as slower learning. All the same, more may be learnt by these subjects than used to be the case for the students from villages who would learn very fast at school as a result of experiencing simple and largely similar situations all the time [anectotal evidence from an Irish country school teacher]. This is in no way to be seen as a call for more television and computer games though...

The successes of programmed learning can also be explained using Guthrie's theories. Programmed learning, whether using machines (computers) or paper based tuition, is founded on a reduction of stimuli and a standardising of the sets of stimuli present or provided. Tests which are conducted in the same environment (using the checking function of the Computer Aided Learning (CAL) software or, in the case of paper, multiple choice tests) will therefore show very good performance, much better than what could be expected from more open learning situations. CAL, in particular, places the student in an unreal situation because it uses a narrowly defined range of stimuli. For this reason it is likely to result in failure once the student is faced with a real, more complex situation. The very mechanistic view of student learning at the heart of CAL is exemplified in a paper by Wong et al. [1990].

Only realistic learning environments lead to real learning since it is almost impossible to recreate realistic sets of a stimuli in a superficially simulated environment (see section 13.4.5.2 for a more detailed discussion of the problems of simulation). The development of ever more realistic aircraft simulators is an indication of the continuing relevance of Guthrie's work. To achieve rapid and effective development of particular skills it is important to replicate an environment which presents the same restricted sets of stimuli as reality. When providing a rich learning environment of the type discussed in section 5.8.5 Guthrie's views about realistic sets of stimuli must be remembered.

Guthrie's theory may also provide an alternative explanation to the theories concerning partial and total reinforcement: if every correct response is rewarded, it is highly likely that some will be bonded to non-typical sets of stimuli since learning happens in one trial per set of stimuli. This will lead to confusion for the subject participating in the learning process. The results of this confusion can be observed in both animals and children.

5.6.3 Cognitive and Gestaltist Theories

The members of the working party on engineering education of the Engineering Professors Council [EPC 1, 1989] accuse behaviourist psychologists of ignoring understanding, of only acknowledging it as something which can be inferred from behaviour. Instead, they postulate that intelligent thought is an important aspect of good engineering. In reality, this is no contradiction since intelligent thought can only be inferred from its results, that is, intelligent actions or utterances (another form of action). However, ever since the development of behaviourist approaches there has been more fundamental criticism of the underlying philosophies and concepts.

5.6.3.1 From Behaviourism to Cognition

W.K. Estes adopted a view similar to that of Guthrie in as far as he related an individual response to many stimuli. However, he postulated that bonding between the situation and the response occurs only gradually since the subject only perceives a small sample of the stimuli present in each trial. The stimulus sampling theory developed by Estes explains learning as a statistical process during which more and more of the stimuli present in the learning situation (S) become conditioned to the desired response. The mathematics of this are straightforward:

$$P_n = 1 - (1 - P_1)(1 - \theta)^{n-1}$$

where P_n is the probability of an A_1 response occurring on trial n. $(1 - P_1)$ is the probability of that response not occurring on trial 1 (equivalent to the proportion of stimuli out of the sample θ not conditioned to A_1 at the start of the experiment while $(1 - \theta)$ is the proportion of stimulus elements in the situation which are not sampled on trial n. The key to the success or failure of Estes' theory is, as a matter of course, the choice of θ which remains constant throughout the experiment. By later explaining learning as a Markov process[73)], Estes returned to Guthrie's model of one trial learning.

Estes also introduced cognitive mechanisms into his analysis of learning: rather than stimuli and sets of stimuli directly leading to a response they elicit memories of previous experiences. It is the interaction of the current stimulation with memories of previous experiences that produce behaviour. In his scanning model of decision-making Estes postulates that in any decision-making situation, an organism will use whatever information it has stored in memory concerning response-outcome relationships and will respond such as to produce the most beneficial outcome. Hergenhahn [1988] writes: 'Estes (1971) says that complex human behaviour such as that involving language: "is better understood in terms of the operation of rules, principles, strategies, and the like than in terms of successions of responses to particular stimuli".' This is related to cognitively generated motivation as proposed by Bandura (see section 6.2.3). H.F. Harlow (also quoted by Hergenhahn) then showed experimentally that subjects could acquire discrimination and learning strategies through training.

Both Estes' theories and Harlow's practical work are important in the design of learning situations and environments since they result in the requirement for varying the learning situation as the organism or student progresses through different stages of the experience. This was recognised intuitively in the design of the CIM course and led to distinct phasing of the process as described in section 12 of the thesis.

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73) in queuing theory, a Markov process describes a particular behaviour of random variables based on the Markovian property or memoryless property which is true for the geometric random variable (discrete systems) and the exponential random variable (continuous systems). The latter can be used, for example, to describe the time between the arrivals of successive raw workpieces in a manufacturing system.

5.6.3.2 Gestalt - Insight

The word 'Gestalt', German for 'form', 'shape' or 'figure', can refer to a shadowy outline of a human figure on the horizon or to a detailed portrait of a person, a complete pattern. Wertheimer and his followers used the abstract meaning of the word, which appears in Hergenhahn's [1988] translation as organisation or configuration[74]. The more straightforward translations of shape or form would be perfectly adequate though: put simply, the Gestaltists believe that organisms coalesce the sum of related sensory experiences available in a situation into a meaningful whole. In this the Gestaltists are direct descendants of J.S. Mill. Dissecting a situation, in their view, is to distort it. The Gestaltists' stance with regard to psychology identifies them as field theorists: there exists a continuum of sensory experiences where only the intensity varies, just as in an electric field.

The Gestaltists rejected the elementistic approaches adopted by the proponents of both structuralism[75] and behaviourism. They accepted introspection as a valid tool as long as it was used to investigate whole, meaningful experiences. Perceptual phenomena must be studied directly and without further analysis. Countering the claims of the behaviourists that the 'mind' is nothing but the synthesis of people's experiences, the Gestaltists declared that the brain organised incoming sensory information and made it more meaningful. Impulses from the physical world can only be experienced once they have been transformed by the brain. Behaviour can therefore not be influenced directly by the physical environment but is determined by consciousness or subjective reality. Learning is a cognitive phenomenon where the organism "comes to see" the solution after pondering a problem, that is, the learner thinks about all the ingredients necessary to solve a problem. She or he then puts them together (cognitively) in different ways until the problem is solved. Once this happens the learner can be said to have developed insight. However, this process tends to be rather lengthier than would be the case for more conventional learning.

5.6.3.3 Gestalt Theory and Learning

The Gestaltist principle of most relevance to learning theory is that of closure: the human mind will tend to complete or close incomplete experiences. This is in line with the law of Prägnanz which is best translated as the law of pith[76] or quintessence. The mind will interpret a situation so as to extract patterns which may have been encountered before (e.g., recognising a mushroom as edible) or to form a new concept which can be stored for future use. For the designer of learning situations this leads to the essential condition of achieving similarity between the learning environment or the learning task and the real life situation for which the learning is a preparation. Teachers must also accept that the processes which they design will be subject to moderation by a part of the student's organism which is to some considerable extent genetically determined.

Reaching understanding involves, according to Wertheimer, many aspects of a learners' mental make-up: emotions, attitudes, perceptions, their intellects. A logical approach is generally neither needed nor desirable, rather the student should cognitively rearrange the components of the problem until one of several (open endedness) possible solutions based on understanding is reached. The process will vary from student to student. The Gestaltists introduced the concept of memory traces which assist in the solving of problems whose make-up is similar to that of a problem solved in the past.

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74) it is likely that the originators of the theory used the verb 'gestalten' since its meaning is precisely that of assembling elements into a coherent whole. A 'Gestalter' is a designer able to perceive the whole through its elements.

75) a short-lived theory of learning which relied on introspective analysis of consciousness.

76) or significance, substance, essence, condensation (figurative) which are all better translations of the word Prägnanz than the term 'precision' used by Hergenhahn [1988].

Gestalt-Insight theories of learning postulate that the learners gain insight by seeing for themselves the whole conceptual pattern of what they are learning. The words "for themselves" are essential: the insight must come from within, it cannot be injected by anybody else. The teacher (or lecturer) cannot transmit his or her own insight, the learning experiences must be arranged such as to maximise the chances of the learners achieving their own insight by a personal thinking and puzzling process. The Zeigarnik effect is an important discovery of the Gestaltists: since the motivational properties of a problem persist until it is solved, there is a tendency to remember unfinished tasks better than completed ones. This can be explained by the motivation arising from cognitive disequilibration as discussed in the context of Appley's theories (section 6.2.2). This statement also agrees well with the observations made on the CIM course where substantial motivation derives from the fact that an incompletely solved problem is handed from one year to the next (see section 12.4.1).

5.6.3.4 Transaction Based Learning

An extreme position with regard to learning has been adopted by the humanists who have an ideological commitment to the idea that learning should be primarily a process of personal growth, one that is typically achieved through interpersonal relationships [Richardson, 1994]. While not every teacher will adopt so extreme a stance, all will have to choose at some point both their own philosophy of education and their own theory of learning. Pittenger and Gooding [1971], field theorists and Gestaltists[77], proposed a model for the foundations of teaching shown in Table 9 which summarises their view of philosophy, theory and practice. All three should be in harmony if teaching is to produce consistent results. Pittenger and Gooding are clearly opposed to behaviourism although they accept that elements of the theories have become part of the Gestalt theory. They view human capacity as essentially open ended. They put forward a transactional philosophy of education whose emphasis on change the writer finds useful even though it is extreme in its insistence on the social relevance of the teaching process.

Successful Teaching	
Daily Teaching Behaviour	Educational Technique
Basic Strategy of Teaching	Educational Practice
Interpretation of the Learning Process	Theory of Learning
Basic Values of Education	Educational Philosophy
The general Meaning of Existence	Philosophy of Life

Table 9 A Humanistic Model of Teaching

Appendix C is devoted to a more detailed exploration of Pittenger and Gooding's work and includes Table 41 and Table 42 which give overviews of the philosophies and practices advocated. Students are expected to make mistakes because this is an integral part of the testing, trying and growing process of learning. This principle dictated the development of the CIM course as far as the provision of a safe environment for making important mistakes[78] was concerned.

5.6.4 Further Theories and Principles

Jean Piaget introduced the concept of schemata (one of the facets of knowledge listed in Table 7 in section 5.5.2.1) and defined optimal conditions for learning. For learning to take

77) Pittenger and Gooding profess themselves to be phenomenologists, in the footsteps of Combs and Snygg [Pittenger, 1971]. The phenomenologists see man as an organism forever seeking greater personal adequacy (their term for self actualisation) and place emphasis on personalistic factors. They also express leanings towards a humanistic psychology.

78) in particular, mistakes concerning project management, the mistakes most frequently encountered in first industrial posts.

place in the most effective manner, information[79] must be presented that can be assimilated into present cognitive structures but which is, at the same time, sufficiently different to require a change in those structures. If the information is too complex to be assimilated, it will simply not be understood. E.C. Tolman combined Gestalt principles with behaviourism and studied meaningful (whole) behaviour patterns rather than atomic elements. He moved to a position which recognised purposive behaviour and goal orientation (see appendix D for a discussion of purpose). He also reiterated that an effective problem solving strategy, once found, will transfer to related problems.

R.C. Bolles studied innate responses and how they affect learning performance: the more unnatural a required response is for the organism, the more difficult it will be to learn it. A. Bandura, whose work is also important in the area of motivation, discovered that learning can occur simply through observation of another person experiencing a situation. Depending on the outcome, this can lead to avoidance or imitation of the course of action demonstrated. This was confirmed by Tolman, who experimented with rats and found that they learnt by observation even if not reinforced for success. Bandura also realised that human behaviour is largely self-regulated. People learn personal performance standards from direct and indirect (vicarious) experience. People with a high perceived self-efficacy, that is, a feeling that they can achieve a great deal, perform better than others (refer to section 6.3 for a discussion of the potential for modifying these standards). Bandura deals with moral behaviour and the mechanisms which allow cognitive processes to bypass its tenets even though they may still be upheld.

D.A. Norman advocated the study of cognitive processes in group situations and was very critical of the established learning theories since they failed to address the mechanisms by which a person can become an expert, such as a professional golfer. The sequence in solving a complex problem is [Norman, quoted by Hergenhahn, 1988]: chaos, analysis, synthesis, automatisation. Norman defined the characteristics of skilled performance, that is, the performance of a person who has acquired a skill, as follows: smooth, automatic, with reduced mental effort[80], does not deteriorate under stress, is no longer aware of the movements and acts whose combination forms the skill.

While it would be interesting to study the theory of learning in far greater detail, for the present thesis we must restrict our investigation to the design of learning environments for developing engineering ability and, in particular, engineering ability for advanced manufacturing environments. However, all of the theories discussed above can be seen as having implications for the classroom, laboratory and lecture theatre. Perhaps the most important observations made by a number of theoreticians (Piaget, Tolman, Guthrie, the Gestaltists) are the need for individualised approaches and the perception of learning as a problem solving process.

5.7 Cognition and Problem Solving

5.7.1 Cognitive Background

Careful preparation of individuals for their future tasks is essential since "The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behaviour in the real world - or even for a reasonable approximation of such objective rationality." [Simon, 1957] The formation of engineers must have as one of its stated objectives the education of people

79) this is to be interpreted in the widest possible sense and may include, for example, elements of skills etc.

80) skilled performers can hold conversations with others while carrying out intricate tasks.

able to optimise solutions within the available resources, that is, to cope with problems subjected to a very large number of constraints.

As discussed earlier, successful interaction with the environment, be this at work or in any other living situation, requires both analytic and synthetic mental activity to arrive at the correct actions or reactions. The term 'cognition' as used in this dissertation subsumes both reasoned and intuitive approaches in human behaviour, that is, activities which satisfy both cognitive and affective objectives. As used by the author cognition refers to decisions and responses based on rational knowledge (cognis, as defined in 5.1) but not emotive and wilful actions which run counter to conventional logic. Such behaviour is not considered here because it does not fall within the scope of university teaching. Some authors, group cognitive activity with manual activity and oppose both to intuitive processes.

5.7.2 Capability and Problem Solving

James Reason provides an excellent overview of human problem solving in 'Human Error' [1990]. The following comments are therefore largely a summary of his analysis, adapted to fall in line with the definitions used by the writer.

Reason defines a problem "as a situation that requires a revision of the currently instantiated programme of action. The schematic mode of control can only operate satisfactorily when the current state of the world conforms to the regularities of the past. The departures from routine demanded by these situations can range from relatively minor contingencies, swiftly dealt with by preestablished corrective procedures, to entirely novel circumstances, requiring new plans and strategies to be derived from first principles."

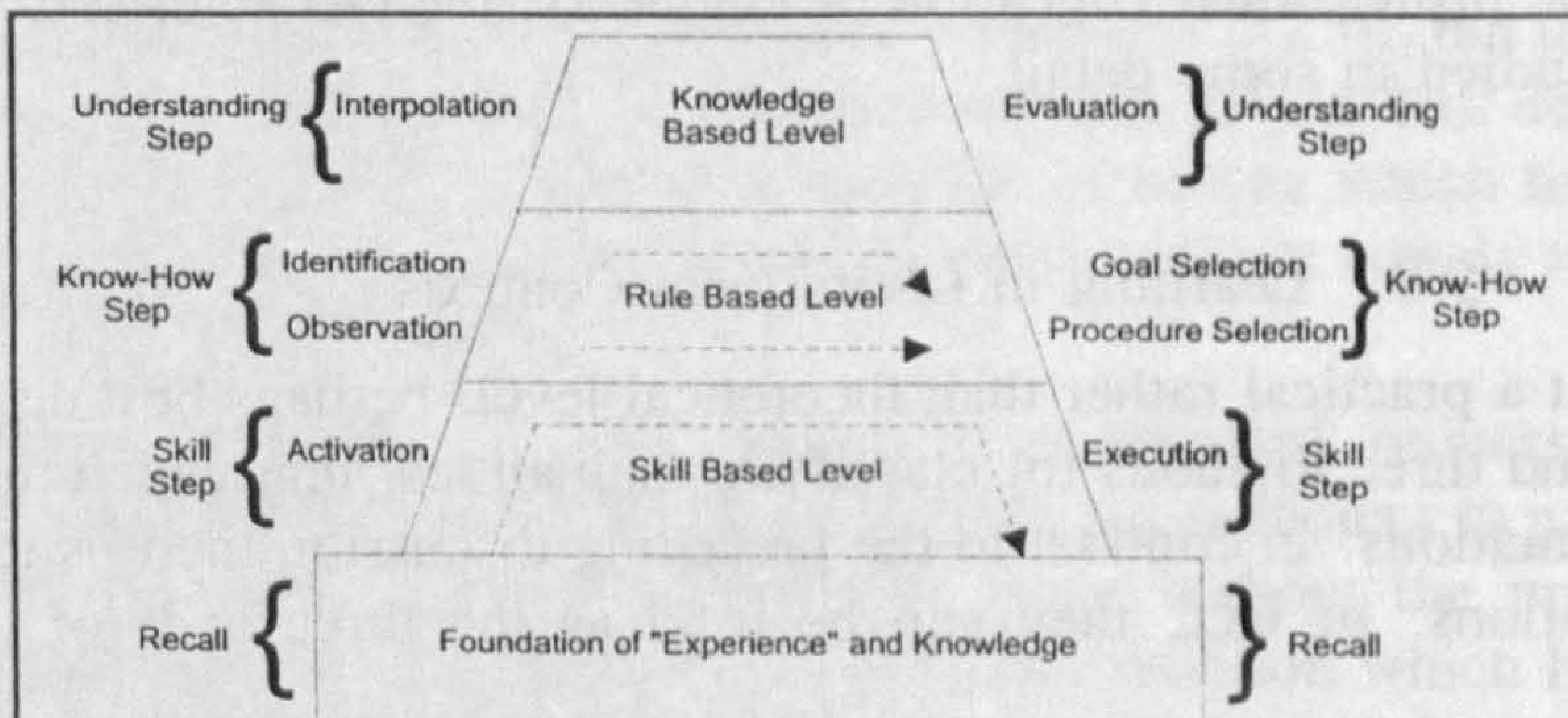

Figure 11 Rasmussen's Decision Making Stages

Human beings will try to reduce cognitive strain in problem solving and concept attaining by applying prepackaged solutions to recurring problems, that is, a form of persistence forecasting. Although perhaps not the most efficient or elegant strategy, in many cases problem solving on the basis of cues that have proved useful in the past achieves better results with far less effort than most other forms of problem solving. This human propensity to use 'shortcuts' has been identified by Rasmussen and Jensen [1974] and their visualisation is reproduced here in Figure 11. The classic stepladder though has been adapted by the author to reflect the faculties described in subsection 5.5.2.3 above and is shown to require a foundation of experience stored in the shape of schemata, rules, concepts etc.

Rouse [1981] states "human beings, if given the choice, would prefer to act as context specific pattern recognisers rather than to calculate or optimise" and defines two types of rules, symptom rules and topographic rules. The former work on the basis of a full match between problem cues and situation specific stored rules and will only be useful if the problem situation is accurately mapped. The latter rules rely on an actual or mental map of the system and a logical consideration of structural and functional relationships. For any rule to be selected it must satisfy four criteria to some degree:

(a) the rule must be recallable (available)

(b) it must be applicable to the current situation

(c) it must have some expected utility

(d) the rule must be simple

The rules, also labelled 'production systems' by Rouse, suggest a link between a stored pattern of information relating to a given problem situation and a set of motor programs appropriate for corrective actions. Loosely interpreting, it could be said that the patterns correspond to the schemata formed about past experiences mentioned above, under the heading of skill, subsection 5.5.2.3. Rouse's comments also go some way towards providing a basis for the discussion of the differences between serialist and holist learners (see section 5.8.2). Both context specific pattern recognition and calculation belong to the cognitive domain as defined in 5.4.2.

This rigid mechanistic view is not universally shared though: Branton [in Oborne, 1993] is quoted as stating "that past experience is used to predict and anticipate. It should, however, not be inferred that anticipation means automatic, cue-triggered (stimulus response) behaviour." From his work with railway drivers he concludes that "If correct anticipatory behaviour, once acquired, were rigidly automatic, such incidents (passing of signals at danger) could not occur." To control a system (of any kind) efficiently, people need ways of predicting the outcome of their actions. Another important observation of Branton's refers to interest and boredom: "what is known about ... modern man in particular: "there is an irrepressible, spontaneous need for sensory inputs."

So far, the discussion has addressed learning as a general issue rather than an activity taking place in an institution, e.g., a school or university. Since the present thesis is concerned with the professional education of engineers, the characteristics of institutional learning must be studied in some detail.

5.8 Learning in Institutional Contexts

At a practical rather than theoretical level, perhaps best described as phenomenological, we find three methods for classifying human learning which may help in the design of learning situations: in contrast to the preceding discussion there is no overlap between these classifications, in fact, they can be used as the three axes of a coordinate system to describe

Quality and Sequence → Medium ↓	Surface Learning		Deep Learning	
	Serialist	Holist	Serialist	Holist
Verbalise	Lecture	Taught Example Session or Class	School Class	non-tutored seminar
Visualise	Video and Diagrams	Descriptive Textbook	Programmed Learning	Analytic Textbook
Do	Standard Laboratory Session	'Tasks' Type Activity (9.4.1)	Open Ended Laboratory Work	Open Ended Project Work

Table 10 Classification of Learning Situations

differences in learning situations. The system as shown in Table 10 represents learning based on dimensions of student aptitude. The first axis, depth of learning (see 5.8.1), deals with the quality of the process, the second axis with the timing or sequence of the process while the third axis concerns the medium of instruction. The teaching tools which may be used have been selected more or less at random to indicate how the classification could be applied.

More background information on the effectiveness of particular teaching methods can be found in appendix A.3. Table 40 shown in this appendix is incomplete in that it does not show that assessment is an important element of any learning experience.

5.8.1 Surface Learning and Deep Learning

Marton and Säljö [1976] identified different levels of processing of information among Swedish university students. Their research was directed at *what* was being learnt, rather than at *how much*. The authors classified the different conceptions of the content of learning tasks into a number of categories or, in their words, according to levels of outcome. They discovered that the associated learning activities could be described as surface-level processing and deep-level processing (or conceptual learning). Marton and Säljö's described the deep approach as being based on the intention to understand, to question, to compare statements with experience etc (to grasp the intentional content of the learning material), while the surface approach reflects an inclination to memorise without question, to practise skills as instructed, not to look for meanings etc (to learn the text or 'sign' itself). The classification of the learning processes and outcomes must not be viewed as binary - both belong to continua.

Another definition of conceptual learning would make reference to Table 7: deep learning goes beyond the transmission of factual knowledge but helps students acquire relations and links. A most important discovery made was that some students may never be able to adopt the deep approach in some subjects or even in all subjects. From his own experience the writer would be happy to concur with this view since he often had to advise students on particular strategies for the choice of final year options! Marton and Säljö [1976] also discovered that retention of learning was good, supporting Guthrie's views (5.6.2.6), but that changes in outcome, when testing was repeated after an interval, tended to favour less deep levels. Some students would adapt their learning strategy to the type of testing which they expected: it may be useful to let students know in advance that an exam will not simply test the amount of content learnt but also understanding.

The surface approach is adequate for many of the elements of a standard university engineering curriculum where a good memory and well practised skills are sufficient to pass exams with flying colours. However, deep learning cannot take place without the prior learning of some skills and the acquisition of knowledge. This is a precondition which had been uppermost in the minds of the CIM course's designers at the time of its conception. It was decided at the outset that an integrating course could only be offered in the fourth year, after three academic periods where students accumulated skills and knowledge (see section 11.4.1) and three industrial periods where they were able to garner experience and develop their personal and interpersonal skills. Through several elements of the programmes in years one to three students would already have been able to practise conceptual learning.

5.8.2 Holist and Serialist Learners

Beyond the distinction between deep and surface learning there is also some benefit in differentiating between holist and serialist learners [Pask, 1976], the former gaining a broad overview before filling in the detail, while the latter need to follow a well structured and logical path. Pask stresses the importance of understanding in learning a topic. He defines understanding as learning for which the learner has been given an explanation and derivation. Holist students who have many goals and working topics often entertain correct beliefs (adopted content and views) about topics outside their direct area of work. A serialist learner only moves to a new topic when she or he is completely certain about the one currently being studied.

Students are often unable to change a learning strategy once adopted, even if it has proved to be unsuccessful. According to Pask, teachers should therefore try to provide a range of learning opportunities adapted to the different learning styles although he also states that students should be introduced to holist strategies. He warns of the institutional bias towards serial learning situations and serial recall for testing. Lectures and traditional distance learning materials tend to favour serial learners whereas well designed laboratory work[81)], student centred tutorials[82)], discussion oriented use of video support and non-conventional learning situations are more appropriate for holist learners. Pask also makes a distinction between comprehension learning and operation learning and stresses that both are necessary for creating understanding.

5.8.3 Verbalise, Visualise, Do

A similar dimension can be established for the choice of the media of instruction most suited to individual students's needs, depending on whether they are verbalisers, visualisers or doers [EPC 1, 1989]. Verbalisers learn more easily if information is provided in written or spoken form whereas visualisers respond better to diagrams and pictures. Doers prefer learning from practical activities regardless of whether they are dealing with information or concepts. The type of material and its structure are of particular significance in designing distance learning materials - which must serve a 'serialist doer' equally as well as a holist verbaliser! An ideal course would, however, not offer the option of using either deep or surface learning. This decision must be tied closely to the component of capability being taught.

5.8.4 Insightful Learning

Insightful learning is a particular form of deep learning which is discussed by Hergenhahn [1988]. He lists the following characteristics of insightful learning:

- the transition from the pre-solution to the solution is sudden and complete,
- performance based on a solution gained by insight is usually smooth and error free,
- a solution to a problem gained by insight is usually retained for a considerable length of time.
- a principle gained by insight is easily applied to other problems.

The approach has clear links to the Gestalt theory of learning. The product study and artefact study (see section 9.3) are courses which were designed according to this theory of learning.

5.8.5 The Need for a Rich Learning Environment

A rich learning environment offers scope for both deep and surface learning and gives serialist as well as holist learners the opportunities they need. Rich learning environments are also advocated by Hebb [from Hergenhahn, 1988] who found that organisms reared in an enriched environment learn faster than those reared in relative isolation. Theories and background relating to rich learning environments are described in some detail in the first

81) including open-ended objectives rather than fixed goals involving the plotting and analysing of data.

82) where the students present cases and examples and where the lecturer will assume the role of commentator, not that of instructor.

of the bulletins of the Engineering Professors' Council addressing educational issues in engineering [EPC 1, 1989]. Although Table 10 appears to indicate that traditional lectures fulfil a very minor role, it is important to realise that they often play an important role in kindling students' interest when presented in an enthusiastic and clear manner. Cooley's standard HCCIM lecture mentioned in 12.3.5, for example, tends to move about half the students present to explore the subject by themselves and led, in one year, to the formation of a student network which continued after graduation.

Staff in the Department of M&ES[83)] have always been aware of this need for rich learning environments which help maintain students' interest. The original concept of SEP even had its own word for the course elements which provide opportunities for open-ended work: 'Technik' circumscribes the elements of the programme which introduce the main (student) action components: action provides for the reinforcement of learning and the development of important engineering skills. The term Technik was borrowed from the German language where it can express the application of methods as well as a technical content: on SEP it stands for an ethos in which the design, innovation and problem-solving aspects of Engineering are emphasised [after Clark, 1985(1)]. Even the most recent discussions concerning the learning of mature people stress the learning which arises from "being thrown into a problem from which you can extract concepts and theory, rather than by first teaching concepts and theory and trying to apply it to the problem" [Abell, 1994].

The creation of a rich learning environment on its own, however, is not a guarantee for successful learning. According to Thorndike (see section 5.6.2.1) and Guthrie (5.6.2.6) the situations must be realistic. Abell [1994] stresses this point in a discussion of case based teaching: learning should be an iterative process between cases (the study of practical situations) and concepts. Not only is the structure of the learning of great importance but the learning processes which are engendered must be relevant and supported by tutors and mentors. One approach used successfully elsewhere is that of experiential learning, first proposed by Kolb et al. [1973]. Practice Based Learning (PBL)[84)], is a slightly modified, but still recognisably 'Kolbian' form of instruction.

5.9 Designing Contexts for Engineering Education

5.9.1 Implications for the Education of Engineers

The education process is aimed at improving students' performance in both simple and complex tasks through learning. It is an important requirement that this successful performance must not be restricted to tasks occurring at university but must be transferable to later professional activity. As a general observation good performance is related to achieving a satisfactory standard in two domains of learning, the cognitive domain and the affective domain [EPC, 1992]. Depending on the educational or industrial situation where the results of learning are to be applied, one or other domain will be more relevant. In general, the capability for learning will be domain specific and learners may therefore require guidance about their strengths and weaknesses so that they can choose a career path[85)] which optimises the use of their potential or of their intellectual and emotional resources.

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83) as mentioned earlier: Department of Manufacturing and Engineering Systems at Brunel University with its two main undergraduate programme strands, Special Engineering Programme (SEP) and Brunel Manufacturing Engineering (BME).

84) this "label" for the type of real life oriented learning used in the CIM course approach has been created by the writer of the present dissertation to highlight the need for realistic environments.

85) it may be appropriate to mention that this guidance function was one of the reasons for adopting the CIM format.

Engineers must function well at all levels of Rasmussen's 'step-ladder'. In particular, they must be able to decide, subconsciously or otherwise, when they may take a short-cut. Their education should therefore be designed to impart all the components identified above, as well as the experience to handle the processes involved. Reflecting on the evidence presented in footnote 65 it is important to ensure that the 'schemata', and to some extent the 'rules', being imprinted correspond as closely as possible to the present and future 'real' environment in which the engineer will be working. These tools should be taught or supplied in a structured format which allows absorption in a manner which will later not result in situation-inappropriate recall. The facts and information presented should be of relevance to allow the students easy and motivating access.

5.9.2 Shaping Teaching and Learning

Brandt [1984], as a scientist and academic teacher who bases his argumentation on research conducted at the Centre for University Didactics (HDZ) of the Technical University of Aachen, expects universities to equip students with:

(1) domain specific factual knowledge[86],

(2) problem solving strategies,

(3a) the ability to work in an independent and self critical fashion on scientific questions,

(3b) with the curiosity and the courage to question scientific methods and authorities,

(3c) with the desire to communicate their experiences and achievements to others including the general population,

(3d) abilities such that they feel happy to co-operate with many different groups and

(3e) attitudes which allow them to transcend received standards and wisdom.

While objectives (1) and (2) can be achieved more or less wholly in the cognitive domain of learning, the aims listed under (3) require a combination of the cognitive abilities of understanding, analysis, synthesis and judgement and the affective resolve to operate within one's own value system. Brandt's list thus has more than a passing resemblance to some of Rogers' principles listed in Text Box 2 on 98. If the universities are to satisfy the demands of students and society, they must go beyond the realms of cognitive teaching and learning processes. Brandt quotes a number of studies dating from the mid-1970s to support his thesis that university teachers must adopt different teaching methods, particularly those which support experience based or experiential learning. He feels that the university teachers must themselves develop an understanding of the complexity of the situation.

Branton [quoted in Oborne, 1993] forces teachers to face three important responsibilities:

(1) we must not rely on 'programming' students, we must work at all levels: affective, cognitive and subconscious.

(2) in setting up learning situations we must ensure that students acquire the skills needed to predict outcomes based on cues which may be fuzzy or conflicting.

(3) the working environment must be stimulating and provide a wide range of sensory inputs.

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86) which is expected to expand each year, see also section 5.1.

For satisfactory performance in their chosen field of activity the future engineering graduates must acquire not only a level of competence appropriate to engineers setting out on a professional career but also the ability to build on this foundation, a claim which is echoed in the EPC's demand for 'preparation for continuing education and training (CET)' [EPC 3, 1991].

5.10 Conclusion

Problem solving at all levels, from conceiving a product through to handling the environmental issues of its production, operation and ultimate disposal, is the most relevant dimension of engineering work. Rasmussen's view that most human activity is related to problem solving of some kind is therefore highly pertinent. Most theories of learning can claim to handle a particular aspect of the process of formation better than others, however, in reality only a combination of approaches will succeed in preparing people to handle complex situations requiring all facets of capability. The writer of this dissertation feels most at ease with the theories advocated by Thorndike, Guthrie and the Gestaltists but has sympathies with the advocates of transaction based learning. The key performance criterion for any approach must be whether or not it teaches students to learn for themselves. This issue is addressed in more detail in chapter 9 in which the author reviews the approaches to teaching engineering developed by staff in the Department of M&ES at Brunel University, including activities such as the artefact and product studies.

6 Theories of Motivation for Learning and Working

6.1 Introduction

Learning is substantially influenced by motivation. The present chapter is therefore devoted to a discussion of the background to the theory of motivation and also includes a brief discussion of a particular approach to raising students' commitment to study.

> "Our ability to learn is largely determined by two factors - intelligence and motivation. In the past we may well have misjudged somewhat the optimal balance between the two for successful learning, overestimating the significance of the first and underestimating the second." [Dowdeswell and Harris, 1979]

For the author, motivating a large and inhomogeneous group of people to remain committed to hard work on a predefined task was always one of the most draining duties in running the CIM course. Due to the problem and situation oriented strategy which had to be adopted during the development of the CIM approach, the result of severe time constraints[87)], he could not apply well rehearsed motivational techniques but had to rely on a number of 'home grown' tools and methods, some of which are described in chapter 14. However, a theoretical discussion of the topic of motivation is still necessary since it may allow the development of better approaches for the future.

Motivation is a major issue in any working and learning situation. Its discussion is founded on underlying assumptions about the essence of human nature, from rational-economic to psychological being (used in preference to the term 'man'), e.g., McGregor's Theory X and Theory Y. Theories of motivation abound, from Maslow to Herzberg to McClelland and Handy [Alschuler, 1970; Handy, 1985]. Most of the issues can be found to exist in a university environment, apart perhaps from the money motive which is only present in the form of an underlying ambition: "if I get a good degree I will get a well paid job".

Throughout the following discussion it is important to bear in mind the fundamental contention of I. Kant who stated that rational psychology, i.e., non-empirical knowledge of the soul or mind, is impossible. Of necessity, all of psychology is therefore empirical in nature... [after Kant, 1781]. The theory and science of psychology and, by implication, motivation thus rely on observation and deductive reasoning founded thereon. The comments in this section are substantially based on C. Handy's 'Understanding Organisations' [1985] and R.A. Dienstbier et al.'s 'Perspectives on Motivation' [1991]. The information presented here has been drawn, to a substantial extent, from the latter text. Where no detailed references are provided it will be possible to identify the original source in the text mentioned. While the former approaches the issue of motivation from a phenomenological point of the view the latter address it from a psychological angle. The more conventional views though, as well as a synthetic framework, can be found in the first chapter of Handy's 'Understanding Organisations' [1985].

6.2 Theoretical Background to Motivation Issues

6.2.1 Maslow and Co [in Handy, 1985]

It is usual to quote A. Maslow in any longish text dealing with organisational issues and to refer to him as the progenitor of the theory of motivation. The author must comply! In reality, Maslow should be linked to one theory in particular, that of the hierarchy of needs, an intrinsic theory. Maslow postulated that there are five levels of need, each of which is to

87) these arose out of the need to develop the course concept and the necessary teaching tools over a period of only three months, just prior to the first course, with a group of students who had not expected CIM to be part of the syllabus.

be satisfied before the next level comes into play, as shown in Figure 12 which is also used to highlight the overlaps between the lists of needs provided by other authors. Beginning with the most basic needs, the levels are:

(PN) Physiological Needs (Food, Warmth, Shelter)

(SN) Safety Needs

(BN) Belonging and Love Needs

(EN) Esteem Needs (Recognition etc.)

(AN) Self-Actualisation Needs

Maslow's hierarchy can be reduced to a statement about assertion of the self, in terms of physical (PN, SN) and emotional (BN, EN, AN) needs. It deals only with needs for receiving and not with those for giving. As Handy points out, there is also a substantial flaw in Maslow's argument in that, apart from the most basic needs (warmth and, to a lesser extent, food), complete satisfaction does not exist. The transfer of needs from the most basic levels to higher levels is sometimes described as sublimation. Other authors have reduced the needs hierarchy to fewer levels, have introduced dimensions and frameworks of needs and have expanded the classification.

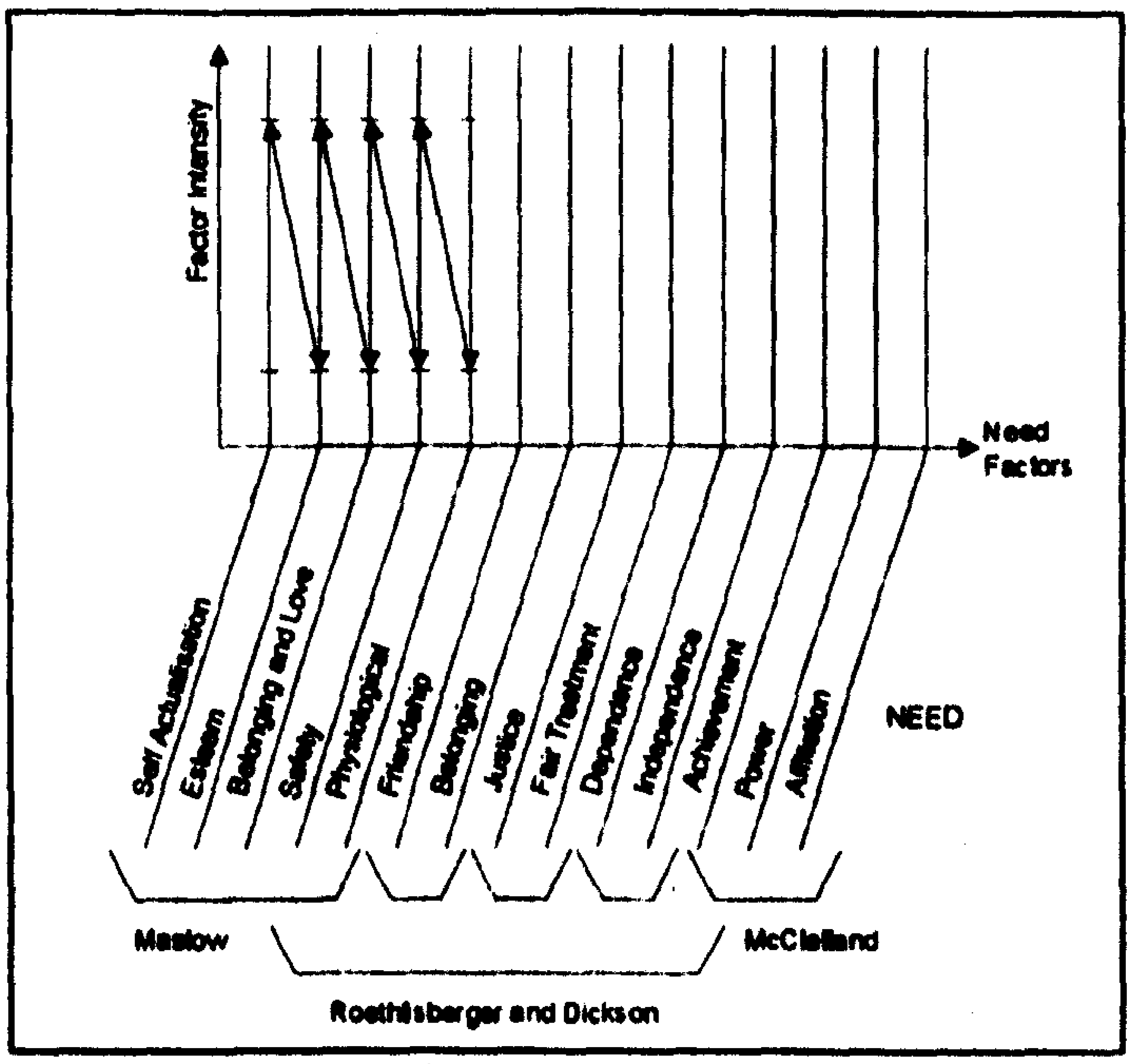

Figure 12 Needs Factor Intensity Models

Two possible graphical interpretations, of Aldefer and Ardrey's needs spaces, have been attempted by the writer and are shown in Figure 13 and Figure 14. The information to develop the pseudo three-dimensional representation was obtained from Dienstbier [1991]. Aldefer's needs space in Figure 13 expresses an individual's needs make-up as a point in a three-dimensional space indicating the intensity of need, at a particular time, with respect to existence (E), relating to others (O) and personal grow (P). Similarly, in Figure 14, intensities of needs are shown with respect to the axes given by need for identity (Id), stimulation (St) and security (Se). These Needs Spaces and also the Needs Factor Intensity model of Figure 12 are intended to show that individuals differ in their needs intensity both with respect to others and to themselves over time. These differences, observable even in

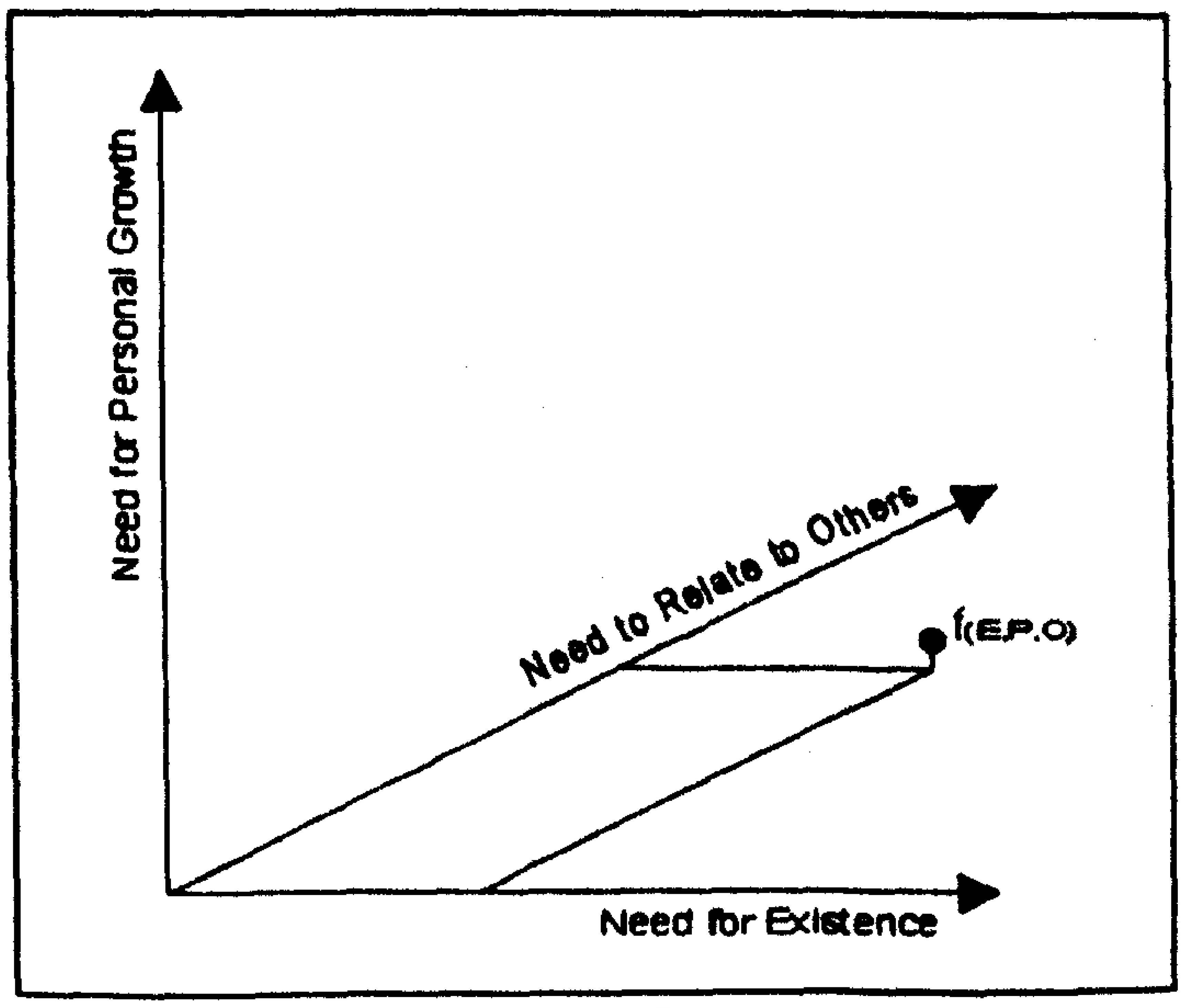

Figure 13 Aldefer's Needs Space

outwardly homogenous groups of people, cause great difficulties for the designers of motivating or satisfying work situations and work environments. Some authors, quoted and quickly contradicted by Handy, argue that involvement of the individual in the design of the work place removes most of the problems. However, it is often difficult to implement such a process in practice, due to technological limitations or due to a lack of self-actualisation need of the individual.

Satisfaction and incentive theories of motivation existed even before Maslow's needs based theory. While the former are not believed to be very useful, beyond providing assistance in creating work environments which reduce labour turnover, the latter can work if (i) the individual perceives the award as worth the extra effort and actually craves for it, (ii) the performance can be measured and (iii) as long as its improved level is not perceived as becoming the new minimum standard.

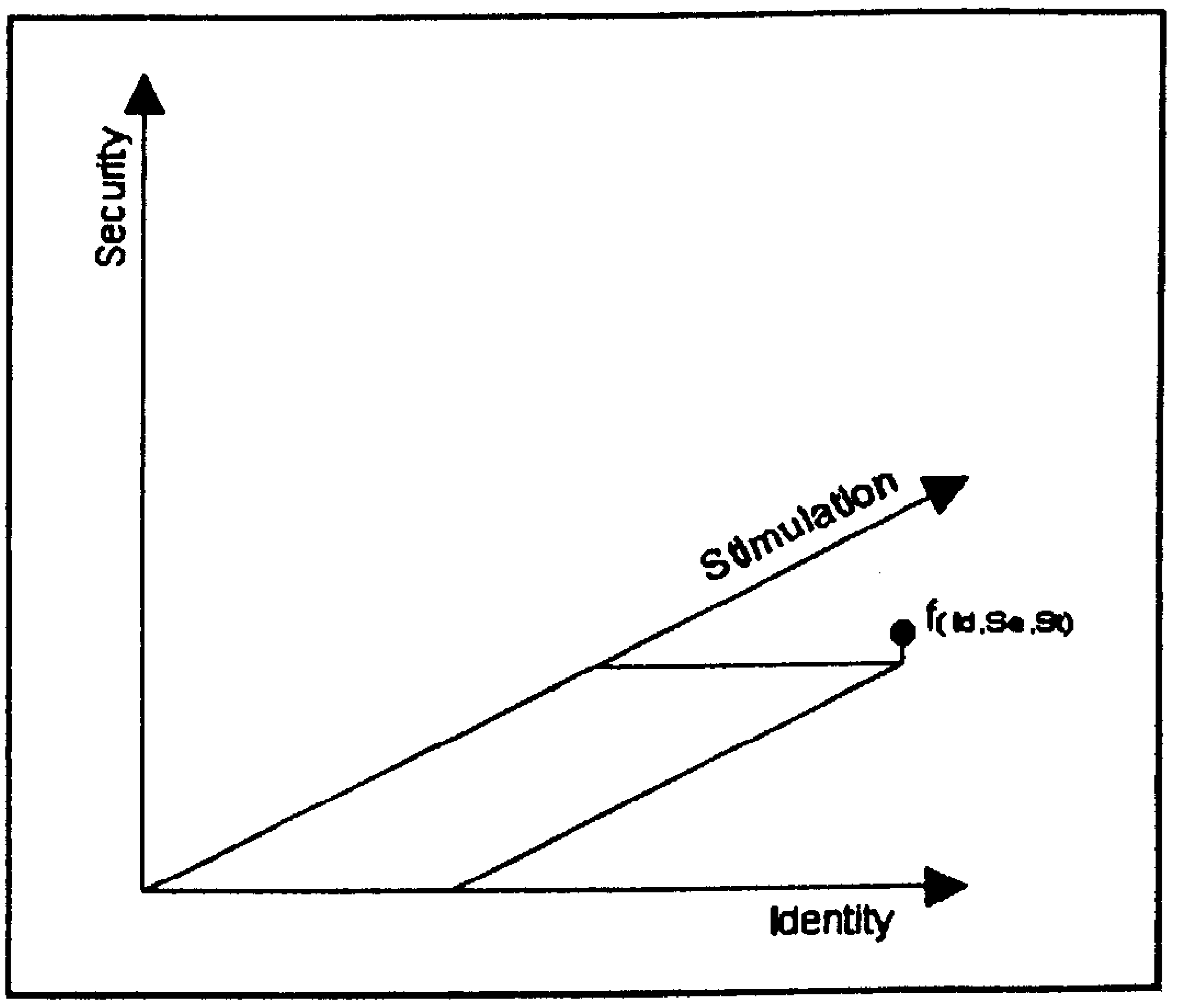

Figure 14 Ardrey's Needs Space

Herzberg classifies as hygiene or maintenance factors those aspects of a working environment which can lead to dissatisfaction if they are not of an adequate standard while he refers to elements which can satisfy a person as motivators. "Why bother coming into work" is a question of hygiene whereas working harder can only be promoted by motivators. The former include conditions of work, such as salary and physical working conditions and the latter achievement, recognition, the type of work, responsibility etc.

All the theories stem from some underlying assumptions about the nature of humans. These have changed over time[88)] and include rational-economic man[89)] who needs to be controlled by the organisation (Taylor's view and McGregor's Theory X worker); social man who expects good leadership skills and a group environment; self-actualising man who will respond positively to responsibility (Theory Y); complex man who finds satisfaction of needs in different situations; and psychological man who is trying to emulate an ideal of his own making (see Appley, below). Handy provides his own model for which he defines a motivation calculus which uses needs, results and E-factors[90)] in a feedback loop influenced by the strength of needs, the expectancy that E will lead to a result and the instrumentality of that result in satisfying the need. The calculus is both conscious and unconscious. The model provided by Weiner (below) points in the same direction as that of Handy but is much more sophisticated.

As will be seen later, in 6.3, and before that in Weiner and Deci, the discussion of people's needs is one of the most important aspects of the psychology of motivation. According to Handy, an individual's set of needs is influenced by heredity, the early environment, education, the individual's self-concept and experience.

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88) in effect, since the industrial revolution, taken by Handy as the starting point of the discussion on worker attitude.

89) 'man' is the term used by theorists and embraces both female and male actors (in the sense of active participants).

90) a rather silly way of lumping together energy, effort, excitement, expenditure etc.

6.2.2 M.H. Appley: 'Motivation, Equilibration and Stress' [in Dienstbier, 1991]

For Appley the fundamental motivational process is that of equilibration (or homeostasis - static balance) which allows a person both to maintain balance and to respond to changes in the environment, the latter leading to an explanation for the existence of personal growth, creativity and the seeking of stimulation. Cognitive processes are taken to be subsystems of motivational dynamics. Motivation itself is often stimulated by discrepancies between the current situation and some comparison standard or memory. Of great importance is the comparison of the current perception of self and an idealised self-image. This is a straightforward concept which can be used to explain the lack of motivation when the gap becomes too great - a mismatch of task difficulty and personal capacity which leads to a reduction in effort as a way to defend the ego; unfortunately a strategy which is not very successful when the goal is very high in value. This is an observation which the writer could substantiate with a number of individual and group working examples.

The existence of a concept of self allows a discussion of the role of the motivator, the person trying to enhance another person's performance by exerting a positive influence. Appley quotes Miller and Turnbull, an analysis worth repeating here: "Perceivers only induced (individuals) ... to accept incongruent conceptions of themselves when the perceivers were certain of their conceptions and ... (the individuals) were uncertain of theirs". This statement, together with some further comments on ways in which people's concepts of and misconceptions about themselves feed on others' reactions, makes a very important point: the motivator must be sincerely convinced that the person to be encouraged is more resourceful than he or she estimates to be their own capacity. A teacher must thus avoid the trap of 'pretending to believe' while really being highly sceptical of the capability of a student.

Appley discusses a wide range of sub-theories to that of equilibrium seeking, from very physical, energy-related approaches via cybernetic descriptions to Lewin's field theories with his notion of life space, tension etc. The human being is viewed as highly adaptable to changing environments and as responding well to challenges by moving to a new equilibrium of social influences, stress, stimulation, sensory activity, threat, anxiety etc. Essentially, the process uses negative feedback, a hypothesis for which Appley has been criticised but which rings true. An analysis or adjustment is avoided by the human, actively or passively, only if a stimulus appears too unfamiliar, that is, the characteristic of a non-linear element in the feedback loop.

This notion of balance seeking further applies to cognitive processes[91)] and not only to those of an unconscious but also to those of a conscious or cognate character (e.g., the intellectual drive to find a solution to a problem). For Appley both of these are subsystems of the motivational dynamic since cognition, whether conscious or unconscious, is required before the human being can respond to any change, i.e., be motivated! He includes anticipation, the confirming and 'disconfirming' of expectations, and of integration and coordination of function in his schema. The decision mechanism for the equilibration function which would be present in any controlled system, is described as being characterised by relatively simple sequential testing of different responses to failure. The self-concept is used not only as the measuring stick in this process but provides the mechanism for selecting and interpreting situational information. Where the self-schema is too ambitious it can constrain individuals or make them vulnerable.

An important aspect of balance concerns the feeling of self-worth which can be restored through ego-tasks (Appley quotes a good performance in a task being likened to an IQ test)

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91) one element of the cognitive process: "psychological explanations in terms of the representation and transformation of knowledge which may or may not be conscious" [Oatley and Johnson-Laird, 1987; cited by Appley].

and which becomes very important in situations which are ego-threatening, that is, potentially destructive of identity, integrity or life. These situations are highly stressful for the individual, and some such situations were created, unintentionally, on the CIM course, see section 13.2.4.

Disequilibration thus serves as an instigation to action - a motivator of behaviour. The conditions that give rise to the disequilibration are not independent of the individual's motivational propensities at the psychological, social and physical levels. This could be drawn up as a vulnerability profile of the person and could be used to determine which kinds of threats[92] would be effective for the individual. The author would argue that university staff and any educator worth their salt builds up such maps for all students over time.

6.2.3 A. Bandura: 'Self-Regulation of Motivation Through Anticipatory and Self-Reactive Mechanisms' [in Dienstbier, 1991]

Social cognitive theory distinguishes biologically based motivators (e.g., cellular deficits from lack of food, hormones etc, all of which are under cognitive control - anticipation of feeding...), social incentives (approval, censure, displeasure, wrath) and cognitively generated motivation, self motivation (anticipation of outcome leading to action). Bandura notes indiscriminate praise and disapproval without consequences as key risk factors in social motivation. For the cognitively generated motivation he offers three theories: causal attribution[93], outcome expectancies and cognised goals. A diagrammatic representation of the three theories is given in Figure 15, quoted from Dienstbier.

Causal attribution relies on retrospective assessment of performance: people who attribute success to their personal capabilities and failure to insufficient effort will undertake difficult tasks and persist in the face of failure while those who ascribe failure to deficiencies in ability will give up when they encounter obstacles. Reasons for past performances affect belief about personal control and thus can change future actions. Bandura discusses both effort and ability, and the latter's link to self-efficacy beliefs in some detail and relates these to achievement motivation (see section 6.3).

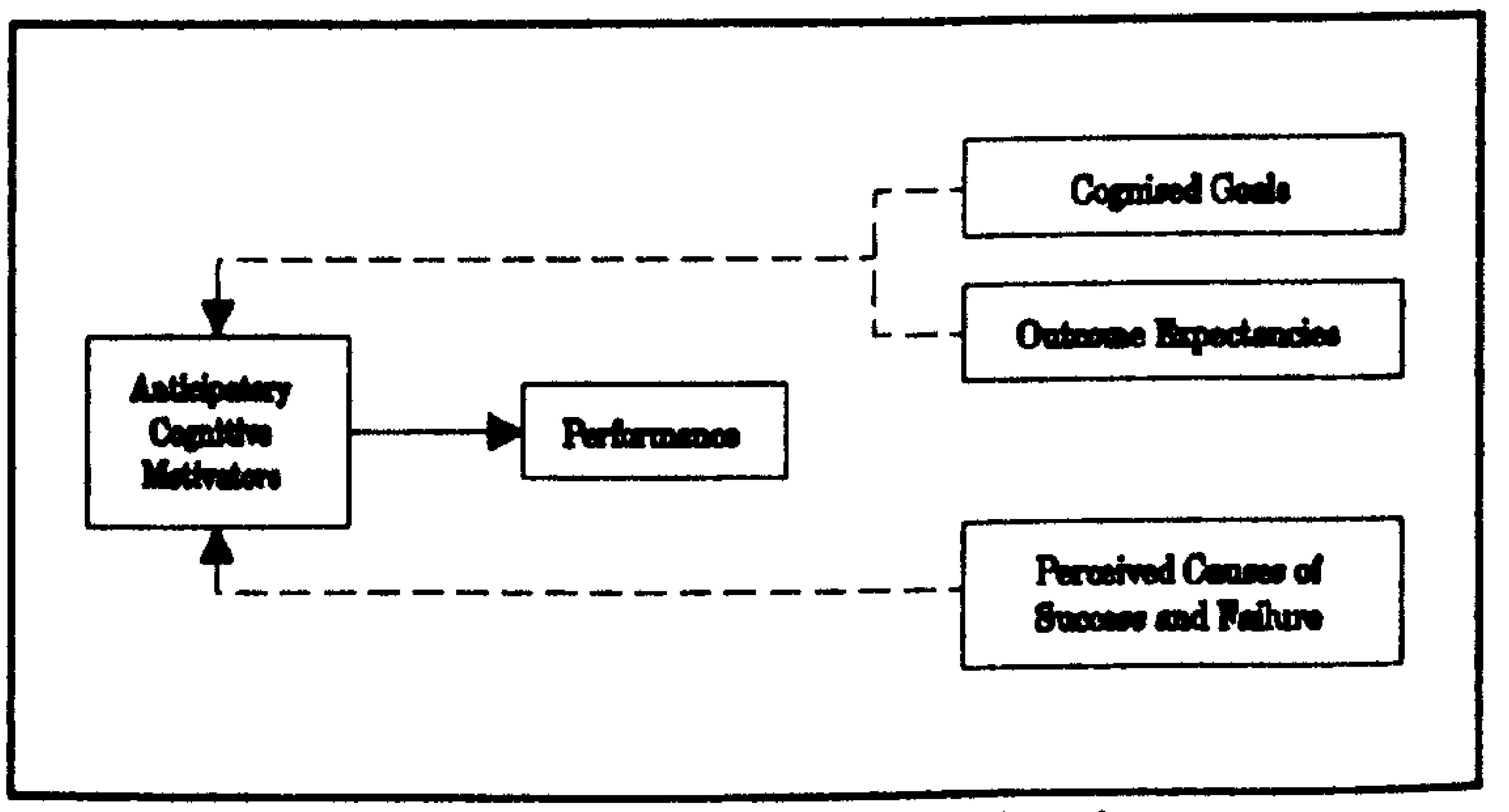

Figure 15 Bandura's Theory of Motivation

Expectancy-Value motivation relies on the expectation that particular actions will produce specified outcomes. People are, perhaps fortunately, not very good at scanning a large range of potential courses of actions and the model is therefore somewhat flawed. They tend to look for satisfactory rather than optimal outcomes, in the knowledge, that the information at hand may be neither fully accurate or complete. Some of the most powerful anticipated incentives are related to self-satisfaction from fulfilling personal standards. The motivation from external incentives depends on the tightness of contingencies between outcomes and actions.

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92) in the sense of stimuli for change.

93) perceived causes of success and failure, compare also with Weiner's model in Figure 16.

There are several areas on the CIM course where Bandura's observations correlate well with observed behaviour: these include the production of interim and final reports where the link to marks is immediately obvious and the project presentation day which acts as a positive target in the expectation of praise from a highly valued public - people from industry.

Goal theory relies on an enhancement of motivation through the setting of explicit challenging goals. The success of such a strategy has been shown to exist in many different domains. The process depends less on direct regulation of action and motivation than on a comparison of the progress towards the goal with the standards which people set for themselves, self-reactive influencing. This can be of three types: affective self-evaluation, perceived self-efficacy for goal attainment, and ongoing adjustment of personal standards, that is, raising or lowering the demands of the goal depending on progress and personal make-up. People tend to change goals as they proceed in an endeavour. Goals must have particular characteristics if they are to fulfil their role: they must be specific (although they may be of a generic type, e.g., completing a chapter of a dissertation), challenging but not impossible, and not too distant[94].

Bandura states quite unequivocally that virtually all of the research on cognitive motivators has been concerned with how self-regulatory dynamics operate in personal accomplishment, further restricted to discrete judgements in static, non-taxing environments. In his own words: "By contrast, in naturalistic environments decisions must be made from a wide array of information within a continuing flow of activity, under time constraints and with significant social and evaluative consequences." Actions taken at one point affect the options for later decisions and the decisional rules for exercising control over dynamic environments must be learnt through exploration while managing ongoing organisational activities. Some of the most important management decisions concern how best to use human talent and how to guide and motivate human effort, because organisational goals must be achieved through the coordinated efforts of others. Managers have to match employee attributes to organisational subfunctions and to learn a complex set of decision rules. The rules concern the optimal use of goals, supervisory feedback and social incentives. The mechanisms and outcomes of such processes do not lend themselves to experimental analysis.

According to Bandura, in the management of dynamic environments self-regulatory mechanisms govern organisational attainments much as they do individual accomplishments: the higher the perceived self-efficacy, the more systematic people are in applying analytic thinking to discover optimal decision rules. There are many complexities though in the relation between personal goals and group attainment. Personal goals are readily translatable into performance attainments when people have the knowledge and means to exercise control. Goals can affect performance by channelling attention and mobilising effort but sheer managerial effort does not ensure attainment of group oriented goals. Efforts to enhance the level of organisational functioning often require changes in particular aspects of the social structure and the way social resources are allocated.

Personal goals influence group performance by promoting effective managerial rule learning strategies but do not have a direct effect on performance. In a complex social environment, difficult to fulfil assigned goals may detract from organisational attainment. Again, managers who view capability as an acquired power perform better in the long term than those who view capability as a static and stable aptitude. The latters' performance declines over time as they start to doubt their managerial efficacy. Individuals who believe they are inefficacious are likely to effect little change even in environments that provide many opportunities and are highly responsive to the exercise of personal competence and vice versa. People who

94) it may be necessary to define sub-goals when goal proximity is not adequate.

manage an organisation under a cognitive set that organisations are not easily changeable quickly lose faith in their managerial abilities, even when standards are within easy reach, and they also have a tendency to lower their sights for the organisation.

Social comparison with other managers affects organisational attainment a great deal since people who see themselves increasingly surpassed by similar social referents suffer from undermining of perceived self-efficacy, disrupted analytic thinking and unremitting discontent. It is, unfortunately, impossible to discuss the many experimental findings described by Bandura but they provide an excellent background to some of the work undertaken on the CIM course. The reinforcement mechanism illustrated in Figure 15 of Bandura's analysis is of particular interest since it shows the influence of performance measurements for sub-goals (very relevant in the context of regular task reviews).

6.2.4 B. Weiner: 'On Perceiving the Other as Responsible' [in Dienstbier, 1991]

Weiner is accused by Appley of abandoning the equilibration theory of motivation even though he had been a strong advocate. He now promotes affect[95)] as a motivator in preference to cognitive or mechanistic concepts. Weiner criticises the view which held hedonism, the striving for pleasure and avoidance of pain, to be the drive for action. He is interested in emotion or affect as a 'push' or 'pull' mechanism, in particular in the context of reward systems which can have an effect contrary to that desired. Weiner describes himself as an attribution theorist since relating an outcome to an attribute of the 'self' (e.g., effort) results in different affects than ascribing the same outcome to factors outside the self. He is also critical of psychologists who neglect affiliation needs in favour of achievement needs.

Weiner postulates a near infinite number of causes for success and failure in the achievement domain, including ability, effort, strategy, task difficulty, luck, and help or hindrance (from others). In his contribution he introduces a (rigid) classification of the nature of causes in a 2x2x2 matrix[96)] with the dimensions of locus (external or internal to the actor), stability (enduring or not lasting over time) and controllability (the person is or is not able to influence the cause at will). Aptitude as the cause for an achievement outcome, for example, he classifies as internal, stable and uncontrollable. Being rejected for an affiliative engagement (a date) because one is too short has the same causal properties.

Weiner's own model of motivation and emotion, based on an attributional sequence, is reproduced here in Figure 16 and is discussed briefly, step by step:

(1) the outcome of an action influences the affect or emotion while its current state has a bearing on the interpretation of the outcome.

(2) depending on the outcome there is a search to determine why it occurred. This is more likely if the outcome was negative, that is, not as predicted.

(3) actors and observers will ascribe the outcome to different causes upon evaluation of specific information, e.g., praise for completing an easy task is viewed by an actor as a confirmation of low ability[97)].

(4) some ascriptions result directly in particular affects,

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95) affect(3), n. *Psychol.* a feeling, emotion, or desire, esp. as leading to action [The Concise Oxford Dictionary, 1990].

96) initially used in a binary manner but clearly capable of a continuous interpretation between the extreme values.

97) Weiner describes ability and effort as the most important causes for achievement while physical characteristics and personality are salient in affiliation.

(5) others need to be 'mentally plotted', on the 3D causal matrix discussed above, before the process can continue: this can in turn affect the causal attribution.

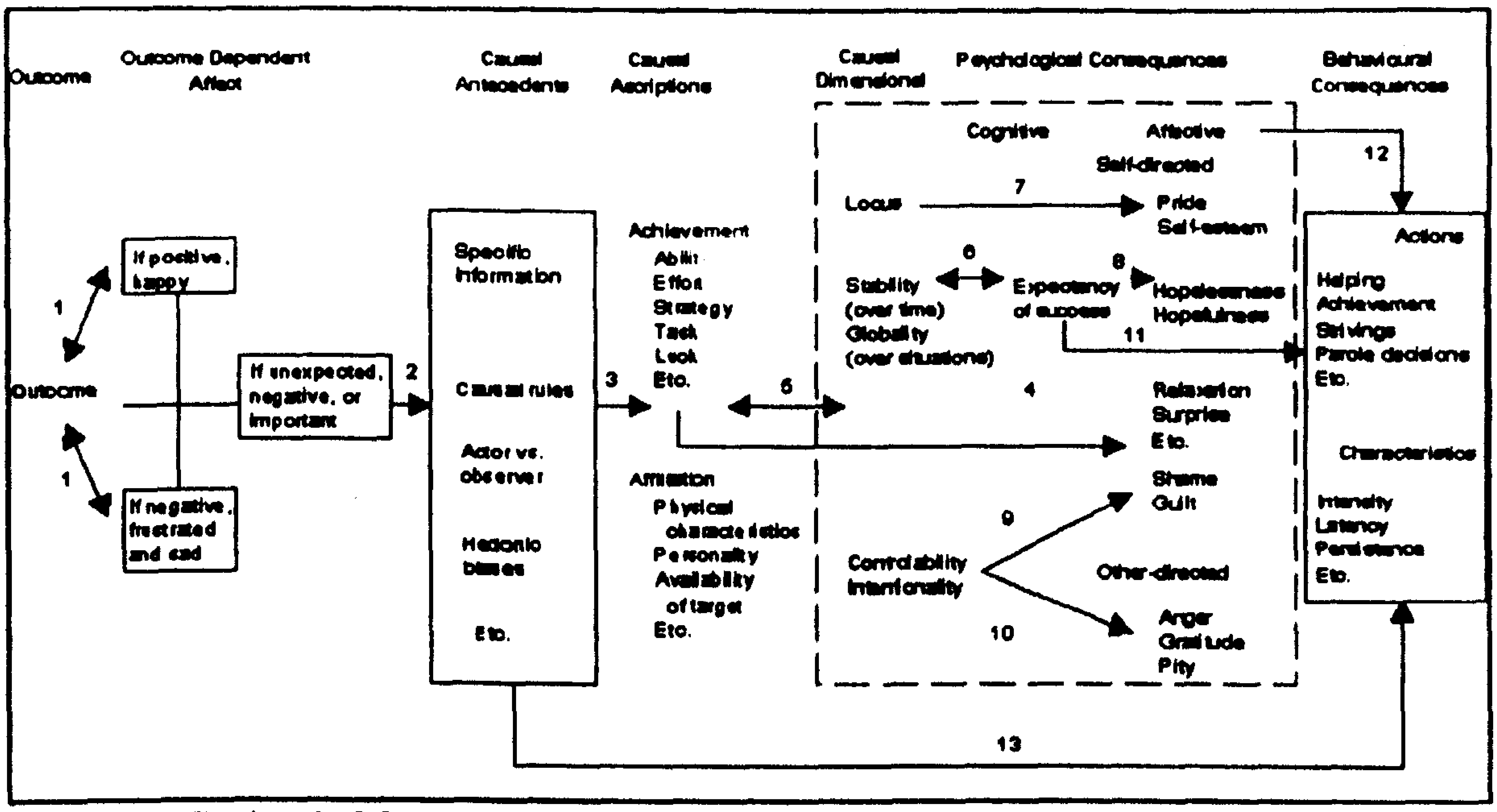

Figure 16 Weiner's Model of Emotion and Motivation

(6) the perception of causes as stable and the expectancy of success are mutually dependent.

(7) the perceived locus determines the self-worth experienced by the actor ("I am the greatest / to blame").

(8) the degree of expectancy of success determines the attitude towards future action based on the experience with the current action.

(9) depending on the perceived controllability of the cause and of its perceived locus social affects are directed towards oneself (9a) or others (9b).

(10) feedback, which will be discussed below.

(11) expectancy of success has a direct influence on the expending of effort etc. in the actions ahead. This influence is the result of a cognitive process.

(12) the affective state following the attributional processes (note: on the diagram these include all the factors from pride to pity) influences the approach to actions.

(13) the outcome dependent affect directly influences the attitude towards future action.

The influence of other-directed affective psychological consequences (10) is of interest not only to Weiner but also to anybody managing large projects and companies: since the individual, still according to Weiner, is searching for general laws in their environments, single mistakes can have far-reaching consequences. The affects or emotions of concern here are anger and pity although the former is perhaps more relevant in a management context. If a cause is perceived to be controllable then a person is held responsible for an outcome. This personal responsibility resulting from assumed or real controllability of a situation immediately leads to the apportionment of blame and anger. Uncontrollability, on the other hand, leads to sympathy or pity. In both cases the motivating effect can be positive or negative: anger signifying dissatisfaction with the level of effort committed by a person can lead to increased effort while an expression of sympathy can lead to a strengthened belief in one's lack of ability. Teachers and managers have to be very aware of these issues. This is not the place to delve deeper though.

In his quest for nice and simple theories Weiner tends to oversimplify: a typical example of this is his definition of the three dimensional matrix mentioned above where one of the axes refers to stability, which he restricts to the classification of variability over time by excluding variability over types of situations. The author of the present dissertation would contend that a four dimensional matrix or table with independent axes for temporal and situational stability would be more useful. He has attempted such a representation, for the binary case (the use of continuous values would require a true matrix approach), in Table 11. In line with engineering terminology he has replaced 'stability' with 'invariance', a term known in control theory. As an example, a few constellations of factors are shown in the table indicating a positive influence on motivation with '+++' etc. The table has been laid out to show the dimensions directly related to the actor as being of primary relevance while the aspects of invariance are shown as subordinate. This reflects an arbitrary decision.

Dimensions of Motivation			Locus			
			Internal		External	
		Temporal → Invariance Situational ↓	no	yes	no	yes
Control	full	specific	+++		-	
		global			--	
	none	specific				
		global	-			---

Table 11 Causal Dimensions of Motivation

The writer has dwelt on Weiner's model rather longer than might have been expected since it represents an engineering or systems oriented approach to motivation and because it highlights the significance of the personal history in generating motivation. It is notable that Weiner does not attach much significance to positive reinforcement. Although he never mentions people's need for balance, much of his writings could easily be interpreted as conforming to a negative feedback model and thus to equilibration theory.

6.2.5 C.S. Dweck: 'Self-Theories and Goals: 'Their Role in Motivation, Personality and Development' [in Dienstbier, 1991]

C.S. Dweck[98)] differentiates between two personal patterns, that of mastery-orientation, characterised by persistence and adaptive behaviour, and that of helplessness, characterised by maladaptive behaviour and lack of persistence in pursuing goals. As a matter of course, individuals exhibit aspects of both in a continuum of expression. She proposes two classes of goals in achievement situations: performance goals and learning goals. Both classes of goal are natural and universal but performance goals tend to create or reinforce vulnerability to the helplessness pattern.

Learning goals include errors and obstacles as expected parts of the situation, a natural, instructive element of the acquisition process. Depending on whether people view their ability

98) the research reported by Dweck was conducted mostly with children of primary school age but it seems germane to the discussion of motivation undertaken here.

as static or dynamic[99], they will choose easy to satisfy performance goals[100] or challenging learning goals respectively. According to Dweck the former behaviour sets up a permanent conflict since performance goals are inimical to people tending towards a helplessness pattern, exactly the sort of people who believe in being of fixed intellectual capacity and who tend to have basic needs or goals which are in conflict with each other. They also tend to shun the prolonged expenditure of effort, which is the way most competencies are built, because in their view high effort is taken to indicate low ability...

Teachers must be aware of the problems which can be caused by these different patterns and may be able to guide students appropriately.

6.2.6 E.L. Deci and R.M. Ryan: 'A Motivational Approach to Self: Integration in Personality' [in Dienstbier, 1991]

Deci and Ryan discuss the issues of intrinsic and extrinsic motivation, the former being concerned with the integration of aspects of self and of the environment which may be in conflict with each other. To do this requires the development of schemata and regulatory processes some of which may simply be 'borrowed' from the social world and will therefore not be firmly implanted. People are viewed as having three basic needs; for competence, self determination (autonomy) and relatedness. In its most simplistic interpretation, extrinsic motivation is based on threats or rewards. The authors agree with Bandura though in not insisting on a dichotomy between the two forms of motivation. They discuss the internalisation of externally motivated behaviours but fail to establish the link to the transformation of external goals into personal standards.

Of particular relevance to this dissertation is Deci and Ryan's discussion of competence[101] and the social environment: on the basis of intrinsic growth strivings people seek optimal challenges; in their interactions with the environment they look for competence-enhancing feedback, they attempt to express personal choice and initiative (autonomy) and they work to feel meaningfully related to others. Success in this endeavour depends on the interpersonal dynamics of the context in which it occurs. People give their own meanings to inputs from the real or imagined social environment and those psychological meanings (or functional significance) form the roots of action, rather than direct stimuli. Circumstances which afford access to competence relevant information and clarity of contingencies are more likely to promote motivated, intentional action. Intrinsic motivation though also requires an autonomy-supporting (non controlling) ambience. They specifically describe deadlines, imposed goals, surveillance and social evaluation as undermining intrinsic motivation. These are experienced as controlling because the intent behind them is usually to 'motivate' or pressure people to behave, think or feel in specific ways. There must be enjoyment!

While immediate involvement[102] has been shown not to be essential for intrinsic motivation it is necessary for internalisation because this requires the significant others to provide the regulatory structures and to endorse and demonstrate the values that are to be internalised. The 'others' must act in a way which recognises the target's individuality and frame of

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99) Bandura describes the latter in the following words: "In one perspective, intelligence is construed as an incremental skill that can be continually enhanced by acquiring knowledge and perfecting one's competencies."

100) it may be useful to compare this statement with the views expressed by Alschuler et al. regarding achievement motivation - people with a high need for achievement could be seen as mastery-oriented in Dweck's parlance.

101) where being competent with respect to an activity is defined as "being reliably able to achieve desired outcomes and to experience effectance in action" [in Dienstbier, 1991].

102) significant others' (reference persons') devoting psychological and material resources to interactions with a target person or group of people.

reference and not simply as though it served for their own gratification. Deci and Ryan see no conflict between autonomy and relatedness because the former requires initiation and endorsement of one's behaviour and thus a dependence on others which is introduced by free choice.

In essence, Deci and Ryan subscribe to the 'equilibration' model of motivation but disguise it as 'striving for dynamic harmony'. In functioning to satisfy the three basic needs, one's self-related processes are synthetic and operate to assimilate aspects of one's inner and outer environments, thus expressing interests, conquering challenges and internalising values, practices and styles of being. Actions that emanate from the self are experienced as spontaneous and volitional because they stem from processes that reflect the most vital and integral aspects of one's personality.

6.3 Achievement Motivation

Following the general introduction to the question of motivation, important in the context of any teaching situation, it is time to return to a topic anticipated in section 1.4, the issue of achievement. In the present section therefore we shall be concerned only with a very small aspect of motivation, that of instilling students with a desire for personal improvement.

> **"A certain amount of achievement is integral to a person's sense of worth and identity." [Alschuler, 1970]**

In 1970 Alschuler, Tabor and McIntyre, researchers from the D.C. McClelland school (or tree, as the authors themselves put it) published a teacher's guide to improving class room performance, entitled 'Teaching Achievement Motivation'. As already intimated in section 1.4 this text on a particular form of psychological education seems very germane to the investigation in hand since the authors aim to help teachers create an environment characterised by "involvement, relevance, independent inquiry, individualized instruction, student directed learning". It is their stated belief that thought must not be isolated from action, that feeling must be integrated in learning and that education must serve to help students clarify values and enhance creativity, interpersonal relations and sensitivity. They contend that "the need to achieve"[103)] is a basic human characteristic even though it is not present to the same extent in every person. The writer of this thesis feels that he can subscribe fully to this view and that a further discussion of the approach is therefore justified.

Alschuler's team rate the importance of this need to achieve as higher than that of curiosity and adaptability since it allows students to get away from "don't care, an enveloping student reaction not only to problems of school and work but also of life and self" [Alschuler et al., 1970]. They want to use the classroom to develop <u>all</u> the students' motivation towards achieving <u>personal</u> excellence and thus to increase their chance of attaining other personal goals such as having close relationships and exerting influence.

6.3.1 Implementation

Even though Alschuler et al.'s approach is aimed at children of primary and secondary school age it is just as relevant for the final year of a university degree course where students should be encouraged to go out into 'real life' with a positive determination to pursue high standards, some experience of how to plan to attain excellence and strong feelings about doing well. The approach is founded on a removal of comparative targets, where there is

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103) for which they coined the rather corny acronym "n-Ach" ... which the writer refuses to use!

nothing left for the 'poorest' students[104], and the installation in their place of individual targets. Students are to be helped to set high, but achievable aims and to revise these upwards later. Teachers must create excitement, joy, self understanding and awareness of non-verbal communications, from all of which should flow self reliance. The skills taught as part of the process are to be valuable over a person's whole life, in other words, they are transferable skills (see chapter 10), and will take root in feelings, thoughts and actions.

Teachers who wish to create learning and achievement opportunities and the necessary motives can follow the 'six steps to success', a process for managing change:

1) Get Attention: focus students on what is happening here and now (dramatic settings).
2) Create Experiences: students must vividly experience thoughts, actions and feelings comprising the motive.
3) Conceptualise: to clarify the motive students must conceptualise and 'label' elements of the motive.
4) Relate: test the relevance of the motive by relating it to the person's own values, feelings, demands of life.
5) Apply: use several real goal setting situations to stabilise the motive.
6) Internalise: progressively withdraw external support while maintaining its voluntary use and satisfaction.

Alschuler and his colleagues emphasise the importance of group and team based work (see also section 13). This is to some extent founded on the circumstances of school environments, in which motivation is to be created, and partly on the existence of the two other important human needs[105], those for power and affiliation (friendly relationships). Both the attitudes and the output of groups depends substantially on the orientation of the leader, with respect to the three dimensions of power, affiliation and achievement, an observation made by Lewin, Lippitt and White [1939] and quoted by Alschuler.

Teachers must be aware of the ethical problems inherent in wanting to improve students' performance by changing their attitudes. This is, unfortunately, a dilemma which cannot be solved and which is inseparable from the condition of being a teacher. Alschuler et al. are very clear about this but believe firmly that problems can be avoided as long as teachers recognise the boundaries of their competence and maintain clear formal rules in the classroom. They may establish learning contracts with the students to ensure 'client welfare' for the latter. It is possible to define thus a safe environment for motivating the need for achievement where feelings of success stimulate further work. Manipulation and the use of tricks, playing of games and dependence on hidden intentions is outlawed. Motivation and interest in maintaining motivation are important, for life!

6.3.2 Achievement Motivation and Assessment

The success of any programme of teaching aimed at creating new values and at internalising approaches and skills must be assessed and measured differently from other learning situ-

104) on many university courses marks are normalised, often around a relatively arbitrary average of 55%, to provide a distribution of marks which does not change from year to year. This is, in fact, a hidden introduction of comparative or zero sum grading. See also section 15.1, 15.2 and, specifically, footnote 205.

105) power and affiliation, which can only exist in groups, are statistically unrelated, that is, a high achiever may or may not need or want affiliation.

ations. Classical testing, for example, measures the past, the retention of information given. Motivation to achieve can be enhanced by choosing the right method of judging students' performance. Alschuler quotes three main types of assessment, each of which furthers the satisfaction of a different need[106]:

1) ZSA or Zero Sum Assessment (furthering the setting of power goals): the overall sum of marks is fixed and what one person wins another loses. Normalised marks are a hidden form of ZSA. Decisions are referred to leaders, opponents must be beaten.

2) NSA or Non zero Sum Assessment (furthering the setting of achievement goals): the overall sum of marks is higher or lower depending on the sum of all individuals' performances. Obstacles tend to be personal and environmental.

3) SSA or Shared Sum Assessment (furthering the setting of affiliation goals): NSA of groups or teams with each member achieving the same mark - may be difficult because of unequal contributions, friction in the team.

The issue of whether to maintain absolute standards or to ensure that assessment patterns do not change between cohorts of students[107] is also discussed in section 15.3.1, which deals with the use of assessment as a motivational tool on the CIM course. In any learning and employment situation the evaluation of people's performance is a thorny problems: the potential users of the output of an assessment process, be it the individual, peers, teachers, careers advisers and employers, all have different agendas and see 'fairness' in a different light. are put.

6.3.3 Summary of Achievement Motivation

At all levels of education teachers should encourage students to acquire a strong need for achievement with the aim of furthering their personal development and of creating a climate for successful learning. The team of Alschuler and McClelland advocate a number of methods for assisting students in this:

- personal targets and emotional peak experiences[108].
- pursuing of individually achievable high standards.
- involvement in the process.
- linking of thought and action.
- taking of moderate risk.
- acquiring team building skills.
- creation of personal pressure to be successful within the individual targets (NZSA).
- the development of safe and supportive environments.
- pride in accomplishing something difficult.
- regular feedback to maintain interest in achievement and where necessary the setting of intermediate goals.

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106) they illustrate this with game situations but the same analysis applies to conventional assessment, marking.

107) that is, to adjust the spread of marks until a stable mean and 'normal' standard deviation is established.

108) "one characteristic that sets these peak experiences apart is the simultaneous intensity of radically new thoughts, actions and feelings."

When setting their targets, people with low motivation or 'need to achieve' will bid either unrealistically high (making aims not achievable), or they set extremely easy goals taking satisfaction out of the resulting success. High achievers, in contrast, are realistic but prepared to take a sensible risk, which Alschuler gives as a 50:50 chance of success.

Some of the guidelines and checklists prepared by Alschuler et al. will be used by the author to evaluate the performance of the CIM course in promoting a positive environment for learning, in section 17.3.3.

6.4 Theories of Motivation and Education

6.4.1 A Critical View of Motivation

Wittenzellner [1994], in her review of Sprenger's [1993] work, attacks the tenet that it is possible to motivate staff through rewards which are perceived as external to the process of work. She rejects the use of bonus systems, praise, promotion prospects and perks for changing the attitude of individuals or whole work forces. The key motivators, according to Sprenger, must be the work being carried out and the clear leadership from management. Managers must not be led to believe that they can off-load their responsibility onto a well-honed system of organisation with built-in motivators. Perhaps the most important realisation concerns the timing of motivation campaigns: they usually take place once a work-force has already been demotivated!

While Sprenger's criticism is valid, it relates to what could be termed 'incentive motivation' rather than the motivational approaches which were described in section 6.2. Most of his views could be supported with quotations from the writings of Handy, Maslow, Weiner and Bandura since they are very much in line with behavioural and Gestaltist ideas. Sprenger's conclusions appear to be common sense: motivation is created by the agreement on clear objectives and individual decision space.

6.4.2 Motivating Students

Difficulties arise not only in the design of motivating and satisfying work systems but also, as a matter of course, in designing educational contexts. Teachers often view students as Theory X individuals who require spoon-feeding of information and methods for solving problems. This is especially true for Swiss and traditional French engineering courses but can also be observed on full time degree programmes in the UK. Most lecturers feel that most students[109] work only as hard as is necessary to achieve a set of marks sufficient for their ambition in terms of degree classification. The offer of linking marks to performance measures would therefore act as an incentive type motivator. In the past, motivation was not seen as a serious problem since totally demotivated students disappeared as a consequence of the punitive or coercive nature of marking: they failed the year. Recently, the pressure on maintaining student numbers has moved university environments much closer to those existing in commercial enterprises, with a concomitant increase in the need for motivation.

There are three main reasons why the author feels that engineering students need to have an experience of being strongly motivated towards achieving a set of objectives:

- it is much more fun working with a team of motivated people than to attempt dragging along a group of tired and uninterested wastrels.

109) although every university teacher have her or his example of an outstanding student who, as a result of motivation by the teacher, takes a real and sustained interest in their work.

- a real world oriented problem of a large scale can only be handled successfully by motivated people.
- as highlighted in 3.1.3 and 14.4 young engineers in Britain and elsewhere tend to move very quickly into line or project team management positions where they need to motivate people themselves.

As in real life, in the CIM approach such motivation cannot be achieved by the simple expedient of attaching marks to a performance. There must be different motivators for different aspects of the personalities of different people. Neither an incentive based approach nor a satisfaction theory will be of much assistance on their own although the former may provide some motivation, in particular where the simpler elements of a course design are concerned, such as the writing of assignments. Most efforts should therefore be channelled into addressing the variety of needs, from physiological to affiliation, encountered in the preceding sections. Of particular significance is one of the observations of Bandura which states that, whatever the design of the organisational environment, it is important that the individuals involved perceive it as changeable: even the best designed system will ultimately fail if people no longer view it as adaptable to their changing needs.

For the CIM course Deci and Ryan's comments result in demands on the relationship between course staff and students which must be neither too loose nor too controlling but which may on no account be 'cold'. Universities have a reasonable array of methods to enforce commitment and conformity, both hierarchically and amongst peers (see, for example, the case described in section 13.2), but often do not seem to be too aware of other approaches for developing good performance. Just like managers of any other organisation, university teachers can ask or oblige students to conclude different kinds of psychological contracts: coercive, calculative and co-operative (after Handy [1985]). Once students have registered with a university, they themselves, the institution, parents and government combine to exert substantial coercion to reach the single target of a good degree. All have the possibility of applying punitive measures. A second, calculative contract is based on the marking schemes and the expectation of good references. A co-operative contract, where the student identifies with the goals of the teacher, is rather less frequent and depends both on free choice and involvement in decisions. The introduction of optional modules is one of the tools used by many course designers to enhance students' commitment to study. This type of contract became much easier to establish at Brunel once the CIM course (a brief outline was given in section 2.7) became a fourth year option rather than a compulsory subject for BME students.

6.4.3 Course Team's Approach

As mentioned earlier, the time constraints imposed on the course's development did not allow the evaluation and subsequent incorporation of formal methods of motivation. The course team, led by the author, used a number of informal techniques, some of which are described in chapter 14, to support the two important elements of their motivation strategy, covering the sequence of events shown in chapter 12:

- advance information campaign and recruitment of key team members, a long term motivation approach,
- short to medium term motivation maintenance work throughout the course.

The satisfaction of the physiological needs of the team members on the course gradually improved through the provision of specially equipped working areas and rooms with their own computer facilities and terminals. At the same time this also enhanced the social standing of the group as a whole, leading to a satisfaction of some of the self-actualisation needs. Another element in this process was the acquisition of leading edge equipment for the manufacturing system being developed as part of the course.

Appley's equilibration model is almost immediately useful since it can explain some of the negotiations concerning effort and stress and some behaviours where students concentrated all their work on the CIM course, to the detriment of performance in other subjects (see section 13.2.1). It is difficult to imagine applying Weiner's feedback model of Figure 16 directly to a course using the CIM approach, as a tool for developing methods for enhancing performance. However, step (1) in the attributional sequence is very relevant since the student's interpretation of an outcome as positive or negative is often determined by the reaction of the teacher. The teacher's major input will probably be in the area of modification of psychological consequences, e.g., in moderating a misdirected expectancy of success which could otherwise lead to hopelessness (8).

Acknowledging one of Bandura's conditions for successful work in organisations, the writer, and with him the other members of the CIM team, insisted from the outset that students' capabilities were to be considered as acquired powers and that willingness to learn was more important than established capability. This message is brought home to students at an introductory meeting before the course and through the use of 'skill cards' (see section N, O and appendix O).

Deci and Ryan's comments proved to be applicable since the teams worked best if the staff members were seen to be committed to the course, for example, by working themselves in a motivated manner on a particular problem and by observing longer working hours than is the norm for university staff. This is certainly not feasible in the very long term, however, some sacrifices in terms of time normally devoted to research or consultancy could get across the right message. Students were fast to note an absence of such 'leadership'[110].

The issue of goal complexity which, according to Bandura, has an important influence on individual and team motivation and performance was addressed in two ways: outline goals for each task team were defined before the start of each course and were then modified at the task reviews (on the basis of a co-operative contract) to take into account capabilities and time commitments. This process was particularly important and difficult in the case of relatively peripheral tasks such as the development of a multidrop RS485 network over several years, the design and build of a gripper system for a non-integrated robot and the writing of post-processors. Motivation relied on perceptual integration into the overall project and the establishment of clearly defined goals.

An essential requirement, that of maintaining changeability (again formulated by Bandura), proved to be relatively easy to satisfy both between different instances of running the course and within each course: technological developments meant that the hardware and software concepts being used changed from year to year, thus requiring different tasks and task structures as shown in Table 17 on 137 and Table 21 on 152. Changing availability of equipment and other resources, as well as financial constraints, introduced the same element within each course implementation. This slight unpredictability automatically established mental patterns supporting change, a consequence of which was the establishment of a 'strategy' team first mooted by the team members of the academic year 1988/89 and implemented by the team of 1991/92.

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110) this became very apparent during the appraisal by the students of the course staff at the end of the academic period 1990/91 where the four people involved received very different assessments and where the level of perceived interest was strongly criticised in one member of staff.

It is in the nature of a university course at final year level that students have developed relatively stable social environments which help them cope with the pressure of studying for exams and completing a major project. By satisfying their affiliation needs they create the motivation to work determinedly on their thesis, etc. The structure of the CIM course reduces the potential for social interaction due to the increased time commitment. The course tutors, recognising this, thanks to feedback from the students, allowed the development of a social 'scene', which they supported financially.

6.5 Conclusion

It has proved impossible to review more than a small range of the literature and theories which abound in the areas of knowledge classification, learning and motivation. While they are fascinating and might well be highly relevant to the discussion of the education of engineers for modern manufacturing environments, the theories of capability, of learning and of motivation should not be taken as 'gospel'. They have been reviewed here, on the one hand, to give an idea of the scale and scope of the debate surrounding the issues and, on the other, to allow the reader to define her or his own context for the teaching 'tools' described in chapter 14.

7 Applying Theories of Learning and Motivation to Education

A number of requirements for an education which could be expected to result in the formation of "good engineers" were stated in section 4.4, most notably a call for reality oriented learning. Particularly so in the UK, two rationales are given for this move away from theory oriented to practice based learning:

- industry's perceived need for immediately useful engineers,
- academics' realisation of graduates' difficulties when confronted with real problems.

Although the two objectives appear to be similar at first sight, there are two very different underlying concerns in that industrial managers' needs are frequently stated in terms of directly relevant knowledge, combined with applications experience, while the academic aims can be paraphrased as "learning to learn" (see below) and coping with the often ill-defined problems occurring in real life. The industrial objective can be satisfied to a substantial extent by ensuring that up-to-the minute and relevant knowledge is transmitted and that engineering paradigmata are learnt, in part, through practical experience (laboratories and applied examples). The academic objectives, however, require more sophisticated approaches, that is, completely new learning environments as stipulated in section 5.8.5.

In the present chapter, a brief review of conventional teaching approaches will be followed by an extended discussion of experiential learning and its derivatives.

7.1 Conventional Teaching Methods

Traditionally, university education has relied on a mixture of lectures, tutorials, seminars, laboratory sessions and individual project work[11] to prepare students for their future tasks [cf EPC1-5]. Lectures are a very useful tool for the transfer of factual information and for the presentation of intellectual concepts. Tutorials run by experienced teachers can serve to further the understanding of concepts while seminars provide opportunities for students to demonstrate that they are capable of structuring and transmitting information themselves. Laboratory sessions are usually intended to train students in narrowly defined skills or to allow them to experience the practical manifestation of theoretical concepts. Although these methods are suited to preparing engineers and managers for their technology oriented tasks they are rather less useful in generating an understanding of people and business related issues. As highlighted in section 4.4.3, these aspects of engineering education were traditionally imparted during the first two or three years of postgraduate industrial experience. However, the cost of such induction periods is no longer acceptable to many businesses. As a result, universities and other institutions of higher education were forced to develop alternative approaches, some of which are illustrated below and elsewhere in the thesis.

The traditional teaching and learning methods should not be dismissed out of hand. Most of an engineering education should still be based on traditional approaches, because the vast quantities of factual and conceptual information which must be transmitted cannot be taught in any other manner. Many of the skills required by engineers (and managers) are of a mechanistic nature and do not necessarily benefit from open-ended learning situations.

7.2 The Case Study Approach

The Master of Business Administration (MBA) movement has led to the development of the case study teaching method which is based on real life problem situations. In a formal case

11)project work and its benefits and drawbacks are discussed in section 8.1

study, of the type created at the Harvard Business School, the background to the problem is described in some detail, a great deal of emphasis being placed on one particular angle, e.g., the issue of technological change. The information given would have been vetted and approved by the company which provided the case study situation. Students are invited to analyse the situation and the company's approach to generating a solution. The analysis should lead, wherever possible, to the definition of a generic problem which should allow students to identify similar situations once they have moved into professional positions. Alternative response possibilities are also discussed, so as to allow paradigm based solutions. This is both the strength and the weakness of the case study approach: a traditional case study does not necessarily develop engineers' and managers' problem solving abilities, it is based on pattern recognition and relatively automatic responses. The approach does, however, teach students to work fast and to develop a methodology for solving case studies. But reality is rarely presented in the form of a background paper with questions! Learning which goes beyond that possible through a case study must therefore be based on experience which is founded on real life.

7.3 Experiential Learning

7.3.1 Carl Rogers' Principles of Learning

In 1969 Carl Rogers formulated the ten principles of learning, listed in Text Box 2, perhaps one of the first comprehensive programmatic statements on learning based on a real environment and relying on students' interest in the subject studied, coupled to participation and furthering of independent work. The principles are really about freedom, choice and the need for an education where people "learn to learn" such that they are able to enhance their own performance.

In the context of this dissertation, principles 1, 2, 6, 7, 8 are non-controversial and derive more or less directly from the education and motivation theory presented in chapters 5 and 6. Principle 10 is no longer challenged even though it may have been viewed as very progressive in 1969! The need for life-long learning and openness to change is now recognised fully. Principles 3 and 4 deal with obstacles to the process of learning, however, they are not meant to prevent teachers from introducing 'threatening learning' and 'change'. They simply advise caution in introducing such elements. Principle 5, in Rogers' own view, is more or less an extension to the preceding principle. He emphasises that threats to the organism - which would also

<u>10 Principles of Learning [Rogers, 1969]</u>

1) Human beings have a natural potential for learning.

2) Significant learning takes place when the subject matter is perceived by the student as having relevance for his/her own purposes.

3) Learning which involves a change in self-organisation - in the perception of oneself - is threatening and tends to be resisted.

4) Those learnings which are threatening to the self are more easily perceived and assimilated when external threats are at a minimum.

5) When threat to the self is low, experience can be perceived in differentiated fashion and learning can proceed.

6) Much significant learning is acquired by doing.

7) Learning is facilitated when the student participates sensibly in the learning process.

8) Self-initiated learning, which involves the whole person of the learner (feelings as well as intellect), is the most lasting and pervasive.

9) Independence, creativity and self-reliance are facilitated when self-criticism and self-evaluation are basic and evaluation by others is of secondary importance.

10) The most socially useful learning in the modern world is the learning of the process of learning, a continuous openness to experience and incorporation into oneself of the process of change.

Text Box 2 Rogers' 10 Principles of Learning include the rational mind - are different from those to the ego or self, as represented by the person's perception of himself or herself. The experience of the CIM course bears out this observation to a substantial degree. Principle 9 is, in the writer's opinion, far too idealistic. The 'real world of work' cannot rely on basic self-criticism and self-evaluation. Evaluation by others is unavoidable and students, people must learn to handle this type of threat. Rogers' ten principles will be discussed further in section 17.2.2.

Most recent literature sources [Boud and Pascoe, 1978; Kolb, 1984; Lederman, 1984 & 1992; Hammel, 1986; Thatcher, 1986; Gibbs, 1993] refer to this type of approach as experiential learning, a term which has unfortunately been devalued through overuse. An alternative term, heuristic methods, is perhaps not ideal since it has the connotation of a trial and error approach which, as we shall see later (in Footnote 112 and section 7.3.2), is not appropriate.

The writer of this thesis will attempt to show that it may be useful to go beyond 'conventional' experiential learning in defining scope and impact of the CIM course. He will propose as a further label "Practice Based Learning (PBL)", that is, real world oriented learning. This may be a better description of the approach adopted by the Brunel CIM team than experiential learning.

7.3.2 Models of Experiential Learning

John Dewey [1929] and other pragmatists believed that experience and what is drawn from it are the raw data out of which real learning grows. Based on this early work, Kolb, Rubin and McIntyre [1974] developed a model of learning which relies on a structured use of experience and which they labelled Experiential Learning (EL). The restrictive adjective 'structured' is important since it stands for the realisation that experiences on their own do not provide a learning opportunity[112]. Kolb et al.'s approach was based on a cyclical process, the experiential learning cycle, as shown in Figure 17. In an extension of this model, postulated by the writer, the learning of complex concepts and subjects can be likened to a spiral process leading to understanding at ever increasing levels, as shown in Figure 18. If experiential learning is to happen with some degree of success it must take place in four stages:

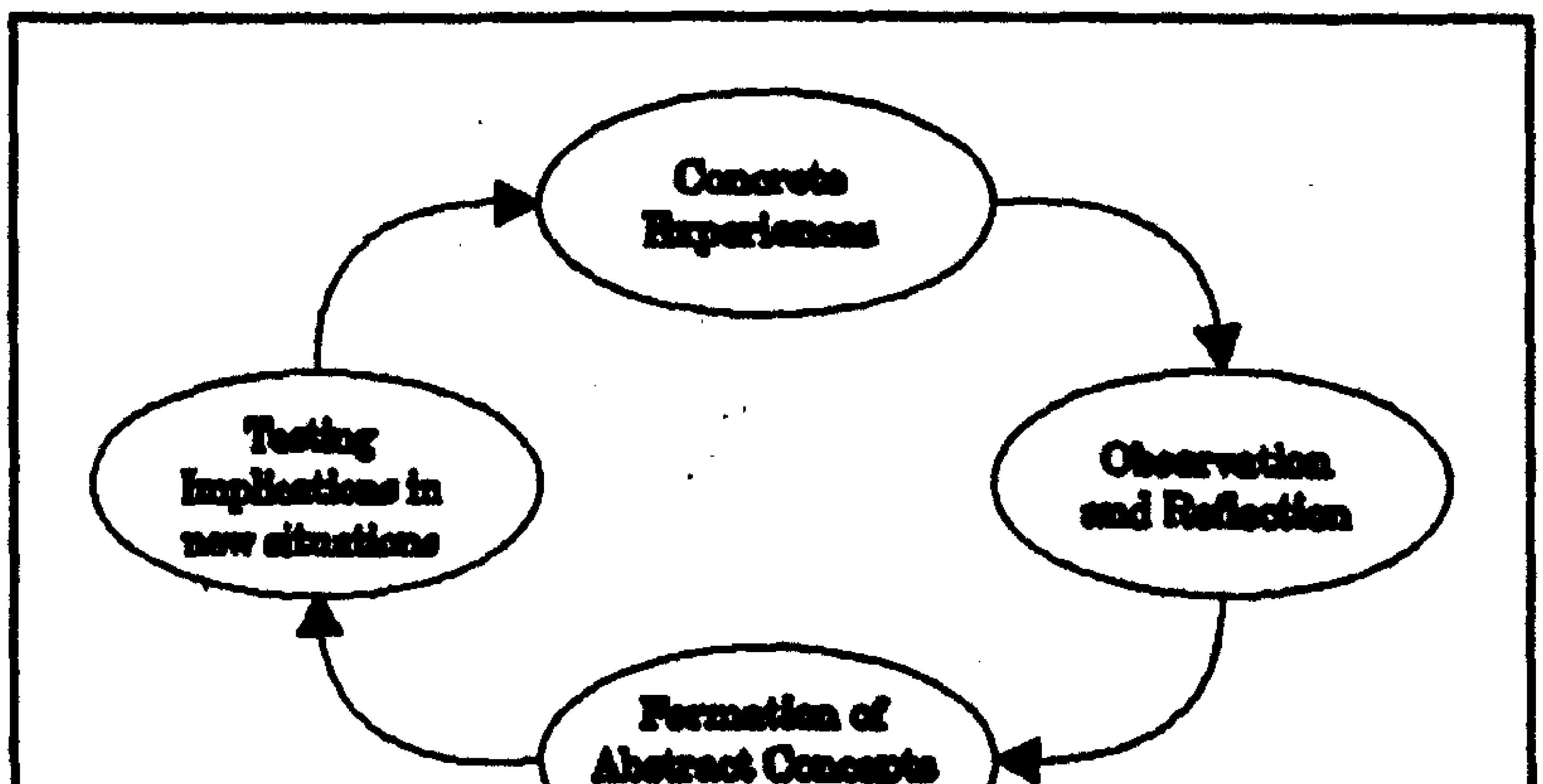

Figure 17 Kolb et al.'s Model of Experiential Learning

(1) concrete experiences (do, praxis). This is followed by

(2) reflective observation, that is, assessing the outcome of the practical experience, which then leads to

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112) It is this requirement for a structured approach which distances experiential learning form trial and error learning where students are expected to derive the correct conclusion purely from realising a failure to achieve their objective(s). This is a very slow method of learning, even when assisted by peers involved in the same process, and cannot be expected to lead to the expected learning in all situations.

(3) abstract conceptualisation (the forming of abstract concepts and generalisations, that is, theory building, hypothesising), and which requires

(4) the testing of the implications in new situations, that is, active experimentation, allowing the student to resume reflection in a new cycle.

Experience without reflection and generalisation, without the development of hypotheses, results in ineffective, non retained learning. Kolb et al. strongly refute the allegation that the cycle corresponds to trial and error learning. It is the reflection[113)] stage which differentiates experiential learning from an approach which is said to be that of a child[114)]. In terms of general learning theory this part of the cycle, as well as the generalisation phase, are clearly cognitive elements while both application and experience are more related to the affective domain of learning.

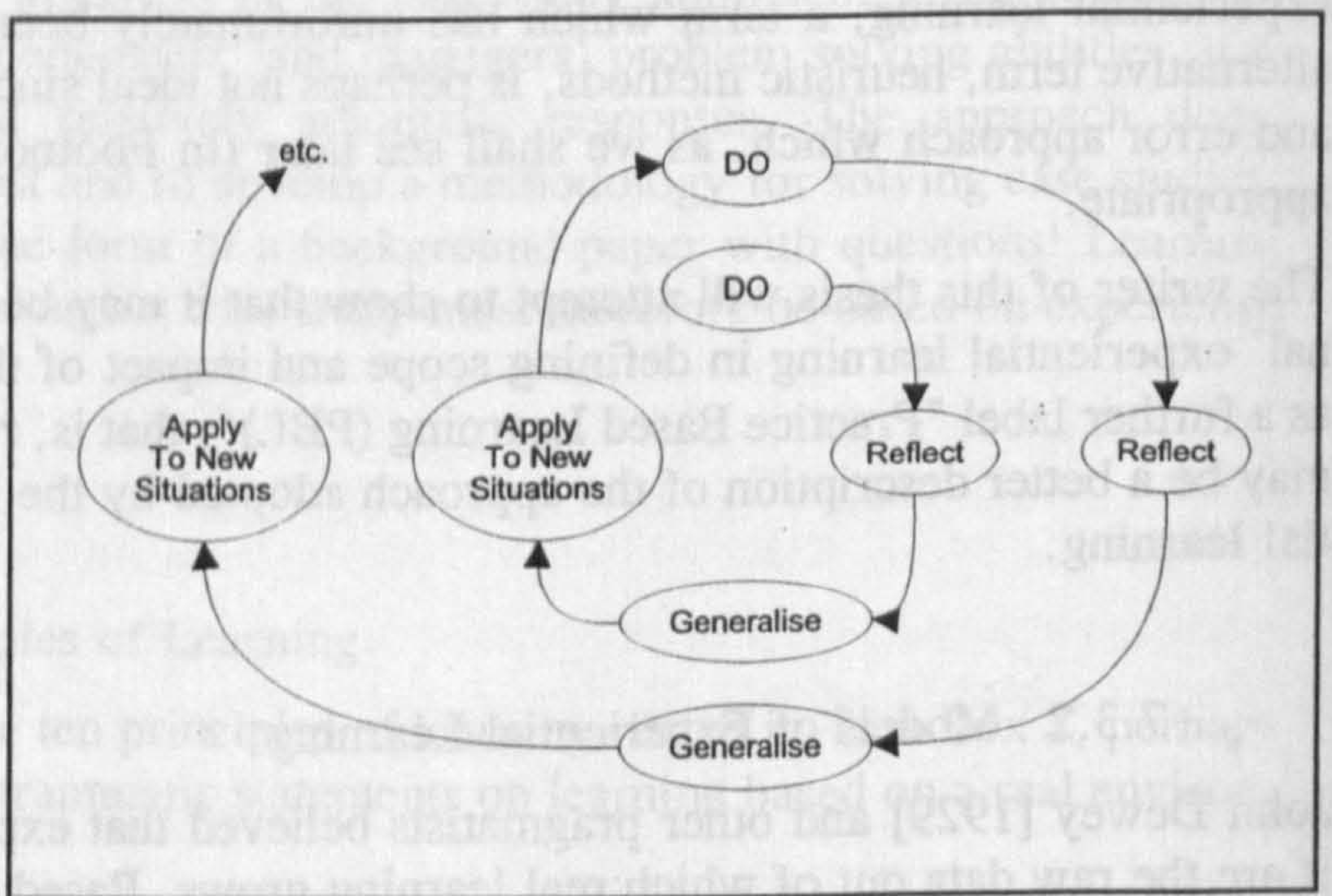

Figure 18 Spiral Model of Experiential Learning (developed from Kolb)

The cycle is an idealised representation, rather than a reality which holds true for all individuals: As found by Newland [1987], a majority of people exhibit a bias for one or a combination of the phases (or dimensions) of the experiential learning process, that is, they will spend more time and effort while they are engaged on one or two phases of the process even though they must complete the cycle. Teachers who wish students to use the complete cycle must design learning situations amenable to this. They must insist, in particular, on the reflection stage without which the process cannot be deemed successful.

Handy [1985], in his introduction to Understanding Organisations, offers his own learning cycle, reproduced in Figure 19, which differs from Kolb et al.'s model in replacing REFLECTION by QUESTIONING and in that he introduces an EXPERIMENTATION stage rather than Kolb et al.'s Application to New Situations (or TESTING). In Handy's model the student is expected to question either the situation or the teacher's input, to conceptualise by moving from the particular to the universal, to experiment for better understanding and prediction

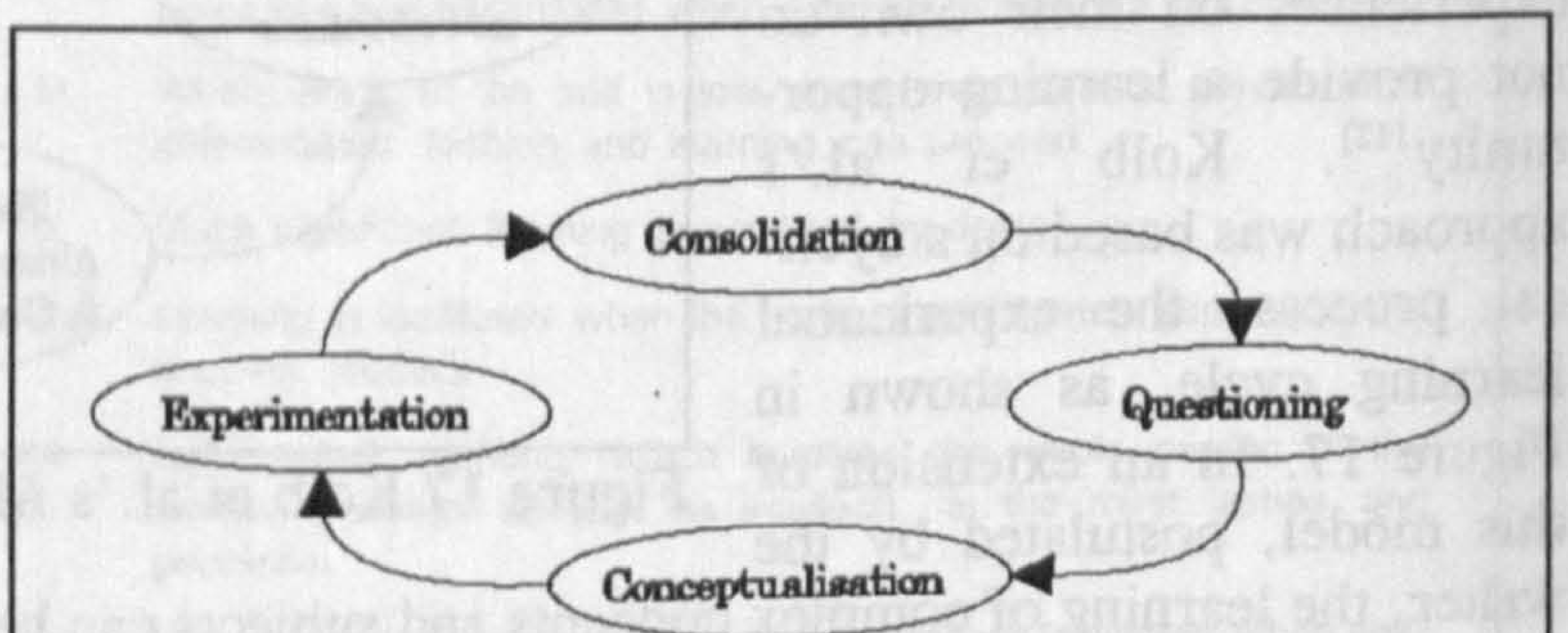

Figure 19 Handy's Model of Learning

113) Stewart writes [1992]: "reflective observation (reflection) is the crucial link between experience and the process of change that makes the elements of the experience a part of the conceptual foundation of the learner".

114) although it is clear that children do indeed reflect a great deal on their experiences.

and to consolidate by internalising. Gibbs [1993] has re-interpreted Kolb et al's cycle slightly although, beyond adding example activities as shown in Figure 20, he has not made significant changes.

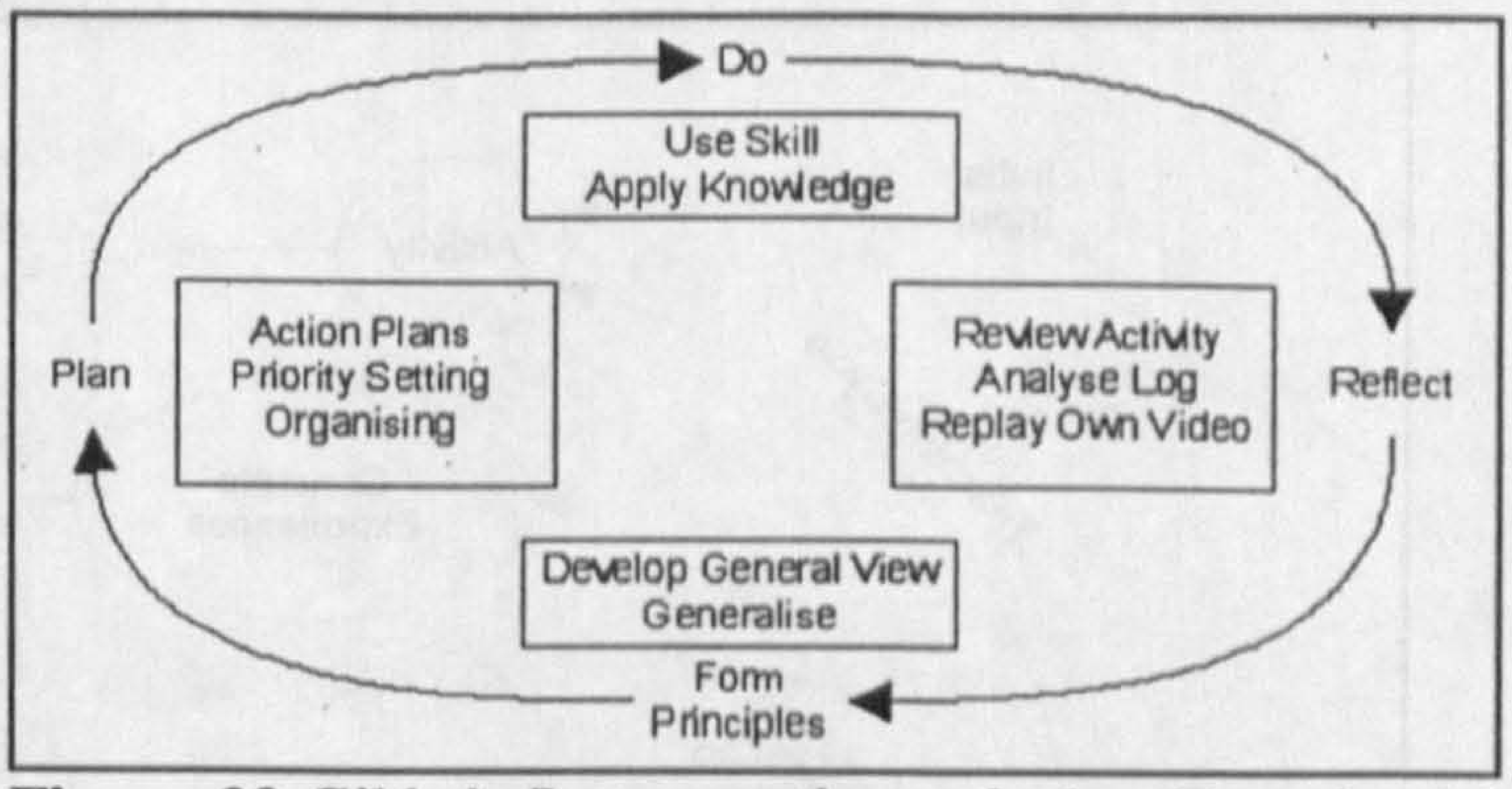

Figure 20 Gibbs' Interpretation of the Experiential Learning Cycle.

It may be of interest to compare the traditional experiential learning cycle with that of the five phase model of problem solving in project engineering, familiar from the quality discussion, shown here in Figure 21. The main differences are the focus on an individual task or problem rather than a learning activity, and the division of the plan or experimentation phase into a development stage and an implementation stage for the solution. The monitoring of the solution can be equated directly to the DO phase of Kolb et al.'s model since it involves the experiencing of reality. Otherwise the two cycles are very similar, particularly in that they both highlight the issues of change and continuous improvement: while a cycle is being completed the environment will change so much that a new improvement cycle must be started immediately, problem solving is thus a fairly exact image of the learning situation.

Up to this point, we have been content with approaching the learning process from the learner's point of view, assessing her or his needs and approaches. However, we must also consider the requirements imposed on the learning process necessary to allow teachers to fulfil their role. This role is defined, at least partly, by the demands of the "customer", society, which are based on the needs for measurable achievement and useable "outputs". The next paragraphs will be concerned with these issues.

Kolb et al.'s model fails to interpret the teacher's role. It is therefore necessary to adopt the enhancement of the theory, provided by Boud and Pascoe [1978], based on Kolb, Bach and Miller and represented diagrammatically in Figure 22. This includes the influence of the teacher on the learning process of the student: during the Input Phase the teacher structures the learning process by providing content and time oriented boundaries, but does not prescribe what is to be experienced as learning. During the Activity Phase, teachers may offer input but most of their role will be limited to monitoring and advising the learner who will work within the boundaries defined earlier. During the Processing Phase the teacher has to counsel and advise the learner to optimise reflection and to open up areas which may have been overlooked. The role of the teacher in the Generalisation Phase is concerned with the creation of a learning situation where the students exchange results freely with other members of a group and where the teacher ensures that the learners go beyond simply restating 'facts' with insufficient analysis. The New Input Phase is concerned with deciding, in co-operation with the learners, which of a number of hypotheses should be tested further.

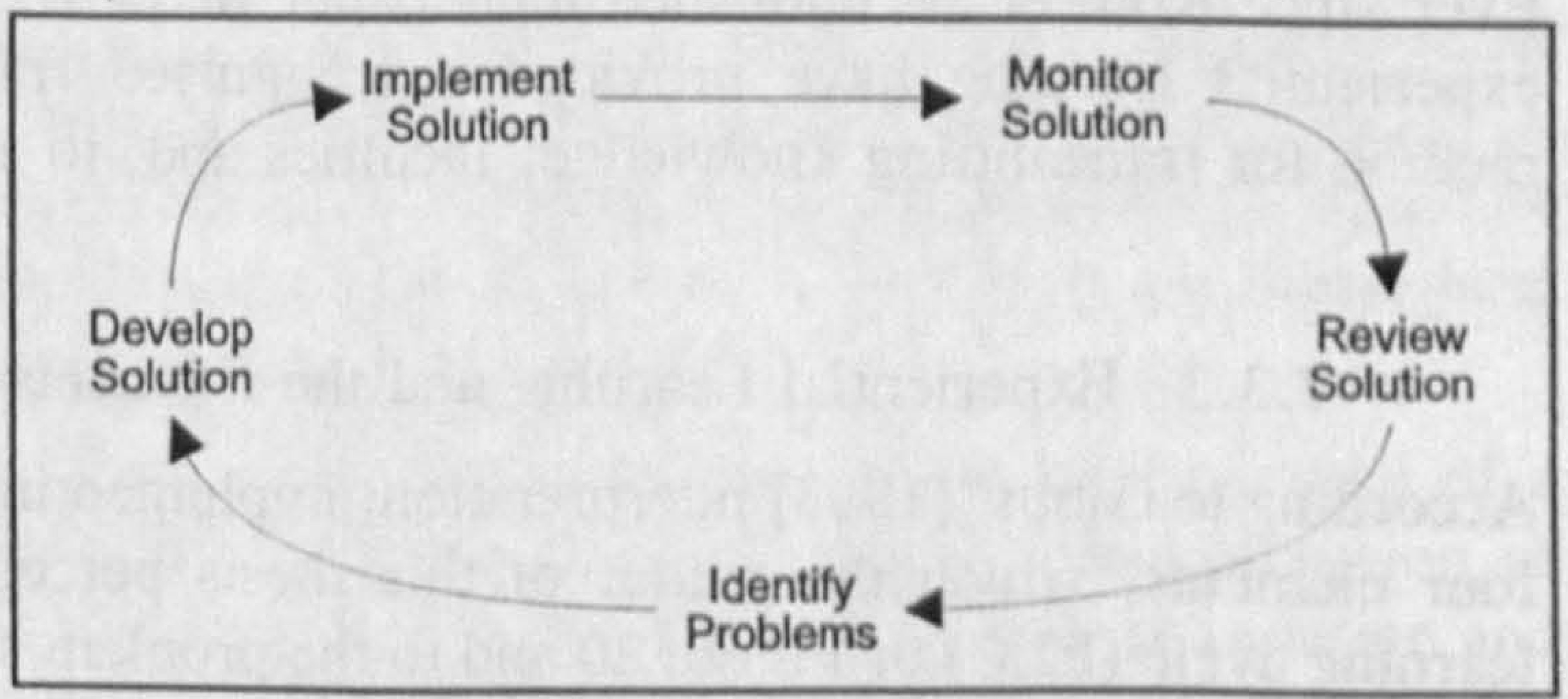

Figure 21 The Traditional Problem Solving Cycle

Often, experiential learning is implemented as team based learning involving groups of peers. For such team work to become effective, a sufficient time period must be allocated for the group to develop a suitable working relationship and, where necessary, to overcome initial

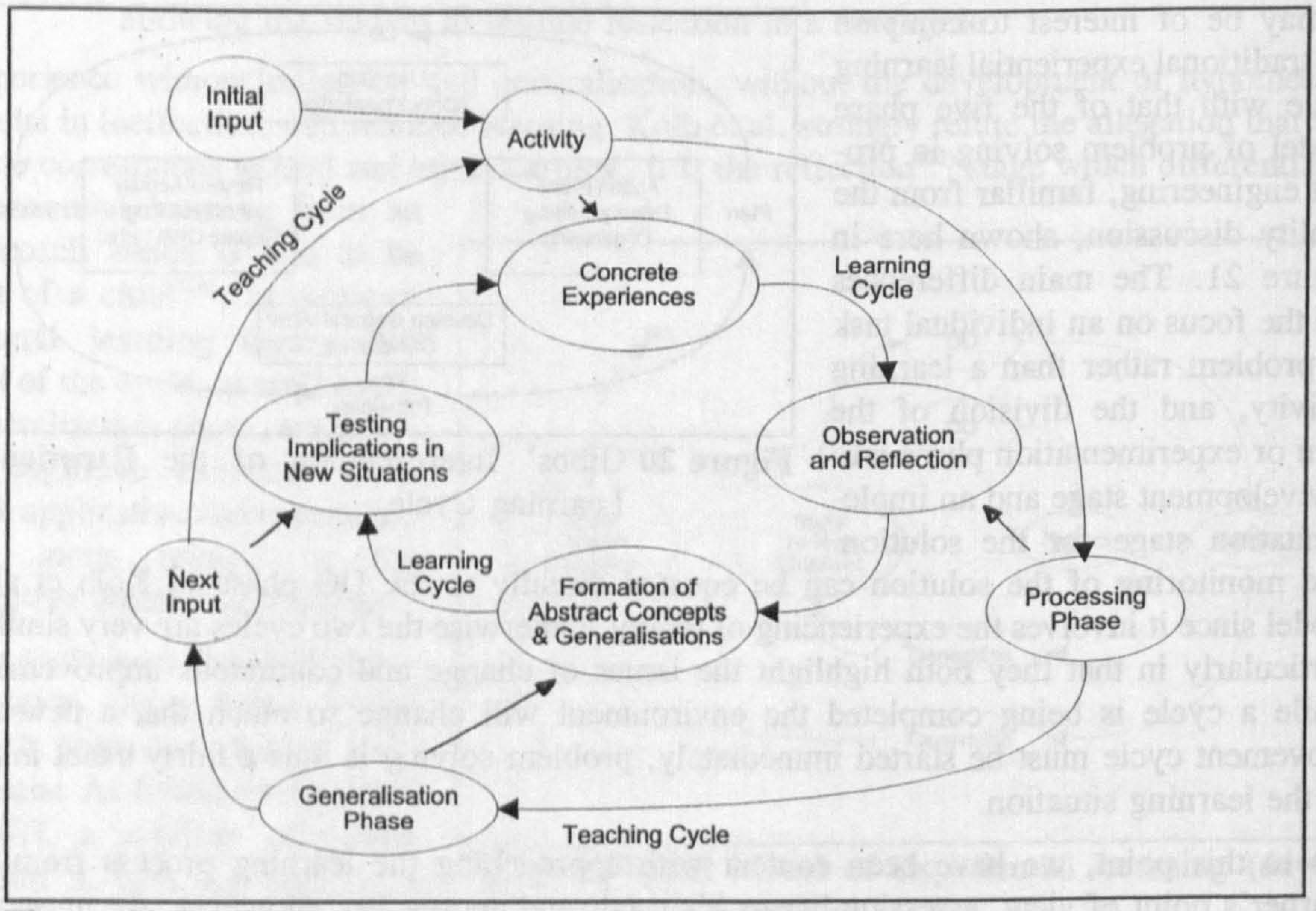

Figure 22 Boud and Pascoe's Model of Learning

problems connected to unfavourable group dynamics (see section 13.2.4). Although some group based experiential learning may be established specifically so as to provide training in conflict resolution and associated skills[115)], this will not be the general pattern. Familiarisation and group working skills may be acquired through an activity such as the SCANCO case method described in section 14.2.

Ever since Kolb et al. published their paper in 1974, the concepts and the terminology of experiential learning have provided a recognised framework to describe and advance a method for transmitting knowledge, faculties and, to a limited extent, qualities.

7.3.3 Experiential Learning and the Elements of Skill Development

According to Gibbs' [1993] interpretation, implementing effective skill development involves four elements, which the author of this thesis perceives to be related to the experiential learning cycle (ELC) of Figure 20 and to the problem solving cycle shown in Figure 21. The labels though, Training, Demand, Monitoring and Assessment (as shown in Figure 23), are completely different. The starting element, TRAINING or teaching, would have to be equated to the phase of the ELC which Gibbs describes as PLAN (whereas a more Kolbian author would refer to 'testing in new situations'). This is, in fact, the stage of the ELC where the learner receives an input in Boud and Pascoe's model. A new TRAINING element is triggered if the ASSESSMENT has shown that learning or internalisation has not taken place to a sufficient degree. DEMAND is closely allied to the all important DO phase of the ELC in

115) see section 13.4.6 for an, unintentional, near-textbook example, where the team emerged strengthened.

that students are given time and targets (demands) to practice the skill(s). All learners, not just students, require well designed learning activities though to practice the skills as part of this demand element. The use of the term 'demand' is not in conflict with the third of Rogers' ten principles of learning even though it might appear so at first sight. Changes in self organisation cannot be avoided in learning situations. It is essential though that the whole environment presents a minimum of external threats. Once practice has taken place, or while it is still taking place, the students monitor their performance, e.g., they reflect on their work using checklists. MONITORING is not a teacher led activity in this view.

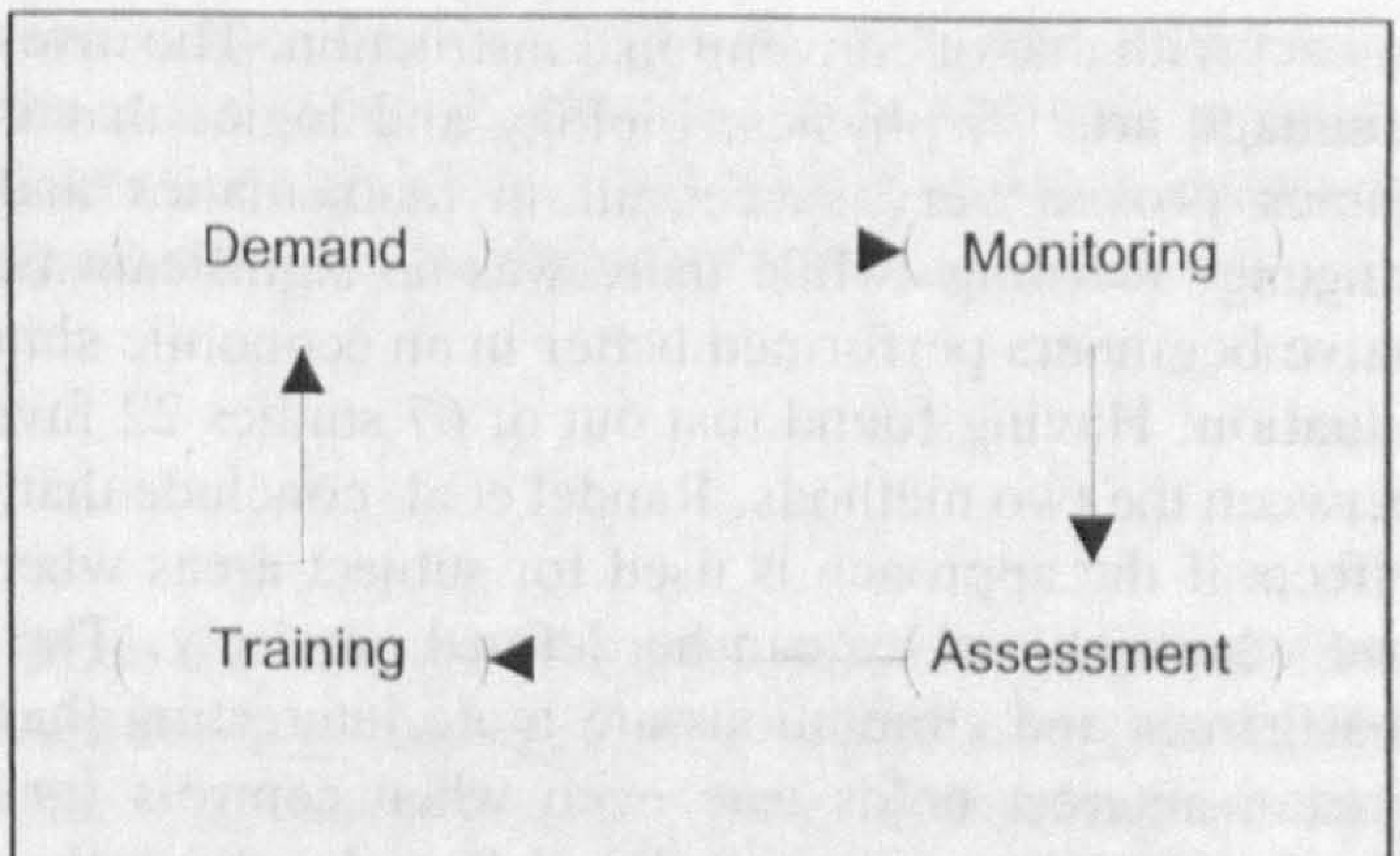

Figure 23 Gibb's Skill Development Model

The ASSESSMENT element is essential since it gives students both feedback and a reward based target towards which they can orientate their work. Tutorial comments at this stage must address both the content of the work submitted and the quality of the process which led to its completion. The assessment phase is perhaps the part of the cycle which differs most from the ELC although it could be argued that assessment can only be useful if it addresses learners' ability to GENERALISE. The discussion of this approach will be resumed in section 10.5 and chapter 17.

7.3.4 Experiential Learning versus Simulation and Gaming

In recent years, the concept of experiential learning has become somewhat devalued as a consequence of its indiscriminate adoption by education policy makers and teachers[116)], some of whom fail to understand the need for implementing all the stages of the experiential learning cycle or who are normally not prepared to invest the effort necessary for successful performance in all phases of the experiential learning cycle and, especially, the reflection stage. The author has noticed this type of development even in the Department of Manufacturing and Engineering Systems where staff are very aware of the issue at stake. A second and perhaps even more significant concern is students' perception of the concrete or practical experience, doing, as a simulation or game. Both these problems are highlighted in the case study describing a simulation activity in section 13.4.5.

In simulation and game based teaching the construction of the activity (the creation of a simulated reality), its content and the debriefing phase are important. The discussion of Guthrie's work in section 5.6.2.6 helps explain why the design of the learning situation and the provision of appropriate sets of stimuli are so difficult but also important: since complete learning can be assumed to take place in just one trial, that is, since a particular set of stimuli can lead to the learning of an appropriate response without a need for repetition of the same situation, the situation must be free of conflicting sets of stimuli and should not present the same sets several times over.

In a review of recent literature (from 1963 to 1991) on the topic of the effectiveness of games and simulation games for educational purposes, Randel et al. [1992] compared their

116) compare this with the fate of transferable skills, see chapter 10.

impact with that of conventional instruction. The investigation covered social sciences, maths, language arts[117], physics, biology and logic, that is, a representative spread. (Computer) games proved very successful in mathematics and also in the more atomic aspects of language learning, while there was no significant benefit in the social sciences. Here only naive beginners performed better in an economic simulation than in a lecture cum discussion situation. Having found that out of 67 studies 22 favour games while 38 show no difference between the two methods, Randel et al. conclude that gaming can show beneficial educational effects if the approach is used for subject areas where very specific content can be targeted and where objectives can be defined precisely. The research yielded the consistent finding that games and simulations are more interesting than traditional classroom instruction. The greater interest holds true even when controls for initial novelty (Hawthorne effect, see Handy [1985]) were used. Randel et al. advise the use of gaming or simulation situations where classes have motivation problems. They also suggest that research in the effectiveness of games and simulations is not yet sufficiently advanced to give clear guidelines for successful implementation.

Gosenpud and Miesing [1992] studied the influence of the environment, in terms of a large variety of factors, on the performance of small student groups in a business simulation. They found that two motivational and two interest variables had a significant influence on the outcome while ability, confidence, cohesion and organisational formality did not. The motivational factors were a 'desire to play the game' and 'easy to work with' teammates while the interest variables were the students' specialisation and plans for the future. Organisational formality had some influence on performance but was not shown to be significantly correlated. The latter observation is important for the work discussed in this thesis: the authors of the study explain the lack of significance of cohesion and formal organisation with the small proportion of the duration of the simulation during which the students were working in teams (five out of twelve weeks).

Stewart [1992] differentiates between postexperimental and postexperiential debriefing. While the former is mostly encountered in the context of psychological experiments, the latter is germane to the type of simulation involved in experiential learning which often has a behavioural aspect. It must be designed to achieve positive change and not just as a method to remove negative consequences. The debriefing is a phase separate from the experience being processed. Amongst other goals of the debriefing process, Stewart cites 'recognising ethical issues' and 'developing analytical skills' as important. "Participants should leave with a clearly defined view of themselves as manager and team member" Bailey, 1990, quoted by Stewart]. This is perhaps the most relevant element of the assessment and appraisal processes which take place on the CIM course.

Experiential learning contains, as a subset, simulation and game based learning and is often viewed to be virtually equivalent to these approaches. In any learning cycle where the 'concrete experience' is intended to approximate a (near) real life situation, distinct from a game, effective management becomes very important. Course organisation and monitoring must ensure that the learners do not interpret the semi-artificial situation created in terms of a simulation or game. Such an interpretation would make it more difficult for students to translate the lessons learnt into practical decisions at a later stage of their studies and in professional life. The resource implications of providing the appropriate teaching inputs for (near real) experiential learning differ substantially from the inputs required for running games. However, it is not possible to draw up a definitive comparison between, e.g., a simulation and a lecture with associated discussion. While the former will demand a great

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117) which included reading, vocabulary, spelling, punctuation, syntax and verbal analogies.

deal of resource in the case of a social work study, there would be no staff input in the case of a computerised simulation, at least not at the point of delivery. A lecture and tutorial, conventionally seen as a very economical form of instruction, will appear resource intensive by comparison. Further input to these discussions may be found in sections 13.4.5, 14.3.2, 14.4 and 14.8.

7.3.5 Conclusion

Even though twenty years have elapsed since the concept of experiential learning was first mooted, it is still accepted as a powerful approach to managing learning of all types. While it was originally lauded as a panacea, today it is clear that other forms of learning are also of importance. Indeed, in some situations other forms of learning must precede experiential learning in order to provide a starting point for the cycle. Problems arise in experiential learning as the result of inadequate involvement of teachers and wrong perceptions of learners.

As already mentioned in section 2.4.1.3, Branton [in Oborne, 1993] is of the opinion that the constant performing of computations, that is, the existence of 'un*self*conscious intentions' may help explain skilled activity. The writer of this thesis would contend that this is one of the factors which affects the design of experiential learning environments where predictions of motivation, learning and leadership performance are difficult and unreliable because people's models and the use they make of the models are changing over time (a cornerstone of the transaction based philosophy of learning, see appendix C).

7.4 Practice Based Learning

7.4.1 The Model and its Justification

The writer of this thesis has adopted a model of learning, reproduced in Figure 24, which is a combination of the cycles proposed by Kolb et al. and Handy. The writer has inserted Handy's question phase into Kolb's cycle because only a questioning attitude can lead to useful reflection. Learners will only be motivated to reflect on new learning if they perceive a difference between previous or remembered experience and the latest contact with reality. Depending on the situation and the strength of disagreement, this discovery and thus the questioning of the relationship between reality and own perception will take place spontaneously or it will need to be prompted by a teacher[17)], tutor or other person external to the process. "The process of articulating one's thinking is a vital part of the process of converting experience into learning or of using one's conceptual apparatus in a concrete experience. The process can be very much assisted by promoting discussion of an experience by raising to the surface the thoughts and embryonic ideas of the individuals in the learning situation" [Thatcher, 1986]. In essence, this process can be likened to postexperiential debriefing, discussed in section 7.3.4.

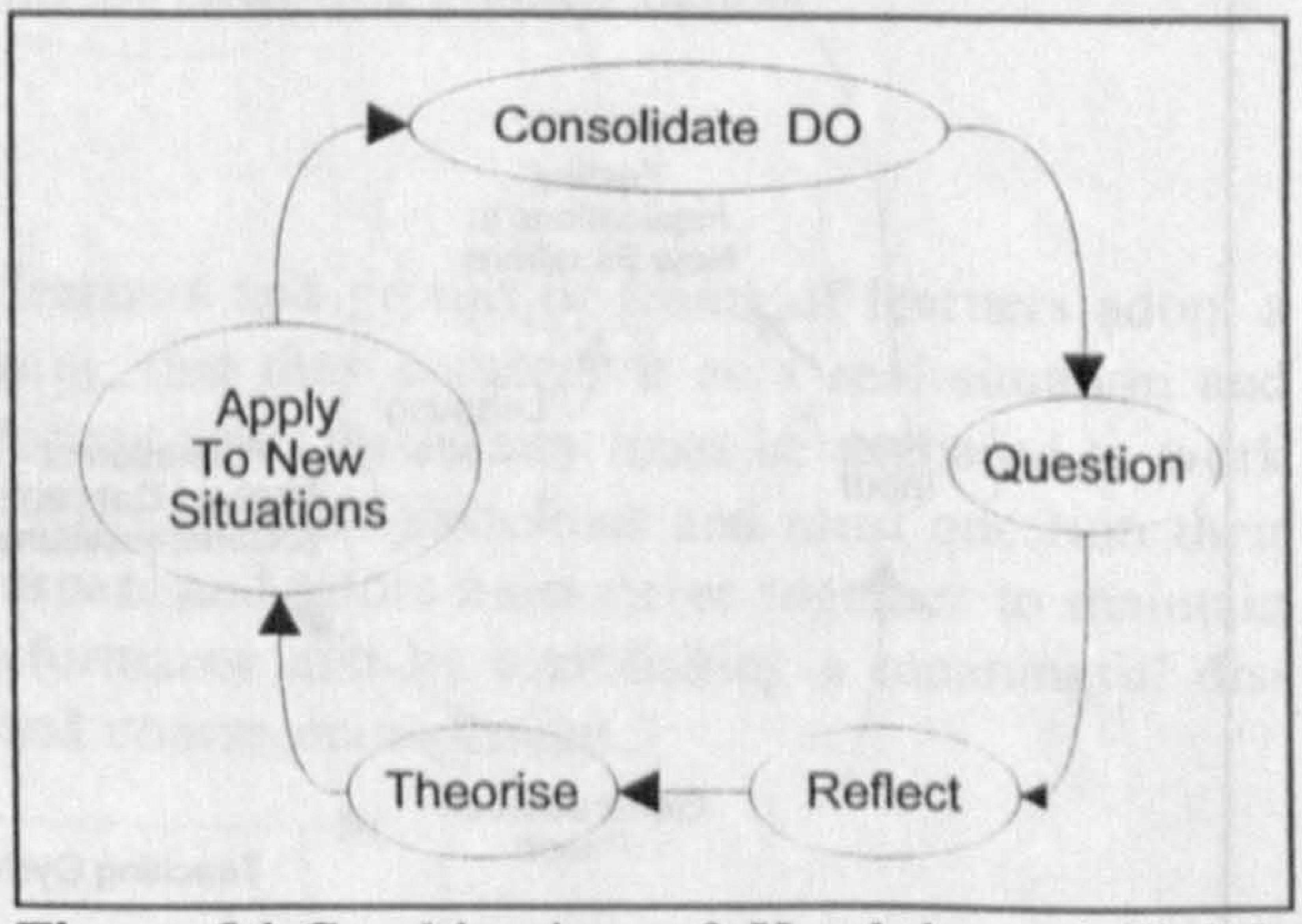

Figure 24 Combination of Handy's and Kolb's Models of Learning

Lederman [1992] offers a three phase model of the debriefing process which follows on from the concrete experience and which ends with the generalisation phase of Kolb et al.'s model. This debriefing sequence is shown in Table 12. It thus substitutes two stages for the reflection phase. The first stage involves the introduction of the learners to a systematic process of self-reflection, that is, the development of a questioning attitude. The second stage can be equated, more or less, to the reflection phase in the experiential learning model. This provides further justification for the modified cycle presented in Figure 24. In the paper quoted, Lederman provides a detailed discussion of the three phase model together with a list of relevant literature.

PHASE	PURPOSE	DESCRIPTION
Phase 1	Systemic reflection & analysis	Phase 1 is an introduction of the participants to a systemic self reflective process about the experience through which they have just come.
Phase 2	Intensification & personalisation	Phase 2 is the refocusing of participants' reflections onto their own individual experiences and the meanings they have for them.
Phase 3	Generalisation & application	Phase 3 is the exploration that takes participants from their own individual experience to the broader applications and implications of that experience.

Table 12 Lederman's 3 Phases of the Debriefing Process

The whole practice based learning cycle can be viewed as an opportunity for the consolidation of new learning which is internalised as the result of the cognitive stages of Questioning,

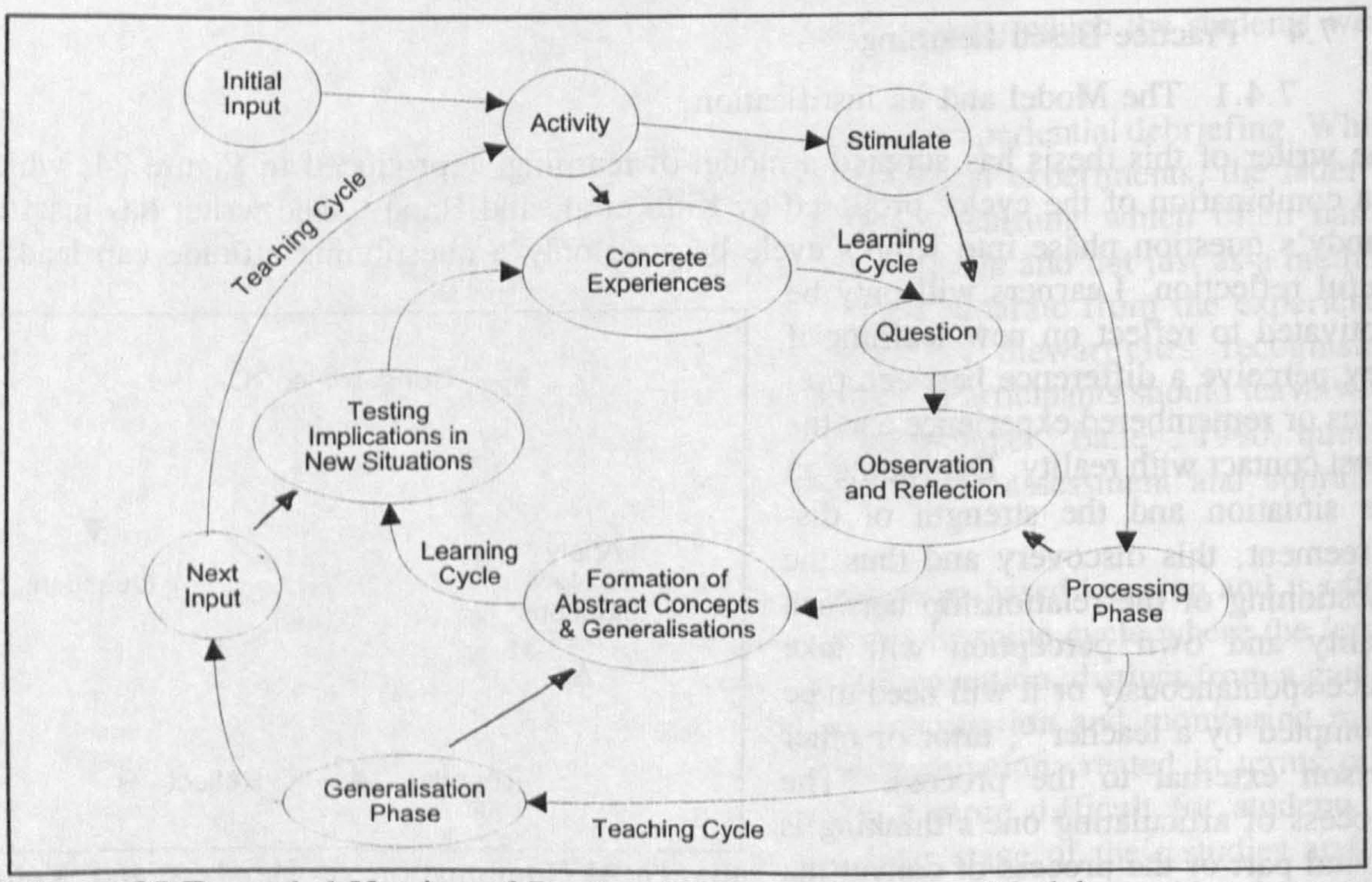

Figure 25 Expanded Version of Boud and Pascoe's Learning Model

Reflection and Generalisation and the affective processes of Testing on New Situations and Use in the real environment. Day to day use of the new skills[118)] may lead to the discovery of new discrepancies between reality and experience or unexpected ramifications of having internalised previous learning.

Where the practice based learning cycle is used to improve the performance in a particular activity or set of activities, rather than to learn new skills[118], the question or enquiry phase becomes an assessment stage during which the effectiveness of the previous learning is measured or questioned. The reflection phase must then result in either an acceptance or revision of the applicability of the approach learnt. The suggested model highlights the demands on the teacher since she or he must create the right attitudes on top of supporting students in the task oriented phases. In Figure 25 the author interprets Boud and Pascoe's approach of combining the teacher's role with the student's learning cycle presented in Figure 24. The teacher's role in stimulating and directing students' enquiry and questions is highlighted. Unfortunately, it is near impossible to find a completely meaningful relationship between the elements of the practice base learning approach and Gibbs' cycle for moderating learning.

7.4.2 The Role of the Teacher

It could be argued that the role of the teacher in practice based learning is very much reduced, that the students learn of their own accord, that they learn by interacting with each other. However, careful consideration of chapter 12 will show that the role of the teacher in coordinating, managing and developing a course of the type represented by the CIM activity[119] is important, especially in terms of the adoption or modification of qualities. This can be seen as an expression of Bowers' views on the duties of teachers. Bowers [1984] is opposed to one of the tenets of liberalism in education, because for him, "the phrase 'autonomous individual' reflects the myth of being free of the past". Instead, he stresses the shaping influence of the past on individual identity. The process of socialisation reproduces in the individual the tacit historical knowledge of a culture. He observes though that the traditional authority arising from social practices, conventions and patterns of belief is being de-legitimised and must be replaced by, in his words, 'new definitions'. In his view teachers are responsible for giving people the tool for negotiating these definitions, that is, communicative competence. He declares that this is made difficult by the Taylorisation of the teaching process (subject specific teaching). Teachers must allow students to make informed choices and must insist on scrutiny of taken-for-granted beliefs.

7.4.3 The Role of the Learner

Practice based learning demands that the learners and groups or teams of learners adopt a professional attitude to the learning situation, that they consider it as a real situation and accept the demands and pressures which follow from this. They must be prepared to work under their own control according to externally defined guidelines and must question their experience at all stages of the process. Learners and tutors must strive together to maintain motivation, by providing feedback on performance and by establishing a meaningful discussion on course design, course content and course management.

7.4.4 Summary

Practice Based Learning is a concept which has been derived from Kolb's and Handy's models of learning. Its key characteristics are highlighted in Text Box 3. The concept has

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118) the term 'skill' being used in its everyday meaning rather than the narrower definition used in this thesis.

119) sometimes also described as BCIM, the Brunel CIM company, a corporate identity for the course, developed by one of the business management groups on the CIM iteration of 1991/92.

been developed in an attempt to enhance students' learning by formalising a transition in the experiential learning cycle which is ill defined in the original concept. This failing has been highlighted by several authors, some of whom are quoted above and in section 7.3.4. The modification of Boud and Pascoe's model highlights the more significant involvement of the teacher necessary during the questioning phase if real world oriented learning (a term including both experiential and practice based learning) is to become fully effective.

- Real Life Objectives -
- Realistic Deliverables -
- Intermediate Targets -
- Structured Learning Process -
- Experiential Learning Cycle -
- Questioning Phase -
- Debriefing and Appraisal -
- Maintaining Motivation -
- Team Work Orientation -
- Problem related Duration -
- Strong Teacher Support -

Text Box 3 Essentials of Practice Based Learning

8 Enhancing Project Work on Engineering Courses

8.1 Engineering Courses and Conventional Project Work[120]

8.1.1 Purpose of Project Work

Project work on engineering courses, be this laboratory based work or design tasks, is intended to equip students with faculties which are deemed to be essential in professional work. Dowdeswell and Harris [1979] classify the aims of project work at university as follows:

Student Aims

(1) adopt an active approach to learning in a real context,

(2) assume greater responsibility for own learning,

(3) greater depth of knowledge in limited area based on interest,

(4) integrate existing skills and develop new ones,

(5) optionally: work with other students to develop team ability,

(6) optionally: work in an interdisciplinary context.

Project Aims

(1) atmosphere in which student can feel maximum involvement,

(2) atmosphere of reality/research,

(3) reasonable chance of success,

(4) close relationship between student and supervisor(s),

(5) atmosphere of minimum constraints,

(6) discourage passive assimilation,

(7) discourage uncritical approaches,

(8) encourage students to use lateral thinking approaches.

As a matter of course, the project aims must include the encouragement of attitudes listed under the heading of student aims! There are also a number of implied aims (implicit aims) which must be satisfied if project work is to be successful:

(1) project work must be sufficiently adaptable to satisfy the needs of many different students and situations,

(2) project work must fit in with and be complementary to other forms of teaching,

(3) it must be designed to constitute an integral part of the curriculum,

(4) the demands of the project must not exceed the available time, manpower and resources,

(5) the process and its end products must be assessable. The assessment procedure must be acceptable to students and staff.

Dowdeswell and Harris' analysis is the most thorough of the reviews of project work encountered by the writer, but some other results are also of interest: in the eyes of the members of a working party of the Engineering Professors' Conference, project work is the key tool for developing skills and understanding on engineering courses. Through conventional project work students are expected to acquire the skills of [adapted from EPC 6, 1993]:

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120) project work in this context is defined more narrowly than in section 4.2.4 of this dissertation: here it refers purely to task oriented individual or group work as found on university courses. It does not refer to major industrial projects or product developments.

(1) analysing a problem using a structured approach,

(2) researching potential solutions through the selection and study of relevant literature,

(3) finding and implementing a solution to the problem,

(4) gathering data to validate the approach used,

(5) reflecting on the solution process and

(6) communicating the results verbally and in writing.

These are very much the skills of the classical engineer who is conducting research and development as an individual, a working situation which is discussed below. A summary of the learning approaches advocated by the EPC, including comments on project work, can be found in appendix A.2.

Campbell [1990] goes further than this in setting the following objectives for a project based element of the final year of a sandwich type engineering degree course[121]:

> "to expose the student in an educational environment to an industrially relevant engineering problem,"
>
> "to develop in the student the critical faculties, appreciation of practical problems and communication skills required by the practising engineer in industry..."

He advocates close links with industry for the projects which are undertaken on an individual basis and closely supervised by a university tutor.

On most engineering programmes accredited by a major engineering institution, students are expected to complete several different pieces of project work. Where such work is undertaken before the final year it is usually of a straightforward nature, starting with very basic and well defined tasks at the beginning of a course. It tends to be rather more substantial and complex in the case of final year projects. But even at this stage the tasks must be clearly delimited so as to allow a student to reach a conclusion within a reasonable time and with limited support from the supervisor. Instances are rare where original results are achieved without clear input from the supervisor.

Depending on the ethos of the institution and of the supervisor, a final year project can be purely an assessment opportunity, a test of mental strength or a learning experience. The issue of whether a final year project provides a suitable learning experience will be addressed after a discussion of the other objectives in setting such a task, in section 8.1.3.

8.1.2 Conventional Projects and the Image of Engineering

Universities and Polytechnic Institutions in Germany, Austria and Switzerland have always required students to complete a substantial piece of independent project work at the end of their studies[122]. In England final year projects are a relatively recent phenomenon on engineering courses; for the materials science course at Cambridge, for example, this requirement was introduced as recently as the 1960s. The objectives though in asking a student to carry out a substantial piece of research or design work on his or her own have not changed since the late 19th century, that is, the early years of formalised academic

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121) although this is a practical task linked to an option rather than the final year project as such.

122) a significant change which has taken place even in these countries though is the extension of the time allocated to such a project. In Germany today most students take six months full time for their final project or Diplomarbeit while Swiss engineering graduands are limited to between ten and twelve weeks.

engineering education. The French Grandes Écoles have not yet introduced final year projects. The assessment of a graduand's readiness for work in industry is based on a long industrial placement which must be documented in a major report.

There is a first objective to 'prove' that a student is ready to take on a task and complete it successfully within a deadline, working independently from beginning to end. A second objective is to provide an opportunity for assessment which goes beyond the testing of content which can be learnt by rote. A third objective is often the solution of a technical problem in which the supervisor or an industrial sponsor has a strong interest but where "a pair of hands" comes in useful... Perhaps the most significant objective though is the selection of those students, from amongst the best in a year, who are most likely to succeed as researchers - where the definition of research is perhaps best described as "old-fashioned".

The image of engineering work which stands behind these final tests of graduands' ability is not realistic. It is the concept of the engineering designer or engineering researcher who is given the specification of a product or process and then goes away to her or his drawing board or laboratory to work quietly on their own and to return with the finished design when required. A quote from Finniston [1985] may serve to illustrate this view: "Engineers ... are problem solvers." The image is, in other words, the myth of the GREAT ENGINEER, the Stephenson, Brunel or Thorn. A myth because, in general, the great engineers worked not by themselves but with apprentices and skilled craftspeople who would contribute their ideas and experience.

8.1.3 Usefulness of Final Year Projects

Project work in the final year of an engineering course should be designed to allow students to apply the powers[123)] they have always possessed or acquired during the course. At the same time it should allow students to experience, in a controlled environment, the type of work situations with which they will be faced in later life. Conventional (final year) project work fails, at least in the latter respect, all but the students who will later be working as individual researchers. Depending on the choice of project and the academic or industrial support it may succeed in providing an opportunity to apply faculties and knowledge learnt during the course to a real problem. In the author's experience this is not a common outcome in the case of manufacturing engineering graduands. This is confirmed in a further quotation from Finniston [1985]: "Students are given guidance in many ways on how to go about achieving solutions, e.g. by case studies, by project involvement at university, vacation experience etc. These are not of themselves sufficient to measure the capability of individuals ..."

One of the important realisations, and perhaps the author's main objection to the exclusive use of conventional student project work, is linked to Gibbs' observation [1993] that any skill which has once been taught must also be used, monitored and assessed if it is to be internalised by the student. If any of the later elements in the chain are missing then there can be no feedback to the student. On the SEP course at Brunel, staff introduced a third year project, based on group tuition, specifically to ensure that students could obtain feedback on their performance in the key stages of a design project before undertaking the individual fourth (final) year project [Ellis, 1985].

While final year projects reflect one range of views of engineering work rather well, namely that of research, industrial design, product design or development work, they fail signally to show whether the prospective engineers have the skills required for the successful integration in the ever larger and ever more multidisciplinary teams becoming the norm for project

123) See glossary for an explanation of the meaning of 'powers' in this context.

work in industry. "They will usually be integrated into an experienced team at the beginning of their professional careers and assigned concrete tasks." [Hernaut, 1993]

8.1.4 Individual Project Work versus Project Work in Teams

Corfield [1983] was very clear on this subject of the management of engineering projects: "... we are perhaps only on the fringe of learning the techniques by which large teams of engineers can be brought together to work not in series but in parallel to reduce the time-span of complex projects." and: "The more progressive educators are asking industry to spell out its requirements and have adopted a more flexible approach ..."

In most institutions the students are directed to complete the final year project and the associated thesis on their own or, occasionally, in teams of two although a few institutions will accept larger teams. Even where group work is permitted the project must be undertaken in a way which allows an individual assessment of the students' contributions thereby fostering a degree of competition within the mini-team. This is a requirement imposed by the engineering institutions. This can be very useful in stimulating the generation of new ideas but not for learning about cooperative work.

Teams are of particular importance for new projects in AMEs (Advanced Manufacturing Environments) and for their management. The author defines AMEs as manufacturing situations where advanced manufacturing technologies and methods are being used[124)]. In fact, it is very probable that it is the team working skills which are essential and differentiating qualities of the manufacturing engineer, although she or he must also have an excellent grasp of traditional engineering disciplines (cf. Brummett in the passage quoted in section 4.5.2). Conventional project work cannot provide the necessary learning opportunities since they are too limited in both scope and content.

As stated already, in the introduction to this thesis, there is thus a need for courses which satisfy Corfield's requirements while providing a challenge to the students.

8.2 Designing a Project Based Course for future Advanced Manufacturing Engineering Professionals

Advanced Manufacturing Environments (AMEs) are characterised by the use of advanced technologies (CAD, CAM, CAQ etc) and advanced management approaches (just in time, lean manufacturing etc.). They are aimed at combining the benefits traditionally associated with mass production with those normally associated with job shops and batch manufacturing: short lead times, customisation and economies of scale. The powers required for successful practice as a manufacturing engineer in a team in an advanced manufacturing environment can be divided into two categories, namely, technical and scientific components[125)] on one hand and people and systems oriented components[125)] on the other:

Technical and Scientific Faculties and Knowledge

- Software Design Methods
- Interface Design and Use
- Methods of Computer Communication

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124) Advanced Manufacturing Technology is defined by the author as a technical system whose output is not solely determined by the effort of an individual operator. Advanced Manufacturing Methods refers to the application of the approaches of control engineering (e.g., the laws of feedback) and of MSE to the management of operations in a manufacturing plant.

125) 'components of capability', as defined in 5.5.2.

- Robotic Technologies
- Workpiece Handling and Interfacing
- Database Design
- Machine Tool Operation
- Measurement, Quality, Control

People and Systems Oriented Qualities and Faculties

- Systems Oriented Thinking
- Strategic Thinking
- Interpersonal Communication
- Motivation
- Team Leadership
- Ability to Initiate and Promote Change
- Ability to Manage Change
- Activity Planning

Some of the above are equally applicable to working as an individual while others are only relevant in team oriented work situations. The components are discussed in more detail in chapter 10, together with the issue of whether such attributes can be acquired through learning and which methods would be most appropriate to achieve this. In addition to the generic faculties and powers listed above, "Ingenieurs need additional in-depth fundamental knowledge of their specialized fields, general knowledge of problem-solving methods in engineering and special application knowledge in accordance with workplace demands." [Hernaut, 1993] The course described in this thesis (see brief introduction in section 2.7) is designed to impart a substantial proportion of the above powers or faculties and also some of the faculties demanded by Hernaut.

8.3 Discussion of some Reference Models

Courses aimed at developing competence for working in Computer Integrated Manufacturing have been developed elsewhere. However, the author has been unable to find a model which corresponds to that which will be described in chapters 11 and 12. Most follow the approach used at Cambridge University on their MEng course where groups of students are given a quite narrowly defined 'integration task', for example, the control of an automatic assembly system by computer. While the task can be difficult it is limited both in time and scope: the duration is three to four weeks full time and both the equipment to be used and the outline solution are fixed by the course management.

As an alternative to university based learning Züst et al. [1991] describe an industry based teaching environment for CIM which is designed to give students an appreciation of the problems of integrating different technologies with the help of computers. However, the approach chosen does not involve the young engineers in the process itself - they experience neither the problems of building networked solutions nor those inherent in successful teamwork. Students simply watch designers and production operatives carry out their tasks using computer systems.

The writer has identified a range of paradigmata which cannot be described here, for reasons of space and time. These relate to the teaching of advanced engineering skills, with a particular emphasis on manufacturing industry. However, he has included some of the more interesting novel teaching approaches in section 13.4 and intends to prepare an extensive paper for later publication.

9 Process of Education and Practice Oriented Teaching in the Department of Manufacturing and Engineering Systems

The Brunel Manufacturing Engineering Programme (BME) and the Special Engineering Programme (SEP) are demanding four year undergraduate engineering courses following the industry linked "thin sandwich" model[126]. Both courses appeal to bright students, generally with no industrial or technical experience although the BME course attracts each year a small number of students from a BTEC or technician background. The programmes though have two very different foci:

the Special Engineering Programme (SEP) was designed to form future design and research engineers and managers for manufacturing industry [Clark, 1985 (1)] while

the Brunel Manufacturing Engineering Programme (BME) was clearly a product of the Anglo-Saxon debate on how to enhance the capability of manufacturing industry. It was thus designed to form engineers with a good understanding of manufacturing systems design and operation.

The separate educational objectives are partly products of the history of the two programmes, partly derived from the different professional destinations of the graduates formed, as detailed in the following sections.

9.1 Introduction to the Programmes taught by the Department of M&ES

9.1.1 The Special Engineering Programme

SEP was set up in 1978 as one of the Dainton [Dainton, 1977] 'enhanced' engineering courses to "provide competent engineers for manufacturing industry". It attracts, almost exclusively, students with A-level qualifications, typically of AAB standard. SEP is a very broad based course where the first three academic periods are devoted to the study of a full range of general engineering subjects such as mathematics, electronics, computing, mechanical engineering and materials technology. A distinguishing strand throughout the four years of the course is the concept of design and all its theoretical and practical aspects. Students specialise during the fourth year of their course, choosing options leading later to chartered electrical or mechanical engineering status.

9.1.2 The Brunel Manufacturing Engineering Programme

The BME programme was introduced in 1985 as the successor to a production engineering course and was designed to provide an engineering education for students who wish to take up a career in manufacturing systems engineering, subsequently progressing to manufacturing management. It was the aim of the course designers to develop a programme which would stress the management aspects of engineering, from facility design to legal factors, while still ensuring that students had a good grounding in the main areas of "classical" engineering. Again, students study a wide range of subjects for the first three academic periods and then choose from a range of mostly management options in the fourth year. The common strand of the course is the management of modern manufacturing systems as mentioned in 9.2.1. The programme also leads to chartered engineering status. This places demanding constraints on the design of courses and the monitoring of industrial periods and engineering practice as well as engineering applications aspects of the programme.

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126) the normal pattern, until semesterisation in 1993, consisted of three cycles of six months at university followed by six months in industry at the end of which followed a whole year at university.

9.1.3 Sponsorship and Industrial Links

On both programmes, until the economic decline of the 1990s, eighty to nearly one hundred percent of students were sponsored by major UK manufacturing and research organisations. Sponsorship involves the provision of structured industrial training, nomination of an industrial mentor, a bursary and personal development support. University and sponsor company thus form a strong bond which places responsibilities on both partners. The sponsor company undertakes to provide good training for the student while the University commits itself to prepare students well for working in the industrial environment. The students do not commit themselves to a career with a particular company although there is some degree of moral obligation to return to a sponsoring company on completion of studies.

9.2 Teaching, Learning and Contents

9.2.1 Teaching and Learning

So as to satisfy the exacting demands, the structure of the two engineering programmes provides for a balanced mixture of conventionally structured tuition and of transaction based learning (see section 5.6.3.4 and appendix C). Figure 26 offers an overview of the education process experienced by the students. As illustrated clearly in this diagram, the characteristic strands of each course, Design for SEP and Manufacturing for BME, are also the areas where part of the learning takes place in a transaction oriented mode, that is, an environment in which students acquire competencies through interaction with each other, with staff and with engineers and managers from industry. The diagram shows both the teaching modes and the respective weight of courses.

Both programmes require students to maintain log-books in several learning areas, an essential element in documenting work carried out as a professional engineer. They are encouraged to adopt this method in year one of the programmes as described in section 9.3. Students are made aware of their responsibilities with respect to product liability and professional conduct as part of the process of encouraging the appropriate use of the log-books.

9.2.2 Learning Contents

One particular concept which can usefully be approached using the Gestalt-Insight theory of learning (see section 5.6.3.2) is that of the open ended character of engineering problems. A-level and, to a lesser extent, B-TEC studies condition students to assume that there are exact deterministic solutions for any scientific and engineering problem. The two courses discussed in this chapter are purpose-designed to give students a "feel" for engineering even though only a very few students at this stage of their studies know, for example, what a Vernier calliper is. By the end of the first academic period students have learnt to accept that many different solutions each have their merits and that only the combination of various aspects will result in the selection of a (locally) best solution. It is interesting to observe, as the courses progress, how students start to accept incomplete and tentative answers to their queries from lecturers, since, at the start of the courses, they invariably expect staff to know exactly how something works and how it is made.

9.2.3 Systems and Communications

According to Finniston et al. [1989] communications must be highlighted more on a broad based course than would be normal on engineering degree courses. Of particular relevance are writing skills, according to Finniston (21% to 24% of working time is spent on writing

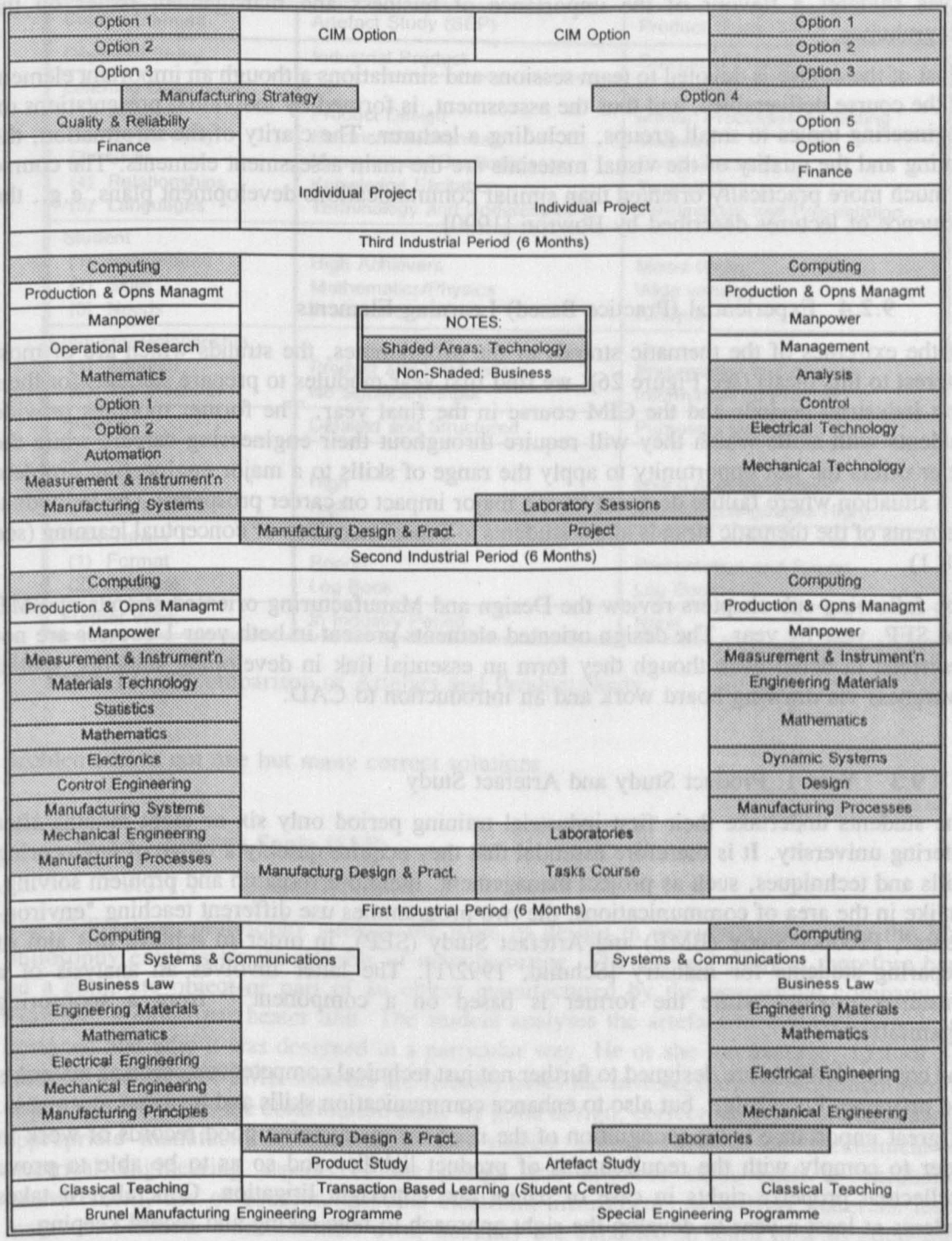

Figure 26 Structure of the BME (left) and SEP (right) Programmes

[Bowron, 1990]). The clearly perceived needs of the two programmes regarding the acquisition of communication skills and the creation of an awareness of systems thinking are satisfied by a course common to both programmes and taught in one big group since it is also intended to foster a sense of community. A substantial part of this course is taken up by practical training to improve information gathering and handling, report writing and presentation techniques. This process is started with a business game in which the students participate during induction week. The game, sponsored by one of the consultancy majors, gives students a flavour of the importance of business and management issues on the programmes.

Most of the course is devoted to team sessions and simulations although an important element of the course deliverables, and thus the assessment, is formed by individual presentations on engineering topics to small groups, including a lecturer. The clarity of the information, the timing and the quality of the visual materials are the main assessment elements. The course is much more practically oriented than similar communications development plans, e.g., the sequence of lectures described by Bowron [1990].

9.2.4 Experiential (Practice Based) Learning Elements

At the extremes of the thematic strands of the programmes, the strands which are of most interest to this thesis (see Figure 26), we find first year modules to prepare students for their first industrial periods and the CIM course in the final year. The former modules provide students with skills which they will require throughout their engineering careers while the latter offers the last opportunity to apply the range of skills to a major engineering problem in a situation where failure does not have a major impact on career prospects! The individual elements of the thematic strands allow students to experience deep or conceptual learning (see 5.8.1).

The following sub-chapters review the Design and Manufacturing oriented strands of BME and SEP, year by year. The design oriented elements present in both year 1 courses are not described in detail even though they form an essential link in developing students' spatial awareness via drawing board work and an introduction to CAD.

9.3 Year 1: Product Study and Artefact Study

The students undertake their first industrial training period only six or eight months after entering university. It is therefore essential that they acquire quickly a range of engineering skills and techniques, such as project management, literature research and problem solving. Unlike in the area of communications, the two programmes use different teaching "environments", Product Study (BME) and Artefact Study (SEP), in order to achieve this aim of preparing students for industry [Schmid, 1992/1]. The latter involves an analysis of a consumer product while the former is based on a component[127] from a sponsoring organisation.

The course elements are designed to further not just technical competencies, such as materials and processes knowledge, but also to enhance communication skills and business awareness. Of great importance is the recognition of the need for maintaining good records of work in order to comply with the requirements of product liability and so as to be able to prove intellectual property rights in case of patent and copyright litigation. Generally, it takes students at least a year to develop the right approach to note taking and record keeping.

For the University it is essential that its students be able to make a useful contribution to the company even in their first training period. The two courses mentioned are thus both intended to introduce students to systems and engineering approaches, although they are using different teaching environments and methods. This is illustrated in Table 13 which provides an overview of the two courses' characteristics. As indicated above, both courses also introduce to students the concept of "openendedness", the realisation that engineering

127) this can be complex or very simple, examples ranging from a fuel pump for a jet aircraft to a plastic carrier bag.

Course Element	Artefact Study (SEP)	Product Study (BME)
Object of Study	Industrial Product	Consumer Product
Learning Objectives (1) Analysis (2) Engineering (3) Skills (4) Relationships (5) Languages	 Product Design Electrical/Mechanical Measurement/Oscilloscopes Knowledge Elicitation Terminology and Understanding	 Manuf. Processes & Costing Materials Communication Teamwork Terminology and Presentation
Student (1) Background (2) Skills (3) Needs	 High Achievers Mathematics/Physics Practical Skills	 Mixed Group Wide variety Analysis
Industry Relationship (1) Sponsor (2) Manufacturer	 Product and Information No significant Input	 Presentation to Company Information on Product
Briefing	Detailed and Structured	Purposely Limited
Staffing (1) Number (2) Expertise	 High High	 Low (Languages High) Medium (Languages High)
Deliverables (1) Format (2) Informal	 Report Log Book	 Presentation and Report Log Book
Further Work	In Industry Period	None

Table 13 A Comparison of Artefact and Product Study

problems have not one but many correct solutions.

9.3.1 Artefact Study (SEP)

9.3.1.1 Course Objectives

The SEP course philosophy stresses the issue of design in manufacturing while the BME philosophy emphasises the process of manufacturing. The artefact study is therefore based on a complete object or part of an object manufactured by the sponsoring company, for example, a motor car heater unit. The student analyses the artefact to discover how it was designed and why it was designed in a particular way. He or she (on average, 15% of SEP students and 20% of BME students are female) bases the investigation on the function of the object and identifies the contribution made by good design, correct selection of materials and appropriate manufacturing processes. The student is interested in the mechanical and electrical engineering aspects of the design and acquires skills such as mechanical measurement, use of oscilloscopes and electronic instruments as well as materials testing methods. Students work on their own, but they are expected to learn how to elicit information from "experts", that is, lecturers and company personnel. The thrust of the investigation is thus analytical.

9.3.1.2 Course Process

The artefact study takes up three hours of laboratory based work per week. During the first few weeks of the course, students conduct a mini-artefact study in groups of three or four people, with the aim of acquiring some of the basic engineering observation and investigation techniques. They do this on the basis of a list of recommended actions : study of mechanical design, electrical systems and marketing. The briefing specifies the areas of investigation but does not detail the techniques to be used. All the groups are supplied with the same deceptively simple artefact, a battery powered fan costing a few pence. At the end of the induction period each group prepares a report and students proceed to analyse their own artefacts on an individual basis.

Students prepare a time plan for the artefact investigation which is agreed with the tutor. Over the following weeks they work in the areas of engineering most appropriate to the artefact and acquire essential skills in the process. Students learn to use tensile testing equipment, commission electron microscopy work and build their own anechoic chambers to test the acoustic behaviour of equipment. A lecturer acts as artefact manager who ensures that good quality test equipment is always available and who schedules the contribution of ten course tutors. They each spend at least one hour per three hour session with the students and are available to answer anything from straightforward Ohm's law type questions through to the design of relatively complex test protocols. Often the lecturers cannot provide answers though and the students have to contact engineers at the sponsoring organisation - who too are frequently baffled...

Much time is taken up by the discussion of design issues: why was the artefact designed in this manner, what other approaches could be used, does the component satisfy the requirements, why were particular materials chosen, what are the quality requirements? In some cases sponsoring companies purposely issue a student with problematic artefacts, either hoping to get new input or to test the student's ingenuity. Although students are expected to research marketing issues at some stage of the study very often this has to be left for the first placement with the company.

Learning is thus achieved as a result of independent thought, library based research and intensive interaction with course tutors.

9.3.2 Product Study (BME)

9.3.2.1 Course Objectives

The product study is based on a domestic product, such as a toaster or a cassette recorder, not necessarily in working condition. In line with the BME philosophy students analyse the product as a whole, from a manufacturing angle. They acquire knowledge about engineering materials and the manufacturing processes most suited to the materials present in the product. They are particularly interested in the cost of materials and processes. As future managers they have to enhance their communication skills within the study team, in liaising with manufacturers and course tutors. The result of the investigation is a synthetic review of several similar products, carried out by the group as a whole.

9.3.2.2 Course Process

BME students start the product study in the first week of their first term at university[128]. They receive an outline briefing by a lecturer and are allocated to groups according to the type of product they have brought along, e.g., electric kettles or motor driven equipment.

Only one hour per week is allocated to the product study, students are therefore expected to undertake much of the work outside timetabled sessions. The first three or four weeks of the course are, in the eyes of the student, wasted in a mire of group dynamics. The members of the group have to get to know each other, have to allocate tasks and plan the work to be undertaken. The brief requires that they gain a thorough understanding of the features of the product which distinguishes it from competing products and which give the manufacturer a

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128) in the new semester system the course is held as a block during the inter-semester week.

marketing or cost advantage. Although the students are not expected to research all the products exhaustively they must choose individual components and carry out an in-depth analysis for each of these, including design for purpose, design for manufacture, selection of manufacturing process, quality attributes and production costing.

Formal tutorial support is intentionally minimal. If students require information about their study they approach staff outside scheduled sessions. If they need information from manufacturers they are allowed to use University stationery to write to companies. They receive full support, however, for the presentation on the group's products which takes place at the end of the study period.

In contrast to the SEP students their BME colleagues largely learn by interacting with other members of the team and by seeking information from sources which are notoriously difficult to tap, that is, manufacturers and overworked course staff! They thus learn to cope with the three major problems which they will face as managers: incomplete information, communication problems and lack of time.

9.3.2.3 Deliverables and Further Work

The end products of the product study are a report and a presentation. In line with the course objectives the latter is designed as a communications exercise in which managers from many sponsoring companies participate. It is a harrowing experience for students who have to present their findings in front of 40 to 50 people. However, it is also the most rewarding elements of the whole of the first year BME course. Each group prepares and submits a detailed report on their study which is assessed for content and quality of presentation. Reports are available for inspection by sponsoring companies.

The artefact study culminates in a relatively low key meeting with a company engineer to discuss problems and further work. The final result is a report which is completed during the industrial period, in general with company support.

9.3.3 Local Company Project

One of the most innovative and effective courses developed for the BME programme is the Local Company Project which offers students an opportunity to experience real life project work in a commercial context: groups of three to five students are allocated to a manufacturing company within easy commuting distance from the University. They receive a full briefing from company management, in the presence of the academic tutor, about a project of limited scope and scale, to be carried out over a period of one week. Examples of such projects might include the rearranging of a manufacturing cell or the investigation of better stock control methods. Students work in the company for the whole of the week although they may contact members of staff at the university if they need information to solver particular problems. The week's work is documented in a report, assessed by both company personnel and university staff. The project culminates in a presentation to senior management of the company, followed by a discussion on the possibility of implementing the results.

9.4 Year 2: Tasks Course and Manufacturing Simulation

9.4.1 SEP: The Tasks Course

In the second year of SEP students undertake the Tasks Course [Clark, 1985(2)], an engineering design course. In contrast to the artefact study the tasks are fairly closely defined. The course aim is the integration of theory and practice within a problem-solving framework. Normally, learning on a university engineering programme is organised around a combination of lectures, tutorials, structured laboratory course and project work. While the former two elements are used to communicate theories and information in self-contained subject areas, the latter two are expected to provide the practical background. The tasks course was designed so as to provide, within a design/project context, the means whereby a body of knowledge, in a particular subject area, could be acquired in a holistic fashion.

The course is made up of a mechanical part and an electrical part, each of which consists of a number of distinct tasks which are carried out in sequence by the students over a period of two terms. Each task is again subdivided into a theoretical and a practical part. The theoretical part requires preparatory book work involving appropriate use of text books. Although this part of the task is essentially self-study based, staff are available as consultants. Most students are sufficiently motivated to seek by themselves the information needed to enter the practical part of a task. The practical part is concerned with the design of a simple system using specified parts to satisfy a specified function. In moving from the theory - where absolute accuracy is possible - to practice the student learns to deal with imperfections and, very importantly 'noise', e.g., tolerances, loading of measuring devices etc. The main goal is that of engineering: the creation of a functional piece of equipment where the theory and the practical construction complement each other, are integrated with each other.

The course is organised in a succession of themes during which groups of six or seven students work on different aspects of a similar task in teams of two, partners changing from task to task. Approximately fourteen hours are allocated to each task, split between preparation and practical work - students must therefore learn to plan their own use of time. The course is assessed partly during oral presentations of pairs of students to the whole group and partly by means of written reports handed in exactly two weeks after completion of the task.

9.4.2 BME: Manufacturing Simulation, Video and Poster

BME students follow a less structured programme of practice based activities during their second year of study. Activities include formal laboratory sessions centred on manufacturing processes and control systems design, a manufacturing simulation (described in section 13.4.5) and two open-ended activities, a video presentation and the design of a poster. For the video presentation each student prepares a brief lecture on a topic of interest which is recorded and then discussed in groups. The poster design is a group activity aimed at developing students' awareness of design issues and their creativity. Its secondary objective though is the learning which can be derived from a seemingly straightforward task with very generous time constraints. About half the groups each year fail this test by producing a very inferior poster at the last minute.

9.5 Year 3: Design Project and Introduction to CIM

9.5.1 SEP: Design Project

"The year 3 projects ... act as the bridge between year 2 work and the major individual final year project." [Ellis et al., 1985] Work in the year two tasks course concentrated on the early part of the design process, especially so the development and evaluation of different options for solving a problem. The year 3 design project normally follows on from a design activity during the preceding industrial period and is concerned with the design of a component of a system. Students carry out individual tasks but meet with the project supervisors in theme oriented groups which provide opportunities for peer group learning. Students benefit from this arrangement through broadening of the range of subject matter since they have to understand colleagues' work sufficiently well to be able to comment critically. Groups can also be used for brainstorming and other creative activities. In most cases the project tasks will have been defined by the sponsoring company of the student. This is an important aspect of the learning experience since it involves negotiation at the beginning of the project and since it results in a much better focus: the company will expect a real deliverable at the end of the period - the pressure on the student to perform becomes substantial.

9.5.2 BME: Manufacturing Group Project

Over the duration covered by this dissertation many different approaches have been used to prepare students for the practical work to be undertaken in the final year. Activities ranged from 'standard' laboratory activities, with tasks taking up between four and six hours and mostly concerned with modelling and simulation of manufacturing systems, to group tasks involving four or five students in major projects over a whole term. The themes for these projects would be from the general area of manufacturing, from human centred CIM to lean production and object oriented programming of factory control systems. The group projects were not structured by staff but relied on the informal groupings of students which had occurred naturally during the first two years of the course. Output was therefore highly variable but the projects provided a better introduction to fourth year work than the scripted laboratory activities. In academic year 1991/92 the group projects were supplemented by a set of brief introduction to the CIM course, organised by the fourth year students involved in CIM. This activity was expanded in 1992/93 with a full introduction programme including assignments set and assessed by the fourth year students as briefly described in section 12.1.2.

9.6 Year 4: Individual Project and CIM

During the fourth (final) year of the course about half the students on the programmes undertake industrially oriented projects, mostly supported by their sponsoring company. The other half work on university generated projects, also frequently closely related to industrial problem solving. The objectives of the fourth year project are the same as in any other institution of higher education: to offer the students an opportunity for integrating as much of the theoretical learning assimilated during the first three years of the programmes and to create an assessment opportunity which goes beyond rote-learning and short pieces of analytic and synthetic work. Some of the more traditional fourth year courses are also slanted towards integrative work, e.g., the option 'Organisational Change' and the compulsory (for BME) module in Manufacturing Strategy. The CIM course is described in detail in chapter 12.

9.7 Summary, Review and Outlook

A substantial part of the programmes of study of BME and SEP have been shown to be strongly practice related and practice based. Throughout, students are guided to self-motivated study and the use of a great variety of information sources. They also learn to cope with uncertainty, open ended problems and they learn to present information, the results of their work, in a clearly structured and succinct form. They learn to make oral presentations and to write competent reports covering both their process of work and its results.

The environments in which today's engineers work have now been investigated in some detail. Together with the changed roles of engineers they result in particular educational demands. This was followed by a discussion of theories of knowledge and learning, and of the practice oriented elements of the engineering education process as applied in the

Department of M&ES at Brunel. The general analysis must now lead into a more detailed discussion of the issue of competence in engineering or, indeed, in any professional activity.

10 Competence, Skills, Transferability and AMEs

10.1 Introduction

In 'Skill and Competence for the 21st Century' Cooley [1993] wrote: "we shall have to be capable of thinking holistically, working in multidisciplinary groups, coping with change and developing systems and products which are sustainable and caring of nature and humanity." Cooley reviews the causes for the present environmental problems and postulates the need for change in education, away from narrow specialisation and training towards holistic forms. He maintains that the education process should be a vehicle for transmitting culture. While not as radical in its philosophy, the CIM course at Brunel was designed with the intention of completing the preparation of graduating engineers for such a future remit, thus providing a foundation for successful careers in manufacturing industries and related fields.

In the past it was the individual final year project which allowed the student to demonstrate competence, that is, to show that she or he had assembled sufficient knowledge and understanding of their chosen discipline, together with the necessary applied skills, to be deemed ready for work in a professional capacity. This quite colloquial and very broad description of competence is, unfortunately, not a good foundation on which to base course designs.

We have already seen, in section 8.1, that the educational approach involving a conventional final year project fails to provide opportunities for practising team based skills. Although this is a serious failing, it is not the only aspect of engineering work which does not receive sufficient attention - and which is therefore omitted from curricula. As will be seen later, many of these aspects fall into the domain of 'transferable skills' which have started to attract much interest in the education community. In the present chapter the author addresses specifically the transferable skills needs of the engineer being formed[129)] for work in advanced manufacturing environments. The integration into a formal structure of the many individual elements which make up the CIM course will be paid particular attention.

10.2 Engineering and Competence

In line with the practice of the Council for National Vocational Qualifications (NVQ) Macleod [1992(1+2)] defines competence as the ability of a person in relation to an activity[130)]. This must be distinguished from achieving a satisfactory performance in an activity. The colloquial phrase 'a competent person' includes not only a judgment about aptitude but also about the generally expected level of quality (not brilliant but ok). Competence in the more rigorous sense is a necessary precondition for performance but performance is not a necessary consequence of competence. Competence, in his view, should be related to career stages, that is, some abilities may not be required at the beginning of an engineering career while others become superfluous later on (cf. Table 2).

In his paper 'The Competence of an Ingenieur[131)]', Macleod [1992(1)] presupposes the existence of a knowledge base[132)], corresponding to the rational domain of knowledge, which

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129) the expression 'forming an engineer', which is meant to subsume elements of both education and training, evolved at some point during the (engineering) educational debate of the mid 1980s. The expression was modelled on the French 'formation des ingénieurs' and was intended to enhance the status of engineers to a level comparable to that existing in France. It is used here in the way Macleod used it in [1992(1)].

130) competence and competencies are discussed further in section 10.3.1, in the context of transferable skills.

131) this term is a reference to a campaign by the engineering institutions aimed at changing the image of professional engineers by adopting the German / French job title.

132) developed as the result of experience throughout life.

was defined in section 5.1 of this thesis as 'cognis'. Macleod then proposes his own taxonomy of engineering competence for which he introduces three ranges of component abilities, *cognis*, *technis* and *intuis*[133]. The writer's definition of cognis is thus in conflict with Macleod's definition. The latter subdivides each range of component abilities into core abilities, e.g., presentation skills, and domain abilities, e.g., manufacturing systems analysis.

10.2.1 Cognis, Technis and Intuis

Cognis, according to Macleod, is the ability to operate on a knowledge base, that is, to access and describe (in speech or writing) the process of attaining achievement in an activity. It thus relates to the handling of knowledge affecting the process directly or indirectly, and could perhaps be equated with the faculty of recall defined in section 5.5.2.3.

Cognis is acquired from early life onwards, as the knowledge base develops. It can be enhanced at University but cannot be created there.

Technis is defined as the ability to operate with the knowledge base, that is, to perform successfully in an activity when the process can be defined, when one can rely on known procedures. It could thus be seen as equivalent to skill and know-how.

Technis is an essential product of engineering courses but it is not a sufficient condition for the formation of Ingénieurs: Mcleod argues that Cognis and Technis together make up the domain of vocational faculties. Intuis goes beyond the recipe stage.

Intuis is the ability to operate beyond the knowledge base, that is, to perform in an activity when the process of achievement is not or cannot be defined. Synonyms often used colloquially are flair, intuition, creative ability or, in the context of the dissertation, understanding.

In contrast to other authors (e.g., Gibbs [1993]), Mcleod is of the opinion that Intuis can at the very least be furthered, if not taught. The writer agrees with this view, having benefitted himself from a course in innovation and creativity run by Schürch[134] in Zürich. Intuis can develop better in a creative environment but it is important that 'the wheel is not reinvented'. For Mcleod the education for Intuis must start very early in life and should not provide too many methodologies (another word for recipes).

He advocates that students be taught a top-down approach[135] to problem solving as a helpful tool and offers his own four stage sequence which has similarities to that put forward by Kolb et al. (see section 7.3.2). Mcleod's approach to solving problems includes Postulation, Generation and Validation of the solution, followed by an Analysis stage although he does not favour deep analysis because he feels that it is often not necessary. However, in his opinion, engineers' ideas must satisfy the key requirement of 'working'!

Summarising, Mcleod postulates that engineering formation, a package of education and training, must develop in the student a broad ability base for each competence together with a high level of problem solving powers. Mcleod though is not approaching this discussion from a philosophical or psychological angle, rather, he investigates it as an engineer. We have to look elsewhere for a more rigorous treatment of the subject.

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133) terms created by Macleod.

134) inventor of the inverted 'duck' plane who died while investigating a report of potential unstable flying conditions.

135) it is not quite clear what he means by this statement. The context would indicate that he advocates addressing a problem first at a very general level before attempting a detailed solution, as opposed to a sequential approach.

10.3 Competence and Skills for Advanced Manufacturing

In section 5.1 we saw that the components of engineering capability can be classified into qualities, faculties and content. There are, according to the EPC, two domains of content or knowledge, implicit and explicit, as shown in Table 7. The generic qualities which make up the good engineer, aptitudes and attitudes, were discussed in the same section, as was the issue of faculties. A specific subset of the hierarchy of faculties required by the engineer are transferable skills. First it will be necessary to explore the relationship between competencies and skills.

10.3.1 Competencies

While there may be good reasons for establishing an artificial difference between competence and competency (and thus competencies), the Oxford dictionary [Sykes, 1975] does not differentiate between the two and gives the basic definition of competence as 'ability to do, for a task'. The writer concurs with this view. However, it would appear to be acceptable to hone the definition of competence so as to arrive at a narrower range of meaning for the purpose of the educational discussion. In section 10.2 the writer began to discuss Macleod's definition of competence which had been derived from the following NVQ definition:

> 'competence is the ability to perform the activities necessary in an occupation or function to the standards accepted in employment'.

It is worth emphasising, again, that there is no value statement made about the quality of the performance of the activities. The NVQ definition is refined to differentiate between:

'elements of competence'

'units of competence'

This refinement forms a basis from which it would be possible to start defining performance

Competence Scale ➡ ⬇ Scope	Element of Competence	Unit of Competence
Core Competence	individual effect which a person should be able to realise at work in any type of professional situation.	coherent group of elements of competence having meaning and independent value in any work situation.
Domain Specific Competence	individual effect which a person should be able to realise in a particular well defined working situation.	coherent group of elements of competence having meaning and independent value in a specific professional activity.

Table 14 Matrix of Scale and Scope of Competence

criteria and to make range statements about the performance required for satisfactory task execution in a particular job role. The author has tried to summarise this in Table 14 using the most open form of definition possible, that is, he has introduced the term 'effect' to describe any outcome of an activity, be this a physical or any other result.

Core competence, made up of core abilities, has recently [Macleod, 1992(2); EPC6, 1993; Gibbs, 1993] acquired prominence in the context of the discussion of 'transferable skills', that is, 'skills' which are learnt in a particular situation and which, supposedly, transfer with relative ease to other situations, e.g., communications skills. Some of these 'skills' are explicit, easily defined and quantified, and can be taught conventionally while others are implicit and adopted as the result of experience.

10.4 Skills Background in Universities

10.4.1 Industrial Relevance and Usefulness

Since the mid 1980s the UK government has been exhorting universities to "produce" graduates whose skills were more in line with the needs of industry and commerce. In this thrust the UK was not alone: in Germany, Russia and, to a lesser extent, in Switzerland both government and industry were demanding similar action[136)]. The move away from the education of an elite for a relatively small range of professional posts towards mass higher education for raising the nations' competitiveness resulted in the demand for immediately useful graduates not requiring lengthy induction periods to the world of work.

In the past university teachers had simply assumed that it was adequate to equip students with the minimum of skills necessary, that is, library searching technique and laboratory methods, to cope with the type of work essential in classic lecture courses supported by 'practicals' and including one or two major individual projects. In effect, all students received some training towards becoming academic researchers even though in most universities only a very few students per intake would aim for such a career. But even this limited skill teaching only came about as a response to the needs of the "new" students entering universities following the first phase of higher education expansion in the UK of the 1960s. Where practical skills were needed for laboratory work etc these were expected to pre-exist or to develop naturally. The same applied to the important area of examination technique.

Students, having graduated, were meant to acquire the necessary skills for survival and progression in the professional world either by full immersion or through a training programme of one or two years organised and funded by the first employer. This latter model was feasible as long as graduates represented only a very small proportion of a company's work force, an elite destined for high management or engineering positions, and as long as they were committed to staying with a company for most of their career. The former "method" only worked if a graduate was naturally gifted and had a competent mentor - the French system of one Grande École ingénieur following in the footsteps of another from the same institution.

In a time where 25-30% of all entrants to the job market are educated to degree level and where most active members of a population are expected to change jobs several times before retiring such training methods were no longer economically viable. Graduates had to be equipped with a minimal range of skills before entering employment in industry. Due to the more centralised approach to such issues adopted in the UK, government departments and other bodies acted relatively quickly and established the so-called Enterprise in Higher Education (EHE) Initiative. In the next sections the author will concentrate on the principles and methods used in the UK to enhance the initial performance of graduates, their 'fitness for purpose'[137)], by giving training in so-called 'transferable skills', that is, skills which could be used in any professional situation rather than methods and techniques derived from a 'narrow academic specialisation'.

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136) authors voicing concerns in this direction are, amongst others, Hernaut [1993], Morgunov [1991] and Ursprung [1991]. See also Table 3.

137) an appropriate term from the quality debate.

10.4.2 Transferable Skills - The EHE Approach

10.4.2.1 Background

Traditionally, institutions of higher education tended to equip students solely with academic and subject specific knowledge and skills (e.g., chemical formulae and titration, domain specific components of capability). Against this background, the EHE Initiative was set up to support the institutions in establishing new strands and modules for their courses to develop students' immediate usefulness to industry. The EHE programme saw the first pilot schemes in 1989, these were followed by a first national round in 1990. The Initiative adopted the term 'transferable skills' which had emerged earlier as a catch-all description for the vital skills which students need for study and learning and, upon graduation, in the "world of work" [Gibbs, 1993]. While the range of skills is similar in both environments, their individual relevance and attached value will be different.

Transferable skills are thus defined as skills which transfer from one situation to another, from academic contexts to work contexts and from one work context to another, from one human activity in life to another. They are useful regardless of the direction which a person's career may take. Gibbs [1993] argues that domain specific subject knowledge (of a particular vintage) is becoming less and less valuable while the flexibility to be effective in different situations and environments is today essential. Although these different situations may have some knowledge content in common their skills contents are far better matched.

Unfortunately, the simple act of declaring a skill a transferable skill does not solve the problems of today's engineers and their employers since neither training nor its result, skills, transfer very readily from one domain to another [Gibbs, 1992]. The skills must be acquired or internalised in situations which are closely modelled on real life, that is, time management for engineers is best trained using a time-critical multi-stage project [EPC 1, 1989] with real deliverables.

To some extent 'transferable skills' are discipline specific, although there is a substantial range of such skills which are useful in most disciplines, e.g., team work, presentation and organisational skills. Traditionally engineering valued skills such as numeracy, informacy and specific creativity (and problem solving) while business and social studies placed more emphasis on literacy and organisational, as well as personal and interpersonal skills. These clear demarcations are vanishing though because environmental and societal pressures force more and more engineers to work in multidisciplinary teams (see 3.1.1).

Buoyed by its massive funding (ca £1M per supported institution) the Initiative assumed a very high profile and succeeded in placing transferable skills firmly on the agendas and curricula of many institutions, often displacing subject specific course elements. Whilst some aspects of these developments may well have been positive, there are many instances where the introduction of the teaching of transferable skills was being used simply to cope with larger student numbers without expanding staff resources. Often this objective would be hidden by describing it as "trading content for process" [Gibbs, 1993]. In general, the initiative did not lead to new or completely redesigned engineering curricula which would have provided opportunities for creating integrated programmes of study although some such programmes were developed, e.g., the AED course described as a case study in section 13.4.1 which combines domain specific learning and skill acquisition.

10.4.2.2 Superficial Critique of the Approach

As a stimulus to changing higher education in a way which would make graduates more useful to commerce and industry the initiative arrived in some way too late: progressive course managers had introduced the acquisition of industrially relevant skills in the late 1970s while, in the 1980s, schools and sixth form colleges started to equip their students with study and life skills as part of the change from O-levels to GCSE and the moves to make A-levels more relevant. On SEP, in a manner typical for enhanced engineering courses, communication and systems oriented skills were part of the course concept when it was first launched in 1978 [Clark, 1985].

One of the strongest criticisms which can be levelled at the EHE Initiative is its success: in a very short space of time it led to a "standard" approach to the teaching of work and life skills leaving little space for experimentation and alternative definitions of the skills required by students. The same ranges of competencies are being discussed and addressed in most institutions of higher education, with little effort channelled into subject or discipline specific interpretations. Often the schemes fail to take into account students' prior learning, e.g., the substantial amount of team based teaching taking place at primary and secondary school level. Since they deal with 'approved' methods they also tend to become static very quickly.

The thrust of the Initiative was (and is) in marked contrast to the approaches adopted in other European countries (Germany, France and Switzerland) where students are expected to arrive at University equipped with study and life skills as a result of the much broader education leading up to baccalaureate and Abitur [Schmid, R., 1993]. In the author's experience and opinion this assessment is overoptimistic though. He has had opportunity to compare more than twenty graduates or graduands from France, Germany and Switzerland, studying on the MSc course in Advanced Manufacturing Systems at Brunel University, with young British engineers who had completed the BME and SEP programmes with their integrated industrial training. With very few exceptions the British students performed better on open ended tasks and tasks requiring management skills while the students from the other countries performed better in analytical and design oriented tasks. To some extent this is, as a matter of course, an anticipation of the future roles to be played by these young engineers: it is likely that both in Germany and in France they will be working as engineers for much longer before moving into management positions, if ever.

10.4.2.3 Fundamental Critique of the Approach

The detailed consideration of issues such as that of the components of capability (qualities, faculties and knowledge) discussed in section 5.5.2 leads to the conclusion that EHE has attached the label of 'transferable skills' indiscriminately to a bundle of knowledge, faculties and qualities. Although the attempt at a 'classification' of these disparate elements by the proponents of the Initiative has resulted in a helpful scheme to promote a better preparation of students for their future tasks it has also created a great deal of confusion by mixing elements which can be adopted as an outcome of formal teaching while others which can only be acquired.

SNo	"Skill" reference Number	AM	need in Advanced Manufacturing
AP	Aptitude		1 irrelevant
AT	Attitude		2 not very valuable
RE	Recall		3 somewhat valuable
SL	Skill		4 valuable
KH	Know How		5 essential
UN	Understanding	PS	Preexisting "Skill" level
AK	Atoms of Knowledge		1 all possess skill at good level
SC	Schemata		2 most possess skill at decent level
RL	Relations and Links		3 some possess skill at decent level
EN	need in ENgineering in general		4 few possess skill at decent level
			5 hardly anybody possesses skill

Table 16 Notes for Table 15.

Relationships between Transferable Skills and Capabilities in Advanced Manufacturing						Skill Levels		
Domain	Transferable Skill	SNo	Quality	Faculty	Content	EN	AM	PS
Group Work	leadership, chairing	1aa		KH		5	4	3
	co-operation	1ab		SL		5	5	4
	sub-ordination ability	1ac	AT			4	4	4
	team based work	1ad	AP			4	5	2
Organisational Skills	setting of objectives	1ba		KH	RL	5	5	3
	time management	1bb		SL		4	5	3
	project management	1bc		KH	SC	3	5	4
	project evaluation	1bd		SL	RL	3	5	4
	decision taking	1be		SL	RL	4	5	3
Entrepreneurship	take initiative	1ca	AT		SC	3	4	3
	seize opportunities	1cb	AT		RL	2	3	3
Personal Skills	independence, autonomy	1da	AT	UN	SC	4	3	3
	self assessment	1db	AP	UN	RL	3	4	3
	self confidence	1dc	AT			4	5	2
Interpersonal Skills	influence	1ea		SL		3	4	2
	listen, counsel	1eb		KH		2	5	3
	motivate	1ec		SL	SC	3	5	3
	negotiate	1ed		KH	RL	3	5	3
Problem Solving Skills	problem definition	2aa		KH		5	5	2
	problem analysis	2ab		SL	SC	4	5	3
	collection of solutions	2ac	AP	RE,SL	AK	4	3	1
	decide on solution	2ad		KH	RL	5	5	4
Creativity	stimulate	2ba		SL		4	4	3
	develop mental models	2bb	AP	KH,UN	SC,RL	4	5	3
	channel effort	2bc		SL	SC	4	5	3
	lateral thinking	2bd	AP	RE,SL	SC,RL	4	4	4
Practical Skills	electrical	2ca		KH	AK	4	3	4
	electronics	2cb		KH	AK	4	4	4
	mechanical	2cc		KH	AK	4	3	2
	machine tools	2cd		KH	AK	2	3	3
Information Gathering	locate info. sources	2da		SL	AK,RL	4	4	2
	extract data	2db		SL	RL	4	5	3
	evaluate sources	2dc		RE, KH	SC	4	5	3
	interpret data	2dd		RE,SL	SC,RL	4	4	3
Literacy and Language	technical vocabulary	2ea		RE	AK	5	4	1
	read purposefully	2eb		SL	SC	3	4	2
	write simply/accurately	2ec	AP	KH		4	5	3
Informacy	word & data processing	2fa		SL	AK	3	3	1
	use of software tools	2fb		KH	AK	5	4	3
	electronic communication	2fc		KH	AK	3	5	4
	understand drawbacks	2fd		UN	RL	3	5	4
	use of CAD/CAM/CMM	2fe		SL	AK,SC	4	3	2
Numeracy	use of mathematics	2ga		RE,SL	SC	5	4	2
	building of models	2gb		KH	RL	4	4	3
	financial management	2gc		KH	RL	3	5	4
Communication	presenting information	3aa	AP	SL	RL	3	5	2
	writing reports	3ab		KH	SC	4	5	3
	use of graphics	3ac	AP	SL	AK	4	3	3
	documentation management	3ad		KH		4	5	4
Teaching and Training	identify learning needs	3ba	AP,AT	UN	SC	3	4	2
	designing training	3bb		KH	RL	2	3	5
	running workshops	3bc		SL		2	4	3
	instructing others	3bd		SL	RL	3	5	3
Learning	literature search	3ca		SL	AK	4	3	1
	literature review	3cb		KH	RL	4	4	2
	logbook maintenance	3cc		SL		4	5	2

Table 15 Transferable Skills for Advanced Manufacturing

Table 15, which is also discussed later, is a version of the list of so-called 'transferable skills' provided by Gibbs [1993] and expanded and modified by the writer. In its unmodified form the list is characteristic of the approach chosen by EHE and by the Enterprise Unit at Brunel, the body charged with implementing the objectives of the EHE at Brunel. In this form it is also used at many other institutions. The notes for the table may be found in Table 16 (see Table 29 for the complete key to Table 15).

The table has been completely restructured by the writer and thus presents his own assessment of the situation. He has amended the list of 'skills' slightly to reflect the specific requirements of Advanced Manufacturing Environments (AMEs). The list has also been redesigned so as to group 'skills' oriented towards people and organisation (SNos 1a-1e), technically biased 'skills' (SNos 2a-2g) and "soft information transmission" 'skills' (SNos 3a-3c).

In the table, creativity has been removed from the heading of entrepreneurship since it is a transferable skill in its own right. Edward de Bono for one states that creativity must be considered as a skill which can be learnt - even though it may partly depend on talent and personality [de Bono, 1985]. Alschuler [1970] is also of this opinion: "Imagination is a weak muscle that can be strengthened". Problem Solving and Creativity may be considered as two faces of the same coin: both use similar methods in searching for solutions and both require imagination and experience. However, tasks which lend themselves to problem solving tend to be better defined than those requiring creativity. They also tend to be shorter term.

Literacy has been added (amalgamated with language) since the skill of handling words is in many situations today of greater significance than numeracy. "Informacy" describes the skills needed to work with information technology in a way which relates more closely to "classical skill speak" than the heading "information technology" (used by Gibbs) which is usually taught as a knowledge based subject on both engineering and social science courses.

The columns marked Qualities, Faculties and Knowledge in Table 15 have also been introduced by the writer, in order to analyse and differentiate the 'transferable skills' in line with the approach and definitions used in section 5.5.2. The column of most interest is that of faculties where we find all the elements of the hierarchy established, from recall (RL) to understanding (UN), and not just the skills according to the much narrower definition in section 5.5.2. The latter is not a serious problem, as long as the implications for the teaching process are acknowledged. However, it is very apparent that understanding does not feature prominently in this interpretation of GIBBS' and the EHE's analysis.

As shown in the table a number of so-called 'transferable skills' belong to completely different categories - one of the reasons why experienced teachers tend to find the list difficult and unsatisfactory. Terms such as 'elements of capability' or 'abilities' might have been more appropriate but the writer has accepted to use the EHE terminology for the remainder of this chapter - though choosing to express his unhappiness through the use of inverted commas. He has also chosen to do this so that the reader will realise when the term is being used in its conventional meaning.

10.4.3 Metaskills

Ellis et al. [1985] discuss the concept of 'meta subjects' such as problem solving ability, decision-making skill. In some teaching situations, in particular, project based learning, these elements form the key educational objectives. They are closely related to the objective of 'learning to learn', the main tenet of the EHE Initiative. Klein [1994] applies a similar approach when he discusses the way in which corporate entities acquire competencies. He argues that there are at least four corporate metaskills: learning, innovating, skill categorising and embedding. It would seem appropriate also to apply the same argument to individual skills and skill acquisition. At the individual level learning and innovating would be retained, skill categorising would reappear as the ability to structure while embedding could be described as the process of creating the context. Lack of space prevents a further discussion of this interesting avenue which could well be made more rigorous than the relatively unstructured 'theory' of transferable skills.

10.4.4 Networking, an Important Composite 'Skill'

The complexity of systems has increased to such an extent in recent years [cf. Cooley, 1993] that it is only rarely possible to find an individual able to design, build, implement and manage a complete solution to a given problem. As indicated in chapter 3 project work is therefore largely organised on a team basis. Very often, however, some of the qualities, faculties and knowledge necessary to create a new system will not be available within the team or not even within the organisation. Although it may be possible to 'buy-in' expertise this can be costly and may leave the organisation vulnerable to exploitation.

Networking is a phenomenon which developed from uncoordinated and non profit collaboration between groups of computer experts and between environmental activists. It is different from 'old boys / girls' networks in that it does usually not involve the trading of favours but mutual support and the exchange of information. Ideally it is founded on personal relationships but the success of the relatively anonymous computer based 'Internet' indicates that this is not an essential requirement as long as the expertise sought is relatively straightforward. Networking in this form does not rely on people's position in life but on their capability. The development of such networks must be one of the most significant objectives of any education, especially so of a university education.

Networking is an aspect of professional work which relies almost totally on 'transferable skills', most importantly though on people and organisation capability (1ab, 1ad, 1bc, 1ca, 1db, 1ea, 1eb, 1ed in Table 15) and technical capability (2ab, 2ac, 2ba, 2bd, 2c, 2da, 2db, 2fc). It is a composite 'skill' in that any element on its own is no use, that is, communication skills without expertise (2c) will not be sufficient to warrant a person's inclusion in a network. Of particular importance is self assessment (1db) since members of networks must be aware of their own limits so as not to give wrong advice to another member who will trust information given.

10.5 Integration of 'Transferable Skills' in University Engineering Courses

In the author's experience, 'transferable skills' as propounded by the originators of the Enterprise Initiative have their place in a university education but they should be taught at the beginning of a course and should be supplemented by an experience of "real life" in the chosen profession, for example, an industrial placement, to allow the students to experience the relevance of 'transferable skills' by themselves. They must also be given the freedom to set their own priorities, to use choice positively. Not too much time should be devoted to the formal study of these 'skills' but at regular intervals pointers should be given to alert students to learning opportunities which will help them acquire or enhance 'transferable skills'.

Towards the end of their academic education though the students should be given ample opportunity to apply and test the 'skills' acquired in a meaningful way, but still in the "safe" environment of the University. In a way the whole of a university education should reflect the traditional model of skills acquisition, the Experiential Learning Cycle (ELC) and its extension, Practice Based Learning (PBL), discussed in section 7.3.2. This is particularly true with regard to the acquisition of those of the 'transferable skills' which really are skills.

While the learning cycle normally refers to the process of adopting a single skill it can just as well be used for an integrated palette of skills. Since it is, in general, impossible to manage students' skills acquisition programmes on a one-to-one basis[138]), mostly for resource reasons, university courses must be tailored to give students opportunities or slots to practice and internalise the skills judged essential for their chosen discipline by the course designers. As a matter of course, different approaches will apply to the teaching of those 'transferable skills' which are not skills at all.

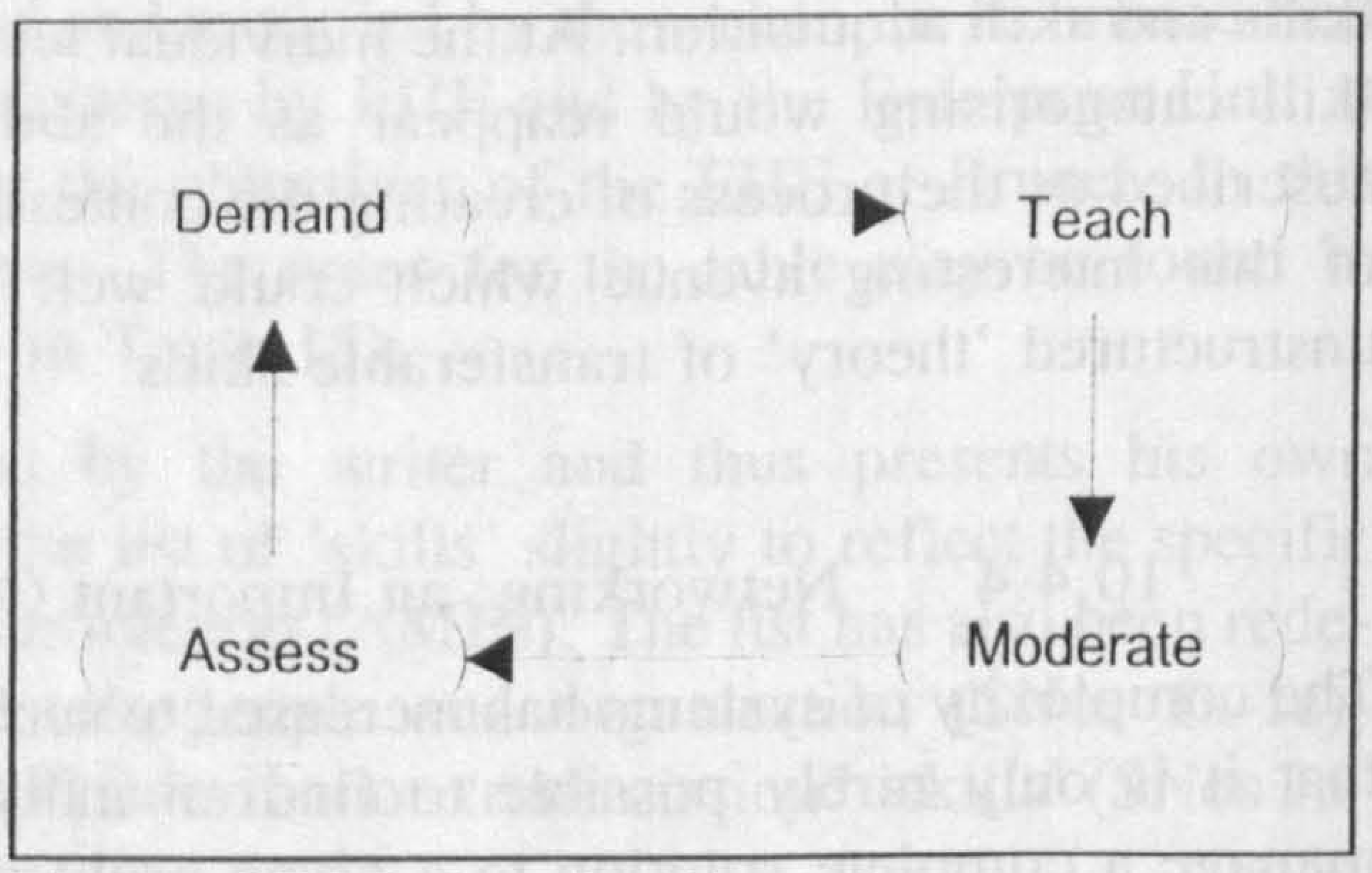

Figure 27 Moderating Learning

10.6 Assessing the Education Process of the CIM Course

Engineers need a very comprehensive range of 'transferable skills' if they are to function well in any professional environment. In this they differ from other professionals who do not change roles as much during their careers, often from junior member of a team to a senior management position outside engineering. As a consequence, any course designed to help students develop the necessary 'skills' will be made up of a great number of different atoms. The course in Computer Integrated Manufacturing (CIM) at Brunel is of this nature and is therefore difficult to evaluate in traditional terms.

The guidelines of the EHE [Gibbs, 1993] include the four-phase approach to moderating learning as repeated here in Figure 27, following a first mention in section 7.3.3. The approach has been included in Table 28 which will be discussed in chapter 17 since it provides a 'conventional' and convenient, albeit perhaps not ideal, way of structuring the analysis of the different activities involved in the course. The four phase approach to moderating learning was likened to the experiential learning cycle in section 7.3.3. It was stated that it is not possible to show a close equivalence between Gibbs' cycle and practice based learning. The key element which is missing from Gibbs' cycle is the creation of a questioning attitude and the associated set of appropriate questions. The CIM course challenges students but, as will be seen later, does not force every student to excel in every 'transferable skill'. Indeed, in contrast to Gibbs' approach, some students may not get involved at all in some activities. They can state their preferences at an early stage on the skill cards (see section N, O) - and may avoid learning experience which would be deemed essential by advocates of the Enterprise Initiative.

Despite the reservations voiced about the Enterprise Initiative, it may prove useful to assess the 'skills' needed for successful operation as an engineer or manager in an advanced manufacturing environment (AME) in the terms and with the criteria developed in the Enterprise Initiative. The CIM course and the associated learning experience will be discussed in this context in section 17 and contrasted against the experience to be gained from undertaking an individual research project[139]). The course and the educational approach underpinning its development are discussed in the next chapter.

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138) proponents of computer supported learning will immediately point out that this is exactly what they attempt to achieve. However, the subsequent comments apply to collectivised learning of all kinds, including computer assisted learning.

139) all students on BME and SEP, including those who chose the CIM option, carry out a final year project of this kind.

11 The CIM Course at Brunel University

11.1 Introduction - Restating the Need

Concurrent engineering and other modern project management techniques rely on multiskilled teams working in an integrated manner to achieve success, as outlined by Cummings and Blumberg [1987] and discussed in detail in chapter 3. More and more engineers thus have to carry out their professional activities and duties in such teams rather than working by themselves in protected hierarchical structures. Although analytical skill and factual knowledge are still very important in designing and operating advanced manufacturing systems, engineers' communication abilities, management and motivational skills have assumed greater relevance. Unfortunately, the classical methods of engineering education fail to address the problems inherent in teaching interdisciplinary problem solving.

Different methods for helping students acquire such skills are being used on engineering courses. They range from lectures on management and communication to role-play and the simulation of team situations, see section 7.3. Yet even a sophisticated simulation can never be expected to model reality in a convincing manner since it must be limited, of necessity, to a short duration, up to a week perhaps. The case described in 13.4.6 provides a telling example. The depth of experience offered is similarly limited because of the difficulty of providing sufficient detail and enough options to make working and decision processes appear real [Lodbrock, 1992]. While it would be justifiable to present the development of the CIM course at Brunel as a response to the needs for a better preparation of students for industry it must be noted here that the course was a product of the particular circumstances present in the Department at a time when the first group of students on the new BME course reached their final year.

11.2 Creation of a CIM Course at Brunel University

Initially the CIM course had been planned as a standard series of lectures addressing individual issues in a descriptive manner. Whilst this would have been feasible, it faced the very considerable risk that it would end up being either a relatively shallow repetition of topics studied earlier, e.g., manufacturing simulation and machine tool programming, or a series of 'highlights' of subject areas normally reserved for advanced courses, such as the design of communication systems. In other words, the course would have run the risk of reflecting the pattern of many manufacturing courses as criticised in Shea's comment quoted in section 4.3.2.

While the course designer's experience in manufacturing and in working with computer hardware and software were substantial, his awareness and understanding of CIM and the concepts of strategic manufacturing were minimal although he was keen to acquire new skills and knowledge in this area. The situation was the same for the other people who were to become the CIM staff team. There was no technical infrastructure available in the Department or the University which would have allowed the creation of a laboratory oriented course of a classical design. However, a whole workshop area was available as were a number of small teaching type NC machine tools and robots. IBM had also just bestowed a substantial donation of brand new IBM PC computers of different capabilities on the Department - in those days an unbelievably generous gesture. The author proposed therefore, that the students should form a replica research and development company to be charged with producing a range of simple products using a new manufacturing facility with a state of the art control system built up as part of the course.

The whole was to be achieved through students working as a semi-autonomous work team, managed by a non-executive board of directors, that is, lecturers. Such teams have been described by Shea quoting the example of the TRW wire and cable plant: "Team members are encouraged to become qualified to operate every piece of equipment ... paid for the highest qualification achieved ... The team ... even makes decisions on manning and operation times to meet schedule requirements" [Shea, 1985]. The management structure was to be modelled on that of a real life small to medium sized enterprise (SME).

In order to inject real pressures into the learning process and to avoid the trap of 'playing' at simulation and gaming, the student team was charged, in every iteration, with achieving a demonstrable level of performance by an immovable deadline about eight months after the start of the project work. This issue of reality is discussed elsewhere (sections 11.4.5 and 13.4.5.2).

Whilst most of the present thesis is concerned with the use of the CIM Company approach to teaching on undergraduate courses, the Brunel Manufacturing Engineering and Special Engineering Programmes (BME and SEP), it must be noted that in two instances a similar approach was also used on a masters course (MSc in Advanced Manufacturing Systems, AMS), once with very good results, the other time with a rather poor outcome. This is discussed in the course evaluation, chapter 17, and in case study 13.3.

11.3 History and Development of the Course

The CIM course was first introduced in the academic session 1987/88. Although this was an experimental year[140)], a substantial amount of work was carried out on the implementation of a basic flexible manufacturing cell for the production of small machined parts, using desk-top machine-tools. During this period management concepts, assessment procedures and marking schemes were evaluated. It was shown that a large group project can provide a teaching tool which goes beyond simulation but which can still be managed successfully by students. The development of the course is charted in Table 17, in terms of the number of students participating (from BME, SEP and the MSc AMS course), the number of tasks undertaken, together with the number of skill-groups and members of academic staff involved.

In each of the academic sessions of the years 1988/89 and 1990/91 over forty students formed what became known as BCIM, the Brunel CIM company. It was decided to change the cell arrangement in order to be more in line with current industrial practice. The system became much more realistic and useable and progress over the two years was substantial, though mostly directed at hardware development. However, foundations were laid for a computer based business system for the CIM company, but this was not integrated with the system hardware.

In 1991/92 the business information systems and real time manufacturing control systems were linked up successfully for data interchange and feedback. Computers were now used routinely to carry out all the functions necessary in a manufacturing company, such as order taking, order processing, planning (including parts explosion and materials requirements), quality control, accounting, cash flow analysis and forecasting. Naturally, not all the functions worked equally well but a complete run-through could be demonstrated to the industrial visitors. An important step forward was the use of electronic mail for many of the internal communication needs involved in running the CIM course.

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140) this first iteration of the course was developed for the first ever final year group of BME students - this new programme had its first intake in the academic year 1985/86, as a result of the transformation of a Production Technology course. It was a 'first' in another sense too: students from BME and SEP were working together for the first time.

Acad. Year	BME	SEP	ALL	TKS	SKL	AMS	$S^{f)}$	Notes
1987/88	23	5	28	9	n.a.		3+1	BME compulsory
1988/89	32	14	46	$17^{a)}$		$6+0^{c)}$	3+1	BME compulsory
1989/90	30	8	38	11		$8+6^{c)}$	3	BME compulsory
1990/91	26	8	34	16	8	$8+6^{c)}$	3	BME compulsory
1991/92	15	12	$30^{b)}$	8	8		3+1	option for all
1992/93	18	5	$26^{b)}$	7	6	3	4+1	option for all
1993/94	$15^{d)}$	9	$24^{e)}$	9	4		3+1	option for all
1987-1994	159	61	$220^{b)}$	77	n.a.	34	n.a.	

Notes:
a) includes 4 MSc AMS tasks in 1988/89 and 5 MSc AMS tasks in 1990/91.
b) figure includes three (and six) Polish students.
c) number of part time plus number of full time students.
d) includes three students on BME with French following a slightly different programme.
e) includes three students undertaking a hypermedia project on the Brunel CIM Company.
f) fully committed + associated staff, there were always between four and five 'consultants'

Table 17 Course Composition, 1987-1994

The objective for 1992/93 was reliability and the integration of a new machine tool, specifically chosen to reflect the industrial relevance of the CIM work while still allowing cost effective operation. Substantial reliability gains were achieved through changing from a RIC multiport card to standard multiple RS232 interfaces for cell communication. Teams and their leaders were briefed to work towards consolidation rather than innovation. One unexpected outcome of this cementation process was the instigation of a student organised CIM conference for local industry, a successful endeavour which was repeated in 1993/94. Virtually all the communication within the course was based on electronic mail thereby allowing some students to work partly from home.

11.4 Defining Characteristics of the CIM Course

Returning to the issue of project work which was raised in section 8.1.1 there is a need to define how the approach chosen by the author differs from conventional project oriented work and how it develops skills and approaches which will satisfy the needs of the future manufacturing engineers and of their industrial employers. This aim will be addressed by looking at several areas of differentiation.

11.4.1 Physical Course Environment

The course environment is provided by Brunel's Advanced Manufacturing laboratory. Most of the capital intensive manufacturing equipment already exists in this laboratory, together with a large number of powerful personal computers[141)] as well as direct high capacity information links to the University network. The configuration of the system though and additional equipment are determined by the students. The work in the laboratory is, as far as possible, closely related to the environment which will be experienced by graduates in industry. This industrial orientation applies to machine tools, robots, computers, system and user software as it does to the standard expected of the design of the physical layout and

141) some of the original machines donated by IBM are still in use but most of the computer systems are of far more modern design and vintage!

protection of the facility. Operating systems of the computers include UNIX, DOS and OS2, with a number of different user interfaces. A representative example of the hardware and software used, together with a schematic diagram, is presented in section 14.8.

The facility developed as part of the course is intended to have all the characteristics of a prototype for the future subcontract machine shop, capable of competitive tendering via direct computer links. While this is a long term goal, the strategy teams, task teams set up with the specific objective of planning for the future, organise the CIM activities with this aim in mind.

11.4.2 Educational Context of the Course

As discussed in detail in chapter 9, the two undergraduate engineering programmes, for which the course in Computer Integrated Manufacturing was designed, have substantially the same underlying philosophy, that of educating broad-based generalist engineers with a strong foundation in management. Both programmes feature common strands throughout the four years of study, beyond their thin sandwich nature. In the case of BME it is that of Manufacturing Design and Practice and in the case of SEP that of Engineering Design. Both are engineering applications oriented strands including laboratory and project work as educational tools throughout the four years of the course. In addition, the course team expect that students have had responsibility for at least one major project during one of the industrial periods. Figure 28, based on the approach used by Hernaut [1993] to highlight the differences between German Fachhochschulen and Technical Universities, shows the respective biases pictorially.

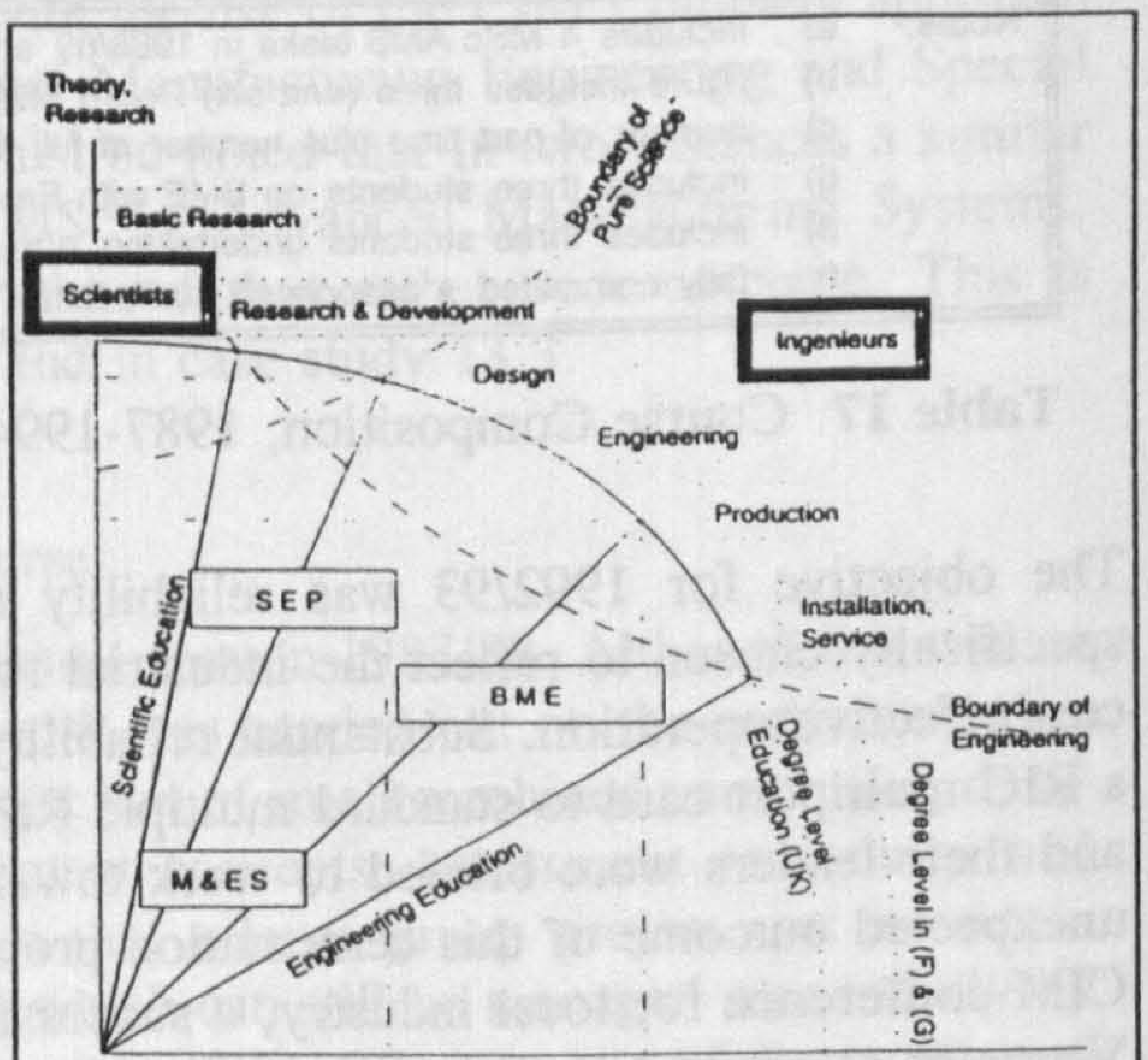

Figure 28 Differences in Educational Objectives between BME and SEP

The scope and design of the CIM course had to tie in with these strands and its approach had to help students with the integration, in their minds, of all the technical and scientific knowledge acquired over the first three years of the course, into a managerial and systems oriented framework. The aim was thus to help students add deep learning to the surface learning which would have been encouraged in previous years of the courses [EPC 1, 1989]. In line with other engineering courses in the UK, and the world over, M&ES staff tended to overteach their students, thereby forcing them to adopt a shallow approach to learning. Even before the development of the CIM course though, the problem had been recognised in the Department and the artefact study [Schmid, 1992(1)], 'tasks' course [Clark, 1985(2)] and design project [Ellis, 1985] were all reactions to this perceived need.

11.4.3 Differentiation by Objectives

The objectives of conventional project work on engineering courses have been discussed in 8.1.1 and are restated below:

- learn to use a structured approach to solve a problem,

- selection and study of relevant literature,
- research potential solutions,
- select and implement a solution to the problem,
- gather data to validate the approach used and
- reflect on the solution process,
- learn to communicate the results verbally and in writing.

Apart from the last objective all these can be carried out without reference to other people, excepting the project supervisor who acts as client, mentor and manager. In most cases the objectives can be satisfied in a purely sequential manner, with perhaps one iteration if a first solution fails to satisfy. It must be emphasised here that the Department of M&ES has not rejected conventional project work, indeed, its approach is described in section 9.6.

In contrast to these objectives of conventional individual project work the objectives of work using the CIM company approach all derive from a central:

Engineering Objective:

development and continuous improvement of a flexible manufacturing facility with all associated business and management systems to provide goods and services to industrial standards, using people and technology according to their respective strengths in an effective organisation.

This CATWOE[142)] type statement, according to Checkland [quoted from Ainger, 1994], leads to sets of objectives addressing different aspects of the problem:

11.4.3.1 Study related Objectives

→ to transfer knowledge on engineering and management methods and topics appropriate to AMEs,

→ to teach new engineering and management skills and to enhance existing skills,

→ to identify students' aptitudes and to create an awareness of their own capabilities,

→ to generate marks for the course which reflect all aspects of the students' performance,

→ to provide stimuli for staff to explore new areas of engineering and to foster a desire to undertake research in the area of Computer Integrated Manufacturing;

11.4.3.2 Student related Objectives[143)]

→ to allow students to broaden their scope and to find new foci,

→ to develop students' communication abilities and to let them experience both the role of a manager and that of a managed person,

→ to improve team working performance and individual and group decision making,

→ to allow students to experience the processes of assessment and appraisal both as active and as passive participants;

142) Customer(s), Actor(s), Transformation process, Weltanschauung (world-view), Owner(s), Environmental constraints [Checkland, 1981, 1990]. This model should be enhanced by the two systems elements Purpose and Soft issues (leading to the acronym COWPATES [Ainger, 1994]).

143) it may be useful to refer back to sections 9.3.1.1 and 9.3.2.1 at this point since the CIM course takes up some of the elements taught in year one of the courses.

11.4.3.3 Philosophy Issues:

→ the formation of engineers is an education process which must involve both the cognitive and affective domains of learning if it is to result in creative, responsible and socially aware designers and agents of change,

→ change is the key issue on the course since students will be faced with continuous change throughout their engineering and management careers,

→ students must be allowed substantial freedom and should be given responsibility for part of the learning process,

→ students are encouraged to think of themselves not in terms of 'learners' but 'doers',

→ staff and institutional commitment must match that expected from the students,

→ group and individual ownership of problems is a key element,

→ trust can exist between people even though they may need to make mutual judgements about performance;

11.4.3.4 Organisational Issues

→ the course is organised along the lines of a manufacturing company,

→ the company is managed using a relatively complex matrix structure,

→ the time commitment both in terms of scheduled hours and the additional input required from students is substantial, approx. eight hours per week for two terms and a half,

→ the course receives its own financial resources which are partly managed by the students,

→ the customer or client role and supervision are separated as far as possible, although conflicts exist as illustrated in section 14.3;

11.4.3.5 Methods and their Implementation

→ classical teaching methods, such as lectures, experimental sessions and seminars,

→ teamwork development exercises based on short simulations and play-acting,

→ multilevel supervision using one-to-one and small-group tutorials, monitoring of management meetings, task and skill reviews, as well as classical 'social work type' problem resolution with individuals and groups,

→ assessment by staff combined with a mutual assessment by the members of the company (including assessment of staff),

→ mutual appraisal of the student members with a view to long term planning of performance improvement,

→ creation of pressure and stress through the imposition of a clear deadline for project completion;

11.4.3.6 People related Issues

→ students, technicians, research staff, support staff and academic teachers form, as far as possible, an integrated team, the members of the company,

→ the minimum number of students for successful operation is around twelve, with at least two teaching staff and one technician. The approach has been demonstrated to function with between 10[144] and 52 students (see Table 17),

→ the group of students as a whole offers a wide range of knowledge from different branches of engineering although individuals may be narrowly focused,

→ prior to participating in the module students have completed at least two industrial placements of six months' duration, in general even three placements (issues deriving from this characteristic will be discussed in the evaluation of the course in section 17.1.1),

→ the staff involved in the running of the course form a multidisciplinary team including not only all kinds of engineers but also social scientists and people from industry[145],

→ the staff student ratio is nominally 1:10 but, in practice, it will vary between 1:5 and 1:30 depending on the phase of the project;

11.4.3.7 Technology and Resources

→ it is not essential that the most modern technology be available, neither in terms of computer hardware nor machine tools. However, it is important that the technology corresponds to industrial standards (refer to section 14.8 for an example arrangement),

→ computer software and management methods must correspond to modern industrial standards and, where possible, they should conform to state-of-the-art,

→ around-the-clock access to good networked computer facilities has proved essential,

→ rapid ordering of materials and provision of workshop services is important.

Not all the features mentioned above receive the same attention every year. However, they are all essential parts of the process and will appear each year in one form or another. The reader will have noticed though that little mention is made of content, as defined in section 5.5.2.1. Content, that is, knowledge in all its forms, is very important on the CIM course, however, its acquisition is seen as a natural outcome of the course process.

On the CIM course, substantial opportunities exist for the acquisition of explicit knowledge, either through lectures, tutorials or individual study from books and, lately, multimedia material. Areas covered include:

- Manufacturing Resource Planning (MRPII),
- Design and Layout of Manufacturing Systems,
- Modelling of Manufacturing Systems,
- Scheduling of Manufacturing Systems,
- Electronic Communications and their Protocols,
- Design and Layout of Electronic Circuits and Systems,
- Financial Management and Accounting Practice.

144) this number is not ideal and was accepted on the MSc AMS course because there was no other option. A minimum number of 20 seems appropriate since such a group size does require a management structure.

145) social scientists are involved in some of the team work and organisational teaching while engineers and managers from industry provide input both through lectures, the CIM conference and discussions with the students which occur on an informal basis.

Additionally there are possibilities for practising manual skills related to mechanical, electrical and electronic work.

11.4.4 Differentiation by Environment

As the summary in section 11.3 and the course description for 1992/93 in appendix M indicate, this course is closely modelled on an industrial situation, a claim made for many project based courses. In contrast to most classical undergraduate university projects, however, it has two 'real-life' deliverables:

→ the results of software and hardware developments must be to industry standard,

→ the system as a whole must be demonstrated to sponsors and local industry at least once a year and must operate with good reliability regardless of changes which may have been necessary.

Within these overall aims the targets for the teams and their managers are tough and immovable while the constraints are absolutely realistic:

→ limited financial resources,

→ reliance on teamwork with limited personnel resources,

→ management by members of a peer group (seniority no longer confers status in industry),

→ group members' recorded performance is affected by that of the team as a whole.

The combination of targets and constraints creates an atmosphere very different of that on an 'ordinary' course. The wish to succeed engenders commitment which manifests itself in the way in which students communicate with each other and with academic staff, the creativity invested and the emotional involvement in the process, as well as the number of hours worked on the project. The deliberate relinquishing of direct teacher control of the learning situation is partly responsible for the development of a positive environment.

Branton [paraphrased in Oborne, 1993] requires that people be given increased autonomy and personal control thus increasing certainty in working situations. Individuals should be put more in charge of the consequences of their actions to reduce stress levels. According to Branton, they will generally act in a responsible way although the autonomy accorded can cause mini-panics and stress when people begin to feel that they are no longer in full control of a situation. On the CIM course students are encouraged to turn to the course staff in such situations.

The course management expect that students work on their tasks for three to four hours per week, with a limit of about five hours. Most students work far more hours than this, though not on an 'as needed' basis but according to clear schedules set by task leaders. While some students work excessively long hours there appear to be virtually no 'freeloaders', a result perhaps of the fact that the mutual assessment system used on the course would penalise such behaviour.

11.4.5 Differentiation from Simulation and Gaming

Many tutors use simulations and games to get across particular points and experiences. It may be useful to refer to section 13.4.5.2 for a discussion of the aspects which make a situation appear to be a simulation or game rather than a real world oriented learning experience. Suffice it to say at this point that the differences are most significant in terms of the duration, the number of learning elements present and the significance of the goal, a deadline not represented by an internal review of the result and the process leading up to it, but by an open day. Engineers and managers of the students' sponsoring companies are invited for this, as described in sections 11.4.4 and 14.5.

By tailoring the CIM course as closely as possible to the real life situation of an industrial environment the tutors hoped to escape the "game trap". All the same there are major differences between working in industry and studying at university which could not be eliminated. These can be found in the areas of remuneration and hierarchical control[146]: people's ambition, when integrating themselves in a workplace, must be to maximise income, personal power and satisfaction while avoiding burn-out. Potential for conflict with other people exists principally in the first two domains although there may well be situations where striving for satisfaction can create hierarchical difficulties. It is difficult to create such situations at a university although the case described in 13.2.4 indicates that this could happen on the CIM course.

11.5 Team Size on the CIM Course

The CIM team as a whole, generally described as the CIM Company, numbers between 24 and 52 members, depending on the academic year under consideration, as illustrated in Table 17. As is also shown in the table this large group is always subdivided into a large number of task-teams working on relatively small but linked projects. These teams normally number between four and six students, that is, very nearly the ideal size as stated in section 3.4. There have been instances of larger teams, numbering up to twelve students, however, these were always divided into smaller sub-teams with clear objectives. Individual students are normally members of several groups. Skill groups within the matrix structure tend to be larger but they do not need to be as pro-active as task teams, since their main purpose is defined as the maintenance of technical and professional standards. The management group, comprising all the task and skill leaders, is large but rarely meets in full strength.

Excepting the first four years of the course where participation was compulsory for BME students, the course has been run as one of the fourth year options, open to BME and SEP[147] students. There are thus teams of people who know each other well and others where one or two people know the rest of the team only marginally at the start of the year. The observations of Hill [1994] and Holcombe [1993] concerning the effectiveness of different group sizes, depending on their objectives and composition, have largely been confirmed, see section 13.4.3. In general, groups beyond 6 members will need to operate with subgroups.

11.6 Matrix Management in the Brunel CIM Company

The writer and his colleagues adopted a traditional hierarchical management structure for the trial run of CIM which took place in 1987/88. The senior management team had the roles familiar from industrial concerns: finance, technical and personnel directors. A quote from the document describing the management structure may serve to illustrate some of the rather simplistic views existing at the time: "The first listed member in each group is the group's manager. The group members report to the manager. Managers report to the chief executives. The (three) chief executives report to the non-executive board." [CIM-DOC-88/89]. Each working group was rigidly limited to three members! After a visit to a major

146) although it would be possible to show that a well designed course can be successful even in these areas.

147) as indicated in the table SEP. students were admitted from the first year of the course's operation, initially purely as a trial because there was some doubt as to whether content and format were appropriate to the needs of the SEP group.

firm of scientific and engineering consultants at around that time the writer started to analyse the performance of the course and realised that many of the successes had only happened because of peer-level communication between the groups.

TASK / Student	1	2	3	4	5	6	7	8	9	10	11	M. Role
1m			MT								F	
2m								S			F	
3m			S	E					S			
4m									D			TL T9
5m		S				S						SL S
6m	S&H.						S					
7m				M				D	H			
8m			E									TL T7
9m									S	H		TL T6
10f	D										F	
11m		S				S						
12f												SC
13m					M	S					S	
14m												SC
15f					MT&S.		D	S				
16m						D					S	TL T2
17m			MT			S						SL D
18f				D		MT			F			
19m						H	E					SL H
20m			MT									TL T8
21m					C			S				SL MT
22m				S	H		S					
23m				M							D	TL T4
24m				H					F	D		
25m			M	MT								TL T5
26m						MT				S		SL C
27m	S											TL T11
28f			MT&D.								F	TL T10
29m	S						H					TL T3
30m					D						F	SL F
31f		D							S	S	F	
32m				S	MT							TL T1
33m		S					H					SL M
34m												SC
35m					E		H					SL E

Key to Skill Groups

- S Software Skills
- H Hardware Skills
- M Mechanical Skills
- E Electrical Skills
- F Finance Skills
- MT Machine Tool Skills
- C Craft Skills
- D Documenting Skills

Key to Task Groups

- T1 Communications OS/2, PS/2, RIC
- T2 Scheduling Software OS/2 and Safety System
- T3 Machining Subsystem Lathe, Mill
- T4 Materials Handling FANUC, PUMA Robot Control
- T5 Control of Coordinate Measuring
- T6 Developing CAD NC Postprocessors
- T7 Developing Multidrop Data Link
- T8 IDEF0 & Real Time Cell Modelling
- T9 Fourth Shift MRPII
- T10 Cell Scheduling
- T11 Financial Model

- f Female
- m Male

Table 18 Task and Skill Matrix for the Year 1990/91 and Key to Abbreviations

Table 18 shows a typical management and task matrix, based on the actual situation on the CIM course of the academic year 1990/91, including a key to the skill groups established for this year and the tasks which were agreed between course members and management. The large number of management roles necessary to operate a differentiated matrix structure is clearly demonstrated by column 'M.Role', for Management Role, in Table 18. Based on the experience of this year in particular, 1990/91, the number of skill groups was reduced to simplify the structure.

As an example of the internal organisation of a CIM team, a modified view of the course matrix for 1991/92 is depicted in Figure 29. It indicates the responsibility (R) of senior coordinators (SC) for skill group leaders (SL) and task leaders (TL) as well as the allocation of personnel to tasks. The job titles tended to vary slightly from year to year. For simplicity the titles have been standardised for the purpose of the dissertation.

As is evident from their title, task leaders are responsible for a clearly defined technical or organisational development task. Skill leaders are responsible for maintaining an 'unité de doctrine' in a specific domain, imposing documentation standards, defining quality levels and providing training as well as support to individual engineers and task leaders who have reached an impasse.

There is no line management overlay present in the CIM course although skill group leaders sometimes take on such a role, in particular in the domain of computer software development. Disciplinary interventions normally involve one of the senior coordinators and the people concerned, intervention of the staff responsible for CIM is avoided, as far as possible.

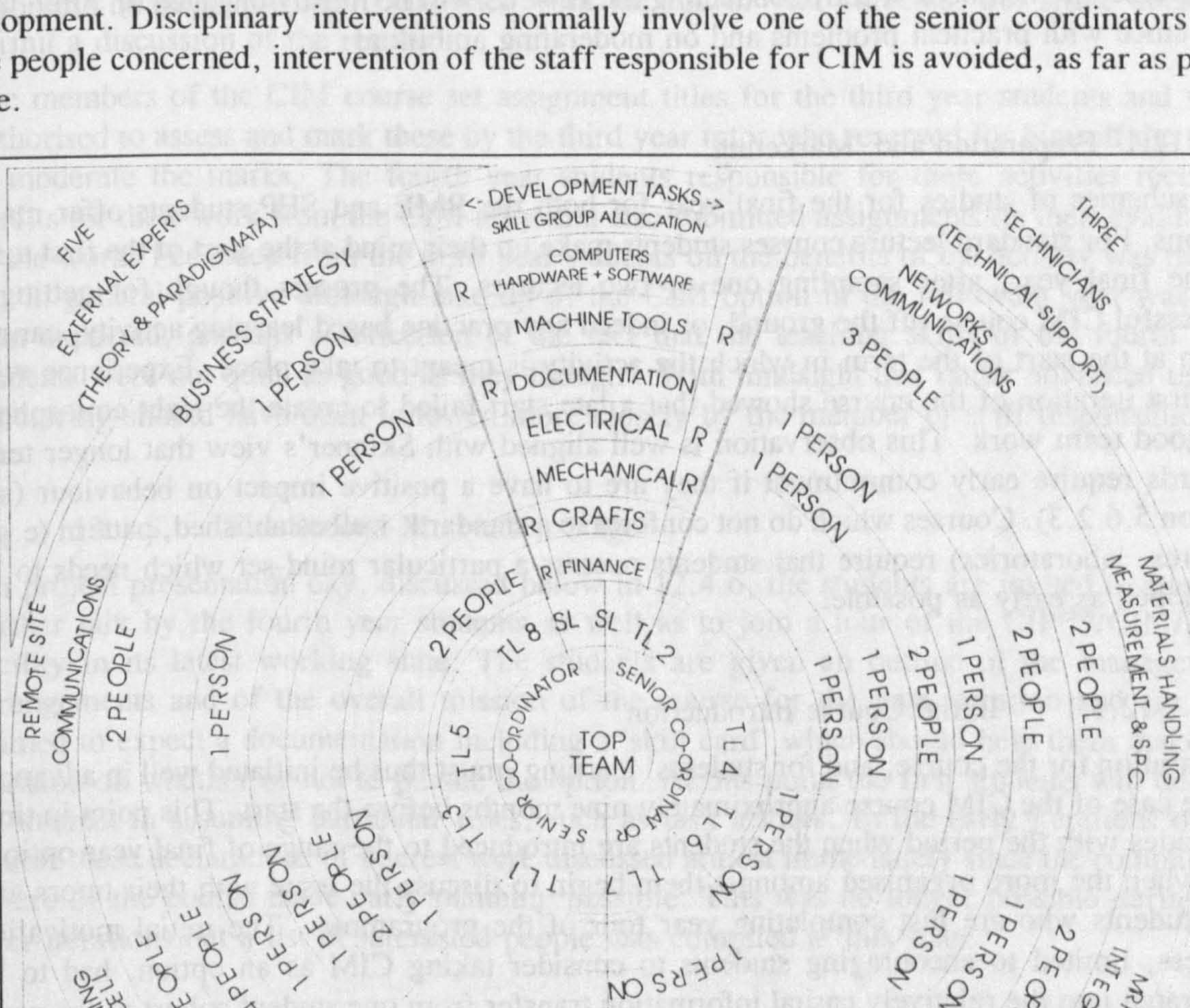

Figure 29 Course Matrix for 1991/92

12 Sequential Process of the CIM Course

The following description of the process of the course is based mostly on the status reached during the last iteration which the writer managed himself, in 1992/93. Reference will sometimes be made to the development stages of a particular activity, however, this should not be interpreted as indicating that any of the elements remained static over the years. Even within each year certain elements had to be changed to comply with Estes' and Harlow's theories described in section 5.6.3.1. An example for this need to adapt to students' progress is the change in the way in which task reviews are held: at the beginning of the course they are mostly concerned with motivation work and with structuring students' work. Later on in the course the members of staff conducting the reviews will be mostly engaged on providing assistance with practical problems and on moderating ambition!

12.1 Preparation and 'Marketing'

The schemes of studies for the final year for both the BME and SEP students offer many options. For standard lecture courses students make up their mind at the start of the first term of the final year, after sampling one or two lectures. The process though for getting a successful CIM course off the ground, or indeed any practice based learning activity, cannot begin at the start of the term in which the activity is meant to take place. Experience with the first iteration of the course showed that a late start failed to create the right atmosphere for good team work. This observation is well aligned with Skinner's view that longer term rewards require early commitment if they are to have a positive impact on behaviour (see section 5.6.2.3). Courses which do not conform to a standard, well established, pattern (e.g., lectures, laboratories) require that students possess a particular mind-set which needs to be developed as early as possible.

12.1.1 Initial Course Introduction

Preparation for the course, and for students' learning, must thus be initiated well in advance, in the case of the CIM course approximately nine months before the start. This point in time coincides with the period when the students are introduced to the range of final year options and when the more organised amongst them begin to discuss the issue with their tutors and the students who are just completing year four of the programmes. The initial motivation process, limited to encouraging students to consider taking CIM as an option, had to be integrated into the relatively casual information transfer from one student cohort to the next.

The presentation of the fourth year options by the graduands was therefore changed and today includes a well prepared presentation on the benefits and drawbacks of choosing the CIM option, the presentation having been included as a standard task for the members of BCIM. In a similar manner to most other course improvements, this was first mooted by a CIM team who felt that they had been prepared inadequately for the course and who were encouraged by the writer to put forward and implement a solution. Third year students are primed to expect a second input on 'tutorial day'[148)] which is arranged to coincide with the project presentation[149)] day of the final year students. Although this process worked well for several years some students were not satisfied:

148) when they return from their industrial placements for a day's visit to the University.

149) that is, the fixed and immoveable deadline of the CIM course!

12.1.2 An Experiment in Sophistication (Proctoring)

In 1992/93 the students on the CIM course decided to enhance the status of CIM as an option by running a number of introductory courses for the third year students. The writer managed to convince his colleagues that this was a worthwhile endeavour and a two laboratory slots were set aside for this exercise. The students used one of the slots to provide a walk-through type of introduction to the concepts of CIM and the implementation chosen by Brunel. The second slot was used to profile students on year three of the BME programme using several techniques, including Belbin's team role analysis. This was intended to provide information useful for selecting team leaders and assembling the task teams on the following CIM course. The same process was also completed with the fourth year students, but space does not permit a discussion of the results.

The members of the CIM course set assignment titles for the third year students and were authorised to assess and mark these by the third year tutor who reserved for himself the right to moderate the marks. The fourth year students responsible for these activities received credits for their work from the CIM team and also submitted assignments on their evaluation of the work. Feedback from the third year students on the benefits of the activity was mixed but in general positive although take up of the CIM option in the following year was less than expected, perhaps a reflection of the fact that the teaching skills of the fourth year students were not quite as good as they thought. With hindsight this rather advanced use of proctoring should have been followed more closely by the member of staff responsible.

12.1.3 The Second Motivation Stage

On project presentation day, discussed below in 12.4.6, the students are invited to attend a further talk by the fourth year students as well as to join a tour of the CIP[150)]/CIM/FMS facility in its latest working state. The students are given an outline of the management arrangements and of the overall mission of the course for the next iteration and are then primed to expect a documentation including a 'skill card' which should help them make the decision on whether or not to pursue the option. At this point the first students will declare an interest in assuming particular roles, such as task leaders. In the early iterations of the course these declarations of interest were discussed almost immediately since the compulsory nature of the course made early planning possible. This was no longer possible during the later iterations but a list of interested people was compiled at this stage.

12.1.4 Motivation by Paper and Feedback (CO)[151)]

The third stage of motivation occurs towards the end of the third industrial period, in late August, when all students on the BME and SEP programmes receive a substantial document, see appendix M for an example, outlining the background to the course, its history, methods of assessment, context and the objectives for the next session. Enclosed with this is a skill card as shown in appendix O which students are asked to return in a reply paid envelope as quickly as possible. The data returned is compiled into a skill table before the return of the students to the University, an example of which is shown in Table 19. This table gives an overview of the students' self assessment which can be used to determine working groups. The returns allow a classification of students into three levels of skill: level '1' indicates

150) Computer Integrated Production - a term preferred to CIM since it includes business systems as well as the more narrow automation of manufacture.

151) abbreviations in brackets behind subsection headings refer to Table 28 and Table 29 which are also provided as a fold-out table at the back of the dissertation.

CIM 1990/91, List of Members Skills (level 1: no skill, level 4: prepared to learn)

Student		Craft S.				Elect.				Mech.				M/c Tool				Account.				Software				Hardware				Doc.			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
BARKER Jamie	B		x			x					x				x				x			x				x					x		
BARNETT John	S												(S1)																				
BAYLEY David	B			x		x						x			x			x					x		x	x				x			
BHASIN Rajesh	B				x				x				x		x					x			x				x					x	
BRIGHT-THOMAS Paul	S			x			x		x	x				x			x		x				x		x		x		x		x		x
CLARK Neil	S		x				x				x				x			x			x		x	(x)	x	x			x			x	
COMYNS Ian	B	x						x		x				x				x						x				x		x			
CURZON Clive	S																																
DUDLEY Martin	B		x		x		x		x	x			x		x		x	x			x		x		x	x			x			x	x
EAGLES Tim	S																																
EDE Clifford	S		x					x	x	x			x	x			x	x						x	x		x		x		x		
FROST Mark	S																																
GIBBS Nicholas	B		x					x		x				x				x						x			x			x			
GRAVES Nicholas	S			x	x		x		x			x	x		x		x		x				x		x		x		x		x		x
HARDY Teresa	B		x																						x				x				x
HARRIS Louis	B		x		x	x					x				x			x						x	x		x		x		x		
HARRISON John	B			x	x	x				x					x		x	x					x		x	x			x		x		x
HEMINGTON Angela	B		x				x						x		x			x						x								x	
HESLOP Tim	B		x				x			x			x		x			x			x				x			x			x		
IFOULD Alan	B			x			x					x				x		x			x			x	x		x		x			(x)	
MICHAEL Suzy	B	x			x	x			x	x			x	x			x	x			x		x		x				x	x			x
MIDDLETON James	B		x				x		x		x				x			x			x		x		x			x			x		
POWER Richard	B			x			x					x				x		x			x	x				x					x		x
PRICE Antony	B			x		x						x				x			x		x		x			x					x		
PRICE Michael	B		x		x		x		x		x			x			x	x						x			x		x		x		x
PRICE Paul	S		x				x					x				x		x			x		x				x					x	
RENE Michael	B	x			x		x		x	x			x		x				x		x		x		x	x			x		x		
RICHARDSON Darren	B			x			x					x				x		x			x	x			x		x				x		
RICHMOND Damian	B		x						x	x					x				x				x						x		x		
SEED Rachel	B	x				x					x				(x)		x	x				x				x					x		x
SIBSON James	B		x			x				x			x		x		x	x					x		x			x	x	x			x
SIMPSON Jonathan	B		x		x	x			x	x				x					(x)		x		x		x	x					x		x
SPAUL Michelle	B		x			x				x					x				x				x				x					x	x
STILES Matthew	B	x					x				x				x				x		x			x				x			x		x
TYLER Jon	B		x				x		x		x			x			x	x					x					x			x		
WALLIS Paul	S											x				x																	
WOODROW Ian	S		x					(x)	x		x				x			x					x				x		x		x		

Table 19 Overview of Skill Card Returns for Academic Year 1990/91

'beginner' while level '3' indicates a near expert. A return of '4' shows that a student is willing to learn so as to get up to speed in a particular area. The cards also provide an indication as to which students are interested in taking on management roles. The return of completed cards is normally well above sixty percent of those sent out.

Further information about the individuals, in particular those interested in assuming a management role, is sought from many sources, including members of staff and other students. An example of very detailed feedback on most of the students of a year is given in appendix H. This information cannot be taken as fact without being corroborated from different sources, indeed the example just mentioned portrayed a lazy, good for nothing group which would never come up to a decent standard: the opposite was true, the group performed extremely well and developed into a real team.

A draft list of the tasks and skills expected to be necessary for the latest instantiation is provided to each student as part of the mail-out mentioned, allowing students to prepare themselves for the choice ahead. Lists of the tasks performed for each of the course years are provided in Table 21. The skill groups established over the years can be found in Table 20. Both tables can be found in section 12.2.4 while a typical matrix structure for one of the course iterations, Table 18, has already been discussed in section 11.6.

12.2 Opening and Running the Course

12.2.1 CIM Timetable (CO)

Normally, under the term system[152], two two hour slots were allocated to the course per week. There were additional slots for meetings and for working with technical support as

Schedule of Time Use for BME 4 and SEP 4 CIM Course — 20 March 19: Issue

Mondays 13.00 - 14.00 Tuesdays 11.00 - 13.00 Wednesdays 11.00 - 14.00 Thursdays 17.00 - 18.00

		Monday	Tuesday #		Wednesday			Thursday
Rooms		TA200	LC210/BLADE	LC062/BLADE	LC263/BLADE	LC263/BLADE	BLADE	BLADE
Wk	Begins	13.00-14.00	11.00-12.00	12.00-13.00	11.00-12.00	12.00-13.00	13.00-14.00	17.00-18.00
1	30.09	-------	-------	-------	S(FS)	S(FS)		
2	7.10	-------	GMO	GMO	CIM91 in Birmingham to 18.00			
3	14.10	-------	MDP	MDP	S(FS)	MDP	mdp	
4	21.10	MB0(*)	GMI	MDP	MDP	MDP	mdp	
5	28.10	MB1	L(PB)	MDP	MDP	MDP	mdp	mdp
6	4.11	MB2	System Test "As Is"		L(JMD)	L(JMD)	TR1	mdp
7	11.11	MB3	S(FS)PE/MDP	TR2/MDP	Visit to AM Graphics Slough/MDP			mdp
8	18.11	MB4	TR3+5/MDP	TR4+6/MDP	L(CH)	TR7/PPE	PPE	mdp
9	25.11	MB5	L(CH)/MDP	S(JE)/MDP	MDP	MDP	mdp	mdp
10	2.12	MB6	L(CH)/MDP	MDP	L(JMD)/MDP	S(PB)/MDP	mdp	mdp
11	9.12	MB7	S(JE)	S(JE)	L(HANCKE)	S(HANCKE)	mdp	mdp
HOLIDAY 13.12.91 - 6.1.92								
		7.1.1992: Hand In Date for Individual Interim Reports						
14	6.1	MB8	MDP	MDP	TR7+6/MDP	MDP	TR3/mdp	TR5/mdp
15	13.1	MB9	L(EVANS)	L(EVANS)	TR4/MDP	TR8SG/MDP	mdp	mdp
16	20.1	MB10	TR1+2	MDP	L(HINDE)/mdp	L(HINDE)/mdp	mdp	mdp
17	27.1	MB11	S(PB)/MDP	L(JA)/MDP	MDP	MDP	mdp	mdp
18	3.2	MB12	S(PB)/MDP	MDP	L(BW)/mdp	L(BW)/mdp	mdp	mdp
19	10.2	MB13	S(PB)/MDP	MDP	HCCIM(FS)	HCCIM(FS)	mdp	mdp
20	17.2	MB14	MDP	MDP	L	S	mdp	mdp
21	24.2	MB15	TR1+6/MDP	TR2/MDP	TR3+7/MDPP	TR4+5/MDP	mdp	mdp
22	2.3	MB16	MDP	MDP	L(COOLEY)	S(COOLEY)	mdp	mdp
23	9.3	MB17	First Combined Test		Second Combined Test		mdp	mdp
24	16.3	MB18	S(FS)PPE	PPE/MDP	PPE/MDP	MDP	mdp	mdp
25	23.3	MB19	S(FS)PE	PE	L(PARKINSON)	S(PARKINSON)	mdp	mdp
HOLIDAYS 27.3.92 - 27.4.92								
30	27.4	27.4.1992: Hand In Date for Group Development Reports 29.4.1992: Hand in Date for Assignments 01.5.1992: Hand in Date for Instruction Manuals + User Guides						
31	4.5	Group Presentations in Lab: Timetable + Format to be announced (Full Week)						
32	11.5	ASS	ASS	ASS	ASS	(Full Week)		
33	18.5	Exams						
34	25.5	Exams						
35	1.6	Preparation for Project Presentation Day						
36	8.6	Week of Project Presentation Day						

	Tasks	Skills
R Pollard	2,4,6,7	electrical, machine tools, craft, mechanical des.
S Cook	1,3,5	computing (hard & soft) documentation, project planning accounts

Notes and Abbreviations

ASS	Assessors' Meeting; L Lecture; S Seminar
PE	Performance Evaluation (PPE = Preparation of PE)
MDP	Manufacturing Design and Practice = Project Time
mdp	Laboratory - BLADE - and staff available for groups wishing to work
MBn	Management Board Meeting (including non-executive members)
TRn	Task Review for Group n; with PB/RJG or FS, always in parallel.
JA:	Jo Au L: Process Monitoring (General Overview, Sensors, Analysis Techniques)

Figure 30 Complete CIM Timetable for Academic Year 1991/92

shown in the sample timetable in Figure 30. Quite clearly, the timetable is rather complex, thereby indicating to the students that the course will be demanding. While members of staff often criticised that, in their opinion, the schedule was too complex, experience showed that students coped well with this manner of managing their time since it provided much variety and clear interim deadlines. The timetable was normally only established once the senior

152) at the time of writing the schedule for the CIM course under the semester system had not yet been defined

coordinators had been appointed so as to be able to use their inputs. At the beginning of the academic year lecturing slots would be left open since the programme had to be adapted to take account of student needs and availability of external experts.

The CIM timetable in its relative complexity and 'otherness' can be considered a discriminative stimulus (Skinner) for the course as described in section 5.6.2.2. This function could be observed in that the students would immediately draw attention to any mistakes in the timetable or would ask for integration of their own changes.

12.2.2 Project Engineering Course (PC)

A postgraduate student from Germany was given the task of organising a software project management course for the academic session of 1989/90. This was scheduled for two days of the first week of term, induction week, and was intended to be a compulsory activity for all the students expected to take CIM. The course was developed as a reaction to the acknowledged deficiency in students' ability to manage software development tasks. Although the postgraduate prepared the activity well it proved to be a failure since the members of the new CIM team had not yet been able to identify their future roles and since their background in software design was in general so limited that they could not cope with the relatively high level conceptual approach presented. The format of the course also did not allow any meaningful practical work.

Most of the students only attended the first day of the three day course and those who returned on the third day for the scheduled planning exercise were very disappointed since the task presented involved the planning of a huge software project, rather than the relatively contained tasks expected on the CIM course. A direct result of the failure of this approach was the provision of software workshops run by one of the staff members involved in CIM.

12.2.3 Introductory Session (CM)

The members of staff responsible for running the course use the first official time slot to give an overview of CIM, highlighting the most important sections of the documentation sent out to students in summer. This is generally just a quick refresher since the great majority of the students present in this first session, even those who are still undecided about joining the course, would have read the information in detail. The most important points of the introduction tend to be the presentation of the current state of the business and factory system, the assessment process including the mutual appraisal (described in substantial detail in section 15.4.2), the final deadline and its importance, and the matrix management structure. The presentation must answer some potential questions but also has to open up new areas for discussion.

At this point a very small number of students tend to decide to drop the course as a potential option since they realise that much individual commitment is required to create a successful experience for all. It is then possible to move on to determine the structure of the company, in some years a very delicate process because most students want to have a management role since they perceive this as useful for their curriculum vitae. In other years there is little competition for the roles but it has never been difficult to fill the posts available.

12.2.4 Electing Leaders and Assembling Groups (LE)

The number of skill groups and their objectives were different in each year of the course, although Table 20 bears clear evidence of consistency between the different iterations. More prominently though, as shown in Table 21, there was a great variety of engineering and management and business oriented tasks, changing from year to year, in line with the revisions to the overall focus of the project work. Depending on the focus of their team's work, task and skill group leaders need strong management or technical skills in particular areas.

Academic Year 1990/91	
S	Software Skills
H	Hardware Skills
M	Mechanical Skills
E	Electrical Skills
F	Finance Skills
MT	Machine Tool Skills
C	Craft Skills
D	Documentation Skills

Academic Year 1991/92	
C	Computer Hard & Soft
M	Mechanical Design Skills
E	Electrical Skills
A	Accounting and Finance
MT	Machine Tool Skills
CR	Craft Skills
D	Documentation Skills
P	Project Planning Skills

Academic Year 1992/93	
S1	Electrical Skills
S2	Computer and Network Skills
S3	Machine Tool Consultancy
S4	Documentation and Information Skills
S5	Quality and Inspection Systems
S6	Mechanical Design Skills

Academic Year 1993/94	
S1	Mechanical Skills
S2	Electrical Skills
S3	Computing Skills
S4	Documentation Skills

Table 20 Skill Groups on CIM

During the first three years of running the course the management teams were assembled and appointed before the start of the course, beginning with the two or three senior coordinators. These were chosen on the basis of the writer's and other staff's knowledge of students' capabilities. The students concerned were approached and thoroughly informed of the complex role they would have to take on, before being asked whether they would like to be appointed. The writer and the senior coordinators would then discuss the potential of the people interested in becoming task (and skill) leaders before drawing up the management structure together. This approach was no longer possible once CIM had become an option for all students, although the information was still gathered as described in section 12.1.4.

The process of electing leaders is described in some detail in section 14.6. Suffice it to mention here that it is important to conduct this activity in a highly professional manner while still trying to be informal. The election process had the secondary role of uniting all the members behind two or three people thus helping them become a large team, the CIM company. Once senior coordinators had been elected who were likely to be accepted as integrating figures rather than hard-nosed managers[153)], task and skill leaders could be appointed. This would happen on the basis of allocating management roles to unsuccessful but suitable candidates for the role of senior coordinators and others who had indicated an interest on their skill cards. Normally there was no further election process involved. As intimated above, in one or two instances people who were not given a management role decided to leave the course.

Distribution of the members over the different tasks and their allocation to skill groups takes place in the following time-slot so as to give the newly appointed managers a chance to review the existing documentation and to prepare a brief presentation of their task. This ensures that people join a group or team aware of the scope and scale of the work ahead.

153) two quotes from the writer's logbook may serve to illustrate the transition from chief-executives to senior coordinators. 1988-11-07: "executives are a service agency to everybody else, not authorities in their own right. Managers must help teams move forward." 1988-11-09: "Executives of the CIM company become (senior) coordinators, from confrontation to assistance." This redefinition of the role of managers happened as the result of a problem meeting early on during the first matrix-based CIM experiment where the use of meetings as tools for 'protecting one's back was strongly criticised and where one of the senior coordinators was attacked for ruling without knowledge...

Academic Year 1987/88 (Hierarchical Structure)

T1 Cell Supervisor using PC-Net
T2 Control and Operation of TRIAC Mill
T3 Control and Operation of EASITURN Lathe
T4 FANUC and Mitsubishi Robots
T5 Co-ordination and Design of Grippers
T6 Inspection Systems
T7 Safety Systems and Shut-Down
T8 Transport Systems
T9 Transfer Devices

Academic Year 1988/89 (Matrix Structure)

Undergraduate Tasks

T1 IBM PC Net Communication and Operations
T2 Scheduling and Cell & Task Management
T3 Software for Controlling the Mill
T4 Software for Controlling the Lathe
T5 FANUC Robot Integration and Programming
T6 Design of a SCARA Robot Gripper
T7 Input Output Conveyor (PLC Controlled)
T8 Inspection using Laser Micrometer Gauge and Robot
T9 Safety System Development and Implementation
T10 Hardware and Software for Automatic Transport
T11 System Modelling and Simulation using PC Model and Hokus
T12 Subcontractor Integration using Electronic Links
T13 Study of the Manufacturing Automation Protocol and its implications

Postgraduate Tasks (FMS Cell Context)

T16 Adaptation of an X-Y Robot
T17 Compliance for Robot Grippers
T18 Design and Production of a Gripper Changer
T19 Service and Emergency Shutdown Systems

Academic Year 1989/90

Split into Technology and Business Organisation Tasks

Undergraduate Tasks

A1 RIC and OS/2 Network System & Communications
A2 Machine Tool Hardware and Control (Mill)
A3 Machine Tool Software and Control (Lathe)
A4 Robot Control and Operation
A5 Materials Handling using Linear Transfer Devices
B1 Factory Management Systems (CAPP, MRP etc)
B2 Project Management Systems
B3 Inspection, Quality Manual and Quality Management
B4 Cell Modelling and Expert Systems
B5 Accounting, Financial and Investment Evaluation
B6 Design of an Interface for a Human Operator

Postgraduate Tasks: Rimmel Compact Assembly

T1 Design of the Materials Handling and Assembly System
T2 Design and Integration of Computer Control

Academic Year 1990/91

T1 Communications Design with OS/2 on PS/2 and RIC
T2 Scheduling Software OS/2 and Safety System

Academic Year 1990/91 (contd.)

T3 Machining Subsystem (Denford Lathe and Mill)
T4 Materials Handling, FANUC, PUMA Robot Control
T5 Control of Co-ordinate Measuring Machine
T6 Development of NC Postprocessors for CAD
T7 Development of Multidrop Link for Data Handling
T8 IDEF0 and Real Time Advanced Modelling of Cell
T9 Fourth Shift Implementation (MRP)
T10 Cell Scheduling and SPC
T11 Financial Modelling of the CIM Company

Postgraduate Full Time: Development of a Disk Drive Assembly System

T1 Control Systems and Electronics
T2 Mechanical Systems and Screw Insertion

Postgraduate Part Time: Improve Quality and Speed of Rimmel Compact Assembly

T1 Control System for Enhanced Speed
T2 Presentation and Assembly Improvement
T3 Vision System and Sensing

Academic Year 1991/92

T1 Communications System using OS/2 and RIC
T2 Design and Improvement of the Cell Controller
T3 Machining Subcell (TRAUB Lathe, Mill and Robot)
T4 Materials Handling Subcell (Track, Conveyors, Robot)
T5 Multidrop Link (Fishnet)
T6 Fourth Shift and ACiT integration (MRP & Control)
T7 Link to Outside Sub Contract Suppliers
T8 Business Strategy Analysis and Development

Academic Year 1992/93

T1 OS/2 Operating and Communication Systems
T2 OS/2 Part Movement Scheduling System
T3 Machining Subcell
T4 Materials Handling Sub-Cell
T5 Fishnet Communication System
T6 ACiT and Fourth Shift Implementation
T7 Business Strategy and CIM Conference

Academic Year 1993/94

T1 DOS Based Generic Scheduler and DDCMP
T2 Mastercam, CAD/CAM Database & Ethernet Link
T3 Improvement of Machining Subsystem, as recommended by last year's group
T4 Improvement of the Materials Handling and Inspection Subsystem, Sensing of Parts
T5 Implementation of SPC Control Link and Softw.
T6 Improvement of the Fourth Shift-ACiT link to include Feedback of Information, Cost Accounting System
T7 Organisation of a CIM Conference
T8 Design and Implementation of Quality System, ISO 9000 approval for BCIM
T9 Business System and Implementation of EDI (link to Tradanet and marketable Products)

Table 21 Tasks for the CIM Course Iterations from 1987 to 1994

12.2.5 Meetings with Senior Coordinators (ST)

Initially, meetings with the executives, directors or senior coordinators happened on an 'as needed' basis and normally involved all the members of staff associated with the CIM course. This approach was soon discovered to be both wasteful and defective. The overarching pattern of the CIM course has to be repeated from week to week although individual activities, such as task reviews, may recur on a longer cycle. Already in 1989/90 weekly meetings were instituted between the senior coordinators and the writer, that is, the lecturer in charge of the whole course. A regular one hour slot was set aside to discuss financial matters, learning needs, assessment procedures and any difficulties which had arisen.

The arrangement not only allowed the writer to maintain a good watch on the pulse of the course but it also permitted him to provide support and supervision (in the sense discussed in 14.4) for the people who were providing the same for all the task and skill leaders and who had to sustain a high level of motivation amongst all the CIM members. An example of the importance of this role is given in the case study in 13.2.8. As a general observation there was at least one serious problem a year in either the relationship of the senior coordinators with the rest of the CIM team or with the writer. In all cases these could be resolved through discussion and the redistribution of work loads. Sessions could be devoted to anything, from financial reviews via detailed problem analysis to assertiveness training.

12.2.6 Task Leaders' Meetings (MC)

The senior coordinators, together with the task leaders, determined by themselves the objectives, frequency, and duration of meetings involving all or a number of task leaders. The main purposes of these meetings were the co-ordination between tasks and the allocation of resources[154)], mostly with regard to finance and computer hardware. In some iterations the meetings were held on a weekly basis, with agendas and minutes, in others they were held infrequently. They were always held outside the timetabled CIM slots thought thus highlighting the additional commitment of task and, sometimes, skill leaders. The approach tended to be a reflection of the senior coordinators' personality and working style.

Although the writer was asked to attend task leaders' meetings during the 1988/89 CIM course this was soon discontinued since he adopted a hands-off policy, leaving the management to the senior coordinators. From then on the member of staff responsible for CIM would only be asked to participate in such a meeting if there was a serious motivation problem or if decisions had to be taken whose impact would go beyond the current year of the course. The resolving of conflicts was never attempted in the leaders' meetings.

12.3 Maintaining the Momentum of the Course

As stated elsewhere the CIM course requires a great deal of commitment from both the students and the staff involved. It is not adequate to remind all concerned on a regular basis of the single long term goal, the development of a working integrated system. Such an approach would lead, very quickly, to lack of interest and no progress. Beyond the actual practical tasks a whole range of other elements ensure that people's attention and momentum is maintained.

12.3.1 Practical Work (PW)

Perhaps the most important elements for ensuring continued interest and involvement are the practical tasks allocated to teams and individuals. Apart from a few highly conceptual activ-

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154) originally it had been expected that the matrix structure would allow the transfer of people from one task to another as and when the need arose. However, this happened only once or twice, because of incompatibility, since people tended to get used to a group and would adapt their individual tasks to the pressures.

ities, most tasks have a substantial practical content ranging from the production of computer network cables via the design and installation of an electrical safety system to the implementation of software 'links' between large software systems, e.g., between an MRP and a shop-floor scheduling package. Some tasks are ideally suited to subdivision into atoms which can then be allocated to individuals while others require the joint involvement of most or all members of a task team. The latter is often the situation for software, data management and data communications tasks.

In either case it is the task leader who must ensure that intermediate goals or milestones are drawn up and that they are observed by the team. For two of the iterations this objective was partly satisfied by using a project management tool, however, this initiative proved not very successful since it relied on leaders updating the management data base frequently. Unfortunately, this proved impossible and the creation of a special project management task was abandoned after one attempt.

It is essential that a course of this nature offers three types of tasks: tangible, touchable hardware tasks which are ideal for engineers who were disappointed in the amount of real (that is, practical) engineering offered on the two programmes; systems and software oriented tasks which do not require a great deal of synthesis work but which offer much analysis and writing and testing; conceptual tasks which stretch students who want to work at the forefront of technology and organisational developments.

12.3.2 Task Reviews (TR, FR)

The general principles of task reviews are considered in section 14.5; here the writer is just concerned with their role in the sequence of running the course. Task reviews normally take place once a month, with an allocation of thirty minutes for each task, and are of a standard format: during the first fifteen minutes the task leader introduces the team to the staff members involved and gives a brief overview of work to date, current tasks and plans for the future. It is open to the leaders whether they make a formal presentation, hand out a summary paper or talk the reviewers through the work of the group. Each member is then given a brief opportunity to comment on their contribution or to raise problems and ask for advice.

The second half is taken up by a discussion during which the reviewers may praise or criticise the team, make suggestions or respond to questions. Although generally very informal, the reviews have a strong motivating influence since they allow the members of staff to monitor deadlines and to re-direct teams who have deviated too much from the plan. The final task review also serves as a formal assessment element.

12.3.3 External Links (EM, PW)

CIM is not simply about communications and integration within a company but also about closer relationships with customers and suppliers. Students tend to be aware of the need for better links as a result of courses, their industrial training and the marketing project which they undertake during their last placement. In 1988/89 one team of CIM members investigated the subject of subcontractor integration by talking to a number of companies in the immediate area of the University [Agarwal, 1990]. This was the first step towards opening up of BCIM to the outside world. Some collaborative work was undertaken with Cranfield Institute of Technology in 1989/90 but only in 1990/91 saw first attempts at external links by MODEM, with Staffordshire University where a member of the CIM team had moved.

In 1991/92 the question of communication was addressed professionally and led to the development of a stand-alone software package which could be used to up- and download any files between a computer in the University and a PC elsewhere. This was developed further as a product and was tested on Brunel University's MSc AMS course which is run in a Distance Learning format. In 1993/94 the task was expanded further to encompass an investigation of a link to one of the major Electronic Data Interchange (EDI) networks, e.g., that developed by GE of the USA.

12.3.4 Communications: Course Meetings, Newsletters, Hi-lites Meetings (EM, GM, NL)

Communications meetings for the whole course were arranged at least twice each term for all iterations of the course. These would normally include a brief presentation from the staff member responsible. He would introduce a topic, for example, assessment, the CIM conference or company strategy. The theme would then be taken up by either the senior coordinators or a designated member of the company. A discussion would follow to state new objectives and define new responsibilities. Such meetings tended to be very effective in creating commitment.

From the 1988/89 group onwards the CIM teams produced newsletters, examples of which can be found in appendix K. Although they fulfilled an important communications role there was also much ribaldry and time wasting involved. This was not a serious problem while the course was very large, but it became a serious drawback once the numbers started to stabilise around 25 and once the tasks started to be very diverse, that is, ranging from the very hardware oriented machine tool operation to business strategy, teaching and conference organisation.

Once the computing facilities at the University were sufficiently improved the writer pressed the students to adopt e-mail for most internal communication. The argument put forward for this move were the benefits to be gained from an automatic 'history trail' being created and from the possibility of moving away from the need for synchronicity in academic work. The transition from zero use to virtually 100% adoption took about three years and was assisted greatly by the installation of terminals dedicated to use by the students on the CIM course (this also had a strong motivational effect). Confer EPC 1 [1989] for a discussion of the wider benefits of computer-conferencing.

In 1992/93 the senior coordinators launched a new approach, hi-lites, which took place every Friday during an official CIM slot and which were strictly limited to a maximum of 30 minutes. For all intents and purposes they were compulsory and totally removed the need for newsletters. Each meeting was chaired by one of the task leaders who would collect an agenda and lead the whole session. During the session each leader was asked to present progress with the task, to highlight interface problems and to put forward his or her next milestones[155)]. The reason for moving to such a new communications approach were founded on the senior coordinators' realisation that the production of newsletters would tie up too much of their time and that they should employ their energy to develop the mutual appraisal procedure so as to create a marketable product[156)].

155) another little tool introduced by senior coordinators in a previous year, aimed at breaking down large overall targets into small manageable chunks.

156) as in other CIM areas, e.g., the development of an investment appraisal process, it was felt that the product of several years' work could be translated into a marketable product - the team came close to realising this ambition.

The hi-lites approach was a great success in re-creating commitment each week and in ensuring that every member on CIM was fully aware of developments in every area. When the assessor from the Partnership Awards visited the Department he was invited to participate in a hi-lites session to get a flavour of the course - he was favourably impressed as evidenced in the acknowledgments, section II of this dissertation.

12.3.5 Lectures, Tutorials and Workshops (CA, CB, CI, IV, LG, LS, OT, ST, WE)

Every year, the course included a number of more or less standard lectures by visiting academics and industrialists. One of the key lectures was always that by Prof. Cooley where he encouraged students to move away from a technology centred view-point and to think of the needs of people (cf. Thorndike's views on learning in section 5.6.2.1). One of the most important aspects of this lecture was the encouragement of students' own initiative in setting up informal networks and working groups (see section 10.4.4). There were technically oriented lectures from IBM staff and management tutorials by outside staff (e.g., the SCANCO activity, see section 14.2). In-house lectures concerned topics from discrete event control, simulation and robot control to practical electronics and communications. Tutorials were arranged at very short notice to deal with particular needs, such as strategy formulation, investment or quality control. These would be run either by qualified members of staff from within the Department or outside experts.

At the beginning of each course one of the members of staff on the CIM team runs a number of computer workshops to familiarise students with the C^{++}-language and with the concepts of multitasking and multiple serial communications. Student experts, e.g., those sponsored by IBM, would supplement these by workshops on specific topics such as the effective use of file stores and electronic mail. It was the responsibility of the writer to co-ordinate these activities. Also organised, by students and by staff, were industrial visits and attendance at conferences and exhibitions.

12.3.6 Mutual Appraisal Trial (MA)

Since the course was intended to be a preparation for positions of responsibility, and since its design made it imperative to be able to assess work which happened outside the field of view of the lecturers, it was decided right at the beginning to allow students to award a proportion of the marks themselves (see Table 22). Already in the first year the personnel director[157)] drew up a staff appraisal scheme based on those of IBM and ICL. This system was refined successively over the years and in its final form includes guidelines, forms, pre-arranged spreadsheets and several documentations for the senior coordinators responsible for administering the scheme. As described in section 15.4.5.1, the appraisal is carried out in two stages, the first phase being both a test for the system and a rehearsal during which appraiser and appraisee can get used to the formalities and the interview structure. It also offers an opportunity to refine the objectives set for each individual involved in the process.

Shortly before the Christmas break the member of staff responsible for CIM discusses the concept of appraisal in industry during a short group meeting which is normally followed by a training session for appraisers, run by the senior coordinator(s). A complete appraisal process is then conducted to give an initial feedback to the people appraised - which tend to include the members of staff. The marks are not used in the final assessment of the course.

157) an early version of a senior coordinator...

12.3.7 Interim Report (IR)

One of the most powerful tools in monitoring the course is the snapshot provided by the interim report produced by each member of CIM over the Christmas vacation, according to a clear brief which is part of the CIM documentation. These are individual pieces of work whose length is limited to three pages and where the emphasis is placed on creating a document which would allow a senior manager to gauge the individual's contribution to the overall programme of work and which also reflects the understanding of the task gained by its author. Whenever possible, the writer marked these pieces of work before the end of January to give feedback to the CIM members as early as possible. Appendix R shows a typical summary of this assessment, for 1992/93, and indicates that the exercise is also undertaken to gain an overview of the status of the project work.

12.3.8 CIM Debate (DE)

At the instigation of a CIM member who had undertaken a survey of other Universities offering CIM or related courses, a debate was arranged in spring 1993 with the students on the Cambridge MEng course which features an element of practical CIM work (briefly outlined in 8.3). The writer agreed to establish contact but the CIM member undertook to organise the whole event. The debate took place at Cambridge, on a free afternoon, with about 15 participants from each institution. The Cambridge side argued for the technology solution to the problems of manufacturing, while the Brunel side argued for the human centred approaches. The members of staff involved had to argue the case of the opposition!

Predictably, given the bias towards human centred systems, the Brunel side won the argument with a large majority in a show of hands. Although this was an achievement, the most important lessons were in the quality of the debate, the interest shown by all people present and the level of learning which had already taken place. As a teaching vehicle, rather than the more usual 'debating society' approach, the method could well be adopted on a permanent basis.

12.3.9 Assignments (EW)

CIM members are given a large number of assignment options set by members of staff in the Department, with the aim of offering students a more conventional way of gaining marks, independent of team effort and the associated risk. They cover all aspects of People Organisation and Technology including very specialised topics such as the use of Petri nets for the control of manufacturing systems. They are generally supported by substantial literature references and are marked by the setters although the manager of the course moderates all these marks. This is necessary because the marks of the essays carry an aggregate weight which is larger than or similar to that of the students' mutual assessment (see Table 22). An experiment was carried out in collaboration with the University of Vienna in 1993/94 to test a hypothesis about differences in information structuring between students of different educational backgrounds. Students were given the option of doing just one assignment instead of two, provided they used hypertext for the essay - a clear benefit of the open nature of the CIM approach. It had been expected that British students would be better than their Austrian peers at structuring "unconstrained" information and at seeking the links between different areas. However, differences between individuals proved to be more significant than those between students from different cultures. The comparative study is to be resumed at a later date.

12.3.10 CIM Conference (CC)

The strategy group of the Brunel CIM (BCIM) Company 1992/93 developed the concept of a CIM conference which had been proposed in the previous year's strategic plan. This was seen as an opportunity for learning, by assembling expert lecturers at Brunel, a way of enhancing the profile of Brunel and BCIM and a potential source of income. The whole project was managed by the students and proved a substantial success with 25 attenders from industry and an extended student group. After a keynote lecture by one of Brunel's associate professors three parallel sessions could be run, all chaired by a student. The exercise was repeated the following year with a similar degree of success. While there is an inherent financial risk in such an activity it is very satisfactory for the people involved and it allows the inclusion of a number of high calibre contributions in a very short space of time. A conference programme can be found in appendix P.

12.3.11 "Teaching the Poles" (OT)

In 1992/93 BCIM faced substantial financial difficulties, due to the acquisition of a new lathe where a shortfall of about £1500, caused by the events of "Black Friday" had to be made up by generating earnings. A happy co-incidence brought a contract from the British Council to provide three weeks' training in modern manufacturing techniques for two Polish university lecturers. The writer set up one week of teaching by Brunel staff, one week of industrial visits and asked BCIM to quote for a week's teaching and training by the members of CIM. By that stage the students had completed six months of the CIM course on top of their eighteen months of industrial training and could be viewed as experts in modern manufacturing. The senior coordinators developed a programme in cooperation with the task leaders and quoted for the job.

The two visitors were highly impressed with the quality of the teaching in all phases of their training. They felt that the approach used by the students, following a product through all the business and manufacturing processes, was very appropriate and gave them a good understanding of the problems involved in integrating the operations necessary in a modern factory. They wrote a glowing report about the experience - even though they had been taught for over fifty percent of the time by undergraduates.

12.4 Managing the Final Stages of a Course

Most of the practical work involved in the course is completed by the end of spring term (Easter holidays) so that the holiday period and one week of the summer term can be allocated to preparing for exams, compiling the final reports and setting up the mutual appraisal process.

12.4.1 Final Reports and Handover (HO, GR)

In the writer's opinion one of the most vital aspects of the work of any engineer worth their salt is that of documentation. For reasons of product liability, patent and copyright litigation and handover of projects, all activities taking place on an individual or team basis must be documented in some form. Students are encouraged to maintain good logbooks right at the beginning of the two programmes (see section 9.2.1) and are reminded of this important duty at the start of the CIM course. Between 80 and 90% of the members of CIM follow the advice and maintain separate bound logbooks for the CIM course. Together with texts written for interim reports and presentations they serve as the basis for the final reports which will serve as the hand-over documentation for the subsequent year's CIM team. The reports evolved out of compilations of notes into polished and highly structured documentations.

> Initially all the work of a team would be assembled into a single report but over several iterations a standard pattern emerged, with the minimum set of reports for a team consisting of an Executive Summary (3-4 pages), a Technical Report (containing the detailed results, listings of software written and any appendices) and a User Guide. The User Guide often appeared in several parts so as to present the information needed to operate a particular piece of equipment, software module or management tool in a coherent manner. Between 800 and 1000 pages of reports were produced each year.

Looking through sets of old reports, it is possible to follow the increasing sophistication possible because of more and more powerful text processing and graphics software. Both the drive for more accuracy and the improved tools led to reports which by the sixth or seventh iteration were very close to perfection. Naturally, there were still mistakes and glossy presentations of sometimes dubious work but it became possible to work from the documentation which was made available to the new teams from the beginning, together with master copies of all the software developed. From 1991/92 all the reports were made available to a CIM exclusive user group on the University network thereby reducing the need for several copies of the documents and the access problems experienced when, as a result of a change of the matrix structure, two or more teams required the results for a particular task. This too was a development originated by the students.

The need for a hand-over process was another important tool since it led to competition between years: each new BCIM group criticised their predecessors for "lying" in their reports and promised to do much better. Lies they were not, just inaccuracies. These resulted, in general, from having ambitious goals for the last two or three weeks before presentation day. An explanation for the motivational effect of taking on an unsolved problem is given in section 5.6.3.3.

12.4.2 Final Task Reviews (FR)

The process of the final task reviews is described in 14.5. From the students' point of view this is one of the most important events since a one hour session determines a substantial proportion of the marks available, as shown in Table 22. Although the reviews take place at the end of the teaching and assessment period, it is still very important that the members of staff involved behave in a professional manner, showing interest and displaying their knowledge. This is necessary for two reasons, namely, to create motivation for the preparation of "project presentation day" (see section 12.4.6) and to assure reasonable feedback during the staff appraisal which is part of the mutual appraisal process.

12.4.3 Mutual Appraisal and Counselling (MA, CS)

The mutual appraisal takes place concurrently with or just after the final task reviews. It involves a complex process where assessment in most years is bidirectional, that is, senior coordinators assess task leaders and skill leaders but are, in turn, assessed by this group of CIM members. The same applies between the non-executive board members and the senior coordinators and between the leaders and CIM engineers. The process is supported by a documentation and relies on individuals well prepared for attending the interview with their manager. The forms are prepared well in advance and should already contain individuals' objectives as well as assessment categories and sample statements about performance.

Element Year	1988/89	1989/90	1990/91	1991/92	1992/93	1993/94
Interim Report	100	75	75	75	75	75
Assignment 1	100	100	100	75	75	100
Assignment 2	100	100	100	75[d]	75[d]	100
Final Report (1)	150	175	175	175	175	40
Final Report (2)[a]						40
Skill Report[b]					[e]	25
Final Task Rev. (1)	125	125	125	125	125	40
Final Task Rev. (2)[a]						40
Mutual Assessment	125	150	150	200	200	265[c]
Scaling Factor	100/700	100/725	100/725	100/725	100/725	100/725

Notes:
a) from 1988/89 to 1991/92 marks for final reports and final task reviews were attributed in a fixed ratio to first, second etc tasks. In 1992/93 this happened on the basis of the percentage of time contributed to each task, as agreed between individuals and the leaders of the teams to which they belonged. In 1993/94 the weighting was not differentiated as a function of time spent on a task.
b) mark included as an additional task report mark for the first time in 1992/93.
c) for the first time the member of staff responsible for the CIM course had to scale the marks for the CIM course: new = old x 0.9613 - 8.22. Range of marks had been too narrow and average too high.
d) equal zero for the one student who took CIM as a single option.
e) weighted like a task mark according to percentage time.

Table 22 Coefficients for the Components of the Overall Mark

After the mutual appraisal has been completed, the senior coordinators compile marks and, where necessary, moderate the outcome[158]. By this stage they have also set up the plan for the counselling interviews. These involve the manager and each member of her or his team on their own, in the presence of an independent observer. In this session the manager attempts to draw a picture of the performance of the individual and tries to show in which ways attitude, personal and professional qualities hindered or advanced the person's achievements. This is a difficult process which also takes place between the members of staff and the senior coordinators. The counselling session though is not restricted to a one way communication of praise or damnation but often gives the manager feedback on his or her performance. The counselling process is also discussed in section 15.4.6, albeit only briefly.

The mutual appraisal should thus not only result in marks[159] but also in a development plan for the appraisee. Reference to the industrial examples and instinct resulted in a separation of the rewards based aspect of appraisal (assessment against objectives) and the developmental aspect of appraisal, counselling.

12.4.4 Marking CIM (TE)

The process involved in assessing the members of the CIM team and the detailed method used for the mutual appraisal are described in chapter 15. Suffice it to say here that the

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158) members of BCIM are given the marks which result from this process and can appeal informally against the assessment. This tended to happen in one or two cases per year and was always resolved in meetings between the task or skill leader concerned, the appraisee and a senior coordinator.

159) an approach whose suitability had to be criticised in retrospect, see section 15.4.1.

process is complex and that it leads to a spreadsheet with around 1000 marks for a group of 25 students. The large number of marks is a consequence of the relatively complex assessment scheme, based on Table 22. The allocation of marks to particular elements of the assessment process is discussed in group meetings of all the students and staff involved in the course. The changes in importance of individual elements in the marking process between instances of the course are the consequences of these discussions.

The spreadsheet is used to produce an aggregate mark which goes forward into the calculation of the degree result. While the average of the marks is normally about 10 points above the 'accepted' average of a university course, 55%, the results were not moderated during the years in which the writer was responsible for CIM since he argued successfully that the high marks were fair compensation for above average commitment.

12.4.5 CIM Video and Hypertext (CP)

In preparing for project presentation day the members of the team each year try to identify new ways of putting across the message of Computers in Manufacturing. Twice they produced professional standard videos, once a hypertext presentation running on a number of Apple computers[160)] and another time a comprehensive brochure [BCIM, 1991]. The following year it was the turn of a colour publicity leaflet for CIM aimed at the industrial market for potential student projects. It was an attempt to go beyond the products which had already been produced for companies closely involved with the CIM work.

12.4.6 Project Presentation Day (TD)

Project presentation day is the final, immovable deadline whose existence distinguishes the CIM approach from the classical experiential learning method, from gaming and simulation. It is an event organised by a team of students aimed at promoting themselves, Brunel and the two programmes, BME and SEP. The day is designed for industrial visitors from sponsoring companies and involves lectures by students, an exhibition of the results of final year projects and a CIM show. In every year this has been the key attraction of the day, even when there were problems with the technical systems. Although this may surprise, failures of the system tended to enhance the performance of the teams since they always managed to impress with their awareness of the reasons for such problems. It is normal practice to present the BCIM company with a walk-through of all the systems, from investment appraisal, product ordering and scheduling, through to production and quality control.

It is usual after the end of exams and a short break that about 80% of the members of BCIM return early for an extra effort. For the writer this was often a nail-biting experience because work was intentionally left for the last two or three days before the deadline - resulting in late nights and only two or three hours' sleep before having to present the results of eight months' work.

12.5 Conclusion

Of necessity, the sequential process of an instance of the CIM course, as described in the present chapter, has to exclude many important elements of the approach. It also does not give a clear idea of the effect of the course structure on students' expectations and behaviours. Suffice it to say, for the moment, that students enjoy the challenge of

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160) they presented Brunel's approach to CIM, in particular the close links between technical and human factors.

independent work and that most flourish in the unconventional environment offered by the CIM course. Some views of former students may be found in appendices S2 and S4. Most students use the opportunities provided in a responsible manner although the case described in section 13.3.3 and the case study compiled in appendix Q illustrate that this is not always the case.

13 Cases and Example Situations

The writer chose to include a number of case studies in the present thesis since he felt that the discussion of an educational technique must be real life oriented and that it is important to include examples of both poor and good practice. The case studies relate personal experience gathered over the whole of his professional life rather than just the involvement with the CIM course. They can be divided into three categories: those addressing problems and solutions found on the CIM course, those describing unconventional teaching approaches used at other institutions and those dealing with general aspects of Computer Integration. They are descriptive in nature and generally not referenced to particular sources since most are based on the personal experience of the author. The first of the general case studies is included here because it offers a parable or allegory for the problems faced in Computer Integrated Manufacture. The second one is used to outline some of the problems associated with the design of systems suited to human centred work systems. Both these general interest cases may help understand why the author felt that a new approach to teaching Computer Integration was necessary.

13.1 The 'Fishnet' Case

The following case study serves to illustrate the atmosphere of the CIM course and the variety of learning situations. The pressures acting on the teams are highlighted and discussed.

13.1.1 Case Description

The 'Fishnet' is a communications network based on a reduced wiring specification to RS485. It requires only 4 wires, 0V, V_{cc} and the two signal lines, but ensures good noise rejection and allows data transmission rates of up to 200 kbit/sec between addressable nodes. The Fishnet concept was introduced into the CIM course in 1990/91 by a lecturer who wanted to benefit from the generally high level of commitment existing on the course. At the time he did not provide a clear rationale for the need for developing this type of communications back-bone, since all the necessary control information could already be transmitted by RS232 while CNC data was provided on node computers.

A team of students undertook to work on the Fishnet, motivated by personal interest and, in one case, in the hope of gaining information for a final year project. The task was perceived as marginal and therefore received attention only when all other tasks had been completed. The team's objective was 'to have something, anything working by presentation day'. This was achieved by a period of very hard work immediately before the target date. A minimal configuration network was demonstrated in a 'dummy' mode but no reliable system was available. The system was, in fact, only working in a unidirectional manner and at much reduced speed. This disappointing outcome resulted despite the high intrinsic interest of the task.

In 1991/92 the network development task was fully integrated into the CIM company project and discussions about its potential contribution to communications between system elements were intense right from the start. The team assigned to the fishnet was given and accepted clear deadlines aimed at completing a working system within the project span, with trial transmission of NC data as a target. This well defined aim with a clear 'deliverable' engendered a completely different attitude amongst the group members: they divided the task into manageable elements which could be tackled by teams of two engineers, with two major intermediate milestones, namely, testing of a breadboard system and testing of a pair of purpose built prototype printed circuit boards (pcbs). Right from the start the leader of the group encouraged the team to plan for a production run of node units once the hardware had been proved. This production was to be subcontracted to technicians and was completed during a holiday period. There was thus a further controlling deadline linked to the 'real' world of limited resources.

Progress on the Fishnet task was good although the members of the team were at times slowed down by poor documentation relating to previous work and also by lack of 'instant' response from consulting staff. Development of hardware and test-software went hand in hand and led to completion of the prototype pcbs only two or three weeks behind schedule. However, at this late stage it suddenly became clear that no decision had been taken about the communication protocol to be used for sending messages between nodes. This was a very fundamental question since the RS485 bus does not prescribe the method of controlling data flow. The leader, together with the key software engineer of the team, therefore, called a meeting involving one of the non-executive managers of the CIM company (a lecturer). The group was well prepared and able to discuss the issues at a high intellectual level.

Even though all the members had declared that they would accept any group decisions it became clear that the senior software engineer had already committed substantial effort to one particular solution. The meeting was chaired by the task leader who stated that he was neither an expert in the hardware nor the software area but that his task was one of project management. He allowed an initial wide ranging discussion of the possible solutions but then guided the group to adopt one of the solutions. The lecturer found himself in a difficult position since he was championing what he considered a workable solution while attempting to leave the choice of options as open as possible. Eventually the group settled for a compromise between the ideal, but virtually untestable, system and the solution proposed by the software engineer.

After the meeting the lecturer discovered that the task leader felt he had detected that the former was critical of the group's performance. It was difficult to dispel this view which was endangering the previously very positive attitude of the group. The meeting was therefore analysed and the task leader realised that he and the team had performed very well. The next day the senior software engineer told the lecturer that he too had gone home after the meeting, totally disheartened, since he felt that all his effort and thought had been wasted. Again it was necessary to rebuild a more positive attitude, this time by showing, at a purely technical level, where the work already invested could be used in the solution chosen by the group. This process allowed the engineer to regain his old enthusiasm.

13.1.2 Case Analysis

In common with the other practical tasks on the CIM course the 'Fishnet' development had features which made it both challenging and risky:

- the task was based on an outline specification which defined its aims and the technology but not the method of implementation. **Work to specification.**
- the task had many elements which were interdependent and could not all be carried out concurrently. Breadboard testing, prototype pcb design / make / proving, test software development and evaluation, parts procurement, pcb manufacture and production software development had to be followed by the combined test. **Parallel vs sequential work.**

- the cost of the first stage production system was high for an academic context since it required a number of working pcb's built to a professional standard. **Significant and visible cost implications.**
- an immovable deadline determined by the need to interface with a large number of other system elements which all had to be ready for a particular day at the end of the 9 month project period. **Time pressures.**

The team used concurrent engineering techniques with good project management to complete the task within the time scale defined by the overall project aims despite the group's resources being stretched. An industrial development task of the kind undertaken by this group of students would have attracted a wage and component bill well in excess of £20,000. It was carried out at a component cost of less than £800 for the ten units and taught the team members new skills in communications engineering, electronics, micro-processor development and, of course, management.

Similar group dynamic processes could be observed in many task teams of each year of the course. In most cases the problems would be resolved by the two students who were acting as coordinators and team counsellors. In general, it was found that disagreements in the group did not affect the fairness of the assessment process.

13.2 Experience of Individual Student Cases

Any novel learning environment has different effects on different students. While a lecture based course with tutorials and laboratories places relatively limited demands on students' ability to cope with change, a less structured environment, such as that of the Brunel CIM course, requires students to set their own priorities, to manage their own time and effort as well as their emotional involvement. Some students find this change easy, because of either their upbringing, personality or schooling, while others fear or loathe any open situation, because it forces them to take their own decisions. This is not only true of a CIM type situation but also of project work in general. Observations highlighting some of the problems have been made in the Fishnet case study, section 13.1, and others are related here in the form of mini-cases. These will not be analysed to the last detail but should serve as pointers for potential problems in introducing a course of this nature.

13.2.1 Inability to Handle Open Situations

Some students find the handling of complex and open ended situations very difficult. Two examples, one concerning a very bright female student, the other an intellectually average male student may serve to illustrate this. The woman was the leader in charge of a little-defined task which was in its introduction phase and which concerned practical quality control. She handled the leadership and delegation aspects of this task well and involved herself in the programming of the computer links.

Beyond following the final year lecture courses and writing the requisite assignments she concentrated all her efforts on CIM and was prominent in the task managers' panel. Although she invested much anguish in her final year project she failed to do any real work. This dangerous situation became apparent only at the beginning of the third term of her fourth year and required immediate action. Her involvement in CIM was coming to a natural end at that time and she was given a one-month extension for her project with the writer agreeing to take on day-to-day supervision. During this month it became clear that the CIM course had provided a better environment for the student than the final year project since it had offered more mutual support and, very importantly, had provided many small intermediate deadlines while the final year project had only one interim goal. As a result the student chose to allocate all her time to the less open-ended activity. As a matter of interest, she managed to rescue her final year project and gained a good degree once she had been given a number of interim deadlines...

The male student's problems, in a later iteration of the course, became apparent as a byproduct of the task reviews held regularly. From about Christmas onwards he no longer attended these compulsory sessions and was described as 'being holed up in his flat' by his peers. Measures in this case had to be more drastic since the student did not recognise that he had a problem. Faced with too many open-ended activities he had withdrawn virtually completely from the course imagining that he could retake the year... Thanks to good co-operation from several members of staff and much effort by the student concerned it was possible to generate a new project and to supervise the work closely such that a relatively decent outcome resulted.

The lessons from these two individual cases are clear: an open-ended learning situation demands more rather than less monitoring. Repeated discussion and creation of deadlines, with and for the student, may well be essential in many cases. By placing heavy demands on students' time and on their ability to manage their involvement, the CIM course provides a valid learning experience. In providing students with this opportunity for learning to organise themselves, teachers must accept the responsibility for assessing students' level of self-efficacy (see Bandura in sections 6.2.3 and 6.4.3) or Alschuler's achievement motivation (see section 6.3). They must not only monitor students' progress but also intervene actively whenever they detect a serious problem.

13.2.2 The Lads

In 1988/89, the year boasting the largest and, on several counts, most exciting CIM team, there was a small group of students who were reasonably bright but who had a very strong need to show off their independence and "insouciance". They shared accommodation and interests and naturally joined together in a task team, in this the first year of the matrix structure. Lack of experience in managing the CIM approach, and little knowledge about the individuals, meant that this was not recognised as a problem. For one of the people in the group CIM was compulsory, for the others it was an option. Most of their work was to be devoted to the integration of a SCARA robot into the FMS cell. Due to unfortunate circumstances this robot was not yet physically integrated into the cell, together with the characters of the team members this was perhaps the main reason for the virtually total failure of the task. However, as later experience showed, the physical separation was not in itself a serious problem. In one iteration of the course, there was a task group designing remote user interfaces and CAM drivers, they never had problems integrating with the rest of the year group.

"The Lads" only ever produced results immediately before a deadline and were destructively critical of the course for the whole of the year. They had, in fact, been a team before joining the course and thus neither acclimatisation nor a transition group → team took place. Later on, the member of the group, for whom CIM had been compulsory, became a lecturer in the Department and continued to be dismissive of the whole experience. The writer can offer no positive outcome but feels that in a later iteration such a problem would not have come about since it could have been detected during the much more carefully managed task reviews. Motivation input throughout the course also tended to be managed much better, especially for teams working independently. With experience the writer also became much more aware of the potential danger signs.

13.2.3 The Freewheeling Manager

In the 1989/90 variant of the CIM course the senior coordinators were a very bright and hard working woman and a man who had been rated highly by a number of sources, including the summary shown in appendix H. Unfortunately, the reports had been overoptimistic and the student turned out to be bright but idle, or simply unable to cope with a responsibility which was allied to much freedom. The problem was not noticed at first because of the good performance of the other coordinator. It came to a head because the first mutual assessment between the senior coordinators and the task managers, for which he was responsible, did not happen and because there was no feedback forthcoming on the task review sheets[161] handed to the coordinator whose contribution was being questioned. The task managers allocated to him felt that they were receiving neither feedback nor were they being managed.

Several task leaders approached the writer who decided to create a positive environment for a meeting between the aggrieved task leaders, whom he had briefed about the difference between assertion and aggression, and the coordinator. This was very important since three of the five task leaders were women who had felt unable to confront the male coordinator. At first the meeting moved along smoothly, with each side stating their position. The coordinator denied the existence of problems indicating that he would have no difficulties in continuing to manage 'his' task leaders. At this point the writer, invited to chair the meeting, had to intervene directly and forcefully. He explained to the coordinator that there was a problem and that he was responsible. The method worked: he drew the aggression which had always been latent in the coordinator on himself and thus allowed him to come to terms with the criticisms of the task leaders. He did improve and did start to pull his weight.

13.2.4 Thwarted Leadership Ambitions

A highly ambitious third year student (student 16f in Table 18) was expressing a strong desire to become either a senior coordinator or a task manager on the CIM course in the fourth year. Conversations with fellow students and members of staff in the Department indicated that the student was unsuitable for such a role although his computing skills and other engineering ability were never questioned. The writer discussed the situation with the student over the 'phone and explained to him why he felt that the student should accept a team-member role. This the student accepted.

Ignoring the advice received, the "leader to be thwarted" became the task leader or manager responsible for developing the cell's scheduling system, by manipulating the selection process. Within two weeks from the start of the course he was also trying to assume leadership of the task team in charge of setting up the communication system for the cell, a team headed up by a calm and level headed student. Very quickly though he lost the support of his group (which he had failed to turn into a team) and technical progress became very slow. The student became himself aware of the problem as a result of the mutual appraisal process at the end of winter term and a solution was found at one of the task reviews: the two central computer systems tasks were amalgamated and the two leaders became jointly responsible for the larger group which was quickly welded into a team.

From the point of view of the team members, the student at the heart of the problem and the staff members involved, the situation was resolved satisfactorily and the student managed to

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161) an innovation introduced by the two senior coordinators that same year to improve the monitoring of task progress and to reduce the need for regular task managers meetings. The coordinators had decided to split the teams between them so as to improve the information flow and to ensure that each coordinator could make a knowledgeable contribution to the managers' work. This split was along the technology / business organisation divide.

regain the respect of his peers. He also made progress towards being able to submit himself to the leadership of other people. However, at several junctures there was a substantial risk that the student would 'crack' under the pressures and that he would no longer be able to be part of the BCIM team since he had managed to acquire a large number of enemies.

13.2.5 Leading a Task is Easy

In 1991/92 one of the software based tasks had reached a high level of complexity as the result of three years' determined effort. Indeed, the students had achieved better results in using an advanced piece of IBM kit than the company's engineers. The team could therefore rely upon (but also fear) a substantial set of documentation. A capable but, as it turned out, idle student took on the task - and did nothing. In his team he had two excellent members, one who would finish the course with the best mark ever, and three people who required substantial guidance. The leader showed no commitment to his task and failed to plan even the process of 'digesting' the existing information. By Christmas the task was in disarray and had to be rescued by the senior coordinators with the help of the writer.

The rescue had to rely on turning the team into a self-managed work team since the leader proved resistant to any attack, made out that anybody but him could be blamed for the problems, in particular the people who had worked in the area the year before. Once the task got under way again and once it started to make progress he even refused to spend time to sit with some of the task engineers and act as their sounding board while they were testing the software which he professed not to understand. The writer eventually took on this role himself even though he had no experience of working with C^{++}, the language used for all the software development on the course.

Replacing the leader by another member of the team was considered but rejected as an option since the team had started to work well without a leader although the task reviews with this team had to be more searching and detailed to make up for some of the management deficiencies.

13.2.6 Integrating an Outcast - The Man with a Communications Problem

During a summer time visit to a student working on placement in industry, where his performance satisfied a demanding manager, the student asked the writer whether or not he should take up the CIM option. The student was worried about the team work aspects of the course since he had been the target of mildly vicious behaviour by a number of other students right from his first academic period on the BME programme. He was deemed to be an upper class snob because of his accent and some 'prattish' flaws in his social skills. There was one particular incident which could only be described as bullying. As a result the student had felt a social outcast for three academic periods. It must be admitted that members of staff saw the student in a similar light as his fellow students, an unfortunate situation.

The writer felt that the student had a number of skills and substantial knowledge of software systems design which would allow him to contribute to one or several tasks. He also explained to the student that the pressures in the fourth year, and on the CIM course especially, would be such that there would be little or no time for personal vendettas. He suggested that the student should join the CIM course without aiming for a management role and that he was free to leave the course after two or three weeks if things did not turn out as hoped. The student also wanted some reassurances as to the proposed marking scheme because he was worried about the mutual assessment aspect.

In the event, the student did join the CIM team and became a valued contributor on the fishnet task where he contributed very substantially, gaining a good reputation and improving his communication skills greatly, although it was still apparent that he had to continue working on his performance. The task group was relatively small, numbering only five people, which allowed him to display much initiative. He convinced his team colleagues to try out new approaches to the design of PCBs, using advanced software tools and to increase packing density while at the same time enhancing board capability. His mutual assessment grade was in the top third of the class, four points above his CIM average mark. His commitment and input had thus been fully recognised by the group since he received this grade not simply from one task group but from two teams with which he had been working, as well as from a skill leader!

13.2.7 The Best Man in the Team

The 1992/93 CIM company team was characterised by a wide span of ability. This was the result of a change in recruitment patterns for the BME course in 1988/89. While most of the students joining the CIM option from SEP were still of a good standard[162)], the composition of the BME group had become more disparate[163)]. Some students, such as the individual described in this case, were bright and very committed while others required a great deal of support and motivation before achieving anything. The CIM company member discussed here was not an average student: he was about three years older, married with children and he had been sponsored by a small company specialising in the design of manufacturing systems software.

Since the software mentioned was being used on the CIM course and since a new version had to be installed the student with a wealth of experience was appointed the leader of the group charged with implementing the software upgrade and with the writing of the software link to the other business management systems. This proved a mistake even though he had all the characteristics of becoming a good manager (maturity, knowledge and commitment) since he was also the 'best man in the team'. The writer was aware of this position from the beginning and counselled the student accordingly, but this was to no avail: as soon as deadlines loomed, the 'best man' took over. The student discussed the problems in his interim report as follows:

> "The task was not without its problems managerially. The author is used to a hands off approach to management and attempted to run the task in this same style. This failed ... As a learning exercise it is felt the management experience has been the most beneficial element of the CIM course... The approach to meetings was intended to be congenial, relaxed and informal. The group would meet to discuss what had been done the previous two weeks, and then follow that with planned actions for the following two weeks. The group would make their own notes and be responsible about the work that had to be done.
>
> This style failed. There was a degree of confusion over what had to be done. The task engineers were either incapable or unwilling to plan their own work, having been given overall objectives. Some engineers were not taking notes and problems arose over what had and had not been agreed. There was also a degree of

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162) as far as the intellectual calibre was concerned - however, SEP students always tended to present more problems at a personal level than their BME peers.

163) one of the theories for this change identifies 1988 as the year in which the peak of the service industry boom in the UK had been reached, leading to a severe reduction in the interest in engineering.

competition with the matrix style of management, between tasks, and engineers felt their priorities elsewhere, particularly those who were themselves leaders."

Following discussions with the senior coordinators, the writer and people at the student's sponsoring company, he changed his management style and introduced structured meetings:

> "Despite inviting contributions to the agenda, none were ever submitted and items were set by the author... By setting out the requirements piece by piece the engineers knew exactly what was required in the next two weeks and could bring those achievements to the next meeting... and immediately the performance of the task engineers increased by an order of magnitude... Latterly, as the engineers began to understand better what it was they were aiming at, one sensed resentment creeping in at the directive style. This was borne out in the mutual assessment forms where some felt the leadership style to be heavy handed and autocratic. However, the author appreciated the clear, and more formal management... and the Christmas objectives would not have been met otherwise."

It is notable that the task leader refers to a group, not a team, and that he does not mention that for some time he had to be (and was) the best worker in the team. He required much support to be able to extricate himself from this situation. The necessary discussions with him centred very much around the problem of having to delegate tasks to people who would not be able make as good a job of them as he would have done and who would take much longer to reach the objectives. In the end the student was successful in handling both his management task and his final year project. For the latter he was awarded a prestigious national award while in the former role he received a mutual assessment mark at the top of the lower quartile.

One year after graduation, e-mail messages from the person discussed in this small case description indicated a very strong belief in the positive effects of having participated in the CIM course, in his own words "the most valuable part of my university education". This comment was prompted by the success in being appointed to a line management role in one of the client companies of his former sponsors. Whilst this does not allow the conclusion that the person benefitted from the course in personal development terms, it indicates that his self-perception and, as a result, the portrayal of his experience during the interview, was shaped by the difficult processes he had undergone.

13.2.8 Coping with the Pressure of Leading or: Senior Coordinators - a Case of Helplessness?

As a result of the multi-stage selection process for the posts of senior coordinator, two BME students[164)] had been elected for these posts who were perceived by the other students as the best possible compromise candidates, when the first round of voting failed to produce a clear set of favourites. Both students had polled well in the first round but neither had been in a high position. The writer had included the students in the list of potential senior coordinators because the two had indicated an interest on the skill cards and because personal knowledge as well as comments from other members of staff supported their suitability.

The two, a relatively shy but very competent woman and one of the brightest men, with a stutter which became stronger under stress, set about their task with great gusto, distributed duties and held first meetings with the task leaders. Within a month though both were

164) in previous years it had been practice to elect representatives from both BME and SEP to the senior coordinators posts. It was a sign of the strength of the CIM approach that this practice could be abandoned.

physically and mentally exhausted and came to one of the weekly tutorials with the writer, prepared to give up their responsibility. The man stuttered badly, the woman was in tears and both expressed the feeling that they just could not handle the pressures. Even at this early stage though they had been innovative and had created the "highlights meeting" which, for an investment of fifteen to twenty minutes per week, replaced the previous CIM newsletter[165] and irregular but drawn out general meetings. In addition they used group-messages on e-mail. They felt that this approach, described in section 12.3.4, was more powerful in motivation terms than the methods used previously. However, as the writer explained to them, this new process was far more demanding since they had to perform in front of large groups (the whole of the CIM team), something which neither had really thought about. They had also not realised that setting things up well early on would lead to reduced stress later on.

The meeting ended with an agreement that the two coordinators would remain in post but that they would use task managers to chair some of the communications meetings, that they would get other people involved in running task leader meetings etc, and that the writer would set aside more time for their tutorials. They delegated very successfully and subsequently became highly effective senior managers! Perhaps the best of the senior coordinator teams ever. As was often the case in both the mutual assessment and the overall CIM mark the two finished up in the middle field, the former being a sign that they had managed the assessment process fairly and the latter indicating that their priority had been team success rather than individual achievement.

In their own way, it was the two senior coordinators who gained for the CIM staff team (P. Broomhead, R. Grieve and the writer) the partnership award for innovative teaching in manufacturing engineering: they arranged the agenda for the visit of the GEC assessor and asked him to participate in one of the general course communications meetings. The staff members who were to win the prize were not involved at all!

13.2.9 Confrontational Management

This case has been built up from notes kindly supplied by Jean-Noël Ézingeard (JNE), the writer's successor in managing the CIM course. In line with the general communication trend on CIM this case started with an e-mail message (1) reproduced in appendix Q, a message which arrived with no warning and which signalled the resignation of the mechanical skill group leader. The message had been sent to all the members of the CIM team as well as JNE. The main reason for the skill leader's decision appeared to be the realisation that his mutual assessment marks were lower than those of people's in whose interviews he had participated.

The two senior coordinators sent an e-mail message (2) to JNE and responded to the skill leader with e-mail message (3), requesting a meeting. This took place and resulted in message (4) which is an accurate reflection of the tactics employed by one of the senior coordinators[166]. A further message from the senior coordinators followed, threatening the resigning leader with dire consequences and attempting to take apart his arguments. This only led to a final acrimonious retort which resulted in the resignation becoming fact, and in another student accepting the role.

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165) a worthwhile but very labour intensive method for keeping all the parties involved in the CIM course abreast of developments. In one year, issues appeared regularly, almost like clockwork, while in another year several issues degenerated into joke magazines.

166) as a background to this it is important to note that one of the senior coordinators was convinced that he had honed his management ability to perfection by many years of student union activity.

Throughout, JNE took a 'let it happen' approach because he felt that all the people involved would benefit from the experience, even though it might turn out to be negative. At the time of writing this it was not clear what would be the final result of the iteration of the CIM course 1993/94, but the signs were that the problem had been resolved. In retrospect it might have been sensible to manage the 'student union trained' coordinator much more tightly from the start but this could have made the course less realistic. The jocular tone of the e-mail message to JNE is perhaps worth highlighting. An intervention at this point, indicating to the senior coordinators that no aspect of the CIM course should be considered a joke, might have helped rescue the situation although personal knowledge of the "key actor in the drama" would rate this chance rather low.

A significant element of this case is the use of a threat of punishment. Just like punishment itself, as shown by Thorndike and Skinner (see section 5.6.2.3), the threat of punishment will not modify unsuitable behaviour, especially not if it is debatable whether or not the behaviour was unsuitable.

13.2.10 Lessons from the Student Case Studies

Recurring themes of the case studies include responsibility, maturity and openness. The issue of openness is of particular importance since an open-ended learning activity can easily be affected by events which, initially, may appear to be of little consequence. In an environment such as that present on the CIM course any issue, perceived to be a problem by the students, will quickly become a real problem because of the many opportunities for formal and informal communication between team-members (the "grape-vine"). It may be useful to provide an example for a situation which could have led to very serious difficulties if it had not been for a student's informed intervention:

During one of the iterations of the course the writer of this thesis made an off-hand remark along the lines that a task review of one of the business teams could be postponed very easily "since it was not critical" (see also section 14.5.3). His use of the term "not critical" was unfortunate since it was interpreted as "not important for the overall project" - while the writer had simply wanted to state that progress was good and that he did not expect any problems. After about a week, one of the students working in the business area brought up this issue and reported that many of the members of the business oriented tasks were demoralised and felt that there was no point in investing a great deal of effort. Only an open and frank admission of being at fault retrieved the situation - and led to higher motivation levels than those existing before the problem had occurred. In fact, the team concerned managed to develop the Brunel Investment Appraisal Procedure (BIAP) which was rated highly by industrial visitors.

Openness must not be translated as meaning public discussion and analysis of private problems or disputes. In a learning situation where respect for people's maturity is rated highly, confidentiality is also critically important.

13.3 CIM on the MSc Course: Staffing Issues

While Brunel University's MSc Course in Advanced Manufacturing Systems was still operating in non-modularised day-release and full-time formats there was an opportunity to try out the practice based learning approach with two groups of postgraduate students.

Although the general results of this experiment will be reported elsewhere[167] it is worthwhile to include here the outcome of a staffing decision: a full-time research assistant was appointed for two years to help with the management of the postgraduate CIM course since the author was stretched to the limit by the undergraduate course. In the first year the person appointed[168] was acting out very much the author's role in that he was learning with the students and only providing expert technical input where this was absolutely essential. The motivation level of both the students and the RA was excellent, several Saturday working sessions were well attended and the end result, a flexible assembly line for eye-shadow compacts, could be demonstrated as a solution which had been developed in a team effort.

The second iteration of the MSc CIM was ill-fated partly as a consequence of a different composition of the student group[169] but mostly because of the much more pronounced ambition of the research assistant who wanted to implement a professional solution to an industrial problem. As a result he took most of the decisions himself, presented his solutions as fait-accomplis and attempted to use the students as 'so many pairs of hands'. He resisted any guiding input from the author on the grounds that "the target will not be achieved if I do not..." While the practical objective of the course was achieved, that is, the automated assembly for disk drives was working faultlessly, the management and personal development objectives were virtually completely disregarded. As it turned out, the research assistant was an excellent and broad based engineer but a less than ideal manager. He generated many unnecessary conflicts with the team. In the first iteration this had not happened since the author had been more involved and since the RA had considered himself a learner, part of the team.

Quite clearly, it is necessary to train staff expected to be involved in unconventional teaching and learning situations. It is the writer's experience that even in an 'enlightened' university department such as M&ES at Brunel there is little opportunity for new members of academic staff to get acquainted with the sometimes very distinctive teaching methods and styles used: very often they are just expected to pick up the necessary interpersonal and theory oriented skills as they get involved in team teaching. The writer made a conscious effort to get his successor on the CIM course involved in its operation as early as possible - it helped that he had been an MSc student who had taken part in the postgraduate CIM experience.

13.4 Unconventional Learning Situations - Case Studies

In the course of his work and in writing this dissertation the author came across a small number of novel or unusual teaching environments with a strong practical flavour. While these differ from the approach adopted on the CIM course they afford valuable insights into the design of teaching situations which depart from the standard lecture format.

13.4.1 Comparison Case Study 1: AED at Coventry

At Coventry University the second year of the BEng course in Automotive Engineering Design (AED) was reshaped to become a one hundred percent practice oriented learning experience. Students spend the whole of the year in a purpose built design office, fashioned

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167) this discussion proved to be outside the scope of the dissertation and will thus be postponed to a paper to be published at a later date.

168) a graduate of the Production Technology course at Brunel who had not participated himself in the CIM activity.

169) the first MSc CIM course was scheduled for the first group of full-time MSc students who joined a small but well established group of part-time students. Both the full-time and part-time groups had intellectually strong students from different backgrounds. For the second iteration student quality (a very subjective term) had reduced somewhat and there were also two groups of students who worked in the same company and who brought their position struggles into the CIM course.

on an industrial situation. Most of the time they work in teams although towards the end of the year more emphasis is placed on individual projects. The year is split up into week long modules in which the students address particular aspects of engineering design, though topics can span several modules [based on Gibbs, 1992].

Tutors present completely new information in brief lectures[170)] (teach) and then set group tasks (demand) allowing students to acquire the necessary background knowledge and experience using model building and design activities. A substantial part of the teaching is achieved through peer tutoring, facilitated by staff. Students reflect on their learning (monitor) by writing notes in their learning journals which are regularly checked by tutors who respond in writing. Comments are usually written to encourage further and deeper learning rather than to correct and admonish. At the end of the year tutors review the learning journals, the results and reports of group tasks and the portfolios created during individual student projects (assess). The marks are discussed with the students. There are no formal examinations although there can be some moderation of marks in an oral examination at the end of the course, an eventuality for which a number of short interviews throughout the course prepare.

Although the information available to the author is very limited, there appear to be, in spirit and execution, a great number of similarities between the Coventry approach and the CIM course taught at Brunel. The lack of a single overarching target and the absence of a student based management structure on the AED course are perhaps the key differences to the CIM course at Brunel. The former is unavoidable because a substantial amount of knowledge content from different disciplines must be assimilated, thus excluding concentration of all the effort towards a single objective, while the latter is really only possible in a situation where students have had a substantial amount of exposure to industrial situations at engineering level.

Considering these differences it is the opinion of the writer that the AED course provides an excellent environment for the acquisition of technical and problem solving skills, as well as teaching and learning skills, but that it is probably not very effective in engendering people and organisation oriented skills. However, there is no claim that the course is meant to provide students with such capabilities. Another notable difference to the design of the CIM course is the totally self contained nature of each year which does not require well structured transfers of information between groups of students, an important feature of engineering work.

13.4.2 Comparison Case Study 2: Informatik im Maschinenbau

Information technology is perceived as a key area in the formation of mechanical engineers at the technical university of Aachen, FRG, since there is no specialist academic discipline of software engineering in Germany. System designers are therefore recruited from the engineering disciplines. This brought about the need for a new course in the curriculum for mechanical engineering students at Aachen. The centre for university didactics at Aachen produced a new and unconventional course to respond to this need. The script (lecture notes) for the course by Henning and Kutscha [1992] is of particular interest since the authors not only present the course content but also outline the course philosophy and the learning approaches. The necessity of creating good interfaces between 'man' and machine is stressed throughout (the authors advocate the dual design approach).

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170) Gibbs [1992] who presents this case as an illustration of good practice discusses the process in terms of the teaching cycle of 'teach, demand, monitor and assess' which is illustrated in Figure 23 in section 10.5. The same terminology is used in Table 28 to structure the elements of the CIM course.

An important element of the course is the group project which is undertaken by all the students on the course (500+) over a period of two months, in teams of five. The groups are formed at the beginning of the course and are expected to devote at least 20 hours to the task, that is, the creation of a system specification for one of three software modules of an automated container transfer station. This time does not include programming, an additional task which many students undertake on a voluntary basis. Due to the limited time available for the completion of the module the task is described in great detail in the script and staff provide surgeries on a weekly basis. The development process is defined in the four stage structure which forms part of the task description. Formal lectures are scheduled at appropriate times to prepare students for the next phase of their work. Work sheets and guidelines are made available to support the groups in becoming teams and in handling the technical aspects of the tasks. The members of each group submit a joint report on their work and there are prizes for the ten groups with the best results.

The approach adopted for this information technology course is very novel for a technical university in Germany, according to one of the originators of the teaching environment. Students are thought to benefit greatly from the group work which leads every year to original and intelligent solutions despite the short duration. It must be highlighted that this course is scheduled for the fourth semester of a mechanical engineering degree programme taking up to twelve semesters of study and project work. Unlike students at Brunel, through lack of exposure to industrial environments the German students are not yet prepared for a large and relatively unstructured task.

13.4.3 Comparison Case Study 3: MAXI at Sheffield University

Holcombe and Lafferty [1993] describe a project based software engineering course run for about 100 Masters level students each year, lasting 25 weeks and aimed at developing many of the skills needed to cope with the activities involved in software engineering, such as project management, quality assurance, formal methods etc. The teams of four to five students all work to the same project specification for the same client, supervised by experienced managers[171)] rather than the university teachers or peers elected to this task (neither approach having worked).

When the Sheffield course was pioneered with 2nd and 3rd year students they were allowed to form their own teams which worked well since people knew each other. In order to avoid the problems which have arisen from 'uncontrolled cultural mix' in the past the members of the course team allocate students to the different groups.

The project carried out by these teams is very real in as far as the 'client' is a person from industry who is prepared to issue a brief which is 'just right' in size and who will allow time for the knowledge elicitation process and for the debriefing of twenty teams. The fact that there are twenty teams working on essentially the same task cannot be described as realistic. It is a daunting task for a person working full time in industry to provide the same input 20 times over at a consistent quality level. The bi-weekly input from the university based industrial managers is certainly useful but reflects poor rather than good industrial management practice. An observation which the writer can confirm, in as far as teams of Masters students are concerned, is the very limited output from 25 weeks of work. In his opinion undergraduates used to co-operating achieve a great deal more.

The very clear differentiation between the roles of teacher, manager and client is a highly commendable characteristic of the course. On the CIM course the teachers are to some extent

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171) no longer working in industry but employed by the University.

viewed as also representing the clients by the students, however during the most recent iterations it has been possible to introduce real clients in the shape of software suppliers requiring interfaces, CIM conference attenders and the invited guests of the tutorial day, as well as lecturers not related to the CIM course who set their own tasks. It must be admitted though that this last type of client is the least demanding... and therefore not as useful as the others.

In conclusion, MAXI is probably the teaching environment most akin to the CIM course of those encountered in the literature. It seems to develop many of the same skills, such as careful planning, handling tight and real deadlines, and working in teams which are to some extent imposed by 'management'. It is also subject to the same demands from students requiring good industry standard software and hardware tools for their work.

13.4.4 Comparison Case Study 4: Projet de Groupe, École Centrale Lille

École Centrale Lille (ECL) recruits students for its general engineering degree course who, prior to entry, have completed a two year period of study of advanced mathematics, physics and chemistry in the 'classes préparatoires'. The objective of the school is the formation of broad based engineers with a strong bias towards manufacturing engineering and the construction industry. The intake of 190 students per year are taught as one group and students undertake only short industrial placements until after the end of academic study of the third year of the programme. The studies are 'crowned' with a major three to six month industrial placement. Experience showed that students often failed to satisfy their industrial managers fully because they lacked team working skills. This deficiency also tended to become apparent in the small-group projects undertaken until now as part of the second year of studies. The writer, in his capacity as tutor of English students following the course at ECL, has had personal experience of this problem.

As part of an important reform of the curriculum of the first and second years of their engineering programme, the board of studies instituted a group project which covers both years one and two of the course. Groups number between four and eight students and are responsible to a member of academic staff of the École. The projects are designed to last the full two years and are often industry related although they are carried out at the academic institution. The groups have access to other members of staff who act as consultants and later as assessors. This new departure is allowing ECL to play a pioneering role amongst French Grandes Écoles where team-work is not part of the official curriculum. The first cohort of students taking part in this experience presented the final results of two years of work during the period of the writer's stay in Lille in spring 1994.

Discussions with the people responsible for the new group projects, presence in two 'défenses du rapport'[172] and analysis of one of the reports indicated that the concept of the project was well thought out but that there were some flaws in the implementation, particularly as regards the skills involved in project management. All the reports seen were quite poorly structured, either missing the description of the project's scope and objectives or lacking a sensible discussion. While one of the presentations was very competent the group was criticised for being too superficial in their approach even though their project was perhaps the most interesting and complex of all[173]. To some extent this criticism was justified but it was quite clear

172) in parallel to the handling of doctoral theses, where the French system demands a public defense or examination, each group had to present their results to a panel consisting of teachers from the institution, industrialists and experts from the Université de Lille who had followed the projects.

173) it involved the technical, commercial and environmental analysis and synthesis of the design of a complete mango processing plant, including the chemistry of conservation.

that the group had not received sufficient input before embarking on the project. The second presentation witnessed was very poor, consisting of a sequence of unrelated mini-presentations dealing with the (very substantial) technical work which had gone into the project. The group had not worked as a team at all but as a set of two-man task-forces.

It must be acknowledged that overall the new course element is deemed a very substantial success by the board of studies of the institution, despite the problems arising from students' problems with the concept of project management. The people responsible for the project approach have recognised the weaknesses and intend to improve the introduction phase. The time-constraints are daunting: students meet for the first time ever in September and must start a team project in October, having had no prior exposure to management topics during the lycée or classes préparatoires! This corresponds very much to a real-life situation in an industrial environment. One of the important areas to develop will be the creation of achievement motivation which is lacking in some of the students, as a consequence of the peculiarities of the admission system and the French education system in general.

The students interviewed on their experience were happy with the course although they acknowledged the difficulties in building effective teams and the risk of some students benefitting from the efforts of others. The process had led to very close and lasting co-operation between some students but excluded others. Some students pointed out the importance of choosing projects with a 'real life' context which created real commitment. The members of staff involved were also pleased with the outcome although they had reservations about the relevance and accuracy of some of the work undertaken. For the teachers it was also the first attempt at such a method of instruction and they found the effort daunting even though each had to look after only one or two groups.

13.4.5 Comparison Case Study 5: Manufacturing Simulation

Two problems deriving from the use of simulation and games in teaching were discussed in section 7.3.4: when designing a simulation or game based activity teachers sometimes fail to consider all phases of the experiential learning cycle (or the practice based learning cycle). Rather than setting up a thoroughly planned and well structured learning situation they simply provide a script and some guidelines. This can lead to trial and error learning even if the activity is worthwhile and benefits from good peer support. However, students' perception of the situation as a game may lead to non valid learning regardless of whether the simulation is originally based on a real problem and its solution or on a made-up case.

13.4.5.1 An Illustrative Laboratory Session

It may be useful to illustrate the two related problems, drawing on the example of a laboratory experiment, developed at Brunel University to teach students about the difficulties of scheduling and managing production activities which are linked to financial targets. This is not the first production simulation undertaken by the students : during the very first four weeks of the BME course they undertake a very simple project, the production of greeting cards, a wholly paper based exercise. This laboratory session is oriented towards "time and motion" analysis.

The production management activity is organised as follows: teams of four to five students are asked to set up a production system for the manufacture of paper aeroplanes to three different designs. They may choose flow lines, cells or job shop type arrangements. The computer is used to introduce the students to the problem. Customer demand is generated by a computer program on a pseudo random basis. They groups perform trial and measured production runs during which they have to take planning decision in real time, subjected to a number of changing constraints, such as fixed set-up times, non-availability of raw materials or labour etc. The sequence and timing of problems is different for each run. Trial runs can be stopped at any time to review progress while production runs do not allow for this.

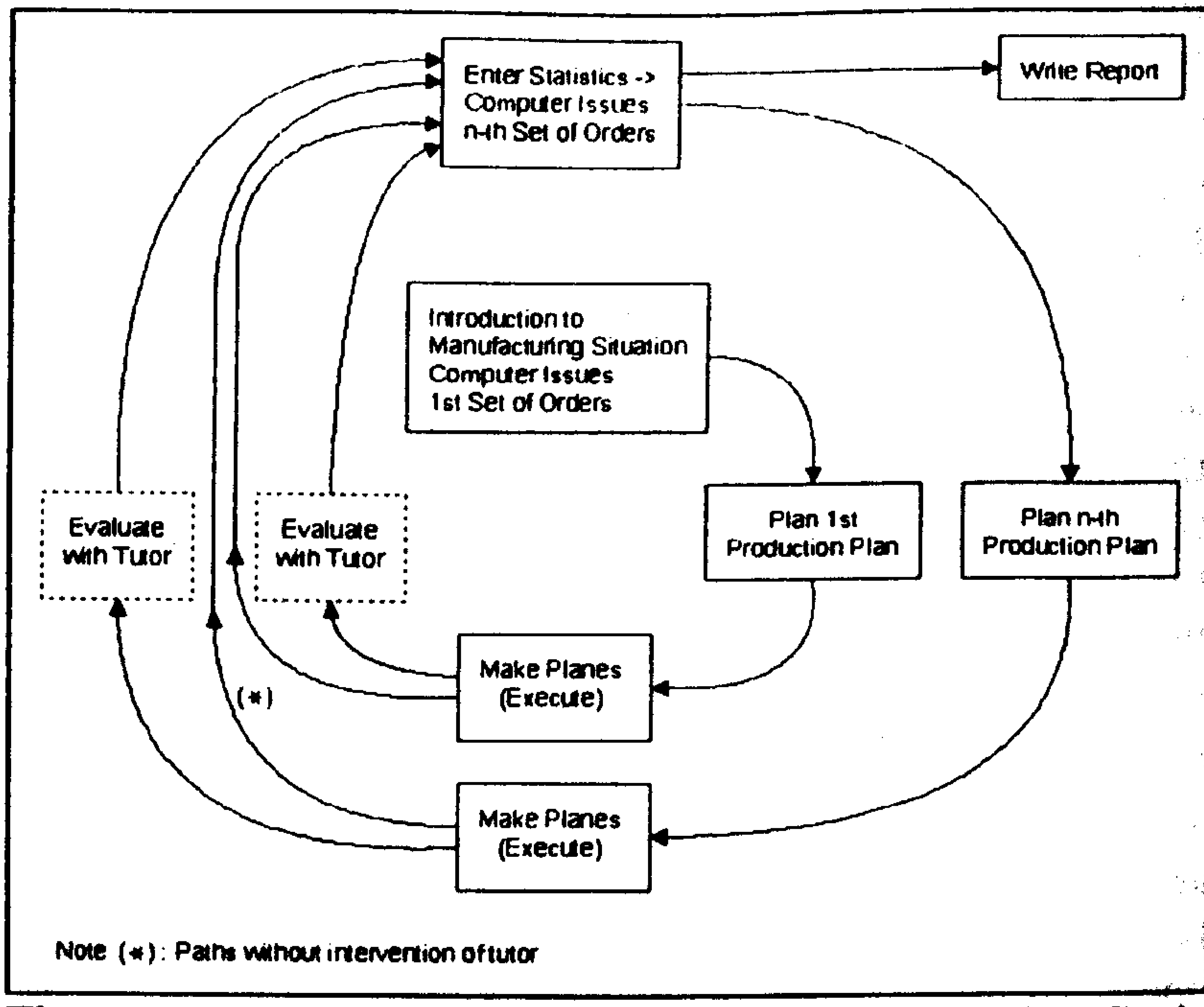

Figure 31 Manufacturing Simulation and the Learning Cycle

During the production runs the students experience both conflicts in the group and strain as the result of the required high level of dexterity and manual performance. The relationship between the tasks, computer support and the experiential learning cycle are shown in Figure 31. Two of the phases of the cycle are handled or assisted by the computer while the reflection phase is ill defined, its structure and content being at the discretion of the member of staff in charge of the laboratory, often a research student without substantial industrial experience. Very often, real reflection takes place only after the laboratory session when the students are supposed to derive generalised principles for their "production experience". This tends to be too late.

A review of a number of laboratory reports has shown that the learning achieved depends entirely on the management of this phase and that only students from groups whose reflection phase had been well managed by a member of staff with substantial manufacturing experience were able to generalise successfully their experience. Students who missed out on this element tended to write factual accounts of the process of making paper aeroplanes whereas the others would reflect on the problems of managing a manufacturing operation. The missing links in the cycle are clearly evident in Figure 31.

13.4.5.2 Perceiving the Situation as a Simulation or Game

Students often view the above laboratory activity as a simulation or game playing session. There are several reasons for this:

(1) the activity is scheduled to last for two two-hour blocks with little planning required from the students for complete success in the task by the end of this period.

(2) it requires a major effort on the part of the teacher to overcome the view that "one folds paper planes in play school".

(3) the guidelines are very clear and the learning to be achieved can be circumscribed accurately and thus does not differ much between students[174)] and student groups.

(4) groups are assembled on the basis of friendship or randomly, rather than on the basis of the skills required for the task.

174) this can partly been explained by reference to the use of a computer for both the introduction to the session and for some of the feedback generation.

While it would be possible to change the design of the experiment to remove the weaknesses mentioned the effort involved is not justified due to the relatively short duration of the experiment.

13.4.6 The INDEL Experience: Simulation and Physical Work as Team Integration Tools

As part of his own academic instruction the author participated, in 1976, in a three-day team development workshop run by experts from the FAO (World Food and Agriculture Organisation) and in a two week work camp in the Swiss Alps. The activities had been organised as part of INDEL, an interdisciplinary postgraduate programme for people interested in careers as development workers in so-called 3rd world countries. The team development workshop was organised by the course management and the work camp by the participants. Both took place before the formal start of the course, both were intended to help in the formation of strong teams and both worked in their way. Management and students were of the conviction that all the participants had to be able to work effectively in teams because of the demands of the academic part of the course and because of the need for close co-operation once they were part of a project team in an alien culture.

13.4.6.1 Simulation and Teamwork

Students on the postgraduate course who had never met before were divided up such as to create multidisciplinary groups with a wide diversity of backgrounds. Each group was then led through a series of exercises ranging from games to planning tasks. Each step was intended to teach one particular aspect of teamwork. Out of the five groups of five to six students four participated in the activity while one group withdrew from the activity after the first exercise and spent the rest of the three days discussing the issue of teamwork at a theoretical level. They did this as a protest against what they perceived as an imposed team work requirement[175].

By allowing the students to concentrate on each exercise for only a very short period of time the experts created high levels of pressure and stress in the groups. They managed to achieve this despite using only simple exercises and simulations. The expert would be present to introduce each task, would at times observe its execution but more often than not would work with another group until shortly before the time at which the group had to present its findings. He would then review the results with the group and discuss typical problems arising in teamwork. On the final day the groups were each given a demonstration task whose solution they had to perform in front of all the other groups. Three of the remaining four groups passed this test and were declared functioning teams. The fourth group performed better in the task set by the expert but failed the team test: one of the members grabbed the initiative and managed the group, a consequence of the competitive pressure.

During the final review session the members of the team which had not participated in the scheduled activity were able to analyse and criticise the performance of the other groups, now transformed into teams. This helped in strengthening further the team spirit in the other teams and it allowed the competitive group mentioned above to support and later integrate the member who had very nearly broken down because he had not been able to handle the requirements placed on him by this new need for working in a team.

175) it must be remembered that the episode related here took place in a time when radical thought permeated universities and when the authority of teachers and course managers was questioned at all times.

On the whole, the activity could be described as a success but this was largely due to the commitment of the course members. The key role of the experts appeared to be the creation of resistance and the emergence of a strong team spirit was based on this conflict between a group of unusually assertive mature students and a course management which had up to then ruled supreme. The banality of many of the exercises was criticised and led to a rejection of this kind of simulation. Similar criticisms apply to the 'Outward Bound' style of team building activities common in the UK.

13.4.6.2 Physical Work and Team Building

For a number of reasons the postgraduate students themselves organised a two week course in the Swiss Alps where people helped with the extension of an old farm building using traditional wood construction techniques. Teams of two or three people were responsible for particular aspects of the work, depending on the skills which individuals could offer. There was a clearly defined goal at the end of the two weeks, namely, the completion of all the outside work, a tough deadline. The teams changed over the two week period, providing many opportunities for establishing good working relationships between virtually all participants. Basic social activities in the evenings also assisted in this process.

The participants acquired many new skills and were able to define their own learning needs at the end of the two weeks. In the remote area of the Swiss Alps where the course took place they found a learning and working situation which was similar to that of a developing country: the mentality of the people was substantially different, the spoke an unfamiliar language (Rumansh) and the available equipment was more primitive. The course members successfully lobbied for language classes and further practical experience so as to be able to benefit the most from the scheduled project work in the 3rd world.

From the point of view of the course management the building weeks produced a large and integrated team which later proved unmanageable since there was near unanimity on any important issue and since the group as a whole had been politicised. Partly as a direct result of this experience and partly because of other changes in the environment the INDEL programme was suspended for two years while its scope and content were being redefined.

13.4.7 Summary to Unconventional Teaching Situations

In this subsection, 13.4, the writer has described six unconventional teaching and team building approaches, each of which presents benefits, drawbacks and risks. On the CIM course many different elements were mixed thus obviating some of the risks but increasing the most significant risk, that of making students work too hard! The creation of commitment is a common characteristic of all the above situations and it can lead to undesirable outcomes when students concentrate too much of their effort on one particular aspect of a programme, see the example given in section 13.2.1. In general, apart from the INDEL situation, it can also be seen that staff input in creating and maintaining such teaching environments is very substantial and may not be forthcoming, thus leading to a lower quality experience than that which would be provided by more conventional approaches. This was certainly the case for some of the groups in the ECL programme and could have been at the heart of the problems experienced with the INDEL course.

13.5 General Interest Case Studies

The following case studies have been included here to provide the reader with some background to the important technological changes which have taken place over recent years and which affect many people's relationship with their work. The new technologies demand a far higher level of understanding, beyond the scope of know-how and skill, because of the high levels of uncertainty and the much more important rate of change compared to the past.

13.5.1 The Human Understanding of Computer Integration - A Real Life Experience

Traditionally, airplanes were controlled by the pilot using his joystick to operate the control surfaces using cables and linkages or hydraulics. Most modern planes are equipped with computer based flight deck systems where digital signals are transmitted to the controllers of the actuators, an approach often described as "fly-by-wire". Although auto-pilot devices based on inertial navigation have been around for a long time the latest systems are far more powerful and include complete route control. It is thus possible to fly a plane from one airport to the approach zone of another airport without pilot intervention since all the systems operate in digital closed loop.

The writer of this dissertation found himself on the flight deck of an Airbus one day and, in the course of a fairly long technical discussion he asked the pilot whether there was a manual control mode for the plane. "Of course there is", said the pilot, "I just flick this switch and I fly the plane myself. Look, on this screen I see the artificial horizon and I control the plane in such a way as to position the little image of a plane in line with the horizon". Was he really flying the plane himself?

No, the pilot was simply acting as an element in the feedback loop. He was not using information from outside the system but he was simply translating the attitude demand signals (issued by the computer) into actuator commands (to the computer). It seemed as though he would not have been able to identify, interpret and counteract a computer malfunction which produced close to 'normal' values. He mistook computer generated images for direct representations of the 'real' world. He had no real understanding of the system and his own role since he appeared unaware of the fact that his intervention probably reduced the performance of the system. From this conversation it became very clear how the pilots of an Air France jet could program it in such a way as to hit a mountain - without ever doubting the correctness of their actions.

How does this story relate to the computer assisted control of manufacturing systems? Well, a factory can be compared to a plane although the former has more unknown inputs and potential internal causes for disturbances than the latter. The manufacturing manager can be likened to the pilot since she or he is trying to control a system in such a way as to produce the desired quantity and quality of goods (outputs) even though he may have incomplete information about inputs and internal behaviour of the system. Both the pilot and the manager need a thorough understanding of the system and the assumptions which were made in its design, they must be given as much information in a useable form to allow them to take the right decisions and they must have some means of maintaining control should the computer based system fail.

13.5.2 The Control of Machine Tools

Early Numerically Controlled (NC) machine tools, equipped with paper tape readers, could be programmed on the shop floor, using the machine tool, or in a tape preparation office, using a more or less standard telex machine. Once produced, the tapes had to be proved on the machine tool by the operator or a setter. The office based approach became the norm for companies in the Anglo-Saxon world[176] where personnel qualifications at all levels of an organisation were limited to the essential, adequate for competent execution of a particular task. Shop floor based programming by qualified machinists though developed in German speaking countries and in parts of Eastern Europe.

The Anglo-Saxon approach dominated the development of NC, Computer Numerical Control (CNC) and Direct Numerical Control (DNC) methods, a development leading to more and more centralised preparation of manufacturing information and concomitant dequalification of shop floor staff. Very sophisticated algorithms and programmes for direct translation of CAD data into process information were introduced in order to optimise the preparation of programmes and minimise the cost of trials.

Fitzpatrick [1992] describes the development of CIM at the Watervliet Arsenal in the USA: "CAD/CAM has been installed at Watervliet Arsenal for over five years. It consists of a GE Calma CAD/CAM system with links to a facility-wide DECnet network which hosts 34 3D workstations, eight 2D draft stations, and a number of plotters. The system, which serves design, manufacturing and plant and facility layout, is hosted by two VAX 11/785 computers. In the engineering and tool design areas, solids modelling is done for purposes of evaluating the thermal and mechanical properties of materials as well as finite element analysis.

Most of Watervliet Arsenal's production machine tools are interfaced to Distributed Numerical Control System provided by GE Fanuc Automation North America, Inc. Each NC and CNC machine tool has its own factory-hardened terminal which has the capability of accessing any manufacturing or business system on the network. This system has eliminated paper part program tapes; the programs are now electronically down loaded via DNC instead of manually transporting tapes. There is also an ability to revise the programs on the shop floor after they are down-loaded."

The description quoted here is typical for a totally technology oriented view of manufacturing, a view which excludes the human being from the discussion - even in a context where their intervention is implicit, that is, when it is stated that there is "an ability to revise to revised he programs on the shop floor after they are downloaded". The system is set up by expert and staffed by people with minimal skills. The issue of adapting systems to harness the capabilities of workers is not considered.

13.5.3 Summary: the Move to Human Centred Approaches

Any better approach, in line with the principles discussed in 2.4, must avoid the two risks highlighted in the Watervliet and aircraft cases: in the former case the human operator is excluded, while in the latter he or she is given a false sense of integration and of involvement. There are situations where human tasks must be retained, even though they could be "automated out". One reason for this can be the need to ensure the commitment of an operator who would otherwise simply fulfil a role of observer. In such situations, the people concerned must be given meaningful tasks with real decision taking - an intelligent person will always discover when they are duped. It may take some time - but the risks are those of Chernobyl and some of the flight-deck failures leading to crashes.

Rosenbrock [1989] developed an exemplary model of an alternative machine tool programming system, combining several different approaches. His team designed a prototype CNC

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176) in particular, the USA where worker qualification had been kept to the absolute minimum necessary for the job, thus taking into account the widely differing levels capability of immigrant labour, an approach which is reflected even today in the American system of education [Bisang, 1994; Education Guardian 5 July 1994].

lathe controller as a demonstration project to show that the removal of human purpose from the system and its replacement with a mechanistic process results in a more constrained and therefore less powerful solution than the approach which combines human skill and machine capability. In his approach, the operator is presented with a CAD-like image of the component to be made and can then programme the lathe with the number of cuts, speeds and feeds either himself or by accepting suggestions made by the computer, derived from algorithms or earlier inputs by the operator for similar tasks. In general, the operator's inputs override those of the computer although the latter checks for dangerous situations.

13.6 Conclusion to the Case Studies

The case studies outlined in this chapter are intended to show the range of problems encountered in preparing people for work in situations where certainty is low, technical interdependence medium to high and where social needs are important (ref. footnote 14). The experience of the CIM course and of the other unconventional learning environments portrayed shows that patent recipes do not exist. Solutions must be tailored to the needs of the individuals and organisations concerned. Technology oriented solutions may be satisfactory in the short-term but they can only address the problems and issues known and relevant at the time of specification and system implementation. Even so-called 'learning systems' can only be designed to handle incremental change, they do not tend to be able to cope with 'catastrophic change' or with step- function innovation, characteristics of the last twenty years of industrial development. In many cases though it may be worthwhile considering the introduction of rich learning environments, in both industry and academia, offering many opportunities for 'one-shot' learning as advocated by Thorndike (see section 5.6.2.1) and Guthrie (see section 5.6.2.6).

The CIM course at Brunel contributes to some extent to attitudinal change in students even though it accounts for only about one sixth of final year marks and perhaps a quarter of the effort invested (a proportion determined by time sheets kept by students over several iterations of the course). The key objective of creating an awareness of the need to manage change tends to be reached over the eight to nine months' duration of the course. Similar objectives should be set for all students completing an engineering degree programme. However, it should be remembered that a university education was always intended to be just the beginning of life long learning. As a matter of course it would be desirable if graduates moved on to undertake substantial continuous professional development (CPD) throughout their careers.

14 Tools for Teaching, Management and Motivation

14.1 Developing Tools to Assist the Education Process

A number of facets of running a course based on practice based learning deserve special attention. The author has chosen to describe these elements of the process as educational tools which can be used to achieve particular aims within the overall scope of the course, or which assist in its day-to-day running. In some cases the tools are designed to be used by the engineers once they have embarked on their future careers. As the course developed over its life-time it became apparent that certain aspects of the process worked well while others had to be modified, replaced or simply discarded.

While it would be possible to argue that all the tools presented below have been designed carefully and methodically, always keeping the overall course objectives in mind, it must be conceded that most of them developed out of the recognition of a specific problem and represent a response to this need. However, whenever an approach was adopted it was discussed with all concerned and, wherever possible, it was improved in an incremental manner, taking into account comments and the changed composition of the student body.

Although some of the educational tools were developed purely as a means to create or enhance motivation, most had a very specific role in running the course. Examples of the former include the tool 'Social Activities as a Motivational Tool' while a good example of the latter is the use of a matrix structure to guarantee good information flows.

14.2 People, Organisation and Technology at SCANCO: A Case Study Approach to Team Building for Modern Manufacturing

14.2.1 Introduction

The SCANCO[177)] Case Study approach, developed by Steve Evans and his team at Cranfield University, is a well defined and extensively tested tool for the development of systems awareness and team working skills in the context of business systems redesign. It is designed as a multi-stage process during which the participants gradually devise a new strategy for a fictitious company. The approach differs substantially from the "standard" case-study approach of section 7.2: (i) the initial purpose in developing the tool was related to turnaround task forces in industry, (ii) the duration can be far longer, e.g., on the CIM MSc at Cranfield it takes six months, and (iii) the output can be measured in terms of commitment to change and motivation.

In this section the author describes the structured approach used and presents some of the results of applications of the tool as a team development activity on the CIM course and during the NATO ASI on 'People and Computers'[178)] which was based on the work at Brunel. There are is an important cautionary remark: the approach requires experienced, skilled and motivated leadership. A fuller and slightly expanded version of the description of the SCANCO approach can be found in Evans [1994]. It includes, in particular, the experience gained with the approach on a NATO Advanced Study Institute.

14.2.2 People, Organisations, Technology (POT)

In the past the world of engineering was dominated by technology issues as discussed elsewhere in this thesis (see section 2.3.3). Improved machines and processes were perceived

177) SCANCO is the name of a fictitious company whose problems are to be solved by the group undertaking the case study.

178) this experience is included in the dissertation since it highlights the wide applicability of the methods.

as the solution to most problems in manufacturing industry. Depending on whether a company was based in a continental European or Anglo-Saxon country people were considered either as essential to the running of a plant or as a necessary evil. In either case their role was not discussed. The method of organisation of production was often not judged important and was therefore left to ad-hoc decisions.

The concept of POT (already mentioned in section 2.4) is closely linked to that of Human Centred Systems Design where the organisation is set up to use people and technology optimally, according to their respective capabilities. However, most existing businesses are not yet able to translate such ideals into REAL performance change. Creating the necessary understanding and commitment across all personnel involved may be the key which unlocks the potential of a company through a business redesign. A case study based tool, the SCANCO approach, can be used to develop this understanding and commitment. It is designed to clarify the integration issues of people, organisation and technology, highlights implementation pitfalls and thus helps to improve plan quality. It demonstrates to the participants in the exercise that individuals with different skills and experience levels can and should work together to meet a challenging, common goal. The approach is suited to solving organisational and technical problems in a number of situations common to engineering activity.

14.2.3 The Case Study Method

The approach is based on the setting of a realistic task to a group of people, often from different backgrounds[179)]. The method has been used in many different settings, in industry and education. It has been used several times on the Brunel CIM course and was also used during the NATO Advanced Study Institute 'PEOPLE and COMPUTERS - Applying an Anthropocentric Approach to Integrated Production Systems and Organisations', with the twin objectives of creating an awareness of the need to transform companies with human factors in mind and of developing strong teams. The latter function was very relevant to the CIM course[180)] because students from BME and SEP (see section 9) had to be forged into one team. The SCANCO method has its roots in the traditional case study, as pioneered by Harvard University and described in section 7.2. However, it goes far beyond this, both in terms of the highly structured process and the intensity of the experience.

14.2.4 Case Description

The case study is based on a substantive document developed from consultancy with a company. For the purpose of the case the company is called SCANCO, a manufacturer of high precision electromechanical equipment faced with a choice of options regarding its business future. While the example company has been made unrecognisable many of the facts about the company (size, financial information) and the outline of its culture are drawn from the original, only name and product are changed. The company culture and situation is conveyed through a number of verbatim transcripts of interviews with senior management. The participants in the group activity are asked to read and annotate the document in preparation of the session which lasts between four and sixteen hours, depending on the audience and the organisers' objectives.

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179) the Cranfield team use the approach, in general, to focus existing teams on new tasks. At Brunel team members would know each other but not in the context of working together.

180) the SCANCO study would be scheduled for one of the earliest CIM time-slots in each iteration.

The overall goal of the exercise or session is the development of an information systems strategy for SCANCO which has 'islands of computer use' but no integrated business systems. In many industrial situations this is, in fact, the real life task facing managers and engineers taking part in the case study.

14.2.5 Objectives of Working in Teams

The objectives of the exercise are, firstly, to bring together groups of individuals with different skills and to allow them to build a process for cooperation. This is useful later in that they more easily recognise the value of other disciplines' inputs and have a way of co-operating efficiently. Secondly, the exercise clarifies many integration issues; real-life complexity is conveyed and the participants complete the exercise having tackled genuine people, organisation, technology integration problems. Lastly, the exercise is tough. Achieving a sensible result in a short time increases team confidence - an important objective for both the situation on the CIM course and the NATO ASI where serious challenges lay ahead. The aims on the CIM course can be summarised as the raising of awareness of people issues and the development of an ability to generate and assess ideas in a team quickly and in a cohesion supporting manner. On the NATO ASI the main aim was the forming of strong teams.

14.2.6 Organisation of the Case Study

14.2.6.1 Internal Structure

In the instances where the method was applied on the Brunel CIM course and on the NATO Institute the case study session followed a simple structure, based on the principle that we learn more by doing than by listening. After an introductory scene-setting and explanation a cyclical process is established. A schematic overview of the process is shown in Figure 32, although it must be noted that the activities marked with an asterisk were not addressed in order to save time since they did not apply to the situation. For each stage a question is presented by the case facilitator, the teams separate into their own work-areas to develop an answer, the answers are roughly presented to the other teams, teams review their answer in the light of all the answers and then the next question is presented. This process can cycle as quickly as 45 minutes; on the CIM course it was normally 1

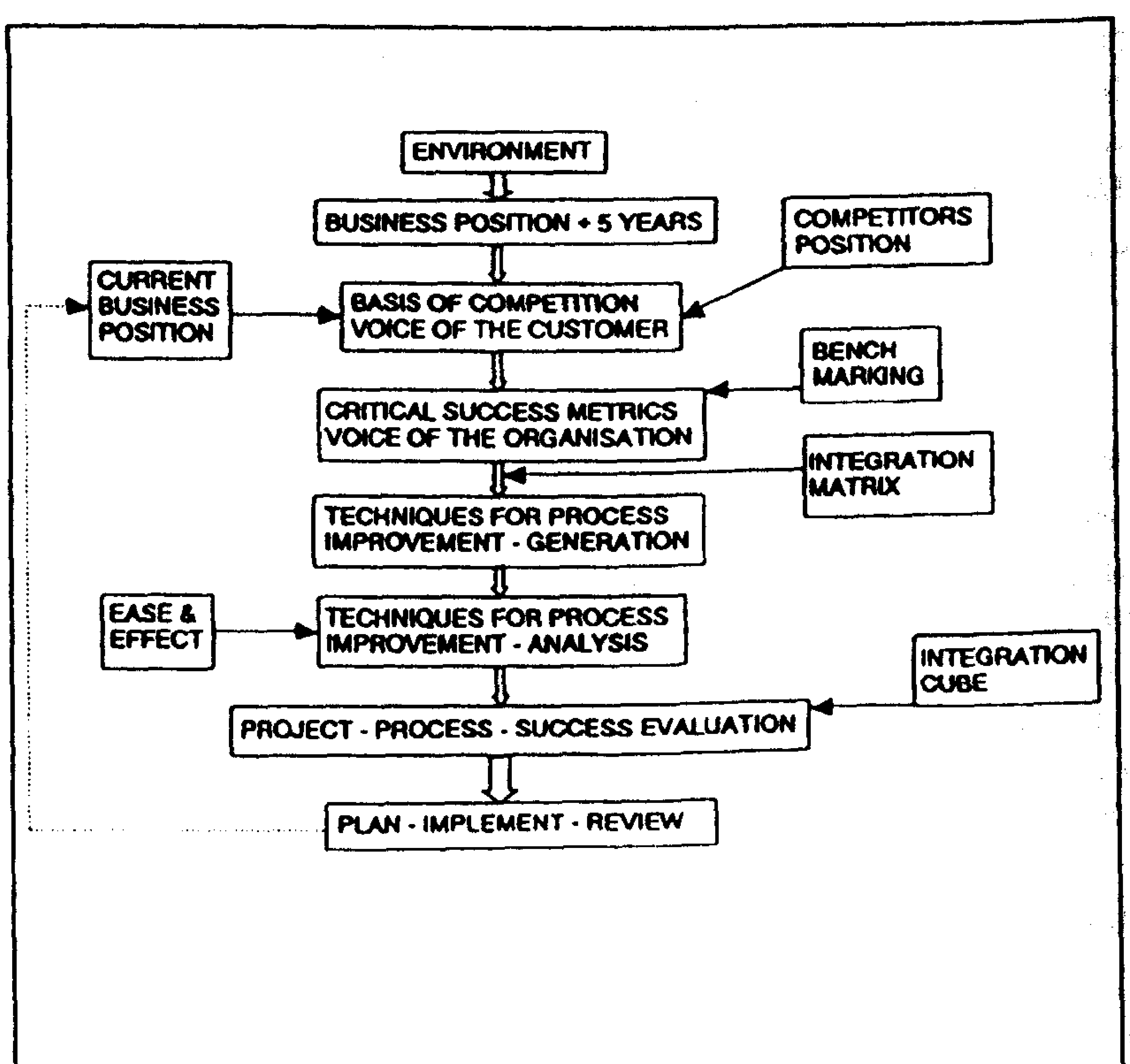

Figure 32 The SCANCO Process

hour while on the NATO ASI each cycle lasted approximately 2 hours (with some opportunity to add unscheduled time to this, such as lunch and evening). The longer period was necessary to cope with the desire for achieving high-quality understanding of integration in practice and to assist multi-cultural, multi-lingual cohesion.

The dividing of the group into teams of about five participants each is needed to provide everyone with a chance to participate. On the CIM course groups are simply designated using a counting method referenced to seating position so as to give people an opportunity to experience team work in a group which is linked neither to their CIM work nor to friendships.

14.2.6.2 Work Flow

The introductory presentation explains all the goals of the exercise, introduces the company 'SCANCO' and briefly explains the environment in which it is operating. But first we must understand the customer - for it is only by knowing for what customers will pay that a company can hope to thrive. This forms the basis of the first question - "Why will SCANCO's customers continue to buy from them?". This question acts as a good ice-breaker as well, because everyone is a consumer and a customer and team members' skill differences are minimized in answering this question. The requirements placed on SCANCO are identified as an ability to be flexible, to respond to an ever-changing customer, to work more closely with customers, etc. This explains the need for a significant change in the way the company operates.

Even at this stage it is possible to see some difference in output between teams. This difference reflects the simple reality that the SCANCO management team can and will make different choices in practice - many of which can be successful. As each question is answered each teams view of SCANCO slowly diverges until the final question - deliver a plan for action - can result in widely different outputs.

14.2.7 POT in Engineering Education

The context which is of most interest in this thesis is that of the demands presented by new education and training approaches, for example, those aiming at a reduction in formal teaching. These require either substantial amounts of individual study or teamwork involving students of varying levels of ability and different interests, the teamwork approach being more appropriate to today's engineering environment. In terms of creating a functioning team out of a group of people this is a most challenging situation. Although there is usually a commonality of purpose (pass an exam) and a relatively homogenous mix of backgrounds there are none of the pressures which can be applied in industry to motivate people into a desired behavioural pattern. Students can rarely be encouraged to perform in a particular manner through an offer of better pay or promotion. Time is usually more limited and more rigidly controlled than in industry, not all subject areas lend themselves to the same approach, exams tend to be immoveable and any tasks are both temporary and part-time.

Since most engineering and management students will ultimately be working in industrial teams it is important to develop an awareness and some of the relevant skills during their studies. Whilst it is possible to impart some of the skills in lectures it is more appropriate to achieve this objective through some form of team work approach even though there are a number of constraints militating against this, in particular the time limits.

As in many other situations, a process of change must be established quickly, a process which improves both commitment to a common goal and which lets experience participants how People, Organisation and Technology can be integrated to get there. Applications of the SCANCO approach on the Brunel CIM course are described below.

14.2.8 SCANCO and the Brunel CIM Course

The SCANCO approach has been used several times on both the undergraduate Brunel CIM course and on the modular postgraduate course, MSc in Advanced Manufacturing Systems (MSc AMS). It is used with different objectives in the two situations: on the undergraduate CIM course it is used to show the teams, different from those normally existing in the matrix structure (see section 11.6), how quickly a group of individuals can be welded together into a task-force. On the postgraduate course the process is used to introduce to the students the concept of 'people and technology' as complementary entities in manufacturing systems. It also gives the students a first impression of the difficulties involved in working in teams. On the MSc AMS course there is no other opportunity to do this even though most students will spend the following six months in industry, often attached to problem solving teams.

14.2.8.1 Observations on the Undergraduate Course

On the undergraduate course, normally, the SCANCO session is introduced about two months into the course, when the students have established their teams and once they have encountered the first problems both in defining their tasks and in working towards a common goal. The SCANCO session has been held four times in this context, twice by the original designer of the process, an external expert (assisted by the author), and twice by the author, with the help of another lecturer. In all cases the session followed the flow described in 14.2.6.2. It may be useful to include here a few comments on the characteristic behaviours observed.

On the two occasions where the writer was involved as a participant observer (see section 14.3) he was moving between groups but remaining with each for at least two tasks. In the activities which involved the generation of ideas or the assessment of ideas, both technical and organisational, there was a clear improvement in performance from one task to the next as the teams learnt to handle time and to allocate roles to the members. Not all teams would appoint chairpeople, secretaries and presenters but most did so quite formally once they realised the pressures. The normal group processes and group roles emerged quickly due to the relative toughness of the situation.

Although the SCANCO activity is not intended to generate tangible results the teams very often produce useful technical and sociotechnical ideas which later on flow into their real CIM work. The human centred approach becomes almost second nature.

14.2.8.2 Observations on the Postgraduate Course

On the postgraduate course the SCANCO experience takes place about five months into the course. A striking similarity between the undergraduate and the postgraduate groups of students is their inability to handle the pressure and time-constraint of the first practical task (the very first task requires only discussion). This task is relatively straightforward: it requires the teams to suggest a number of improvement projects for the company. Towards the end of the time period allotted to this task all the teams expect an extension if they fail to reach agreement on the company's goals during this task.

14.2.9 Conclusion

The aspect of team development is mentioned neither on the MSc course nor on the undergraduate course in advance. However, the groups soon realise that their inability to reach goals during the team work must be addressed. In general this happens towards the end of the second task. At this point groups tend to get organised with the appointment of discussion leaders and scribes. In most instances where the SCANCO case study has been conducted the participants also acquire more of an awareness of the advantages and drawbacks of modern technologies and often come up with novel concepts.

14.3 The Role of the Author: a Participant Observer

The development of people is determined substantially by external influences. Teachers are involved in this process in a number of different ways which extend well beyond the transfer of knowledge and skills. When designing new learning and teaching situations it is important that the intended types of interaction between teacher and learner satisfy ethical principles. In his role of originator and manager of an innovative learning environment the author of this thesis has experienced some of the conflicts arising from close involvement. The issues of manipulation and non-interference, that is, observation, will be discussed in this section in the context of the CIM course.

14.3.1 Manipulation and Role Conflicts

School provides one of the contexts in which socialisation of the individual takes place. Bowers [1984] observed that teachers use communication to shape students and that they often cross the boundary of linguistic manipulation, e.g., by telling a student that she/he is a sensible cooperative individual, by reinforcing particular self images etc. Reflecting on this, the writer of this dissertation has realised that he has at times been guilty of influencing students to behave in certain ways by taking a particular behaviour for granted in his use of language[181)]. This failure to avoid linguistic manipulation was not an intentional modus operandi but it proved to be a very effective tool in achieving ambitious performance targets.

The importance of the issue of influence and manipulation can be gathered by considering the fifth of Bowers' [1984] propositions: "The individual's self-concept is constituted through interaction with significant others: the individual not only acquires the socially shared knowledge but also an understanding of who she/he is in relation to it." Where a student is encountering for the first time a new element or concept, e.g., how to define a researchable problem, he or she is in a dependent relationship with a significant other (the supervisor). In this relationship "the unique challenge for the teacher and curriculum developer is to determine which taken-for-granted beliefs need to be made explicit and examined". The decision not to make explicit a taken-for-granted belief may lead to its unconscious adoption by the student. The issue of manipulation was one of the stimuli which led the writer to review his own position in the context of the CIM course.

14.3.2 Theory and Practice of Participant Observation

Participant observation is a research technique predominantly used in the social sciences in which the researcher studies social interaction directly by becoming a member of the group under observation. Such membership may be overt, that is, the observer tells the group that he or she is a researcher, or covert. In the latter situation the observer adopts a role in the group to disguise her or his intentions. A famous proponent of covert participant observation

181) one example is the description, in conversation, of students as "stakeholders in BCIM", the verbal assumption that all members of BCIM were responsible individuals, another is the constant reference to professional behaviour. The notion of BCIM, the Brunel CIM *Company* in itself encourages the "right" attitudes.

is Günther Wallraff, in his two roles of scandal journalist and Turkish guestworker [Wallraff, 1977 and 1985, respectively]. Both overt and covert participant observers change the groups which they observe.

Overt participant observers (OPOs) often refer to themselves as 'being the fly on the wall', 'melting into the fabric' or 'becoming part of the wall-paper'. This kind of language is designed to suggest that the OPO can report accurately and objectively the performance of the group. However the OPO will often be drawn into the discussions of a group and can influence outcomes simply through body language or refusal to comment. Even though the group situation may be very intense, focusing the attention of virtually everybody present and thereby diverting attention away from the OPO, it is still being modified through his or her presence, as the author himself discovered. The OPO may at any one time perhaps only influence one member of the group but this is enough to change a situation. Any conclusions drawn from the observations must therefore be carefully validated, possibly through the use of non participant observers or through interviews conducted by a non-involved person. Non-participant observation could include, for example, the use of one-way mirrors or video recording of sessions. Unfortunately, the latter also distorts the situation being observed.

An interesting in-between situation is that of actors employed to mime patients in the training of medical students in communication skills for consultation. All the persons involved know that the actors play a role but in the review of the training session the actor has to relate his or her experience of the trainee doctor's approach as though it came from a 'real' patient [Baker, 1988]. Whitehouse, the tutor in charge of this communication training activity, describes a number of aspects of the actors' role: "it was easier for the actors to project the patient's view if they remained 'in role' throughout most of the discussion". "The tutor acts as a facilitator, using his small group skills to encourage the students to participate. An important aspect of his role is prevention of ego damage to the more timid or to those whose interview techniques and sensitivity are especially defective." "... a minority of students may argue, as a defensive tactic, that simulated consultations are merely 'play-acting'" [Whitehouse, 1984 and 1993]. This last point is a constant worry in any teaching activity - the author encountered it only very rarely on the CIM course though.

Covert participant observers (CPOs) tend to play a role, often based on an outline script, which should make them a natural member of the group[182)]. Both police work and investigative journalism often involve the use of CPOs who may well be very effective but whose involvement tends to create a great deal of concern, particularly if they act as agents provocateur. Wallraff played roles which required long planning and training and which allowed him to make strong political statements at the moment of removing the mask. However, in doing so he betrayed the confidence of the group of people whose relationships and behaviour he had been observing. The writer has been trying to find a reference to the use of CPOs in social work, with particular reference to family therapy, since he remembers a discussion of this issue in the mid 1980s, unfortunately he has not been able to do so.

Janet Rachel [Rachel, 1994] describes her observations as an overt participant observer in a project involving major change in a service organisation. Throughout her report she does not describe her own role in the team or her influence on the process although it is clear that she takes sides with the non-technical people involved in the project, in particular with the

182) Examples: N Coggans [1995] reports the results of a study on alcohol and violence where he influences the behaviour of volunteers who believe that they are participating in an experiment concerning alcohol and coordination. He modifies their perception of other staff involved in the process and observes the ensuing interactions. Handy [1985] describes a sociological study where a group of volunteer students were used as experimenters and covert participant observers in their own families: the students behaved as though they were lodgers rather than family members, without telling their parents and siblings, and observed the reactions and resulting role changes.

change management team. The words she uses to describe the workers on the systems technology side of the project indicate that she did not manage to penetrate their ways of working and their concerns.

14.3.3 Participant Observation on the CIM Course

The role of the author on the CIM course had aspects of both overt and covert participant observation. This did not happen by design but was more or less a 'historic accident'. For most of the time during which he developed the course there was never an intention to use this major project as the basis of a PhD thesis. The author was therefore observing the individuals and teams, taking notes and documenting the process only so as to be able to give fair assessments at the end of each course period. He decided to base his PhD work on the process of developing the course just before starting the fifth iteration step. From that point onwards he collected more information and became a 'conscious' observer, declaring his interest to all the people involved in operating the course, that is, students, members of the support team and academic and technician staff. The author thus became an overt participant observer. Even now though there were instances where he was worried about acting in an underhand or covert manner, in particular while being involved in the appraisal process.

A product of the highly differentiated structure of the CIM course is the great number of opportunities for observing individuals, groups and teams throughout the course. The author has not simply observed interaction between students but has also been able to assess the impact of an unconventional teaching situation on the staff involved (see section 17.4).

When he first started to analyse the course the author felt that he was observing its development and the actors as an outsider, that he was simply providing a framework or course structure which was controlled by the coordinators or managers selected from amongst the students. He saw himself as the provider of services such as organising lecturing input, arranging and advertising deadlines, generating the funds to guarantee a high profile development for the course. On closer inspection, however, he realised that his role had been more complex throughout:

Towards the half way mark of the first iteration of the course (academic year 1987/88), the course management, based on a hierarchy with a group of senior executives, was close to collapse because two out of three of the students in charge were failing to provide leadership, were in fact failing to provide any input whatsoever. At this point the author had to intervene and thus started to attend the management meetings involving all the task group managers. As a participant of the meetings he started both to observe individuals and to influence the management process in a more or less didactic manner. He soon took on the role of a non-executive director and thus became a member of the group, albeit a member with more power and authority than the others.

The role of the author of this thesis was at times very similar to that of one of the actors involved in the training of medical students since he was at the same time the customer, the tutor, arbitrator and assessor of the performance of the CIM company team. While it would have been ideal to share out these roles to different members of staff and, in the case of the customer role, to industrialists this was impossible, for a number of reasons. In the case of the customer role (comparable to that of the patient in the situation described by Whitehouse) the integration of other members of staff and industrialists was attempted. Unfortunately some members of staff (section 17.4) proved to be too disinterested in the end-result[183] and too inconsistent to create sufficient pressure on the teams. Industrial people had very clear deadlines and would therefore suffer if a product was not ready on time. However, in one case the development of a software link between two products of different software suppliers was undertaken and completed on time - a very successful proof of the positive influence which can be exerted by a real customer. For practical reasons the author therefore had to remain the end-customer for the tangible 'product' of the CIM company, the working FMS and its support systems.

The other academic members of staff involved in the course managed to maintain the status of external experts even though they were also known as non-executive directors of the CIM-company. This was possible because of their substantially smaller time commitment and their interest which was oriented more towards technology rather than systems and people issues.

14.3.4 Discussion of Instances of Participant Observation

A brief discussion of the specific dilemmas faced by the writer in different situations may be appropriate at this point. The least problematic involvement was his role in the SCANCO Case Study where he acted as an observer of group behaviour while an external expert was running the activity. The first time round he simply participated in a group's work and then fed back his comments to the group. This became more difficult as he became aware of the key objective of the activity, the creation of a close knit team. In subsequent iterations he found it much more difficult to contribute to groups' work because he realised that a group performing too well or too poorly might not benefit as much from the activity as an average group.

Task Reviews (see section 12.3.2) proved to be more difficult because of the triple role of the writer: he was acting as a technical expert, an assessor, as well as being the client for the whole project. He had to be impartial and work, as far as possible, only with the information presented at the review while at the same being expected to manipulate the inactive members of teams to contribute more. He also had to maintain morale when a team faced difficulties outside its own control, e.g., when finances in the Department were tight or when other members of staff were unable to offer the necessary support. In many instances he could have been accused of manipulation and misuse of information, gained as a participant observer with a hidden agenda, even though he documented his attendance at task reviews openly and in detail in his logbook. However, he felt that it would be counter-productive to state explicitly that the main purposes of the task reviews were motivation and technical support rather than the officially 'advertised' monitoring function.

The writer's role in the mutual appraisal process was complicated by the fact that he was being appraised for his role of non-executive board member, while also serving as the final arbiter should there be a disagreement about individual outcomes or the overall result. He tried to handle the conflicting roles by engaging in a limited manipulation exercise designed to ensure that the senior coordinators would discharge their obligation in a way which would avoid the need for intervention: right from the start of each course he would stress to the senior coordinators the heavy responsibility involved in managing an appraisal programme with total honesty. He would convince them that:

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183) this should not be seen as a criticism of the members of staff acting in-house consultants - it is rather a criticism of the British university education system where students are generally not expected to work in a professional manner - unlike the situation in Germany where student projects are often carried out on behalf of industry.

- they were discharging the responsibility for the mutual appraisal on behalf of their fellow students rather than the academics,
- they would be helping colleagues to develop their own potential rather than providing an input to a marking process,
- they should handle the appraisal scheme with this educational, rather than any other purpose in mind.

While this was all true and non-controversial it was also intended to yield a set of mutual assessment marks which would be usable without modification by the examiners. And it worked.

The relationship with the senior coordinators was perhaps the most difficult aspect of the writer's role. He had to be their mentor, manager, tutor and confidant. He also had to assist by arranging mundane things, such as photocopying and access to stationery. He had to teach the senior coordinators how to manage other people in a collaborative manner while ensuring at the same time that he was not perceived solely as the ally of the senior coordinators - he had to remain everybody's ally. Although he was not formally aware of this, the writer was also providing supervision for the senior coordinators, in the sense described in section 14.4, supporting and guiding their own development.

In a fully resourced course environment, planned in advance and in great detail,n ideal world, some of the roles would have been taken on by different people. On the CIM course the writer became responsible for all of them during the first iteration, more or less by default. Since the arrangements worked reasonably well, the combination of roles was retained for the subsequent years. Although the writer made a conscious effort to separate the different obligations in his mind he made mistakes which resulted in demotivation and confusion. Whenever he became aware of a mistake, having been prompted by a member of CIM or realising that the atmosphere had changed, he would explain to all the people concerned what had happened and would seek their advice on the best route to rectification. An example of such an incident is described in section 13.2.10, concerning an injudicious remark about the importance of a number of tasks. Ideally thus, a number of people should share the tasks involved in motivating, controlling and assessing the course.

14.3.5 Summary

Several lessons may be learnt from this discussion: when designing a practice based learning environment it is important to share out management roles, at the very least, to divorce the role of client from that of overall manager and both from the role of assessor. The use of manipulation, even with the best intentions, should be minimised since it can lead to uncontrollable situations. The tutors charged with facilitating learning in such an environment must decide at the beginning whether they operate as observers in an arms length relationship to the senior coordinators, with the overarching objective of a fair assessment, or whether they wish to become overt participant observers, in a position to monitor and support the learning processes much more closely. Tutors should be trained to handle supervision at a professional level because the strain on students given management responsibilities can be very substantial. A possible approach to this is described in the next section of the dissertation.

14.4 Good Leadership, Supervision, Teams and Team Success

Gregor and Hansel's book on 'Innovative Project Management' [Gregor, 1993] offers a number techniques for improving the performance of project based management which is characterised, in their terms, by dynamic company structures where hierarchies and reporting relationships change continually. While project management and "supervision" are both highly relevant to the thesis, the aspect of coaching[184)] is not germane to the present discussion and will be omitted. Gregor and Hansel show why and how project oriented management differs from traditional hierarchical (line) management and then discuss the use of "supervision" as a tool to develop managers' potential.

Similar to participant observation, discussed in section 14.3, "supervision"[185)] is a tool which was originally developed for the social work field, designed to provide support for both individuals and teams, regardless of whether participants were experienced or not. It has become an accepted method for supporting project managers, particularly in Germany. It is included in this study because of its relevance to project oriented management, which resembles the management approach adopted for the CIM course from its second iteration, namely, a flat hierarchy, where students are integrated into small task and skill teams. The resulting matrix places the same types of demands on team members as a project management approach.

14.4.1 Implications of Project Work for Team Leaders

Gregor and Hansel's five dimensions of project management were discussed in section 4.6 and illustrated in Figure 9. The requirement to cope simultaneously with all the dimensions places great demands on the project manager, that is, the engineer required to work as a project team leader. He or she must deal with complexity at different levels, must design innovative processes (which may face opposition etc), and has to cope with insecurity. The tasks involve implementation of suitable structures, managing interdisciplinary teams, working within time limits, balancing of freedom and independence against constraints.

The mix of qualities, faculties and knowledge needed to run a team depends on the level of significance of each of the five dimensions of project management, as applicable to a particular situation. What do I represent? What do the team members need? should be the first questions which newly appointed leaders ask themselves. According to Gregor and Hansel, the most frequent problems in coping with a leadership role are:

- the person is not prepared for handling power,
- the person appointed as leader was a team-member before (peer management),
- the person is given inadequate authority,
- the person fails to deal adequately with formal administrative duties (planning, control or resources etc),
- the leader's model of leadership is determined by her or his background, rather than being their own 'model'.
- the person is not prepared or not ready for change,
- the person tries to avoid political and emotional issues,
- the person is 'suddenly' faced with reduced motivation.

In general, it is not possible to avoid problems of this nature without making a substantial investment in good selection methods and in training. Such assistance is available in many large organisations. Some was provided on the CIM course in the form of seminars and

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184) the social psychology technique of 'coaching' is concerned purely with the individual and her or his internal conflicts.

185) in this context, a technical term referring to a mixture of counselling, group based (personal) problem solving and career planning [Gregor 1993].

workshops run by external experts, J. Elvy and P. Wilson. They covered topics such as team selection, decision taking in teams, discussion management, listening skills, and information handling for groups. Even where a substantial level of support is available though, Gregor and Hansel warn that 'first time right' must never be a priority of innovative projects. They also highlight that power and politics are important in any organisation and cannot be ignored. Indeed, experienced project leaders have the skill to take the power they need to run the project, but no more.

Successful leaders tend to be those who develop their skills 'on the job' but not without guidance and support. Gregor and Hansel describe this process as holistic leadership and qualification.

14.4.2 Alschuler et al. on Team Leadership

Alschuler et al. [1970] have also addressed the issues of managing teams and outline specific requirements for people leading groups: they must not only help the group accomplish its task and goals but must also accept responsibility for group maintenance and thus must be watchful of group processes:

- how is the task being carried out?
- what are the interactions in the group?
- is everyone contributing?
- are people apathetic, angry, distracted, keen?

If they are to function effectively, task leaders must therefore be able:

- to listen superbly,
- not to compete with members of the group or struggle to have their own ideas heard,
- to let everyone have a say and use every team member,
- to intervene in ways which clarify what has happened or let somebody else do so,
- to help people take responsibility,
- to support the learning of positive assertive behaviour.

"Getting on with the job" and ignoring group processes allows a group to deteriorate very quickly. Groups need training in how to work together - especially so if the leader is neither a recognised expert nor elected by the group, a process which democratically bestows authority on her or him. Leaders on the CIM course are elected by their peers in a relatively involved process which has so far led to a substantially successful team management arrangement (refer to section 14.6.3 for more details on the election of leaders). This is also noted by Gregor [1993]: a task oriented but democratic leader can create a strongly achievement oriented environment. There is more to team success than constant chanting of: "we are great!", team success must be achieved through hard work.

14.4.3 Supervision as a Support Tool for Teamwork

"Supervision" as a method for supporting people in their roles exists in many domains on an informal basis, e.g., mentors for staff and tutors for students in universities, and has been a codified field of research since about 1880. There are three types of supervision: individual, team and group supervision. The process of supervision can be arranged within the team or by working with a group of individuals from different teams or even different organisations. In all cases supervision is used to address the problems of individuals working with other people.

The fundamental assumption underlying the approach advocated by Gregor and Hansel is, quite clearly, derived from psychotherapy and developmental psychology: these promoters of supervision relate both the functioning of teams and the performance of individuals in management functions and in other team roles to childhood experiences and people's perception of themselves. These come to bear not only in the relatively unstructured environments of social work teams but also in project teams which operate outside conventional (hierarchical) line management structures[186)]. People must develop body-mind-soul-unity to become real 'persons'.

According to Gregor and Hansel, and the proponents of generic management skills[187)] people in charge of the supervision process must have a well developed organisational background but need no specialist knowledge of the projects undertaken by the people who are expected to benefit from the supervision.

In the writer's experience, this is does not tend to be true for the context of advanced technology where problems are often caused by poor system design, inappropriate equipment and unreliable interfaces, and software which is not stable. A manager of a technical team, with some broad understanding of the technical issues involved, will be able to provide clues and more directed support in the search of a solution. A case in point was the development of a highly complex piece of multitasking software by two students on the CIM course, working in a virtually symbiotic relationship. Quite regularly, they would hit intractable problems with either the hardware or the software of the device. The writer had experience of similar computer problems, albeit at a far lower level of complexity and involving technology belonging to an earlier generation. However, he was able to help the team concentrate on the most profitable avenues towards solution, on the basis of technical knowledge. Even today, there are major difficulties associated with the selection of the most suitable computer hardware and software and mistakes can lead to near-insurmountable hurdles at implementation time[188)]. Managers of advanced technology projects must have a good grasp of the major technical issues involved.

Although the whole of the practice based learning on the CIM course is managed as a large project, embedded in a line management structure, supervision is a tool which has not been explicitly used but which has existed implicitly, without a label of any kind and under far from ideal conditions. The task review method, for example, conforms to Gregor and Hansel's concept of review meetings taking place in small groups for integrative control through interaction. The supervision approach could be introduced formally on the CIM course and could then have an important teaching and management role. Another example of informal supervision is given in section 13.2.8. Situations similar to that described arose almost every year in the collaboration between the member of staff responsible for CIM and the senior coordinators.

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186) this is certainly familiar to members of university staffs who tend to work in unstructured but highly competitive environments - mostly without support. A more formal and better structured mentoring system could be of great benefit to institutions and individuals alike.

187) who would contend that managers with situation and technology specific training are no more effective than generalist practitioners

188) an example of this was the introduction of SELTRAC on London Docklands Railway, delayed for more than two years because the hardware and software were not compatible with the system.

14.5 Task Reviews for Monitoring and Feedback

14.5.1 General Background

The students participating in the CIM course cannot be considered experienced project managers, even though they would generally have worked as members of project teams before joining the course (either as part of industrial placements or other parts of practice based learning on the programmes. Both the task leaders and task engineers thus need support on a continuous basis. Task reviews are therefore held regularly, about once per month, with each of the task teams. The tasks and teams are usually shared out along a technology / organisation divide between two teams of reviewers, made up of two members of academic staff each. This takes into account the particular backgrounds and skills of the staff involved. However, at least once each year the share-out is reversed, in order to give all members of staff at least a glimpse of the work of all teams and also in order to give the teams access to more and different consultancy resources. Depending on the academic year concerned one of the senior coordinators would also be present during the review session, so as to be able to assess progress on the task for coordination purposes.

The students view the task reviews as the only compulsory element of the CIM course, even though a student who does not take part would not be penalised. This perception is a result of the type of behavioural modification described in footnote number 181. However, their uniqueness in environment (a proper meeting room), the presence of two members of academic staff for the exclusive use of the five or six students, the realisation that the reviewers assess the functioning of the team, and other less tangible factors, combine to ensure attendance. Each year only one or two members of teams fail to attend without excusing themselves in advance and only about ten absences are notched up in total, all for good cause.

14.5.2 The Task Review as a Debriefing Situation

Stewart [1992] cites Makay and Brown's [1972] list of ten conditions for dialogue which can be applied to debriefers and participants in experience based learning situations, and are equally applicable to appraisal situations in industry and academe:

- Human involvement from a felt need to communicate,
- an atmosphere of openness, freedom, and responsibility,
- dealing with the real issues and ideas relevant to the communicator,
- appreciation of individual differences and uniqueness,
- acceptance of disagreement and conflict with the desire to resolve them,
- mutual respect and, hopefully, trust,
- effective feedback and use of feedback,
- sincerity and honesty in attitudes toward communication,
- a positive attitude for understanding and learning,
- a willingness to admit error and allow persuasion.

Both the staff and the team members involved in the task reviews should adhere to these guidelines if the process is to be optimised in its contribution to the practice based learning cycle (see section 7.4).

14.5.3 Motivation and Risks inherent in Review Meetings

In 1990/91 the writer made the mistake of stating in a task review that, in his opinion, task B5 was of relatively low priority. This was immediately seized upon by all the team members but not mentioned at the time of the review. It was only brought out into the open when a problem arose with one of the senior coordinators. This was clearly a failure on the part of the author who had, for a very short moment, underrated the significance of the task reviews. He had already run a number of reviews on that day and for him it was just a job. For the team members, however, it was the first contact with the hierarchy, with the people who would be responsible for marking the course and who could influence individual students' degree results!

It is important that members of staff involved in task reviews are seen to be interested and involved in the process (posture control during meetings!). Students expect and deserve note taking and serious questioning. They must be given consistent support and advice in the task reviews so as not to lose motivation. The review is the key management and motivation instrument on a practice based course of this nature. During the appraisal of staff members' performance at the end of each course, criticism was always voiced most strongly if the members of staff responsible for some of the reviews had not taken this role sufficiently seriously.

14.5.4 The Final Task Review

An important element of the course assessment is the final task review which takes place at the beginning of the summer term, following completion of the final reports (handover documents), at about the same time as the second phase of the mutual assessment and before the start of exams. It differs from the standard task review in several important ways, most notable being the duration, one hour instead of half an hour, the presence of all the staff reviewers in each session and the existence of guidelines for its assessment which the teams receive beforehand.

The meeting is chaired by the staff member responsible for all of CIM who stresses in his introduction the importance and seriousness of the occasion. Task leaders would have been asked to prepare a formal presentation outlining achievements and failures of the team. In general they will use overheads and clear summary sheets for a ten minute talk. Each member of the team then presents her or his own work in an informal manner, that is, without prepared notes or OHPs. This is followed by a general discussion during which the reviewers try to gauge group cohesion and also the level of awareness of the performance existing in the team. They also give feedback to the team on the overall performance as viewed by involved outsiders. Often the meeting then adjourns to a laboratory area for a demonstration of the results.

The guidelines specify that the reviewers will expect to be introduced to the targets set by the group and to the extent to which these have been fulfilled. They will judge the quality of the presentation, the technical quality of the work carried out, and the way in which the task was managed. They also try to gauge the attitude of the group as well as the manager's performance.

At the end of each task review the members of staff discuss the performance of the team in private and award both individual and team marks which are weighted as follows:

Overall Individual Performance[189]	weight = 2
Overall Performance of Group	weight = 1
Presentation of Results	weight = 1
Technical Quality of Work	weight = 2
Task Management	weight = 2
Attitude of the Team	weight = 1
Achievement vis-a-vis Targets	weight = 2
Task Manager's Performance	weight = 3

The mark for the task manager's performance is only taken into account when calculating the manager's mark for the task even though it might be argued that the group can also influence this aspect of the work. For several years, the results of this assessment, as well as those of the final reports, were entered into the final calculation with a weight of 1.0 for the task where an individual had made his or her most significant contribution, while the weight for the second task was 0.7 and any further tasks received a weight of 0.3. The general weighting scheme is illustrated in Table 22 on ?, while the complete spreadsheet for academic year 1990/91 (which followed this approach) appears in appendix J. In 1992/93 the method was changed to weight the task performance accurately, in line with people's percentage contributions to tasks. In 1993/94 the scheme was changed again, as indicated in the table.

14.6 The Selection and Appointment of Managers and Team-Leaders

14.6.1 Introduction

In most industrial enterprises managers are appointed by their superiors on the basis of their (perceived) past record and their estimated leadership potential. Very often external appointments and promotions are the results of more or less objective assessment and appraisal processes. One of the few exceptions to this rule is SEMCO, already discussed in section 15.3.2, the company reshaped by Ricardo Semler [Semler, 1993]. In this organisation, managers' appointments are made in consultation with the workforce, preference being given to existing employees if they satisfy at least 70% of the requirements for the post. They can be removed from office by the members of their work teams if they do not maintain an adequate standard of performance - assessed through a multiple choice questionnaire distributed to subordinates twice a year.

Albeit very successful, this arrangement is quite clearly highly unusual. It is unlikely that it will be adopted on a substantial scale elsewhere. However, some companies have started to consult staff at different levels before making some appointments, an example of this is given by Walton [1987] who discusses a company implementing AMT who involved both the management and unions in selecting the teams for the new job roles being created. Disregarding the wishes and input of employees can sometimes lead to lack of acceptance or the resignation of key staff.

Although the CIM course described in this thesis is intended to reflect a real world engineering environment as accurately as possible, it was realised early on in its development

189) in the final task review, under normal circumstances, the Overall Individual Performance mark would be the only one relating to an individual member's contribution. In a very few cases though team members received marks different from those of the team in other areas, but only following consultation with the senior coordinators.

that the manner in which the management hierarchy for the Company is incorporated can have a very important influence on its successful operation. Indeed, it was found that the selection and appointment process could be used to good effect as a team-building and motivational tool. It was therefore decided to test different approaches to the selection process. Table 25 gives an overview of the approaches tested. A major benefit of directive involvement of the lecturing staff, not mentioned in the table, is the possibility to create gender balance and to ensure that people from different backgrounds are represented at all levels of the organisation.

The approaches discussed were applied and successively refined to take account of experience. It must be stressed that it is essential, regardless of the approach chosen, that future 'managers' be consulted in advance with respect to their willingness to take on an extra workload and more responsibility. This is highlighted in the paper by Walton [1987] who reports that in many of the plants investigated this step of highlighting the increased work load and responsibility reduced the number of people willing to take on supervisory roles or roles involving technological change.

A number of different voting systems exist and are used both in the political sphere and in non-profit making organisations, such as trade unions. Several of the systems were tested[190] in the different scenarios outlined in section 14.6.2 for their suitability for appointment as managers and team leaders. In the end, a relatively complex voting system was adopted on a permanent basis. Table 23 is used to summarise some of the systems, currently used in

Voting System	Benefits	Drawbacks	Preconditions
Election by Simple Majority	very simple to use, well known	may disenfranchise a majority of voters	few candidates and clear differences
Single Transferable Vote (STV)	ideal system for selecting representative candidates	needs high number of seats to result in good distribution	minimal size of electorate is relatively large
Proportional Vote	representative of opinion among the electorate	complex to understand and administer, leads to coalition management or government	large electorate with one constituency or several multi-member constituencies needed
Weighted Transferable Vote	likelihood of electing acceptable compromise candidates high	open to some manipulation by the person running election	good explanation of the system, trust in administrator

Table 23 Comparison of Voting Systems and their Effects

elections both for parliamentary and public bodies[191], and to indicate their merits and demerits. From a study of the relevant literature [e.g., Newland, 1982; Lakeman, 1991] the single transferable vote method is the clear favourite in terms of producing results which reflect voters' opinions. However, its administration is not straightforward. It also works better the greater the number of people to be elected in a constituency. Its usefulness on the CIM course, where only two or three senior coordinators need to be elected in a first round of voting, is therefore limited. In the case of electing task and skill leaders it is the limited

190) due to time and resource pressure, only one method could be used in each iteration of the course, i.e., a direct comparison of the different electoral schemes with the same group of students cannot be made.

191) the Association of University Teachers (AUT), for example, has adopted the Single Transferable Vote system.

size of the electorate compared to the number of people to be selected which stymies the method.

The eventual 'standard' method chosen by the writer for the election of the senior coordinators, is a variant on Borda's points system using arithmetic weighting[192] where the results of several rounds of voting are each multiplied by a coefficient specific to the round or preference level (normally decreasing). This system is criticised by Newland [1982] because it can reverse the results of the first round of voting. However, this is a potentially useful feature in a situation where it is important to select not necessarily the most popular candidates but the most generally accepted. The procedure as used by the writer is reliant on secret[193] voting with the counting being transferred 'live' to a white board used to manage the process. The candidates for the senior coordinators' posts, known from the skill cards or nominated by their colleagues, are listed on the white board in alphabetical order and each member of the electorate (all the students for whom CIM was compulsory or who were choosing the CIM option) then write preferences against each name on a slip of paper. Each

Candidates ⇒	Votes per Candidate (and Multiples)								Σ
Voting Rounds ⬇	C1	C2	C3	C4	C5	C6	C7	C8	
First Preference	2	6	11	3	1	7	10	8	48
times 3	6	18	33	9	3	21	30	24	144
Second Preference	0	2	20	3	0	15	5	3	48
times 2	0	4	40	6	0	30	10	6	96
Third Preference	0	2	22	1	0	16	5	2	48
times 1	0	2	22	1	0	16	5	2	48
Fourth Preference	0	2	22	1	0	15	6	2	48

Table 24 Synthetic Example for Voting Pattern using Weighted Transferable Vote

student must allocate preferences for each of the candidates. If there are eight candidates as in the synthetic example shown in Table 24 each member of the electorate must list a preference against each candidate.

The example has been designed to illustrate an outcome which occurred on two occasions: in the case shown, candidates C3 and C7 attracted the highest number of votes in the first round of preferences. In the second round, however, candidate C3 increased his acceptability while candidate C6 overtook C8 and C7 who were popular, as evident in round one, but not as generally acceptable. The third round confirmed this trend. In both course iterations where such a pattern emerged, the selection was very successful, resulting in strong teams of senior coordinators. While it would have been possible, theoretically, to use Borda's method to the full extent, that is to say, multiplying first preferences with a factor of 8, second preferences with one of 7 etc, it is clear from a study of the table that no changes were to be expected beyond the third set of preferences. This third set shows, on the one hand, an improvement of the position of C6, thus indicating further that she was a good compromise candidate. On the other hand, it shows a very poor result for candidate C8. In the experience of the writer, this voting process attracts virtually no criticism and has not led to complaints from the people eliminated after having scored highly in the first round! This can be attributed to a

192) J.C. de Borda, French mathematician and mariner, 1733-1799.

193) in the early years of the course the voting was done very rapidly by arm raising.

careful introduction where the importance of having a leadership creating team-cohesion was emphasised.

14.6.2 Year by Year Description of Appointment Procedures

The first CIM course of 1987/88 was characterised by a very primitive approach to appointing what were then called directors. This happened as a result of the time pressure and the lack of the early motivation phase mentioned in section 12.1. The technical, financial and personnel directors were elected by a simple single-round majority voting process with candidates from a small range 'vetted' by academic staff. Out of the three people chosen, only one fulfilled the role as expected, while the other two relied on applying pressure during the meetings involving all the tasks managers as the sole means for maintaining the momentum of the course. This did not work well, but their behaviour could be excused to some extent since the "directors" were at the same time acting as task leaders and thus perhaps overextended.

N	Summary of Method	Benefits	Drawbacks	Pre-Conditions
1	Selection and Appointment by Lecturing Staff (LS)	good information available, easy to administer	major effort necessary to create a good team	all future course members must be known to LS
2	Volunteers, Appointment by LS	easy to administer, good initial communication channel	non-selected volunteers may become disaffected	early motivation essential, good knowledge required
3	Appointment of Senior Coordinators (SC) by LS, Appointment of TL by SC	good information available, initial commitment can be generated	senior coordinators given great deal of responsibility, too much for comfort	senior coordinators must be 100% trustworthy and well known to staff
4	Selection of Candidates by LS, Appointment by Teams	elimination of unsuitable candidates possible, creates good commitment	team rivalry may leave students disaffected if not elected	introduction of candidates and election process critical to success
5	Volunteers and Nominations, Vetted by LS, Voting Process	excellent way of creating lots of commitment with little risk	LS perceived as assuming role of 'big brother': can cause early mistrust	students know each other and are prepared to take reasonable decisions
6	Volunteers and Nominations followed by Voting Process	best way to create total commitment and well supported leadership	management of election process essential to assure fairness	students must trust each other and must be mature in their behaviour

Table 25 Selection Models for Managers

The year 1988/89 saw the introduction of matrix management and the adoption of election method (1) described in Table 25. This process was based on collecting a great deal of information from all the members of staff in the Department, choosing two managers coordinators and then jointly with them appointing the task leaders. The skill leaders were appointed later, based on the managers' and task leaders' views of their fellow members of CIM. The choice of one of the managers was a success while the other was not as effective as necessary. This proved a substantial drawback, especially so since with a very large course had to be run in that year. There was a great difference in approach between the two leaders: the active manager was very keen on pastoral care but unable to provide technical support to teams. The other manager saw the key role as the chairing of meetings but was unwilling to monitor progress. While his technical knowledge was better he was not prepared to provide leadership. A direct result of this relative failure[194] was the change from the titles of "director" and "manager" to that of "senior coordinator" - a designation which highlights the key duty, coordination of all activities, and the position, that of "primus inter pares".

In 1989/90 early motivation had started to have an effect and substantial numbers of volunteers came forward, allowing adoption of a combination of the election methods (2) and (3) which also involved discussions with the two senior coordinators, once they had been appointed by the lecturing staff. One of these proved to be an excellent choice while the other selection led to the results reported in the case in section 13.2.3. The choice of a seemingly very good candidate turned out to be the result of a popularity test (amongst academic staff) rather than a competence based decision.

Method (3) was used on its own in 1990/91, but strong vetting took place before the discussions with volunteers and nominees started. "Unsuitable candidates" were asked to stand down. For most candidates this worked well although the case described in section 13.2.4 provides some interesting insights into problems which can arise from such a procedure. Out of the three senior coordinators of this year[195] two performed well while the third had no problems with the other members of the CIM course but appeared to be taking things easy from the point of view of the lecturing staff. He may well have been just the right person for the job but he missed a number of important deadlines.

1991/92 was the first year in which CIM was an option for all the students. As a result the procedures for appointing senior coordinators were changed. Method (5) was adopted this year, together with a first attempt at using weighted transferable voting. This resulted in a very good choice of senior coordinators although one of the two was perhaps too good a manager... He managed to delegate most of his work. However, the overall output of the group was very remarkable.

Method (6) was adopted for 1992/93 since it was felt that vetting did not bring any particular benefits. In this election Borda's modified method proved a great success because it resulted in the appointment of the leaders whose performance is reported in the case described in section 13.2.8.

In 1993/94 the voting system was changed again to a simple majority vote which may have been one of the reasons for the development of a difficult situation as described in section 13.2.9. The decision for this change was made because the new course tutor felt that a more complex system was not warranted for the quite small number of students involved. In 1994/95 the voting arrangement was revised back to a preference system where electors allocated a decreasing number of votes to the different candidates in one round of voting, the Borda approach. This method was felt to be better than any of the other methods used since there was neither time nor need to dwell on the discrepancies between the results of two rounds.

Method (4) in Table 25 was never used since it was not expected to yield any particular benefits. The experience from using a range of voting systems has shown that an approach based on Borda's method, supported by vetting of candidates, is best suited to the election of viable coordinators, often the kind of choice described as "a compromise" in politics. The criticism levelled at Borda by some authors relates to the possibility of an election yielding an outcome which is not the first choice of a direct majority. However, a senior coordinator,

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194) as a whole, the iteration proved a great success. Commitment to the company was very high indeed among 85-90% of the year group and so was the general level of activity.

195) a new departure to allow for the inclusion of an SEP student in the senior management team - SEP members now made up about 15-20% of students on CIM.

chosen for competence[196] and acceptability, may not emerge in a ballot based on a simple majority decision such as that used for Members of Parliament. Eight instances of the course have shown that competence and acceptability are the key qualities for successful operation in a situation where "natural authority" or straightforward popularity might backfire.

14.6.3 Choosing the Task and Skill Group Managers

Different methods can be used to choose the 'second layer' of a hierarchy. In most industrial organisations appointments will be made by senior managements either by promoting existing members of staff or recruiting new staff from outside. Many different approaches can be used to achieve a desired result, e.g., personality testing and human resources consultants. In a university context, or indeed in any educational context, it is generally more difficult to obtain a satisfactory result.

On the CIM course, task leaders were chosen using different approaches. In the first year, task leaders were recruited from the candidates for the management roles, with volunteers filling the remaining open positions. For the second iteration discussions took place over the summer with the future senior coordinators and the people interested in taking on management roles. Decisions were then taken by the non-executive board. This was not an ideal solution even though it worked reasonably well. In later years, unsuccessful candidates for the coordinators' positions were automatically considered for the task and skill leaders' positions[197] although the list would be augmented by the other candidates who had indicated a willingness to take on leadership roles on the skill cards (see section 12.1.4). A further vote would normally be needed to reduce the number of candidates to the number of 'posts' available. The task and skill allocation would then be resolved in discussions between the coordinators and the leaders, based on the skills needed for a particular role.

Wherever possible, task leaders were chosen on the basis of their potential project management skills while skill leaders tended to be chosen with the objective of providing the best possible support to the people involved in using a particular skill or set of skills in different tasks. The position allowed people, not natural leaders but experts in a particular domain, to gain experience of managing several others without the high performance expectations placed on a task leader. Even though the situation did occur that a student had a very strong urge to become a team manager this was quite rare (see section 13.2.4, for an example). Only two students left the course during the author's tenure because they were not made team managers.

14.6.4 Choosing the Members of Task Teams

There was no attempt to create a formal system for selecting members of task teams. The basic requirements for integration in a particular task team was the availability of subtasks matching an individual's skill profile (which includes the 'willingness to learn' factor) and her or his interest in the task. In most cases the choice would also be based on the expected ability to work together, an important consideration: once the task teams had been set up there was no mobility between tasks even though mobility and the scope for change are the reasons cited most frequently for choosing matrix management structures.

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196) the term competence is used here in its colloquial meaning of an acceptable level of skill in all the dimensions of project oriented leadership in line with Gregor's [1993] requirements.

197) the situation did not arise that a student marked the skill card (see appendix N, O) to be considered for a coordinator's position but not for a team-leader's position.

14.6.5 Conclusion to the Discussion of the Election Process

The selection processes involved in setting up the course team for a practice based learning activity are critical in generating the right level of commitment and motivation. The methods adopted for the Brunel CIM environment have worked well although constant improvement of the processes involved is essential to ensure that each student benefits as much as possible from the experience while also contributing to the success of the team as a whole. So as to achieve this team objective the selection process must also create a learning and working environment geared towards 'real' outputs in terms of hard and soft systems development and information transmission.

The objective of allowing each student to benefit fully from the experience can be furthered by allowing students to work in several roles, one of which should be that of task engineer. In two (non-consecutive) years the senior coordinators were allowed to have no involvement in a task, a decision which was beneficial for the course, by allowing them to invest more time in managing the BCIM team as a whole, but which failed the senior coordinators by not giving them the opportunity of working on technical or business related tasks under supervision - an important experience for any young engineer.

14.7 Information Transfer from Year to Year

Space and time do not permit a detailed examination of this method of teaching and motivating the members of the CIM course. However, it may be useful to highlight the great burden of responsibility placed on students in as far as the transfer of information from one year to the next is concerned. The technical and managerial reports are only one element of the process, others are the direct briefing in presentations organised for the next group of CIM members, the preparation of videos and introductory brochures and the proctoring scheme established in one of the academic years. Since much of the information is tangible and available to all students there are significant incentives to do better, to make less mistakes and to avoid 'lies' - a recurring theme when CIM members reviewed the work of their predecessors!

14.8 Technology based Tools - Hardware and Software

As mentioned elsewhere in this thesis it is not essential that the technical equipment made available to the students conforms to the latest state-of-the-art but it is important that it represents good industrial practice. The only manufacturing equipment available for the first iteration of the CIM course were desk-top machine tools (lathe, milling machine and teaching robots) without direct numerical control (DNC) interfaces and a laser height gauge with a non-standard interface. The computer equipment though was up-to-date and included several IBM AT and XT machines. A computer network was established using an early RS232 multi-port card and most of the project work was directed at developing the necessary communications hardware and software although some more electro-mechanical tasks were also addressed, e.g., the design of remote-controlled chucks for lathe and mill. Much work was also involved in modifying, setting up and controlling a tracked transfer vehicle[198)] linking the work stations. Quite clearly, the whole arrangement had to be improved quickly if the learning situation was to become realistic as demanded in sections 5.6.2.1, 5.6.2.6 and 9.5.1.

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198) This work was linked to control engineering laboratories run for the year 3 students. The writer devised an open ended laboratory activity for these students where one group would hand over its results to the next group who would then continue the software development. The benefits of this approach were the introduction of the students to the concepts of CIM and their exposure to uncertainty.

A first step was the introduction of IBM-Net, based on the Token-ring technology. This computer networking hardware and software proved to be unsuitable for an industrial environment because of the high levels of electromagnetic interference (EMI) and the less than rugged components from which the system was built, essentially for office environments.

Whenever funds became available, the system was improved to include more and more industry standard equipment. Over the duration of the writer's involvement in the activity there were two changes of lathe, culminating in the purchase of a slant bed multiple turret machine, a sequence of robots and other handling equipment, and the introduction of a full scale five axis coordinate measuring machine, as well as a four axis mill with automatic tool changer. The computing equipment was also upgraded with the purchase of IBM PS/2 computers running under OS/2. For three years the Brunel CIM team was at the forefront of communications technology as a result of the use of the adoption of an RIC card (specialised communications processor for IBM computers) for the data and information transfer within the cell. The team's use of the operating system OS/2 was also highly innovative since piece-parts moving through the cell were associated with individual processes running on the computers, created and removed whenever a part entered or left the cell. The cell control was thus highly dynamic and adaptable to the introduction of new equipment and new product designs.

In a fairly typical year, 1992/93, the equipment list presented itself as follows:

3 off IBM PC compatible 486 work-stations for design and manufacturing control, networked with

2 off IBM OS2 Microcomputers with multiport interfaces for cell control, linked to

4 off IBM PC compatible 386 Microcomputers linked to one of:

1 off STÄUBLI-UNIMATION 500 6-axis robot (with VAL 2 Controller) for materials handling for quality control and cleaning,

1 off FANUC 5-axis robot with half-axis gripper conversion[199)] for machine tool loading and unloading,

1 off KEMCO DNC coordinate measuring machine,

1 off DENFORD milling machine with automatic tool changer, and

1 off TRAUB slant bed lathe with 6 position turret (replacing a basic DENFORD lathe);

1 off tracked AGV and conveyor system, washing stations, orientation devices, all directly controlled by computer.

Human centred software, produced by a software house with close links to the University, is used for production management while design and the creation of machine tool programmes rely on state of the art off-the-shelf packages. Interestingly, the control of the manufacturing cells[200)] is founded on in-house developed software, using novel object-oriented approaches. Although initial development of this software was undertaken by the students, this responsibility had to be taken on by an academic member of staff once the concepts became more difficult and the language (C^{++}) had to be used in a more complex manner.

199) designed by the CIM-team of that year in order to be able to carry out parallel insertion of work-piece carriers at the robot/machine-tool interface, a precision device.

200) once cell is implemented at a physical level using the workshop equipment listed above while the others exist as virtual cells to offer a realistic environment for developing and testing control strategies and algorithms.

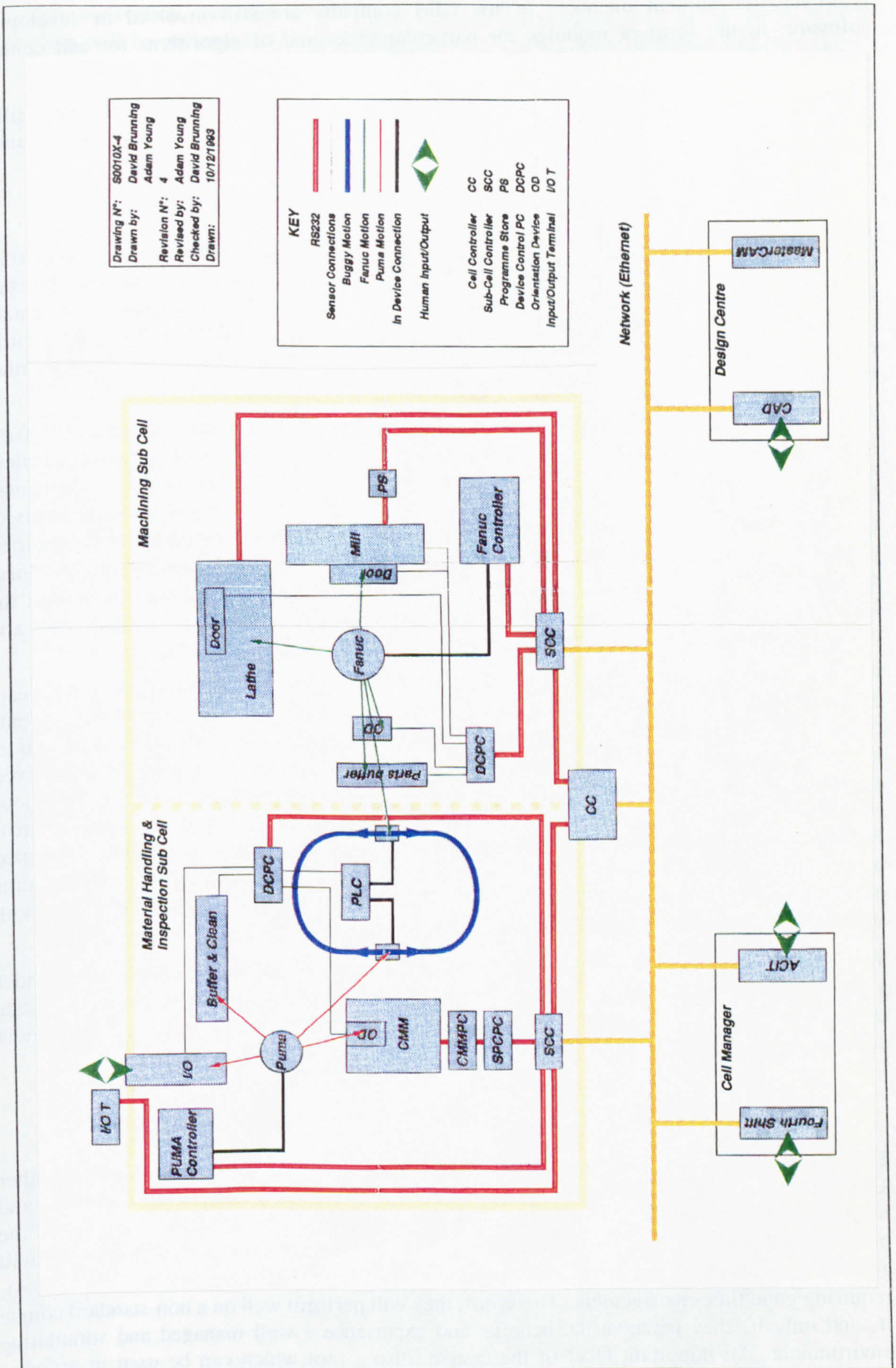

Figure 33 Configuration of the Manufacturing Cell as of December 1993.

However, the student members of the CIM company are still involved in developing software, in the form of modules for particular tasks and of algorithms for cell control optimisation.

Figure 33 provides an indication of the scope and organisation of the manufacturing facility developed in the course of seven years of CIM work in the Department of M&ES at Brunel.

14.9 Social Activities as a Motivational Tool

Many teaching bodies and industrial organisations view social activities as important contributors to team morale and individual motivation. Managements either arrange such activities as part of the normal operation of the business or they support voluntary associations of employees. In both cases there must be some form of open or implied control of the activities in order to ensure that they enhance the organisation's performance rather than resulting in divisive and counterproductive 'extracurricular activities'.

At first there appeared to be no need for such a "side-line" to the normal operation of the Brunel CIM Company (or course). It was assumed that student life as such provided excellent and ample opportunities for social fulfilment of the team members. However, as the course became more and more team oriented and as it increased in significance both in terms of intellectual commitment and time required the students (BCIM members) themselves started to express a wish for an open space for social activities. As a consequence of the course structure they had a very different timetable and outlook to that of other students on the Department's and the University's courses and, consequently, social needs at other times and of another nature. Sometimes this earned the attribute of cliquish behaviour.

An informal gathering at Christmas or a squash ladder, typical activities of the early years of the course, were initially organised at a moment's notice by one or other of the students or by a Senior Coordinator. As the course became more firmly established though, and as it started to develop its own traditions, certain events, e.g., a canal club party, became fixed elements of the timetable. They served as small immediate reinforcers for behaviour (responses) furthering the interests of the course (see section 5.6.2.3 on Skinner and reward). For the academic year 1992/93 one of the members of the company was formally appointed organiser of the social events, on top of a responsibility for 'marketing' CIM to the students of the third year of the course. One of the events organised by him was the CIM debate with students from the MEng course at Cambridge University, described in section 12.3.8.

While most of the social events represent a net drain on the course budget they help engender a feeling of belongingness and create a corporate culture of responsibility since it is made clear to everybody involved that social events can only be supported by a course management as long as they have a positive function in the running of the course.

14.10 Conclusion to "Tools" Chapter

The "tools" described in this chapter, from the SCANCO case study method, used to further team-building, through to organised social activities, used as motivating elements and rewards, have all proved to be helpful in generating sustained interest and support for the project work among the members of CIM. It is worth remembering that these students will generally be subjected to many different pressures in their final year (see section 13.2.1), requiring good time-management. Therefore, they will perform well on a non-standard course if, and only if, they perceive the benefits and experience a well managed and stimulating environment. An important facet of the course, also a tool which can be used in order to enhance motivation, has not been described in this chapter: assessment and appraisal processes will be reviewed in the next chapter.

15 Testing, Assessment and Appraisal Processes

15.1 Introduction

Managers from all sectors of the economy use assessment and appraisal techniques for a number of purposes, from the testing and selection of new staff to the processes involved in promoting and rewarding existing employees. Both students and staff at institutions of Higher Education consider assessment or testing an essential element of the processes of learning or, perhaps more accurately, of gaining a degree. For this reason, educational establishments must have recourse to a range of different techniques to assess the suitability of new students, to test the learning of students on courses and to decide on grades during and at the end of studies. In both industrial and academic settings the results of the processes have very important implications for the future of the individual(s) concerned.

Judging a person's performance is one of the most difficult processes in industry and, perhaps slightly less so, in academic life[201]. It can be attacked from many different angles: political, societal, with respect to its objectivity etc. However, it may well be one of the most powerful tools in managing a group of people, provided everybody involved is fully aware of the objectives of the process and its mechanics. The CIM course discussed in this dissertation contributes nearly 10% of the marks to the overall degree result of students on BME and SEP who take CIM as a double option. The process of assessment and testing is therefore very important if the course is to be valued by students and staff.

15.2 Monitoring and Testing in Education

While the following list is by no means complete, it may serve to provide an overview of the assessment and testing requirements in educational contexts:

- assessment of students for recruitment,
- feedback to students on their performance,
- control of progression from year to year,
- review of the teaching and learning process,
- motivation on an incentive and punitive basis,
- classification of degrees into four bands giving a good indication of graduates' potential.

Even though testing is expected to satisfy a great number of needs it is often restricted to only one or two of the components of capability mentioned in section 5.5.2. Easiest to test are explicit content and, in particular, the atoms of knowledge as listed in Table 7. As far as recall is concerned, it is automatically assessed as part of the tests for content. A widely accepted and used examination which addresses these components, at the expense of everything else, is the American SAP, a multiple choice test. Implicit content, with the exception perhaps of intuition, can be tested, but only with more sophisticated methods. The other faculties listed, most importantly "understanding", require new methods. Qualities are almost impossible to test, in a conventional learning environment.

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201) in the latter though, a clear distinction must be made between the evaluation of academics and that of students. Evaluating the performance of academic staff is more difficult than that of industrial staff since there are virtually no straightforward financial criteria which could be applied.

The question of testing at University is an important issue to which different generations have applied different solutions. At the writer's alma mater[202], for instance, continuous assessment was abolished in the early 1970s and reliance placed on exams and major projects. In the UK, the debate has gathered pace ever since the expansion of the Higher Education Sector of the late 1980s and early 1990s, modularisation and the beginning of the quality discussion.

A working group of the Engineering Professors' Conference has summarised the methods which would be applicable to tests for some of the components of capability[203], namely those which they describe as the three main cognitive domains:

- "Testing for knowledge is essentially a matter of testing for recall by questioning. Multiple choice questions are quite appropriate here.
- Testing for skills is a matter of setting appropriate tasks and of judging students' ability to perform them to required standards. For some skills a pass mark of, say, 95% might well be appropriate ...
- Testing for understanding is a matter of setting challenges which are new to the students and to which the concepts they have learnt are relevant. They should be such as to ensure that factual knowledge and well-practised skills alone cannot provide satisfactory answers. The aim is to get the students to 'think'" [EPC 3, 1991][204].

Whilst testing is a thorny issue in education in general, it is even more difficult where project based work is concerned. Dowdeswell and Harris [1979] have compiled a table in which they analyse five methods of assessment: the use of contracts, the setting of objectives, ranking, the 'romantic' approach, and performance measurement. They list both advantages and disadvantages of the five methods are critical of the 'romantic' and performance measurement approaches: criticism is levelled at the former for its arbitrary nature and at the latter because it can easily become very mechanistic. Contracts and the setting of objectives are looked upon favourably even though they tend to lead to a bunching of marks at the top end of the scale. The ranking method is praised because it results in a clear distribution of marks but, overall, it fails because there is no clear performance expectation for student or supervisor and because it de-motivates intellectually poorer students[205].

Dowdeswell and Harris do not expect project marks to relate very closely to other results of a student. Reasons for this, given by the authors, are the generally extended duration, opportunities for re-working and the much closer cooperation with a supervisor during project work than with a tutor in a large group during normal course work. Wherever possible they advocate an assessment approach mixing different methods. In the paper quoted above they also make a comparison of project marks and final examination marks but do not state whether or not they have taken the project mark out of the compound mark before comparing the efficiency of the different methods.

15.3 Testing, Assessment, Appraisal and the CIM Course

On the Brunel CIM course, substantial emphasis is placed on monitoring the performance of students and, to a lesser extent, staff. A range of methods are used to carry out this process

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202) the Department of Electrical and Electronic Engineering of the Swiss Federal Institute of Technology or Eidgenössische Technische Hochschule.

203) reference is made here to the faculties as identified by the EPC, not the classification in 5.5.2.

204) this objective was already mentioned in EPC 1 [1989] whose author warned that intelligent students are strategic learners who will use the learning method (see 5.4.2) bringing results with the least effort. While the reader is referred to the detailed discussion in the EPC contribution, it is worth highlighting here that an oral examination is a powerful test of understanding.

205) it is, in essence, a zero sum assessment as criticised by Alschuler et al. [1970] for its de-motivating impact.

in as equitable a manner as possible, while at the same time providing students with far more feedback on their performance than is the case in more conventional learning situations. In order to differentiate the approach from the testing used on more conventional courses, the process of student evaluation is based on formalised assessment and appraisal.

Very often the terms assessment and appraisal are deemed to have the same meaning. However, this is not the case. Both the dictionary definitions (see glossary in section 21) and the respective fields of application are different, as indicated in the following sections.

15.3.1 Assessment of Individuals (Employees or Students)

One of the core problems in designing performance measurement schemes is related to the question of whether the exercise is undertaken to assess the quality of the process itself or of its product. By its very nature, assessment is a backwards looking approach to the judging of a person's (or method's) performance. More often than not it is concerned with quantifying performance or linking it to defined statements. It is usually designed so as to allow the assessor(s) to base decisions on what are safely expected to be "objective" criteria. In any system aiming for fairness[206)], past performance must be measured against the objectives fixed at the time of planning for the activity. One of the core problems though in designing performance measurement schemes is related to the question of whether the exercise is undertaken to assess the quality of the process itself or of its product. In the definition of the Engineering Professors' Conference [EPC5, 1992] there are three aims to the assessment of students:

(1) to ensure that students' learning matches the goals specified for the course

(2) to ensure that students have achieved specified levels of knowledge and measurable skills

(3) to grade students' abilities or potential capabilities in understanding and complex skills.

While goal (3), and to a lesser degree goal (2), are related to a measurement of an individual's performance only, goal (1) refers to an assessment of the effectiveness of the course in transmitting the learning which was intended at the time of its conception. Many academic establishment consciously use the results of exams for both purposes, even though the examination procedure was tailored to only one of the aspects. However, some of the more complex methods and their combinations can be used safely to satisfy both purposes [EPC 5, 1992]. All the same, it is permissible to interpret some of the data gathered to measure students' performance as long as the significance of the information is not overestimated.

The process of assessment is not designed to produce a performance improvement since it merely puts a value on achievement and provides feedback to the teacher. The assessment of a person's academic performance can take a number of different forms, e.g., multiple choice tests of knowledge. If the results are to be meaningful, then the form of assessment must be adapted to the type of competency to be assessed. Objectivity is, unfortunately, not always possible, depending on what is being assessed. The measurement of the intangible aspects of a person's performance is one of the key problems of assessment.

Different strategies for the assessment of attainment are briefly described in section 6.3.2, in relationship to "motivation for achievement". A number of authors point out an aspect of

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206) example given, the IBM staff assessment process, one of the methods on which the CIM approach has been modelled [IBM, 1987].

assessment which is often overlooked: the existence of a particular assessment scheme determines to some extent the learning which will take place [Alschuler, 1970; EPC 1-6]. Although the process itself is thus backwards oriented its existence at the beginning of a learning activity determines the future outcome.

Assessment, as defined, cannot be used on its own to determine where and how a person should be used in the future. To achieve this it needs to be linked to appraisal.

15.3.2 Appraisal of Individuals (Employees or Students)

An appraisal process is used to match the future tasks of a person to his or her capabilities, on the basis of a formal or informal assessment of past achievement and an analysis of the competence and learning ability of the appraised individual. While appraisers use information concerning past performance and skill levels they must consider the person's needs (cf. section 6) as well as those of the task in hand. The process of appraisal, if conducted appropriately, affects a person's view of self and may force a person to modify their behaviour and thus performance. It is a powerful tool, but it can be dangerous when linked to control other mechanisms of the organisation (e.g., salary etc).

Organisations implementing formal staff appraisal systems (IBM, ICI, ICL, Brunel University) will put in place procedures covering all members of staff or only those above or below a certain level in the hierarchy. The systems operate in a top-down manner, with a person's line manager performing the role of appraiser. Although there will be one or two questions aimed at eliciting the appraisee's view of the organisation the performance of the supervisor will not be a natural element of the discussion[207)]. However, a survey undertaken in 1992 indicates that 12% of US companies responding have already implemented some form of upward appraisal, for example, AT&T [Heller, 1994]. It is expected that, by the year 2000, 30% of companies will apply such systems. Upward appraisal will normally be used in conjunction with the more familiar hierarchical appraisal and has a dual function: it is aimed at improving leadership, by providing feedback to managers, and at enhancing motivation by formally taking into account the views of subordinates. One company where upward appraisal is used regularly, is SEMCO in Brazil, a conglomerate of manufacturing companies renowned for its unusual management and organisational approaches [Semler, 1993].

The author has attended a number of different appraisals, both as appraiser and appraisee, and has discussed the issue with other people who have been involved in operating appraisal mechanisms. While the processes are generally deemed to be useful they are also described as time-consuming and of doubtful benefit. Continuity, that is, reference to earlier appraisals is perceived to be one of the most important factors for success. Of similar importance is the existence of trust between appraiser and appraisee. As Heller [1994] illustrates with an example from 'Fortune' magazine, "about a third of managers produce self-assessments that match what their co-workers concluded." The all too human need to secure a 100% rating can therefore lead to a great deal of disappointment and must be tempered by good training of the people to be appraised. The ten conditions for effective dialogue, listed in section 14.5.2, are also very applicable to appraisal situations.

In theory, assessment and appraisal are two distinct management tasks with very different objectives. In practice, unfortunately, senior managers in companies frequently confuse the objectives of assessment and appraisal of their staff, particularly in the case of those at higher levels of a hierarchy. As a consequence, salaries may reflect appraisal results and thus the **potential** achievements of people while promotions are based on assessments, that is, **actual**

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207) especially so, since the process is managed by the immediate manager in most cases.

achievements - a reason for the Peter Principle which states that people are promoted to the level of incompetence [Handy, 1985]. Similar misapprehensions have also existed on the CIM course.

15.4 Detailed Review of Assessment and Appraisal Processes on the CIM Course

15.4.1 Role of Assessment and Appraisal on the CIM Course

Because the CIM course has been managed on the basis of a Matrix Organisation for most of its existence, and because it is run in an educational institution, the processes of assessment and appraisal had to be tailored to this type of environment. The purpose of assessment on the CIM course is the generation of a set of marks which can be used as an input to the calculation of a student's overall performance and thus degree classification, while the purpose of appraisal is the creation of personal development objectives. Because of the long term influence of the former, great importance must be attached to the fairness of the assessment process and to its conscientious operation. Due to the broad body of capability to be tested at the end of the CIM course, the assessment scheme is complex, requiring the input of around fifty marks per student (see section 15.4.2 for more information). The scheme was developed over several years and incorporates both staff assessment and mutual (student and staff) assessment elements.

The mutual assessment is described as a process of 'mutual appraisal', a problematic malnomer since this 'appraisal' process leads not only to the personal development objectives mentioned above, but also to a quantitative output measuring the team members against the targets agreed at the start of the period. The resulting "marks" are used as part of the overall assessment of individuals. There were moves to separate out the two elements of the process but time pressures and logistics prevented this from happening. However, there are a great number of safeguards to prevent malpractice, including the provision of neutral observers not involved in the task or skill group being discussed in an appraisal. The process is described in more detail in section 15.4.5 and in appendix I which contains a complete guide to assessment, as prepared by the senior coordinators. A key characteristic is the use of both downward and upward appraisal, developed some time before it became a fashion elsewhere.

As will be shown later, the great number of component marks contributing to the final result, and the very high level of effort invested lead to a shift in the standard distribution towards higher grades and to a reduction in the standard deviation. While the latter effect is self-explanatory, the former can be explained as the result of poor component marks being compensated by individual marks based on dramatically different competencies[208)], or by high marks for activities assessed on the basis of team performance. The results must be defended strongly against moderation, provided a strong case can be made for retention of the calculated set of marks.

15.4.2 Assessment Scheme for the CIM Course

The assessment of student performance on the CIM course is based on the students' contribution to the practical objectives and a substantial number of pieces of written work, some of which are produced individually, others in teams. The aggregate mark of a student covers the whole of the course, that is, lecture elements, tutorials and practical laboratory work. At the beginning of each academic year, at a meeting of all the CIM members (students and lecturing staff) a marking scheme and associated weights are discussed and then

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208) example given, a poor essay mark could be compensated by a high mark for technical skill.

adopted for the course (see Table 22). The elements of the scheme have remained virtually unaltered while the distribution of marks between the components has varied slightly over the years. The individual elements are reviewed in more detail either below or elsewhere[209)] in the dissertation. Although the schemes may appear complicated at first sight, the students seem to have little difficulty in handling the demands. Only very rarely does a student not submit a piece of work, an indication that the benefits of a mixed assessment are grasped.

15.4.3 Report Requirements

Each individual student member of CIM produces an interim report on an aspect of the project which is of special relevance to him/her. This report is handed in after Christmas and may later form part of the group's report (see section 12.3.7). At the end of the course, that is, after 8 months of work, each project team jointly produces a CIM report document as follows (see also section 12.4):

- Summary document (for an executive),
- Technical report outlining achievements and problem areas including recommendations for future work, in the format of a report to a technical director. This includes, as applicable, full development protocols, use-of-time records, list of unsolved problems etc. (ca 2,500 words),
- User manual and application notes in the form of a set of appendices. Size as required. Marking is based on the quality of the complete document which can be very large and complex for a difficult task. The quality of the actual work is assessed separately, as above.

Reports are marked by an appropriately qualified member of academic staff, in line with a common marking directive. Although, in theory, marks may be modified subject to a discussion between two staff members and an individual student whose contribution to the group's effort cannot be ascertained otherwise. This has happened but once or twice. The discussion is used to establish what an engineer has learnt from her/his involvement in the task.

15.4.4 Essay type Assignments

Each member of BCIM must submit two substantial essays[210)] chosen from a wide range of topics as described in 12.3.9. These are intended to give the students an opportunity to reflect on what they have learnt and to act as motivation to read up on the subject(s) chosen. The topics range from human centred design to the analysis of robotic systems. Marking is carried out by the individual lecturers who set the topics but all the marks are reviewed by the course-coordinator to ensure that the marking guidelines are observed. This is necessary because lecturers each mark essays from less than 30% of the whole student group and are therefore not be in a position to introduce an element of comparison across the spectrum of abilities. Students are allowed to define their own essay titles which have to be agreed in advance with a member of academic staff in the Department who feels competent to assess work in the particular area.

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209) Task Reviews are discussed in sections 12.3.2 and 14.5, Final Task Reviews in section 12.4.2 and Assignments in section 12.3.9.

210) in 1993/94 this requirement was reduced to one reflective assignment for students who chose to submit the work in the form of a HYPERTEXT document, a form of presentation requiring the use of a special computer language.

Ultimate responsibility for assessment, appraisal and marking of the students' work on the course rests with the lecturing staff, as a matter of course, in their role of non-executive members of the CIM Company's management board. In its consideration of individuals' contribution to practical work and to the internal management though the assessment is based on a mutual appraisal process handled by the students. This process is described below:

15.4.5 Mutual Assessment or Appraisal

While the assessment of the practical work is partly based on interviews with the task teams, held by staff members about four times in the course of the year[211)], the influence of the results of a peer group appraisal scheme has increased sharply through the iterations. This appraisal scheme, modelled on the structure used by a major UK computer manufacturer, contributes between 25 and 35 % of the total mark for a student. As far as possible, the non-executive board relies on these assessments of the team members or engineering staff submitted by team leaders and on the feedback from 'engineers' about their 'managers'. It is quite obvious that a great deal of trust is placed in the honesty and maturity of the students, which is deemed to have developed over the three years of academic study and industrial training preceding the CIM course[212)]. The appraisal process is carried out in stages to ensure complete understanding of the systems and as much fairness as possible. As explained in section 15.4.1, though, no matter how much care is invested, this is not ideal since it links appraisal to reward.

15.4.5.1 Performance Assessment of Task Members

At the start of term, or the start of a project task, each of the task leaders sets out individually, with her or his staff, the objectives to be achieved over the next six months. Objectives may stem from the task itself or from the 'Guide to Assessments' which is published by senior coordinators and the course tutor.

At Christmas, at the conclusion of the overall project and at the end of a project task[213)], leaders assess the engineer against the objectives, some of which may have changed at that stage, and discuss the outcomes with the job-holder. The leaders may add overall grades to the form, an example of which is shown in appendix I. Only the results of the final appraisals are reported to the non-executive board for inclusion in the overall assessment process. At the beginning of summer term a training and development form may be produced by a leader in consultation with the staff engineer which is intended to provide pointers for future personal skills acquisition. Task leaders and skill leaders are also assessed by their team members using similar procedures. The senior coordinators manage the process and analyse the multiple choice forms completed by team members.

An important feature of the development form is the approach to classification: In the early years of CIM there would be three categories, that is, good, neutral, and 'need for improvement' (or an equivalent range of grades). Since this led to occasional problems the system was changed, first to two categories, 'good' and 'need for improvement', and then to one category, good - which could be withheld[214)]. This very qualitative form of appraisal is very much in line with a suggestion from Mcleod [1992(2)] who prefers 'all positive' categories, such as, halting, moderate and fluent, which may or may not be translated into

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211) although this feeds into the marking process only as a result of the discussion at the time of the 'final task review'.

212) moderation of the marks to account for improprieties was only necessary in academic year 1993/94.

213) since it was extremely rare for people to change tasks the latter happened only once or twice.

214) of course, this still resulted in a second category defining an unspoken 'need for improvement' but in this form it seemed to be acceptable to the course members.

grades. The system described by Semler [1993] is much more powerful since the multiple choice test completed by subordinates about their managers contains judgements ranging from totally unsatisfactory to brilliant.

15.4.5.2 Performance Assessment of Task Leaders and Senior Coordinators

Reviews similar to those described for task engineers are held by the senior coordinators with the task leaders. The former take into account for their assessments the comments on the feedback sheets filled in by the respective staff engineers, thereby closing a feedback loop (the upwards appraisal). Non-executive members of the BCIM board are charged with the appraisal of the senior coordinators and are in turn assessed by them! This latter process tends to be viewed with some apprehension by the students involved since it requires, in essence, an honest critique of the course staff's performance... before the time of the final assessment. This situation is delicate and, as a result, can easily become artificial. However, as discussed in section 14.3.4 the whole of the appraisal process must be viewed as potentially contentious, reliant on the establishment of a great deal of trust between the senior coordinators and the board member involved in the appraisal process. The writer elected to handle the problem of upwards appraisal of academic staff by acting as the sole representative for the board, with the remit of passing on the critical comments to the other members. He had to ensure that the results of the upwards appraisals would lead to improvements either in the second half of a course or, in the case of the second 'appraisal', in the next CIM course iteration.

15.4.6 Counselling Introduction and Counselling Sessions

The mutual assessment process was shown to work well in several iterations of the course, however, a number of students felt that the results or outcomes of the very time consuming activity should be used more effectively to prepare students for their future roles. Space does not permit a detailed description of the counselling process integrated into the CIM approach, first mentioned in section 12.4.3, but it may be useful to summarise the key features.

Students often experienced the CIM course as a potentially stressful part of their final year studies, a phenomenon illustrated by some of the case histories related in section 13.2. Although it had originally been intended that the assessment and appraisal process could be used to discuss any issues affecting BCIM members' well being this proved to be impossible due to the close link between the appraisal element and the assessment function which would ultimately affect a student's degree classification. One of the teams of senior coordinators, together with the writer, therefore decided to put into place an additional process to help students in gaining a fuller appreciation of their involvement in the course and of the impact of their behaviour. More important than this "historic" evaluation though is the opportunity for learning from past mistakes and misjudgments so as to avoid repeating these once embarked on a professional career. The counselling process is thus more or less the capstone of the CIM experience.

Shortly before the end of the course, the counselling process begins with a general information session for all members of an instantiation of CIM which is followed by a more substantial introduction, almost a short course, for the future counsellors. In general, these will be senior coordinators, task and skill leaders. Each counsellor accepts responsibility for discussing the CIM experience with a number of students and staff members, focusing on strengths and weaknesses and aiming for agreement on the future pattern of personal development. Under normal circumstances, the interviews include one or two observers, neutral members of the peer group who are charged with ensuring that the process is future oriented. The observers are also expected to intervene if discussions become highly charged or acrimonious, a situation which tended to arise regularly but which could easily be defused. The whole counselling process takes place over a period of one or two days following the final mutual assessment and could thus run the risk of addressing simply the issues of equitable "mutual marking". Again, it is the presence of the observers which should prevent this.

Given the short time available and the very large number of counselling sessions necessary[215] this part of the course challenges the senior coordinators to provide leadership and to manage within tight time limits. The counselling sessions in which the writer was involved tended to be very useful - an observation reflected in students comments.

15.5 Summary

In terms of Alschuler et al. (section 6.3.2) the assessment process on the CIM course can be described as non-zero sum assessment and can be shown to encourage weaker students to perform better than would normally be the case. The existence of very complex and demanding tasks allows the stronger students to be 'stretched' and to excel with a reward commensurate with the effort invested. For example, one of the top students (a member in three tasks and a skill coordinator) achieved an average mark on CIM of 85%.

It is the writer's contention that the methods of assessment put in place for the CIM course allow adequate testing for content, good testing for faculties and some degree of testing or appraisal of qualities. In the present chapter he has reviews the approaches used and, where necessary, justified their adoption. In chapter 16, below, he measures the performance of the CIM course assessment against the performance of the summarising assessment which results in the degree classification.

215) normally, everybody including the staff members involved will participate.

16 Discussion of the Results of Assessment on the CIM Course

Each year, the results of the CIM assessment process were collected in a highly detailed spreadsheet allowing in-depth analyses of both the performance of the students and of the assessment mechanism. It was of particular importance to differentiate between assessments made by the students themselves, assessments made by individual members of academic staff and by teams of tutors. Conventional wisdom would suggest a great deal of difference between the approaches adopted by the students and by members of academic staff.

16.1 Analysis of Component Marks

A comparison of the means and standard deviations of different components of the marking schemes for all the iterations of the course is shown in Table 26. The table highlights the very rapid move from a basic and straightforward marking scheme to a sophisticated arrangement and should be interpreted in conjunction with Table 22, on page 160, which provides the relative 'weights' of the elements. Some more detailed information on the weighting of components at sub-task level is added in Table 26. It is important to note that the table was prepared for this thesis and did not exist at the time when the marks were generated, that is, there was no conscious attempt at any time to maintain consistency of marking between years. The author favours absolute standards for assessing students over normalised marks, that is, variations of means and standard deviations between years are acceptable and outcomes in terms of degree classifications can change from year to year. Absolute standards are more difficult to achieve than normalised ones where the final outcome will always appear fair with an overall average mark of, e.g., 55% (the 'objective' at Brunel). Individual teachers must maintain their own 'yardsticks' and the provision of detailed historical records did therefore not have a high priority. This statement should be accepted as value free, rather than as an admission of failure or of regret founded on not having used all possible information sources in managing the course's development over the years.

The table is structured as follows: the first line in each row presents the averages for the year groups, while the second line shows the "width" of the standard distribution. With respect to the final task reviews, the third line indicates the weight of each task (students would perform between one and four tasks). The same weights were used to apportion the final (group) report marks where students were assumed to have contributed effort commensurate with task weight.

The first row of the table, below year and group size, shows the results of the mutual assessment: a surprisingly stable set of averages after academic year 1988/89, which had been characterised by an almost over-committed group of students, with very high entry grades, but a relatively large fluctuation of the standard deviations reflecting, in 1988/89, the large course size and, in 1989/90, a relatively disparate student population. None of the mutually awarded marks were moderated between 1990 and 1993, although this was necessary in 1993/94.

Below the mutual assessment we find the marks for the essay type assignments where the averages show a reasonable level of consistency, albeit substantially above the expected 55% average of a 'standard' university course. However, the choice of topics given to students is very wide, raising the level of interest and thus that of performance. As the variability of student groups' quality increased, so did the bandwidth of the assignment marks.

The marks for the interim reports were always generated exclusively by the member of staff responsible for running the course, that is, the writer or Jean-Noël Ezingeard. The means are generally very similar, a phenomenon which may be attributed to the narrowly defined format and content of the report: students have to outline their achievements and describe the tasks in which they are involved. In many cases this can be achieved by providing a sequence of bullet points although most students review their input to the tasks in a critical light. The standard deviations are very small, again an indication of the limited scope of the interim report.

Type of Course	Undergraduate Iterations							Postgraduate Iterations		
Academic Year Student Number	87/88 28	88/89 46	89/90 36	90/91 34	91/92 30	92/93 26+3	93/94 24	88/89 11	89/90 15	90/91 13
Mutual Assessmnt Std. Distribution	n.a.	76.0 10.26	73.4 8.98	72.4 4.09	72.5 7.66	72.7 5.89	67.5 11.51	n.a.	73.6 12.7	74.0 6.93
Assignment Marks Std. Distribution	n.a.	66.9 6.81	66.5 7.21	64.2 8.59	62.7 11.92	65.1 10.64	68.3 16.81	62.2[1] 10.05	64.5 5.78	60.8 6.28
Interim Report Std. Distribution	n.a.	65.9 7.55	65.2 6.05	66.9 6.37	67.7 4.58	67.3 5.63	68.6 8.05	63.3[1] 4.27	61.7 5.97	64.1 7.07
Final Report Std. Distribution	n.a.	67.3 9.60	72.6 4.86	71.8 6.13	73.4 5.68	70.6 3.12	76.4 7.71	62.0 6.15	54.7 6.94	64.0 6.93
Final Review Tsk 1 Std. Distribution Task Weight	n.a.	n,a,	66.0 8.25 1.0[2]	69.4 6.46 1.0[2]	69.9 4.97 0.59[3]	71.9 6.60 0.70[3]	74.0 6.26	n.a.	n.a.	n.a.
Final Review Tsk 2 Std. Distribution Task Weight	n.a.	n.a.	64.5 7.65 0.70[2]	67.7 5.79 0.70[2]	70.4 3.40 0.35[3]	69.3 7.19 0.23[3]	75.2 6.84	n.a.	n.a.	n.a.
Final Review Tsk 3 Std. Distribution Task Weight	n.a.	n.a.	65.0 8.63 0.30[2]	68.8 6.39 0.30[2]	72.1 3.17 0.34[3]	71.5 2.78 0.06[3]	n.a.	n.a.	n.a.	n.a.
Final Review Tsk 4 Std. Distribution Task Weight	n.a.	n.a.	n.a.	76.8 1.36 0.30[2]	n.a.	65.3 7.47 0.13[3]	n.a.	n.a.	n.a.	n.a.
Final Review Avge Std. Distribution	n.a.	68.0 11.91	65.5 6.45	69.0 4.05	70.4 3.77	70.9 6.17	74.4 6.54	60.4 9.35	57.7 4.55	62.6 6.93
Managers' Marks Std. Distribution	n.a.	66.4 11.53	63.8 11.57	64.6 12.56	67.3 10.93	66.8 12.81	n.a.	69.3 8.99	53.0 16.3	58.0 5.72
CIM Overall Marks Std. Distribution	67.4 4.12	68.7 7.28	69.2 3.99	68.9 3.44	69.8 5.0	69.5 4.22	69.8 8.59	58.1 5.64	63.4 7.81	63.9 3.13
Subjective Marks Std. Distribution	n.a.	62.5[4] 9.24	64.3[4] 9.55	65.1[5] 9.83	69.8[5] 10.39	70.5[5] 8.29	n.a.	57.4[4] 8.13	58.2[4] 8.56	n.a.
CIM - Subjective M. Std. Distribution	n.a.	+6.3 8.41	+5.0 7.13	+3.8 8.16	-0.1 7.96	-1.0 6.58	n.a.	+0.7 10.38	+5.8 7.89	n.a.

Notes:
1) non-submissions not included in calculation,
2) coefficients fixed in consultation with students at the beginning of each course iteration,
3) coefficients determined from time-sheets. Individuals' task weights add up to 1.00,
4) generated by the writer some time after the course. Includes only marks for people whom he knew well,
5) generated by the writer immediately following the iteration of the course in question.

Table 26 Overview of Aggregated CIM Marks for All Years

The assessment of the final team reports was carried out, in general, by the writer who would consult with one of the other members of staff wherever software oriented work was concerned. Since most students would have contributed to at least two reports, the marks allocation used a similar procedure to that described in Footnote 216. There are two potential explanations for the narrow bandwidth of the results of the final reports: (i) marks have to be generated in a very short time and involve the review of between 500 and 1000 pages of technical material whose presentation is generally of an excellent standard, and (ii) the report marks are aggregated several times, each student's mark incorporating elements arising from between two and four task group reports. Happily, the sequence of average marks does not just reflect the improvements in report preparation technology available to the students although the jump between 1988/89 and 1989/90 though can partly be ascribed to this. A more interesting explanation for the improvement is the experience gained from using the preceding year group's reports - something which was not really available to the BCIM team of 1988/89, since the previous year had been of a very experimental nature (see section 12.4.1 for a discussion of handover procedures). The average performance of the 1992/93 BCIM team was appreciably poorer. The team was relatively small and could therefore not devote as much effort to the reports as might have been desirable, a possible reason for the lower average mark.

The final task reviews contributed the marks shown as Task 1 to 4, the averages of the contributions made by the students to the individual tasks, weighted to calculate the overall mark for the final task reviews. The weighting was based either on a fixed ratio, determined halfway through the course[216)], or on the proportion of effort devoted to a task, as determined from an analysis of the time-sheets. The aggregate marks for third and fourth tasks generally only reflect a very small number of students, students who were usually of much better than average calibre, and whose skills were therefore required in many places... The standard deviations resulting from the aggregation of the marks for the different tasks are indicative of the levelling which results from a process of this nature.

The task managers' marks[217)], determined largely by the series of task reviews for which a manager was responsible, reflect both the difficulty of the "job", in the relatively low averages, and the variability in performance, in the high standard deviation. These individual performance marks were always awarded by the staff team, acting as a collective, and should be compared with the overall marks of the students with management roles on CIM (see Figure 39).

The overall marks for the CIM course are fairly stable but show, even more clearly than the others, that the aggregation of a great number of marks derived from a multitude of assessment methods will tend to result in a narrow bandwidth of the overall mark. It may be interesting to note that the writer had little difficulty in convincing his colleagues to accept the high marks for the CIM course, since he could make reference to the much greater than average effort invested by the students involved.

In the last two rows of Table 26 the writer has provided a rather more idiosyncratic attempt at marking. Either immediately after or some time after an iteration of the course he awarded a set of subjective marks. Of most interest is the bandwidth of the difference between the marks generated by the official assessment mechanism and these subjective marks. The very high standard deviations for the differences show very clearly that such a subjective approach is risky, even where the marker professes a good knowledge of all the people involved.

The marks for 1993/94 have been included here by courtesy of Jean-Noël Ezingeard who took over the running of the course from the author with the start of this academic year. In general, the pattern is similar to that recorded in 1988/89, that is, the first year where the process could be described as formalised. The key exception concerns the assignment marks

216) e.g., in the case of fixed ratios, task 1, the major task, would be weighted 1.0 if it was the only task of the student, or 0.7 if it was one of two, etc. In some years the weighting relied on the percentage contribution of effort to a task declared by the members of BCIM on the basis of time sheets and approved by the task leaders - in line with the procedure for the mutual assessment.

217) in some years these also include skill managers' marks. All the task review marks were allocated by the academic staff team at the end of the final task reviews (see section 14.5.4).

where the use of a HYPERTEXT task created a wide band. The means, however, are more in line with the results of 1992/93. An element of "new brooms", perhaps?

16.2 Analysis by "Job-Function" and Year

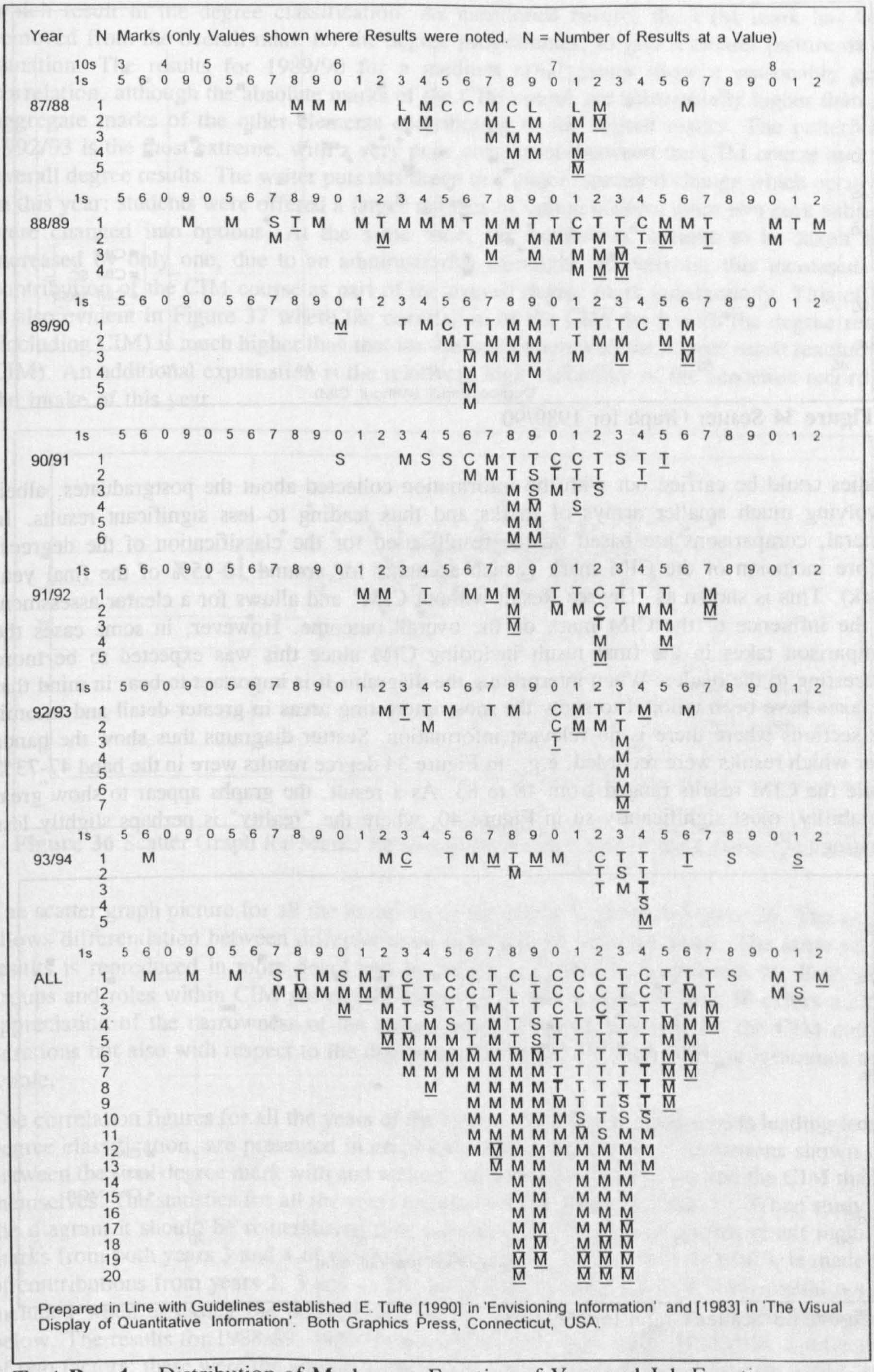
Text Box 4 was developed specifically for this thesis, based on some of the recommendations made by Tufte [1990]. It should be compared with Figure 42 which gives an overall picture, comparing the CIM results with the degree results including and excluding CIM. This provides an informative overview of the assessment patterns on the CIM course. It shows the distribution of the overall marks for the seven iterations of the CIM course, as well as a summary distribution or "bell-curve", for all the years of the course. The general pattern is that of a non-symmetrical normal distribution, although there are pronounced differences between the shapes for, e.g., 1989/90 and 1992/93. The most extreme or widest distributions are those for 1988/89, the first "real" year of the Brunel Manufacturing Engineering Programme (BME), with a very unusual intake (as mentioned in section 16.1), and for 1993/94, where two extreme values were reached in very special circumstances: the student failing the course with a mark of 36% had great difficulties with all "open-ended" course work in all of BME, while the student achieving 81% overall was simply in a different class from the others.

The overall distribution indicates that task leaders (T) and skill leaders (S) have a slightly better chance of achieving a good grade and that senior coordinators (C) are normally quite average, in a narrow range. This is confirmed by Figure 36, below, and ? in appendix N. In 1987/88 the course was run on hierarchical lines and all managers are thus marked (L). Unfortunately, it was not possible to differentiate between skill leaders (S) and members without management roles (M) throughout, due to a lack of data for some years. The difference in outcome between BME and SEP students is always shown by underlining the latters' job descriptions. The clear "dip" at 70% cannot be explained, a conjecture would attribute it to a reluctance for rounding to this very significant number, signifying the boundary between two degree classes.

The available data on students' performance will be analysed in more detail in the next section. It must be emphasised, again, that this analysis was carried out "ex post" and that the information was not available in this form at the time when the writer was responsible for the day-to-day operation of the CIM course. In retrospect, he would admit that much of the knowledge presented here would have been useful to him at the time, however, pressure of many commitments did prevent him from investing the necessary effort.

16.3 Statistical Analysis and Contribution to the Degree Classification

The diagrams presented in Figure 34 through Figure 39 are derived from the database collected between 1988 and 1994 as part of the assessment process for the CIM course. The collection of data was, unfortunately, not fully consistent throughout the period covered, largely because the course developed through a number of iterations. However, it has been possible to present the information in a near uniform manner. The main failing is the lack of consistency in the designation of the management functions of the BCIM Company: while it has been possible to identify clearly the senior coordinators (abbreviated as SC, and originally known as directors and then as executive managers) for every instantiation of the course it has not always been able to retrieve the names of the skill leaders. For some years it was therefore necessary to amalgamate the heading of task leader (TL) and skill leaders (SL) into that of manager (MGR).



Text Box 4 Distribution of Marks as a Function of Year and Job Function.

The analysis has been limited to the results of the undergraduate student groups. Similar

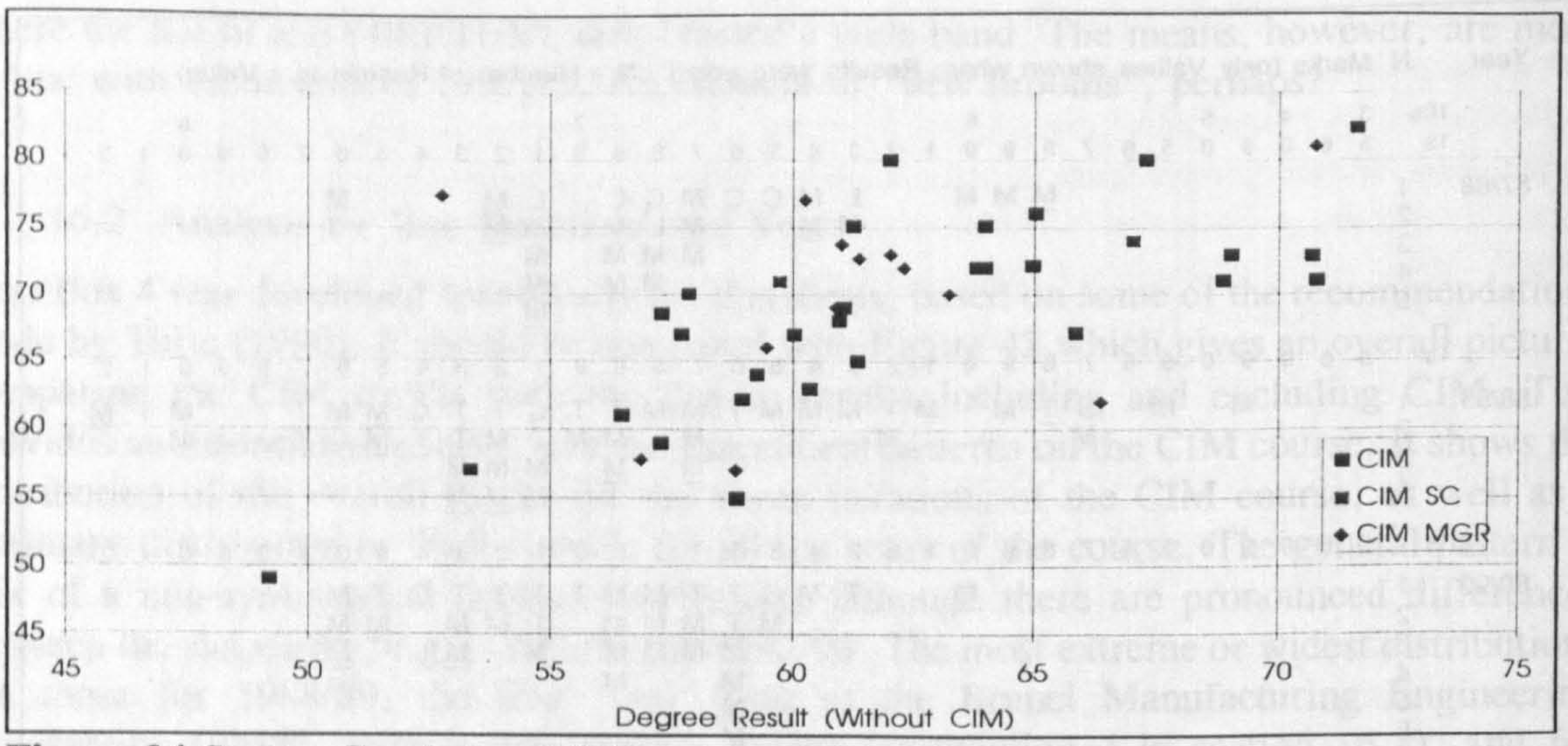


Figure 34 Scatter Graph for 1989/90

studies could be carried out with the information collected about the postgraduates, albeit involving much smaller arrays of marks and thus leading to less significant results. In general, comparisons are based on the results used for the classification of the degrees, before inclusion of the CIM mark (which accounts for around 10-15% of the final year mark). This is shown as "Degree Result without CIM" and allows for a clearer assessment of the influence of the CIM mark on the overall outcome. However, in some cases the comparison takes in the final result including CIM since this was expected to be more interesting to the reader. When interpreting the diagrams it is important to bear in mind that the axes have been tailored to show the most interesting areas in greater detail and to omit the sections where there is no relevant information. Scatter diagrams thus show the bands over which results were recorded, e.g., in Figure 34 degree results were in the band 47-73% while the CIM results ranged from 48 to 83. As a result, the graphs appear to show great variability, most significantly so in Figure 40, where the "reality" is perhaps slightly less exciting!

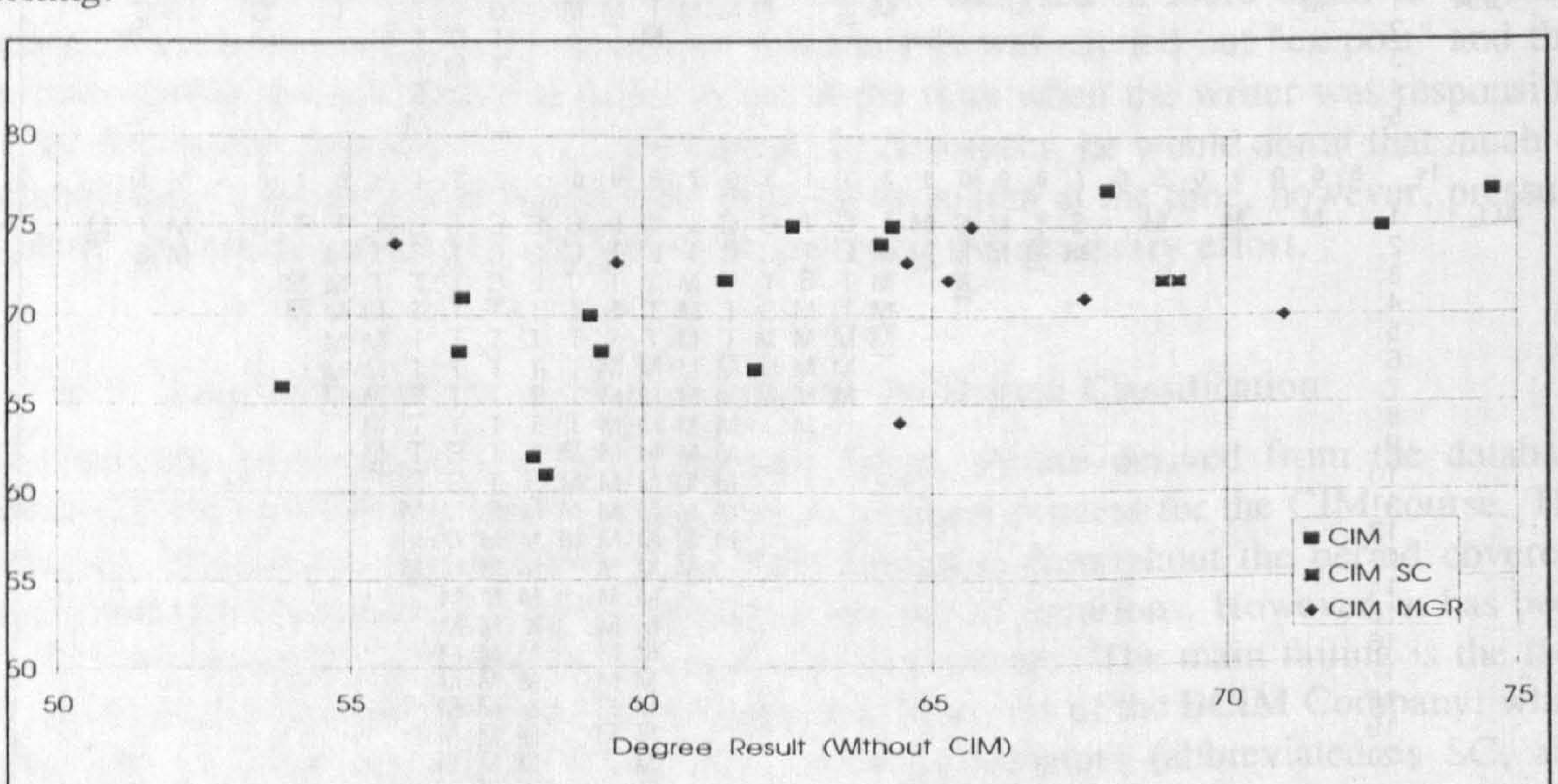


Figure 35 Scatter Graph for 1992/93

The scatter diagrams in Figure 34 and Figure 35 allow a comparison between the results derived from the assessment process on the CIM course and the main body of the marks which result in the degree classification. As mentioned before, the CIM mark has been removed from the overall mark for the degree programmes, to give a clearer picture of the situation. The results for 1989/90 for a medium sized group show a reasonably good correlation, although the absolute marks of the CIM course are substantially higher than the aggregate marks of the other elements contributing to the degree marks. The pattern for 1992/93 is the most extreme, with a very poor correlation between the CIM course and the overall degree results. The writer puts this down to a major structural change which occurred in this year: students were offered a larger number of option choices since two core subjects were changed into options. At the same time, the number of options to be taken was increased by only one, due to an administrative oversight. Effectively, this increased the contribution of the CIM course as part of the overall degree mark substantially. This effect is also evident in Figure 37 where the correlation of the CIM mark with the degree result (including CIM) is much higher than that for the correlation with the degree result (excluding CIM). An additional explanation is the relatively high variability of the academic record of the intake of this year.

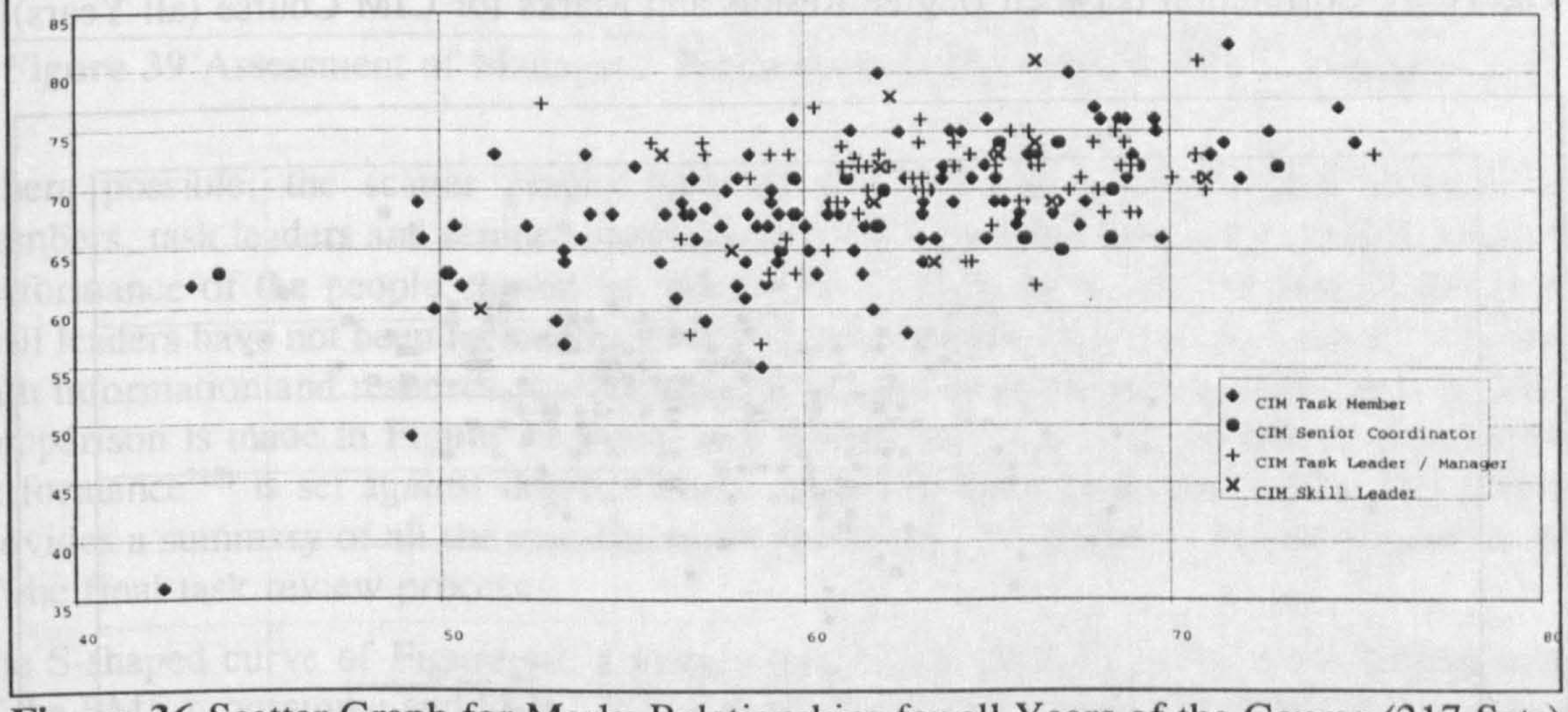


Figure 36 Scatter Graph for Marks Relationships for all Years of the Course (217 Sets)

The scatter graph picture for all the iterations of the course is given in Figure 36. The graph allows differentiation between different team roles but not between years. The same set of results is reproduced in more detail and in colour in ?, shown in appendix N. Both year groups and roles within CIM are clearly identified in this variant. Figure 36 offers a clear appreciation of the narrowness of the main spread of marks, not only on the CIM course iterations but also with respect to the degree results of the SEP and BME programmes as a whole.

The correlation figures for all the years of the course, for the aggregate results leading to the degree classification, are presented in graphical form in Figure 37. Correlations shown are between the final degree mark with and without including the CIM marks and the CIM marks themselves. The statistics for all the years together will be given in Table 27. When studying the diagram it should be remembered that, in the case of BME, the degree result includes marks from both years 3 and 4 of the thin sandwich programme while on SEP it is made up of contributions from years 2, 3 and 4. The result for academic year 1991/92 should not be included when assessing the performance of the CIM course, for the reasons mentioned below. The results for 1988/89, 1989/90 and 1990/91 show the best correlation, a reflection of two factors: these were the academically strongest groups, performing best all round, and the writer devoted enormous amounts of time to the course and the students involved.

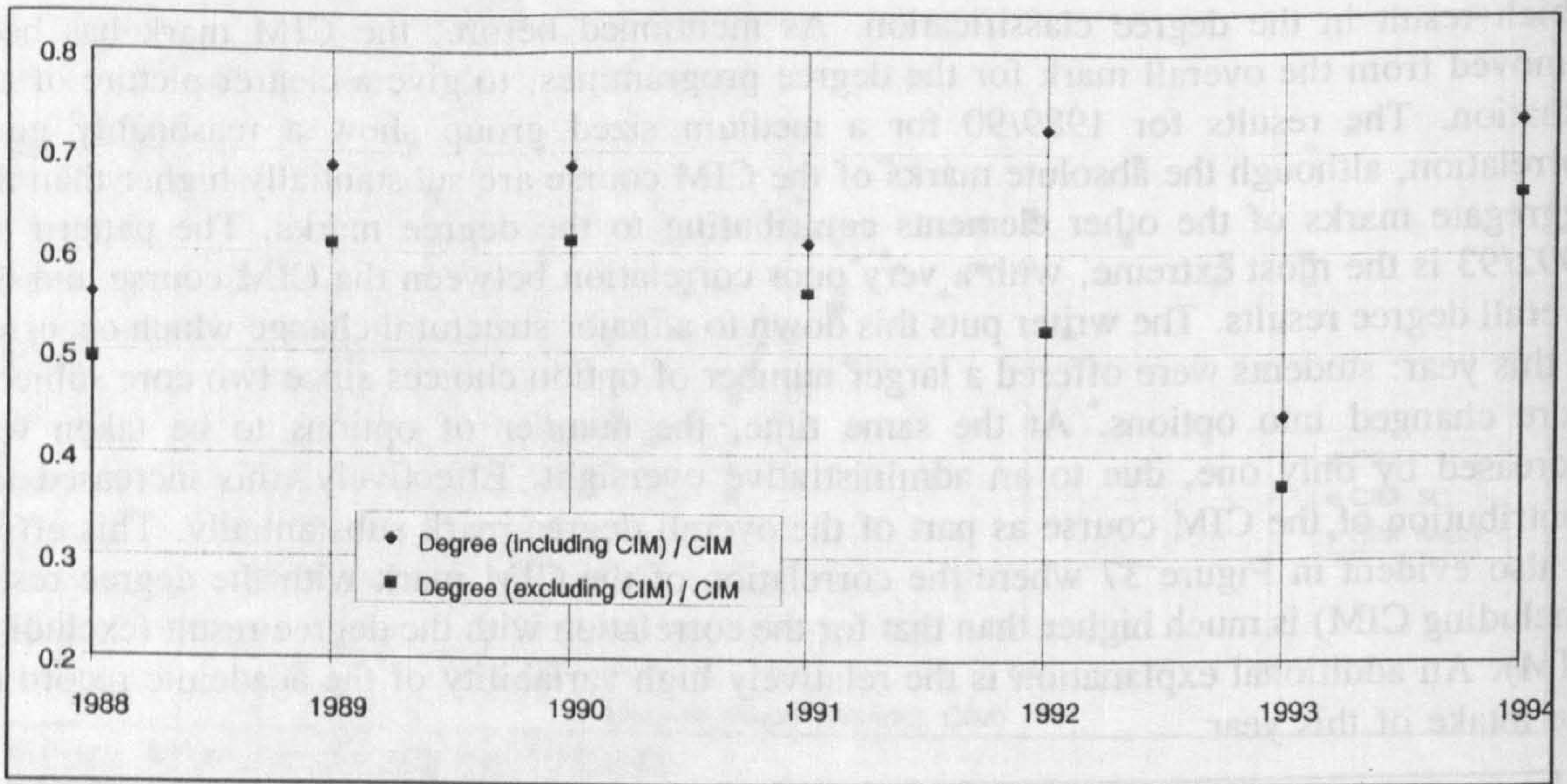


Figure 37 Correlation between Degree Results and Marks for CIM Course (all Years)

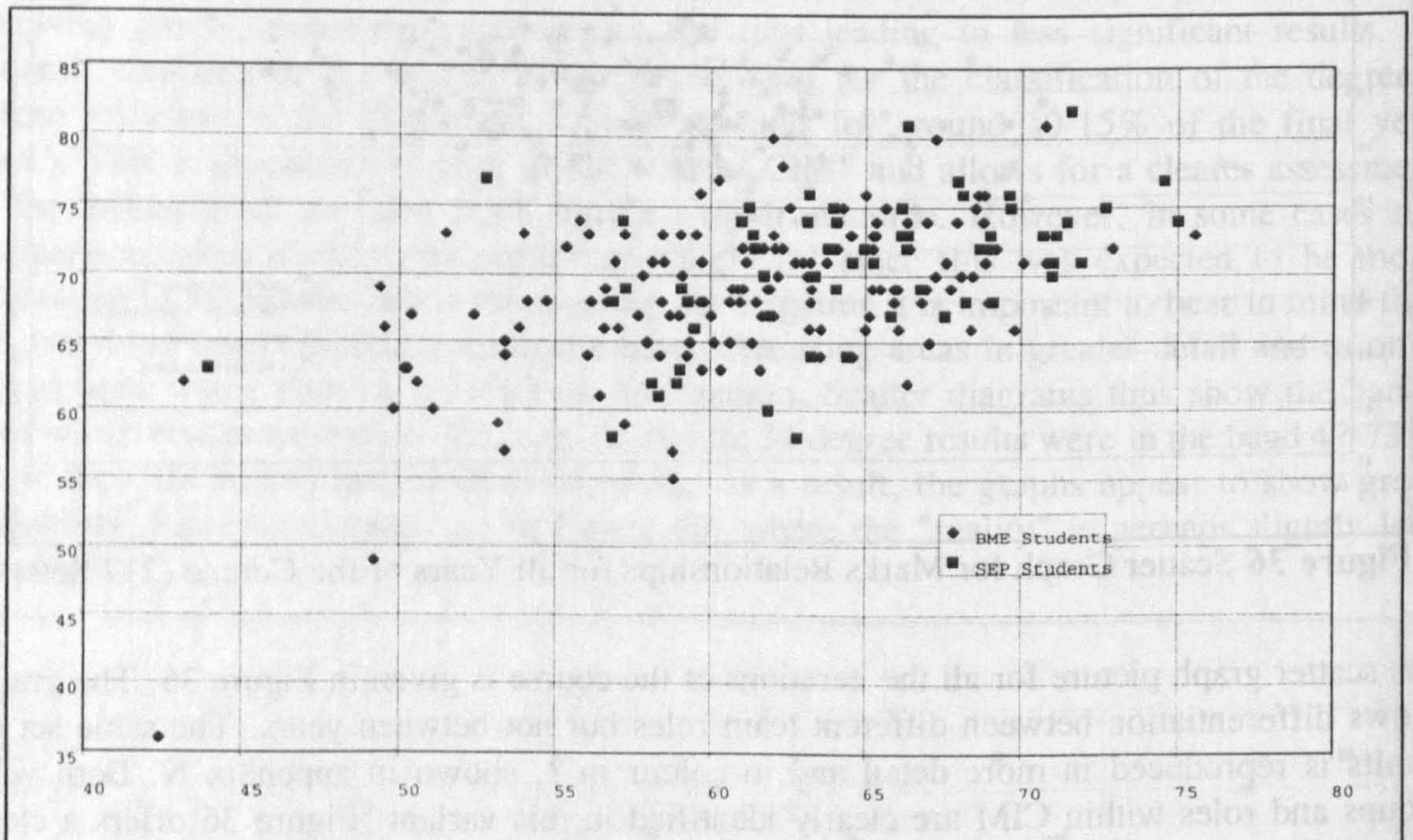


Figure 38 Scatter Graph for CIM Marks of BME and SEP Students against Degree Result

The differences in outcome between the students on the BME and SEP programmes can be assessed by consulting the scatter graph of Figure 38, showing the results of all the iterations of the CIM course against the degree results, again excluding the CIM results. The average mark for BME is 68.76% and that for SEP 70.58% while the respective standard deviations are 5.42 and 5.22. For BME the 0.95 confidence band for the population mean is $\pm 0.85\%$ whereas that for SEP is $\pm 1.32\%$. With the upper boundary of BME at 69.61% and the lower limit for SEP at 69.26 there is an overlap of the confidence bands. However, assuming statistical near-independence between the two groups of results, it is possible to assert the existence of a small but significant difference between the performances of BME and SEP students on the CIM course.

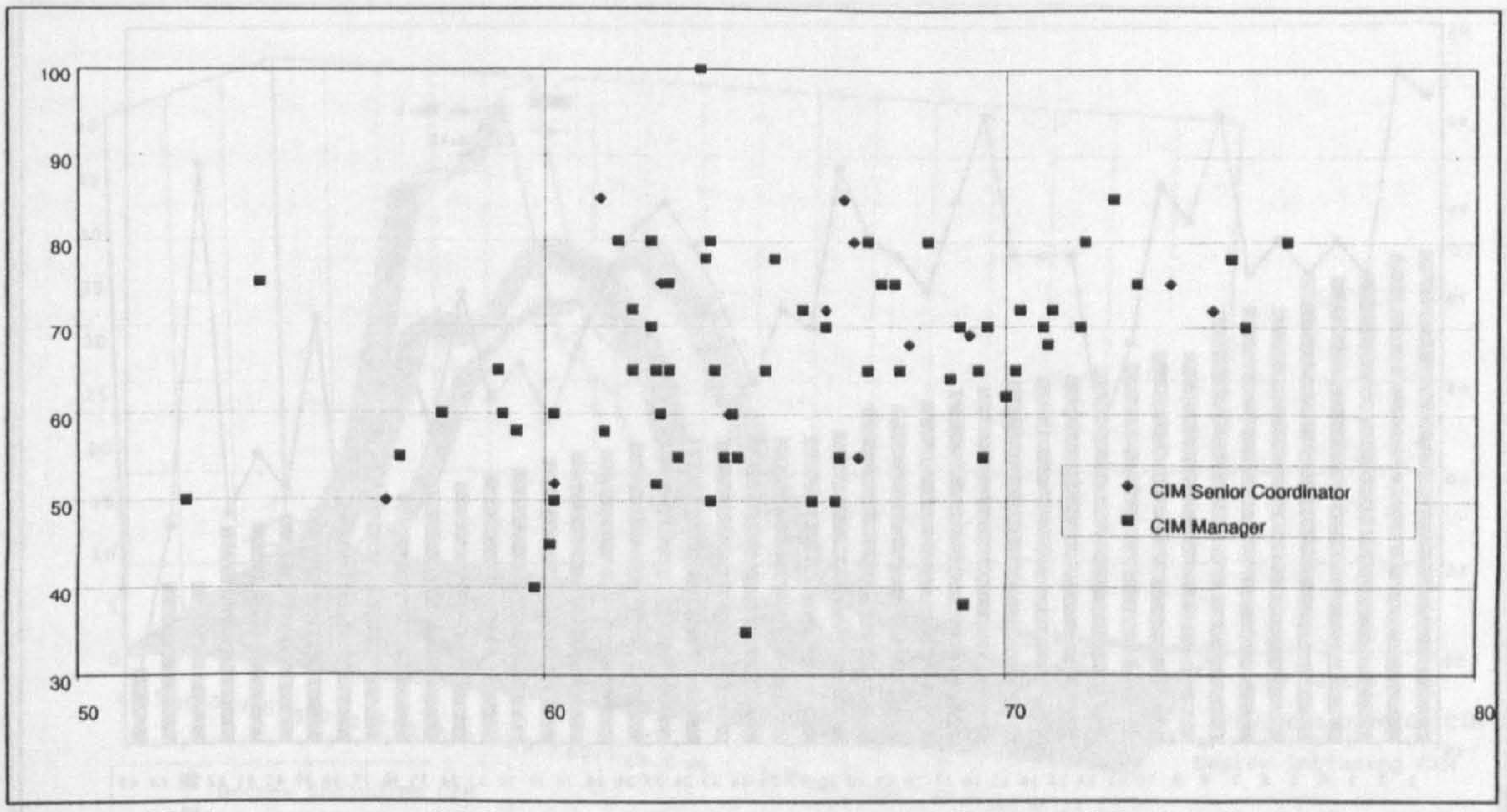


Figure 39 Assessment of Managers' Performance and Degree Marks (including CIM)

Where possible, the scatter graphs have been drawn up to differentiate between task members, task leaders and senior coordinators. This is intended to allow a comparison of the performance of the people chosen as 'managers' by their peers and the rest of the group. Skill leaders have not been included in this comparison since their role was mostly concerned with information and resource sharing and not so much with project management. A further comparison is made in Figure 39 where task leaders' and senior coordinators' management performance[218)] is set against degree results, in this instance including CIM. This diagram provides a summary of all the assessments of managers carried out by academic staff as part of the final task review process.

The S-shaped curve of Figure 40, a pattern typical for virtually every set of degree marks of the BME programme and SEP, reflects the fairly narrow bandwidth of the marks in terms of a standard distribution. This is to some extent a function of the tight control over the student intakes and also one of the effects of including a substantial number of management related classes in the third and fourth years of the programmes. A significant part of the classes or programme elements are continuously assessed, leading to further 'levelling'. However, the graph also shows the relatively poor correlation between CIM marks and degree marks (even though these include the CIM marks in this instance), with some very notable discrepancies. It must be remembered though that this was only the second instantiation of the CIM course - some of the problems may be due to a lack of experience on the part of the writer, at the time.

The influence on the students' degree classification of including the marks for the CIM course in the overall mark leading to the degree classification is shown for all years, 1987/88 to 1993/94, in Figure 41. Details are only shown for students whose class of degree changed as the result of including the CIM mark. It should be noted though that some students were so close to the class boundary that they would most probably have been awarded the higher class in any case. Examples of such candidates include "1990,BME,2.1" and "1988,BME,2.1". Again, the most surprising results are the patterns for 1992 and, to a lesser extent, 1993. The root of the phenomenon has been mentioned above, in connection with the discussions of Figure 35 and Figure 37. Figure 41 indicates that 34 out of the 217 undergrad-

218) as assessed by the staff team on CIM as part of the final task review (see appendix G.2 for an example).

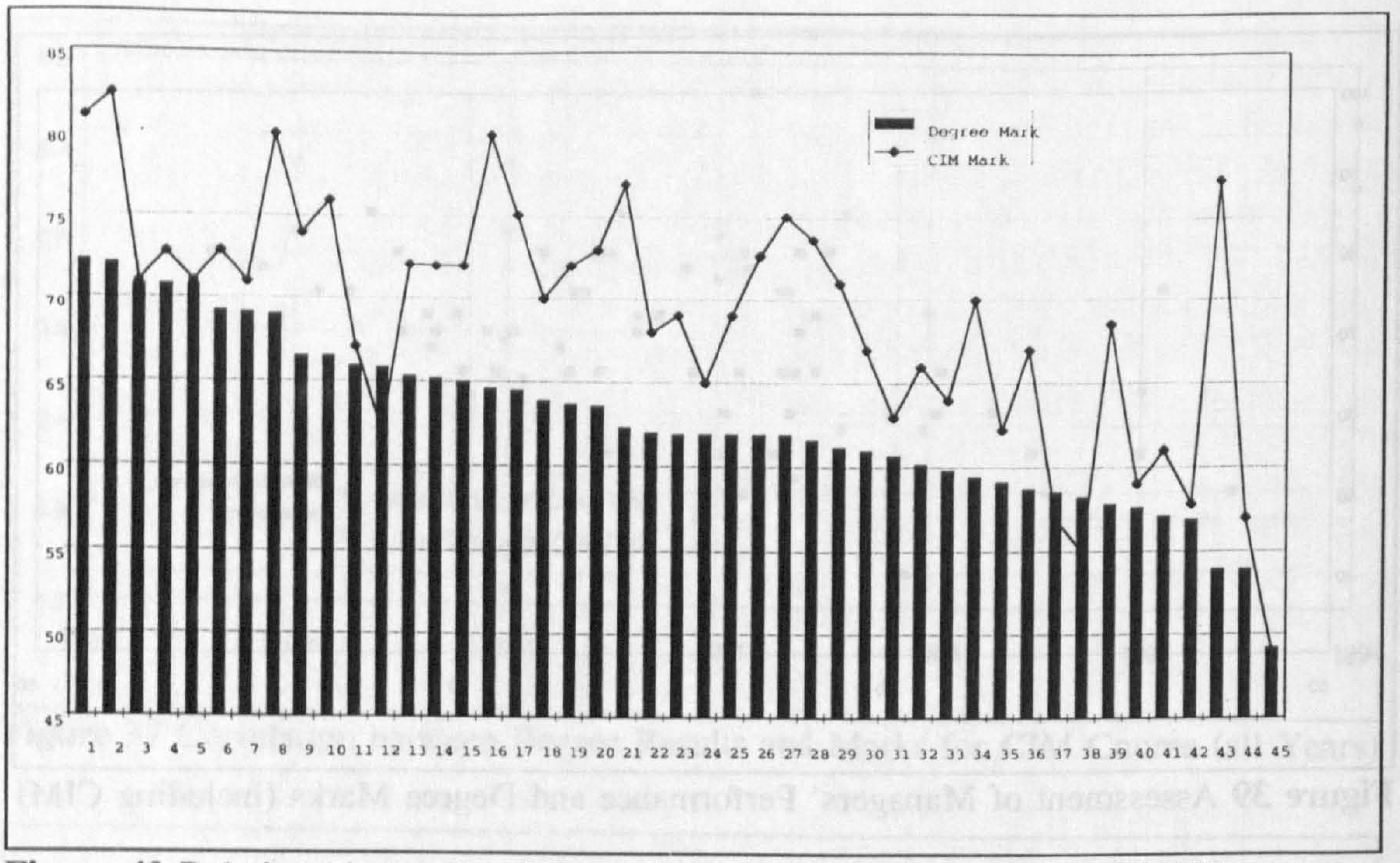


Figure 40 Relationship between Degree Marks and CIM Marks for 1988/89

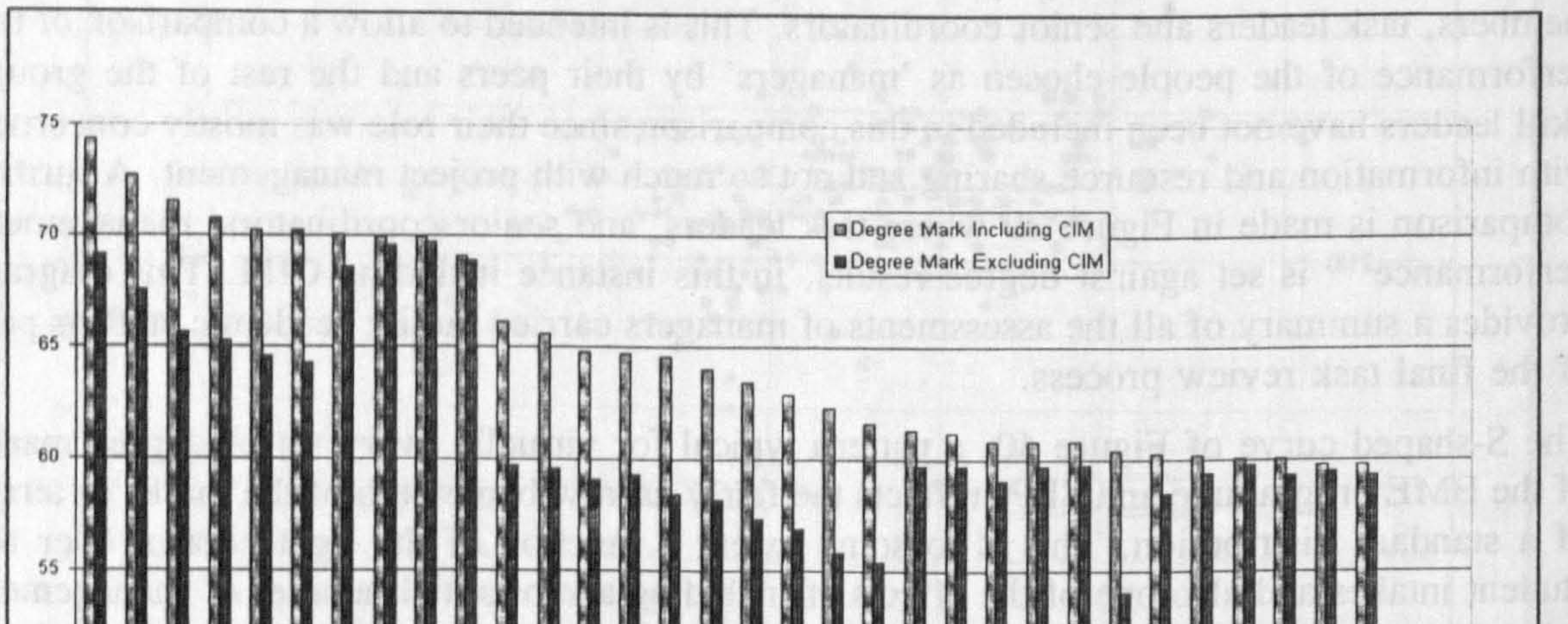


Figure 41 Changes in Degree Classification due to Inclusion of CIM Marks

uates assessed on CIM over this period have benefitted from the inclusion of the CIM mark. While this would appear to be a substantial part of the population it is important to note that the CIM course takes up a proportion of the final year which is nearly equivalent to that allocated to the final year project - its influence is thus not surprising. This is strong influence is graphically illustrated in Figure 42.

Much of the process of marking is public, with the results known to the students. The only marks which are not made available are those of the final task reviews, which contribute about 16%, and those of the final report, which contribute between 20 and 22% to the overall CIM mark. By the end of the course students therefore know about 60% of the marks

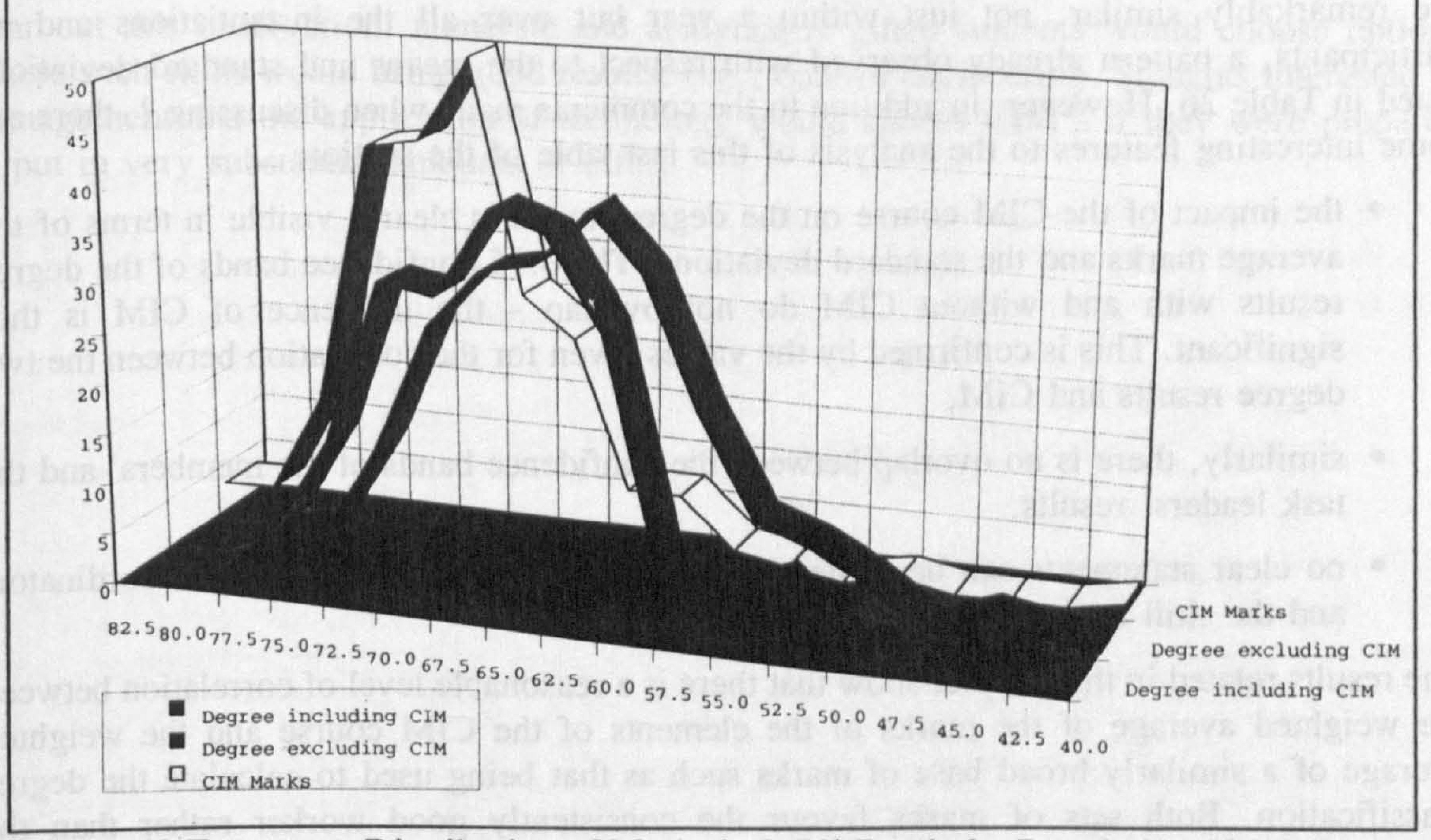


Figure 42 Frequency Distribution of Marks in 2.5% Bands for Population of 217 Marks

which will determine the overall result of the CIM course. This led to problems only twice, once when a very lazy student suddenly realised that she was not going to get a grade B for the course and the other time when a student was unhappy about the marking of essay work. It was the writer's experience that the students would continue investing a great deal of effort regardless of whether they expected a high or a relatively low mark. This positive effect of strong motivation has already been highlighted in section 12.4.6, although it must be recognised that some students may be "banking" on a positive influence of their behaviour on the deliberations of an examiners' board. Although this may not be desirable it has certainly helped the writer when he had to manage the preparations for tutorial and project presentation days.

16.4 Summary and Conclusion of the Results Analysis

It must be accepted that a project oriented and team based course does not lead to highly selective assessment. Table 27, an analysis of the 217 sets of undergraduate results, bears

Statistical Function	Average	Std. Dev.	Confidence	Correlation
Degree Mark (including CIM)	63.664	5.641	±0.751	0.636
Degree Mark (excluding CIM)	62.155	5.891	±0.784	0.535
CIM (All Marks)	69.266	5.433	±0.723	1.000 A)
CIM Task Member	68.521	5.840	±1.000	
CIM Task Leader/ Manager	70.585	4.480	±1.143	
CIM Skill Leader	70.750	5.629	±3.185	
CIM Senior Coordinator	69.400	3.382	±1.712	

A) This figure represents the result of a plausibility check and does not represent a significant correlation.

Table 27 Overview of Statistical Evaluation of Assessment Results (1988-1994) testimony to this in that the statistical summaries of many aspects of the course's assessment are remarkably similar, not just within a year but over all the instantiations and all participants, a pattern already observed with respect to the means and standard deviations listed in Table 26. However, in addition to the comments made when discussing ?, there are some interesting features to the analysis of this last table of the section:

- the impact of the CIM course on the degree marks is clearly visible in terms of the average marks and the standard deviations. The 0.95 confidence bands of the degree results with and without CIM do not overlap - the influence of CIM is thus significant. This is confirmed by the values given for the correlation between the two degree results and CIM,
- similarly, there is no overlap between the confidence bands of the members' and the task leaders' results,
- no clear statements can be made about the sets of marks of the senior coordinators and the skill leaders.

The results related in this chapter show that there is a reasonable level of correlation between the weighted average of the marks of the elements of the CIM course and the weighted average of a similarly broad base of marks such as that being used to calculate the degree classification. Both sets of marks favour the consistently good worker rather than the "genius" who only scores well in a small number of the subjects. The type of assessment used on the CIM course can therefore never replace other methods of assessment, such as written and oral exams, which are designed to discriminate between the abilities of different students based on their performance in a relatively artificial situation with rigid time constraints, working on limited tasks, and recall combined with some know-how rather than understanding. By contrast, the CIM course assessment scheme is designed as a motivational tool to reward long term effort and involvement, rather than as an aid to classifying intellectual.

A comment a the start of this chapter referred to possible differences between assessments made by students and those made by members of academic staff. The experience of the CIM course and elsewhere (e.g., the communications course described in section 9.2.3) has shown that this is not a significant issue. However, a problem can arise if the students managing the mutual assessment process fail to grasp the importance of the tasks or if they are unable to provide the right quality of leadership. The CIM team of the academic year 1993/94 (see Table 26) suffered from such failings and marks had to be adjusted to retrieve the situation.

One of the questions raised very frequently during final examiners' meetings was that of 'normalising' the marks, so as not to influence inordinately the degree classification of students taking the CIM option. The writer successfully resisted such moves because he felt that students choosing CIM as an option would have been aware from the beginning that this choice entailed far more work than a standard option. They were therefore justified in expecting a mark which was on average higher than those associated with standard options, subject of course to making that effort, indeed, the few students who failed to pull their weight on CIM ended up with very low marks. Out of over 200 students who were assessed overall on an iteration of the CIM course, 38 achieved a better degree classification through taking CIM. CIM caused none of the students to a suffer a lower degree classification.

It could reasonably be argued that information regarding the likelihood of CIM influencing the degree mark, and the overall outcome in terms of the degree classification, in a positive manner would become known to students in advance of making the decision on options for the final year. While this represents a potential problem, it is clear that all students able to choose between different options will select those likely to result in the best outcome as a function of their skills and the effort invested. Discussions with the author's tutees tended to bear out this observation: numerate and analytically gifted students would choose options where such skills would bring good results, e.g., control engineering. Students interested in management and the application of technology would choose CIM - if they were prepared to put in very substantial amounts of effort.

17 Critical Evaluation of the Character and Achievements of the Course

In line with the practice suggested in sections 2.4.3, 7.3.1 and 14.2 the present chapter on the evaluation of the successes and failures of the CIM course approach will be segmented into a review of the context of transferable skills, an assessment of the satisfaction of critical factors, a brief review of the relationship to Rogers' 10 principles and an analysis of the people components of People, Organisation and Technology (or POT). The 'people' aspect will be further subdivided to take into account different groups involved in the CIM course. The results of a survey of former students will also be summarised and discussed.

17.1 Evaluation in Terms of Transferable Skills

17.1.1 Application to the CIM Course

With Table 28 the author returns to the issues addressed in Table 15. The latter table has been expanded into Table 28 which is included here so as to provide an overview of the opportunities, tools and methods offered to students to help with 'skills' development in the final year of the programmes run by the Department of M&ES at Brunel University. The learning to be considered here takes place as part of two very different activities occupying the majority of students' time in the final year, that is, the individual project and the CIM course or experience.

In Table 28 the elements of the learning processes involved in individual projects and in the CIM course are abbreviated, but a key is attached in Table 29 and a fuller explanation of each element can be found in the sequential description of the course in chapter 12 where the abbreviations are included in brackets in the subsection titles. Table 28 should not be interpreted as a definitive summary of the current level of scientific knowledge in the field of education for Advanced Manufacturing Environments (AMEs). It represents an overview of the writer's perception of the link between so-called "experiential learning" (see section 7.3.2) and the learning process engendered by the CIM course. The columns labelled EN and AM, in particular, reflect his own views rather than the results of extensive surveys of the skills needs of engineers in general (EN) or those of engineers working in Advanced Manufacturing (AM). The column headed PS is also based on the writer's and other staff's assessment of potential CIM students' capabilities in the particular aspect of "transferable skills". However, the stringent selection procedures for students on BME and SEP and the extensive skills development throughout the programmes would support the view presented in the table. Several observations can be made on inspecting Table 28:

1) when comparing EN and AM the 'skill' levels required of engineers in industry in general tend to be slightly lower than those required for the team oriented work in AMEs, with the exception of personal autonomy, collection of solutions and some purely technical 'skills'.

2) PS, the column referring to pre-existing 'skills', indicates that the general level of preparation of students entering the CIM course is good. There are only a very few areas where their background is deemed insufficient, indicated by '4'[219].

It may be worth reminding the reader at this point that at the time of writing this dissertation the programmes of study offered by the Department of M&ES at Brunel were exclusively

219) as indicated in the text, this assessment, as well as that for the adjoining two columns concerning the relevance of individual skills for engineering work in general and Advanced Manufacturing Environments (AMEs) in particular, has been made by the writer on the basis of his experience.

Relationships between Transferable Skills and Capabilities in Advanced Manufacturing						Skill Levels			Individual Student Project Work				Computer Integrated Manufacturing			
Domain	Transferable Skill	SNo	Quality	Faculty	Content	EN	AM	PS	Teach	Demand	Monitor	Assess	Teach	Demand	Monitor	Assess
Group Work	leadership, chairing	1aa		KH		5	4	3					ST,MC	MF,MC	TR,TW	FR,MA2
	co-operation	1ab		SL		5	5	4		WM			TG	DW,MS	GM,MA1	MA2,TR
	sub-ordination ability	1ac	AT			4	4	4	WM	WM			(TG),TR	TW	GM,TR	MA2
	team based work	1ad	AP			4	5	2					TG,(ST)	DW,PW	GM,MA1	MA2,FR
Organisational Skills	setting of objectives	1ba		KH	RL	5	5	3	WM		IP	IR,IP	MC,TR	DW,PW	TR,GM	TD,FR
	time management	1bb		SL		4	5	3	WM	DW,PW	IP	IR,IP	SA,(ST)	DW,PW	MC,TR	TD,FR
	project management	1bc		KH	SC	3	5	4	WM,IP	DW,PW	IP		(PC)	DW,PW	MC,TR	FR,[GR]
	project evaluation	1bd		SL	RL	3	5	4		PW		[TH,OE]	(PC)	FR,GR		TE,[SY]
	decision taking	1be		SL	RL	4	5	3		DW,PW	DW,PW		TR	GM,MC	TR,MA1	FR,MA2
Entrepreneurship	take initiative	1ca	AT		SC	3	4	3		DW,PW		WM	(TR)	GM,PW	MC,MA1	FR,MA2
	seize opportunities	1cb	AT		RL	2	3	3				WM	(TR)	CC,IV		MA2
Personal Skills	independence, autonomy	1da	AT	UN	SC	4	3	3		DW	WM			TW,PW	GM,MA1	MA2
	self assessment	1db	AP	UN	RL	3	4	3		DW,PW	WM		TG	IR,MA1	GR	MA2
	self confidence	1dc	AT			4	5	2		DW,PW	WM	IP,[OE]	PW	GM,MC	MF	FR,TD
Interpersonal Skills	influence	1ea		SL		3	4	2				IP,[OE]	TG,LG	MC,GM	MA1,ST	MA2
	listen, counsel	1eb		KH		2	5	3					CI,(ST)	MA1,MA2	(ST)	MA2
	motivate	1ec		SL	SC	3	5	3	WM[2)]				LG	MF,LE,SE	MA1,TR	FR,TD
	negotiate	1ed		KH	RL	3	5	3	WM	DW,PW	WM	IP,[OE]		LE,TG	TR,PW	MA2
Problem Solving Skills	problem definition	2aa		KH		5	5	2		DW	WM	WM	(PC)	DW,PW	MC	FR,[GR]
	problem analysis	2ab		SL	SC	4	5	3		DW	WM	IP	(CA)	DW,PW	TR	FR
	collection of solutions	2ac	AP	RE,SL	AK	4	3	1		DW,PW		[TH]		SA	GM,TR	[GR]
	decide on solution	2ad		KH	RL	5	5	4		DW,PW		OE	SA,(ST)	MC,GM	TR	FR,[SY]
Creativity	stimulate	2ba		SL		4	4	3			WM,LA	OE		SA	GM	MA2
	develop mental models	2bb	AP	KH,UN	SC,RL	4	5	3	WM	DW	WM,LA	OE	LS,LG	DW	TR	FR,[GR]
	channel effort	2bc		SL	SC	4	5	3		DW	WM,LA	OE	TR	DW,TW	ST,LA	TR
	lateral thinking	2bd	AP	RE,SL	SC,RL	4	4	4	WM	DW,PW	WM,LA	OE	LS,LG	DW	GM,TR	TD
Practical Skills	electrical	2ca		KH	AK	4	3	4		DW,PW[1)]		WM,[TH]	ST	DW,PW[1)]	LA[1)],PW	TD
	electronics	2cb		KH	AK	4	4	4		DW,PW[1)]		WM,[TH]	WE	DW,PW[1)]	LA[1)],PW	TD
	mechanical	2cc		KH	AK	4	3	2		DW,PW[1)]		WM,[TH]	ST	DW,PW[1)]	LA[1)],PW	TD
	machine tools	2cd		KH	AK	2	3	3		PW[1)]		WM,[TH]	OT,ST	DW,PW[1)]	LA[1)],PW	TD
Information Gathering	locate info. sources	2da		SL	AK,RL	4	4	2		LR		IP		EW,DW,LR	TR,CC	EW
	extract data	2db		SL	RL	4	5	3		DW,LR		IP		EW,PW	TR,IR	IR,EW
	evaluate sources	2dc		RE, KH	SC	4	5	3		DW,PW		TH	ST	EW,DW,LR	TR,IR	IR,EW
	interpret data	2dd		RE,SL	SC,RL	4	4	3		DW,PW		IP,[TH]	LS	PW,DW	TR,IR	IR,FR
Literacy and Language	technical vocabulary	2ea		RE	AK	5	4	1		IR		[TH]		GM,MC	LS,LG	
	read purposefully	2eb		SL	SC	3	4	2		LR			HO	EW, LR	PW,TR	EW
	write simply/accurately	2ec	AP	KH		4	5	3	WM	TH		WM,[TH]	HO	IR,EW,GR	(MS),EM	EW,IR,GR
Informacy	word & data processing	2fa		SL	AK	3	3	1		TH		TH[4)]		IR,EW,GR	CC	
	use of software tools	2fb		KH	AK	5	4	3		DW,PW		TH[4)]	CA,CB	DW,PW		IR,[GR]
	electronic communication	2fc		KH	AK	3	5	4				TH[4)]	CB,ST	EM,PW,DW		TD
	understand drawbacks	2fd		UN	RL	3	5	4		DW,PW	WM	IP,OE	LS,LG	GM,MC,TR	GM,CM	
	use of CAD/CAM/CMM	2fe		SL	AK,SC	4	3	2	WM			TH[4)]	IV,OT	DW,PW	CC PW	FR TD,[GR]
Numeracy	use of mathematics	2ga		RE,SL	SC	5	4	2		DW,PW		[TH]		PW	TE	
	building of models	2gb		KH	RL	4	4	3		DW		[TH]	LS,LG	PW	TE	FR,TD
	financial management	2gc		KH	RL	3	5	4					(ST)	SC,TW	MC,GM	
Communication	presenting information	3aa	AP	SL	RL	3	5	2		IP,OE		OE,IP		TR,FR,TD	DE,CO	DE,TD
	writing reports	3ab		KH	SC	4	5	3		TH	IR	[TH]		IR,EW,GR	MF	IR,EW,GR
	use of graphics	3ac	AP	SL	AK	4	3	3		TH				GR,TD		(EW)
	documentation management	3ad		KH		4	5	4					HO	PW	MF,SC	GR,[SY]
Teaching and Training	identify learning needs	3ba	AP,AT	UN	SC	3	4	2						GM,MC	PW,MA1	MA1/MC
	designing training	3bb		KH	RL	2	3	5						EM	GM	
	running workshops	3bc		SL		2	4	3						CB,EW	(TR)	MA2
	instructing others	3bd		SL	RL	3	5	3		IP,OE			ST	CB,EW,GM	MA1	MA2
Learning	literature search	3ca		SL	AK	4	3	1		LR		OE,[TH]		EW	EW	EW
	literature review	3cb		KH	RL	4	4	2		LR				EW	EW	EW,GR
	logbook maintenance	3cc		SL		4	5	2		DW,PW			LS,GM	GM,PW,LA	TR	

Table 28 Transferable Skills and their Teaching on Individual and Group Projects

Specific to CIM Course	
CA	Computing workshop by staff
CB	Computing workshop by students
CC	CIM Conference
CI	Counselling Introduction for appraisers
CM	Course Meeting
CO	Course Organisation
CS	Counselling Session
DE	Debating Exercise
EM	Electronic Mail, e-mail workshop
EW	Essay Writing on sociotechnical or technical topics
FR	Final task Review
GR	Group (final) Report
GM	skill or task Group Meeting
HO	Hand Over (based on documentation from last year etc)
IV	Industrial Visit
LA	Laboratory Active support
LE	Leadership Election
LG	Lecture by academic Guest
LS	Lecture by member of Staff
MA	Mutual Appraisal (phases 1 and 2)
MC	Management Committee meeting (all members with a management function)
MF	Management Function (SC, SL, TL)
MS	Matrix Management Structure
NL	NewsLetter
OT	Outside Training
PC	Project engineering Course
SA	Scanco Activity
SC[4]	Senior Coordinator role
SE	Social Events
SL[4]	Skill group Leader role
ST	Small group Tuition
SY	assessment by Subsequent Year
TG	Team Games, social studies type activities
TL[4]	Task Leader role
TR	Task Review
TW	Task Worker
WE	Electronic engineering Workshop

Common to Individual Project and CIM	
DW	Design Work
IR	individual Interim Report
LR	Literature Review
PW	Practical Work
TD	Tutorial, project presentation Day
TE	TEsting by discussion and interview

Specific to Individual Project			
IP	Interim Presentation	OE	Oral Examination
TH	THesis		
WM	Weekly (or regular) Meeting with supervisor		

Qualities, Faculties and Content			
AP	Aptitude	AT	Attitude
RE	Recall	SL	Skill
KH	Know How	UN	Understanding
AK	Atoms of Knowledge		
SC	Schemata		
RL	Relations and Links		

Further Abbreviations and Codes for Table

- SNo "Skill" reference Number
- EN need in ENgineering in general
- AM need in Advanced Manufacturing engineering. Categories for EN and AM are:
  1 irrelevant
  2 not very valuable
  3 somewhat valuable
  4 valuable
  5 essential
- PS Preexisting "Skill" level:
  1 all possess skill at good level
  2 most possess skill at decent level
  3 some possess skill at decent level
  4 few possess skill at decent level
  5 hardly anybody possesses skill
- [ ] no feedback from assessment possible
- ( ) limited feedback from assessment

Short descriptions of most of the individually identifiable CIM course elements can be found in chapter 12, while the most significant innovations may be found in chapter 14, the chapter on tools for the CIM education process. Quite clearly it is impossible for every student to use all the tools, apply all the methods or experience all the processes. However, since each student is active in a number of different groups, she or he will learn at least an essential minimum about most of the skills, activities and issues addressed.

Notes:
1) applicability depends on student's project or task,
2) applies particularly to industry based projects requiring substantial effort to maintain good working relationship,
3) applies to software oriented project work,
4) these roles are (usually) mutually exclusive.

Table 29 Key for Table 28: List of Activities on CIM and Standard Projects

of the thin sandwich format[220]. As stated elsewhere the author's teaching experience in Britain relates almost exclusively to this type of programme although his own studies and his teaching in Germany and France enable him to generalise some of the observations. It is, however, very important to realise that the thin sandwich model has unique advantages in the way it prepares graduates for the 'world of work'. The traditional (as opposed to the semester-based and modular) thin sandwich degree programme prepares the student extremely

220) university or college courses where periods of academic study alternate with periods of industrial training. A thin sandwich programme offers at least two industrial periods during a 4 year programme.

well for a project oriented final (fourth) year at university since she or he will have completed both industrial and university projects. The slightly more substantial academic input (three times six months rather than two times eight) make it feasible to offer choice over a larger proportion of the content of the final year rather than asking students to follow a predefined route to a narrow specialisation.

Most university teachers with relevant experience would thus probably agree that the fourth year of a thin (or thick) sandwich programme should be concerned substantially with the 'Monitoring' and 'Assessment' of 'skills' acquired earlier, that is, reinforcement and application of the skills acquired. In Table 28 the sub-headings under 'Individual Project' reflect this position very clearly. The writer of the present thesis would contend that the element of 'Demand' should also be strongly represented to ensure that a holistic process takes place, assembling all the jigsaw pieces. The same columns under 'CIM Course' indicate that in some areas 'Teaching' could also be appropriate, particularly in domains where students may lack the knowledge or skills from earlier years to develop understanding for the particular elements. The teaching patterns for students on 'traditional' three year courses would have to look quite different since many students lack maturity and will not be familiar with concepts such as compartmentalisation, empire building, company and work place politics, and project approval processes, all of which characterise real-life working in industry. It is quite possible that the CIM approach would have to be changed very significantly for students on full-time programmes of study. The key issue in either case though must be the creation of pattern or habit of life-long learning.

17.1.2 Discussion of the Cross Reference List

The four phases of Teach, Demand, Monitor and Assess represent Gibbs' [1993] view of successful teaching as described in sections 7.3.2, 7.3.3, 10.4.2 and 10.5. The Teach phase (sometimes described as Training) is of relatively limited significance in any project oriented final year activity since the acquisition of most of the facets of content (e.g., atoms of knowledge) belongs to the earlier part of the period of academic study. In a final year, the syllabus should be restricted to the teaching of higher level skills and to imparting content of a more sophisticated nature (schemata, relations and links). Very often, therefore, students are given a choice of advanced options maximising their level of interest.

Where a reference of type (1ac) is given in the following text, this refers to the skill number in the column giving the skill number (SNo.) of Table 28.

17.1.2.1 "Teach" Phase of the Learning Cycle

The writer's analysis of the individual final year project and the CIM course highlights the reduced role of the "Teach" phase. In the context of the final year project any "teaching" happens during weekly (or less frequent) tutorials with a supervisor. On the CIM course there is a much greater variety of teaching and training situations, devoted to developing more advanced capabilities, appropriate to a high level course in a high technology area (e.g., 1aa-1bd, 1ea-1ec, 2fb-2fc). Many of the teaching situations are interactive, for example, group meetings, student computing workshops and task reviews. Teaching is aimed at creating understanding of the issues involved (e.g., people issues in automated factories) and, more particularly, their interactions and relationships.

17.1.2.2 "Demand" Phase of the Learning Cycle

"Demand" forms an important part of the individual project and the CIM approach, although in the case of the former there are some important gaps, especially in the areas of organisational and interpersonal skills, opportunities for being involved in teaching, and group working skills (where only subordination to tutor and technician is required, except in the rare situation of project pairing). The demand is created virtually exclusively by the practical situation faced by the student and is thus dangerously one dimensional: individual student projects frequently lead to unexpected difficulties, more often than not caused by equipment failures and delivery delays. Such problems can result in very good students not achieving their full potential while less gifted students may experience complete failure (see section 13.2.1).

On the CIM course, a great deal of effort has been invested in creating the right tools to ensure satisfactory handling of the Demand aspect. There is a temptation to assert that this was the result of careful course design, however, only the analysis undertaken as part of the writing of this dissertation has highlighted the importance of the Demand aspect. The wide variety of demand oriented situations helps achieve participation of all students in the learning process. Although design and practical work account for a substantive proportion of this aspect of project oriented learning in the CIM approach, strong emphases are also placed on group based activities (group meetings, management committee, management roles), reports, and essay work.

17.1.2.3 "Monitor" Phase of the Learning Cycle

With its strong emphasis on independent work, mentioned in section 8.1.2, the final year project offers only limited possibilities for monitoring of progress and feedback to the student. However, an interim presentation[221)] provides an opportunity to monitor performance in terms of personal organisation, while regular meetings with a supervisor and her or his support in the laboratory offer a means for observing problem solving and creative skills.

The team responsible for the CIM approach developed a whole range of methods for monitoring the task team and management performances. The respective column in Table 28 accentuates the high degree of importance attached to monitoring the development of skills on the course. In a very few areas it has been impossible to implement a method of monitoring, generally because of timing problems, e.g., spontaneous actions (1cb) cannot be supervised easily. Task reviews and meetings form the mainstone of the monitoring activity, together with reports and the first phase of the "mutual assessment" which provides feedback on the students' or members' of BCIM ongoing performance.

17.1.2.4 "Assess" Phase of the Learning Cycle

An individual project with a structure similar to that established in the Department of M&ES at Brunel provides a good opportunity for assessing performance in many of the "transferable skills", with the notable exceptions of group oriented, personal and interpersonal skills. By its nature, the individual project will allow an assessment of information technology skills only in situations where the project was concerned with such issues. A student's ability to act as a teacher or trainer cannot be assessed at all, even though this is an important skill for managers who frequently 'have to get a message across' [ref: any management text of the 1980s and early 1990s].

The final column of Table 28 provides an overview of the ways in which students' achievement in terms of "transferable skills" is assessed in the CIM approach. Meetings, group reviews, reports and the "mutual assessment" are the most significant elements. While these methods provide an acceptably broad picture of a student's performance an assessment of the overall outcome, that is, of the tangible results, must also be possible. The CIM

221) a standard requirement at the project's half-way point, at Brunel and at many other institutions.

approach has involved the project presentation day (TD)[222)] where the results of the work are demonstrated to an expert audience, in an integrated manner, from the business functions through to machining the products.

Whilst it would be possible to put in place an even more sophisticated "assessment machinery" this would require a greater proportion of the available time and would thus run counter to the real-life orientation of the CIM teaching approach.

17.1.3 Summary - Transferable Skills in the Context of the CIM Approach

The analysis of the CIM approach which resulted in the information given in Table 28 can be summarised as follows: the CIM environment and course structure provide

- an adequate environment for developing some transferable skills through formal and informal teaching and learning,
- an excellent framework for challenging students to apply and enhance their skills,
- a well developed system for monitoring the skills acquisition process (learning by doing), and
- a near optimal assessment structure leading to broadly based marks and scope for feedback to enable and encourage future learning.

The approach to practice based learning reviewed in this thesis can thus be described as providing a good environment for developing and reinforcing the transferable skills needed for work in advanced manufacturing. It has been demonstrated to be superior in this respect to the individual final year project.

17.2 Evaluation in Terms of Theory and Practice

Table 30 to Table 37 provide an alternative overview of the demands placed on a practice based course as developed in the 'experiment' described in this dissertation. In contrast to

Precept	Source (Rogers)	See	Elements
education is about change human capacity is unlimited	Pittenger and Gooding (1)	S. 5.6.3.4	CS, PC, PW
students need to learn at cognitive, affective and subconscious levels	Branton (8)	S. 5.9.2	CS, DE, ST, TG
natural responses are easier to learn	R.C. Bolles (1,2)	S. 5.6.4	DW, PW, TG
learning can happen in one trial without conditioning	E.R. Guthrie (1)	S. 5.6.2.5	Whole Course
teaching must exploit the law of association	Aristotle	S. 5.6.1	CB, HO, IV
rules, principles, strategies are better than trained responses when dealing with complex situations	W.K. Estes (5,10)	S. 5.6.3.1	LA, LS, TE, TR
questioning phase is an essential part of learning	L.C. Lederman	S. 7.4.1	ST, TR
provide organised and interrelated learning experiences	D.R. Krathwohl (7)	S. 5.4	CO, GM, PC
teaching and learning should be individualised	Piaget, Tolman, Guthrie etc. (7)	S. 5.6.4	CS, PW, ST

Table 30 Some Key Factors determining the Learning Process

222) replaced by two open days on computer integrated manufacturing for schools in the 1994/95 iteration! This can be viewed as an extension to the use of the students' teaching skills.

Table 28, which is based on Gibbs' framework for experiential learning, the tables below are intended to relate the elements of the CIM approach to the core factors or precepts identified by a number of authors, as discussed in chapters 2, 3, 4, 5, 9 and 10. This summary of their assessment of educational needs, when related to the author's own views, can amount to no more than an approximate statement of the potential contribution of an approach designed along the lines of the CIM course. It may prove useful though to other teachers by offering a method for selecting teaching "tools" or "education elements", suited to the pursuit of similar objectives in learning environments which may well be different from that of advanced manufacturing technology but which exhibit some or all of its characteristic traits (rapid change, integration of people and technology etc).

The abbreviations in column four of the tables refer to the activities and elements of the CIM course listed in Table 29. The numbers in brackets in column 2 (Source) of Table 30 to Table 37 provide a possible cross reference to Rogers' 10 Principles of Education for Freedom, listed in Text Box 2, on page 98, as interpreted by the writer. A brief discussion of Rogers contribution follows in section 17.2.2.

17.2.1 Detailed Discussion of the Summary Tables

The summary of some key factors of the learning process contained in Table 30 is used to highlight the scope of the human mind and the complexity of the learning process. Learning is facilitated by realistic and natural situations, e.g., practical work (PW), the project engineering course (PC), and direct support in the laboratory environment.

Precept	Source (Rogers)	See	Elements
adapt learning situations to people's self view (dynamic or static)	C.S. Dweck (3)	S. 6.2.5	CI, CS, DW, PW, ST
teaching and learning should be individualised	Piaget, Tolman, Guthrie etc. (7)	S. 5.6.4	CS, PW, ST
promote individually achievable high standards, allow taking of moderate risks etc.	A.S. Alschuler et al. (4,5,7)	S. 6.3.3	IR, MF, PW, TW
intentional, motivated action is promoted by competence, relevant content and clarity of contingencies	E.L. Deci and R.M. Ryan (2)	S. 6.2.6	DW, LA, PW
provide organised and interrelated learning experiences	D.R. Krathwohl (7)	S. 5.4	CO, PC, GM
rules, principles, strategies are better than trained responses when dealing with complex situations	W.K. Estes (10)	S. 5.6.3.1	LA, LS, TE, TR
avoid unintentional shifts from the affective into the cognitive domain of learning	D.R. Krathwohl et al. (5,8)	S. 5.4.2	CC, CI, CS, ST, TG
create opportunities for peer group learning and subject broadening	C.D. Ellis et al.	S. 9.5.1	CM, FR, GM, LA, MC, ST, TR

Table 31 Some of the Key Factors in Effective Teaching

The importance of individualised and focused teaching, adapted to students' needs, is mentioned by several authors, as shown in Table 31. The quality of "content" taught, as defined in section 5.5.2.1, must not be neglected, but factual content should not be imparted at the expense of accommodating students' personal development. As indicated in row seven, there are some activities included in the CIM approach which support work in the affective domain, a precept advocated by Krathwohl et al. However, this is an area which requires more attention, both in perfecting the CIM approach and, even more so, elsewhere in higher education. In the great universities of the past it was the college tutor who helped students growth in the affective domain. Expanded higher education (a 1970s phenomenon) and mass higher education (1990s) have yet to develop fully their own approaches.

Precept	Source	See	Elements
adapt learning situations to people's self view (dynamic or static)	C.S. Dweck (2,3,4)	S. 6.2.5	CI, CS, DW, MF, PW, ST
teachers must cater for surface learning and deep learning, for holist and serialist learners, for verbalisers, visualisers, doers.	F. Marton and R. Säliö, G. Pask EPC 1 (6,10)	S. 5.8.1 S. 5.8.2 S. 5.8.3	CA, EW, LR, LS, PW, ST, TR
human beings prefer pattern recognition to analysis. Topographic rules are more powerful than symptom rules	Rouse	S. 5.7.2	DW, EW, PW
human beings use shortcuts to solve problems: recognition is necessary but creating awareness is better	Rasmussen (7)	S. 5.7.2	FR, PW, TR
unfinished problems are remembered better than completed tasks (Zeigarnik)	Gestaltists (10)	S. 5.6.3.3	FR, TR, TW

Table 32 Some of the Key Factors in (Learning) Behaviour

To be effective, a learning situation must be adapted to students' learning behaviours. Table 32 shows not only that these vary widely but also that there are some approaches which should prove more helpful than others. Most significant, from the writer's point of view, is the importance of practice (DW, PW, TW), aimed at equipping students with the experience of a wide range of situations and problem solving approaches and with an awareness of possible outcomes, preparing them better for a "real" work environment. Equally important are the monitoring processes put in place for supporting students' work and opportunities for providing formal feedback. On the CIM course these are provided in the shape of the task reviews (FR and TR), the computing workshops (CA) and the counselling sessions (CI and CS). The inclusion of virtually all the elements of the CIM course into Table 32 could have been defended quite easily, however, this would have been counterproductive.

In the case of Table 33 no such restraint was deemed necessary or appropriate since the range of skills required in advanced manufacturing environments and in project oriented engineering work is such that only a course offering a very wide variety of activities can be expected to prepare students adequately for their future roles. In essence, a course must provide many different sub-environments for a patch-work like learning experience. All the same, particular elements appear more frequently than others. Row 4 of the table offers a particularly multi-faceted approach to communication and social skills: students acquire the necessary experience in situations as diverse as the CIM Conference (CC), Debating Exercise (DE), Group Meetings (GM), the leadership roles (SC, SL, TL, TW) and the Final task Reviews (TR). Row 5 provides a matching picture by listing the many opportunities for acquiring and adopting technical skills, a list which is by no means complete! The skills needed for project management type work (row 6) require a different, but overlapping range of activities. Again, one of these is counselling[223)], used on the CIM course both as a vehicle

223) that is, two types of relatively low level counselling: an informal activity in the hierarchical support given to senior coordinators by staff, to skill and task leaders by the senior coordinators and to members or "BCIM engineers" by their team leaders; and a formal activity undertaken as part of the mutual assessment (see section 15.4.6).

Precept	Source	See	Elements
skills can only be acquired if meta-skills have already been developed; skills are made up of many acts	J.A. Klein E.R. Guthrie	S. 10.4.3 S. 5.6.2.5)	LA, PC, PS, SA, ST, TG
manufacturing managers need breadth and conceptual skills	W. Skinner	S. 4.3.2	DW, LA, LG, LS
transferable skills are essential; conventional problem solving skills	EHE and Gibbs EPC 6 (6-10)	S. 10.4.2 S. 8.1.1	CB, CI, CS, GM, OT,PC, SE, TG
manufacturing engineers must have communication and problem solving skills; communication and social skills needed	F.D. Brummett F. Schmid	S. 4.5.2 S. 8.2	CC, CS, DE, FR, GM, GR, HO, IR, NL, OT, SC, TC, TE, TG, TR, TW
manufacturing engineers must have a good science and technology base; technical and practical skills are needed	F.D. Brummett F. Schmid	S. 4.5.2 S. 8.2	CA, CS, DW, LG, LS, OT, OC, PW, WE
abilities to handle the 5 dimensions of project management; skills for generic project management	Gregor and Hansel Drobek et al.	S. 4.6 S. 4.6	CI, CS, MA, PC, SC, SL, TG, TL
students should learn to predict outcomes on the basis of fuzzy and conflicting cues	Branton (4,8)	S. 5.9.2	FR, IR, ST, TR
developing networking skills	F. Schmid	S. 10.4.4	CS, MC, MS, OT, SL, TG

Table 33 List of Suggested Skills for Advanced Manufacturing

for maintaining students' momentum and as a preparation for the professional working environment to be faced by students.

Precept	Source	See	Elements
introduce upward as well as downward appraisal	R. Heller	S. 15.3.2	CI, CS, MA, MS, TE
prepare engineers for managerial roles	Shea, Corfield, W. Skinner et al.	S. 2.5	CI, EW, M, MS, PC, SA
prepare engineers for interactive leadership	Gregor and Hansel	S. 3.3	GM, MS,TG,TL
promote the use of human centred approaches	A. Ainger, DTI (1,2,3,4,7,8,9,10)	S. 2.4.4	CI, EW, LG, LS

Table 34 Objectives in Preparing Engineers for Management Roles

The objectives in preparing engineers for management roles listed, amongst others, in Table 34 are just a small selection of the range of objectives implied by academics and industrialists when designing qualification programmes for engineers. Very often, in the past, there was little recognition of the tendency for engineers to enter for management careers after a period of working as design, development or test engineer. The creation of the job-title of manufacturing (systems) engineer, amongst other factors, developed an awareness of the potential scope for integrating engineers formally into management hierarchies. In Britain this came relatively late, however, the process is now much more formalised than in the rest of Europe where engineers tended to be promoted into management roles without receiving appropriate training.

Thorndike's call for restraint in designing learning environments which appears in row 5 of Table 35 does not fit in with the concept of the CIM approach. By its very nature, the course is multi-faceted and complicated. However, one of the reasons for adopting the matrix structure (MS), was to make the more complex processes, characteristic of a project oriented

Precept	Source	See	Elements
establish realistic learning environments	E.R. Guthrie (2,6,8)	S. 5.6.2.6	CO, PW
teachers should provide a rich learning environment	EPC 1 (2,7,8)	S. 5.8.5	LG, LS, LR, PW
industrially relevant problems, critical faculties, communication	D.R. Campbell (2,7)	S. 8.1.1	EM, PW, TD
industry oriented tasks provide a better focus for students' work	C.D. Ellis et al. (2)	S. 9.5.1	IV, LA, OT, PW, TD
mimic real life situations but keep learning situations simple, do not expect students to handle multiple associations	E.L. Thorndike (2,6,7)	S. 5.6.2.1	MS, PW
work to specification, concurrent vs. sequential work, cost implications, time pressures	F. Schmid	S. 13.1.2	GR, PW, TD
working environment should be stimulating with multitude of sensory inputs	Branton (1,8)	S. 5.9.2	CA, CO, CS, DE, IV, LG, LS, MA, M, PW
sufficient time for teamwork	J. Gosenpud P. Miesing	S. 7.3.4	PW, TG
take account of controllability issues in designing situations	B. Weiner (3-5)	S. 6.2.4	CM, CS, FR, GM, IR, MS, ST, TR
meaningful and concrete challenges for average students	Klein (2)	S. 4.4.2	DW, EW, PW

Table 35 Key Factors in the Teaching and Learning Environment

environment, transparent and manageable. Wherever this is possible without having to compromise the reality of the situation, the CIM course employs simplified approaches. It is one of the tasks of staff teaching on the programme to ensure that students become aware of the simplifications and will not apply the paradigmata learnt in an unthinking way, once they start working in industry.

With the benefit of hindsight, the teaching and learning methods used on the CIM course can be matched to the precepts of a number of leading thinkers in the fields of education and learning theory, as summarised in Table 36. The tools and elements of the CIM course were not developed in a conscious attempt to satisfy requirements, such as those for realistic learning environments postulated by Guthrie and the Engineering Professors' Conference (see Table 35). They grew out of a situation where students had to be prepared to work in a new engineering situation, more open-ended than many 'conventional' environments - even that of manufacturing with its characteristic breadth. Most relevant, perhaps, is the first row: catering for different types of learning. On the CIM course this objective was pursued, at first unintentionally, by providing many different learning situations. Many of these micro-environments were created in response to students' requests, e.g., the CIM Conference and the CIM Debate at Cambridge University. Interim and final task reviews, design and practical work feature strongly in the table, the former because it is at the core of developing questioning and self directed learning and the latter because it provides opportunities for doing as well as deep learning. Small group teaching, lecturing, the Scanco activity, workshops and the counselling process also play important roles.

17.2.2 The Context of Carl Rogers' 10 Principles

Carl Rogers' ten principles of learning from "Freedom to Learn" were briefly introduced in the introduction to the concept and practice of experiential learning in section 7.3.1. Even though the principles can be criticised, their impact on the development of educational theory and practice demands that the CIM course be evaluated against the principles. To some

Precept	Source	See	Elements
teachers must cater for surface learning and deep learning, for holist and serialist learners, for verbalisers, visualisers, doers.	F. Marton and R. Säliö, G. Pask, EPC 1 (2,6,7)	S. 5.8.1 S. 5.8.2 S. 5.8.3	CA, CB, DW, EW, LG, LS, PW, OT, ST, TG, WE
avoid reliance on existing schemata and old knowledge	Bartlett (Reason)	FN 65	CB, DW, EW, LA, PW
exploit the law of association	Aristotle	S. 5.6.1	CM, IV, PW, SA
rules, principles, strategies are better than trained responses when dealing with complex situations	W.K. Estes	S. 5.6.3.1	CA, SA, ST, TR, WE
where a non-standard behaviour is expected, a clear discriminative stimulus must be provided	B.F. Skinner(7)	S. 5.6.2.2	CM, CO, FR, ST, TR
rewards need to be presented quickly and just after detecting the desired behaviour, use rapid feedback, not constant praise	B.F. Skinner	S. 5.6.2.3	CM, MC, ST
use non zero or shared sum assessment; ensure that testing addresses understanding and not quantity of content learnt	A.S. Alschuler et al. F. Marton and R. Säliö (2,9)	S. 6.3.2 S. 5.8.1	satisfied by the CIM process as a whole
problem solving and learning cycles	Handy and Gibbs	S. 7.3.2	CA, DW, FR, PW, TR, WE
students should frame their own questions questioning phase in experiential learning question phase in practice based learning	E.L. Thorndike L.C. Lederman F. Schmid (2,8)	S. 5.6.2.1 S. 7.4.1 S. 7.4 S. 7.4.4	FR, IR, PW, ST, TR
arrange for good debriefing	L.P. Stewart	S. 7.3.4	CI, CS, FR, TR
equilibration and disequilibration as motivators	M.H. Appley (3-5)	S. 6.2.2	MA, ST, TR
avoid unintentional shifts from the affective into the cognitive domain of learning	D.R. Krathwohl et al.	S. 5.4.2	CM, FR, MC, TR
use a structured approach to technology oriented learning	RWTH Aachen (7)	S. Figure 7	CO, CA, LG, LS, OT, PC, WE

Table 36 Recommended Teaching and Learning Methods

extent, this has already happened in Table 30 to Table 37, with the notes in brackets in column 2 indicating a tentative correspondence with some of Rogers' principles. In essence, the CIM course provides an environment which allows students to develop further a range of skills and understanding based on existing and new content (knowledge etc), with low threat to self. The student's obligations within the CIM course environment can be viewed as an unwritten learning contract, another Rogers concept, aimed at achieving substantial professional competence for the student and an enhanced facility for the institution. Although no formal learning contract is signed by the partners involved, the CIM document sent out before the start of the course (see section 12.1.4) could easily be interpreted as such, with the acceptance declared by the return of a skill card.

Principle (1) regarding the natural potential of humans for learning permits the use of a different type of learning which does not rely on formal tuition, an environment such as that of the CIM course where there is little overt coercion. Most students appear to view the content and approach of the CIM course as relevant to their future careers, in line with the requirement of principle (2). This principle may also account for the rapid progress students make once they join the course. The relevance of principles (3) and (4), relating to threats as the result of a need for change, has been demonstrated in the case study reported in section 13.2.4 where a student had to adopt new patterns of behaviour. The writer is convinced that the demands of principle (5) have been satisfied in the course design, with the members of staff providing a 'buffer' which could be tuned to the demands of the situation.

The whole of the CIM approach is based on 'learning by doing', as suggested in principle (6). Principles (7) and (8) outlining the students' relationship to the learning process would also appear to be satisfied. Quite clearly, principle (9) had to be ignored since evaluation both by self and others is an integral part of the approach and cannot be ignored in any formal education situation which must, almost by definition, result in an assessment. The question of whether or not the approach leads to a pattern of life long learning cannot be answered at the present time. Neither is it possible to state whether or not the approach is more successful in this respect than more traditional engineering courses.

17.2.3 Theory and Practice - Overall Assessment

The overview which has been presented in this section, covering a whole range of issues, precepts and solutions, appears to confirm that the CIM approach offers a balanced learning environment for learning skills and gaining understanding in complex technological and societal contexts. A more systematic use of teaching and learning theories and the associated practical methods might have been beneficial, especially so if the approach had been based on an early and full understanding of the background to teaching, learning and motivation, until recently not seen as an important feature of the preparation for the post of university lecturer. A clear grasp of the differences between training and education, skills and understanding etc, would have been very helpful. A further summary of precepts and their implementation will appear in section 17.3.2, in the shape of Table 37 which is devoted to the issue of motivation.

17.3 People: Students as Members of BrunelCIM

Students are exposed to new working situations, new learning contents, stimulating discussions, a great variety of teaching and learning methods, and are encouraged to develop their own problem oriented engineering approach. To be successful in this pursuit they must invest a great deal of sustained effort over eight months, much more than would be the case for a 'standard' option. The case study in 13.2.1 highlights some of the risks involved for students who are not able to share out their time between different activities. Problems arose relatively frequently because students devoted all their effort to CIM, a multifaceted activity, at the expense of both lecture courses and their individual final year projects. It is one of the tasks of the member of staff managing such a course to listen out for potential problems and to help students in finding solutions.

In this sub-section the writer will attempt to show how far the CIM course has succeeded in satisfying the demands for an environment which maximises opportunities for learning and which creates motivation and, especially, a need for achievement. Perhaps the most important success of the CIM concept is the creation of a challenging goal, the demonstration of a working 'factory' to industrialists, which is of a nature which accords with the goal theory discussed in section 6.2.3.

17.3.1 Preparation

In section 11.4.3.6 the writer lists people related issues which the course design needs to address or which may influence the performance of students once they have joined the course. It was, unfortunately, impossible to prove or disprove the assumption that two industrial placements were essential for successful participation in a practice based learning activity like the CIM course. Even the German and Polish students who joined the course tended to have at least one long period of practical work in industry 'under the belt'. It is reasonable to assert, however, that the industrial training instils students with an awareness of the need for mature and responsible integration into a working situation, an essential ingredient of practice based learning, or real world oriented learning.

Students' responsibility for their own learning, as postulated by Etmian and Sell [1984], must be recognised before the start of an open ended learning experience such as that of the CIM course. On BME and SEP this is developed through a number of course elements in earlier years.

17.3.2 Learning, Motivation and Compulsion

Discussions of the issues of learning theory were reported in section 5.6 and those of motivation were presented in chapter 6. While it would have been desirable for the CIM course to satisfy all the requirements stated by the different authors this was not possible. All the same, many of the behaviours to be expected according to theory could be observed in practice and most of the potential threats to good performance of groups and individuals could be addressed using the concepts and methods proposed.

As mentioned in section 11.5 the course was initially compulsory for BME students, one of the groups for which it had been designed. This had substantial logistic advantages in that numbers were known in advance, in that it was possible to plan ahead with the appointment of senior coordinators and in that there was no need to worry about the course not being run. However, the price paid for this was that there was each year a substantial number of students[224)] who simply could not be motivated to get involved in the course. The case described in section 13.2.2 highlights such a situation. As Pittenger and Gooding [1971] explain, this is quite a normal phenomenon: "Phenomenologically speaking (that is, from the behaver's view) one is never unmotivated. Every person is continually seeking personal adequacy (or self-actualisation) ... such an 'inadequate' person ... is highly motivated and active in the process of seeking adequacy." This quest just happens to point in a different direction from that intended by the teacher and is therefore viewed as disruptive. Luckily, once the course had been made an option for the whole of the student cohort, only a very small number of students, one or two per year, were disruptive, in the writer's opinion, as a result of participating in a course which required more than passive consuming.

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224) that is, between a fifth and a quarter of the BME group.

Precept	Source	See	Elements
promote individually achievable high standards, allow taking of moderate risks etc.	A.S. Alschuler et al. (3-5)	S. 6.3.3	IR, MF, PW, TE, TW
use non zero or shared sum assessment; ensure that testing addresses understanding and not quantity of content learnt	A.S. Alschuler et al. F. Marton and R. Säliö (2,9)	S. 6.3.2 S. 5.8.1	OVERALL COURSE PROCESS
equilibration and disequilibration as motivators	M.H. Appley	S. 6.2.2	CM, FR, MC, TR
rewards need to be presented quickly and just after detecting the desired behaviour, use rapid feedback, not constant praise	B.F. Skinner	S. 5.6.2.3	CM, MC, ST
avoid total reinforcement	A. Amsel	FN 72	FR, ST, TR
motivating students: summary	various	S. 6.4.2	Whole Process

Table 37 Key Factors in Motivation for Learning

In Table 37, the writer has attempted to provide a summary of the links between some of the teaching approaches used on the CIM course and theories of motivation. This is by no means an exhaustive overview, it simply provides a few ideas about more formal methods of addressing this important issue. Particular aspects of motivation and personal development are addressed in the next section.

17.3.3 Furthering Individuals and Achievement Motivation

In section 3.1.1, points (2) and (5) provide a resume of the statements of Gregor and Hansel [1993] regarding the necessity of a continuous process of (re)qualification of professional staff. This is a re-statement of some of the remarks made by industrialists which can be found in sections 4.3.1 and 4.3.2. By offering learning opportunities on the CIM course rather than prepackaged learning[225)], students are prepared for a future where they have to acquire new faculties and knowledge all the time, usually in an unstructured, but nevertheless time-critical process. Initial processing of information and thus learning takes place very early on in the course, through the analysis of the hand-over documentation. As the course gathers pace, students have to take more and more responsibility for collecting information. They will negotiate with suppliers and arrange topical courses with individual members of staff and with outsiders.

In the chapter on learning, chapter 5, we saw that Alschuler et al. regarded [1970] the 'need for achievement' as the key motive which students should have acquired by the end of their formal education. They must have identified Achievement IMages[226)] which should help them in their striving for excellence. It is both the foundation for personal improvement and one of its objectives. Rephrasing earlier observations we can summarise this striving as:

- compete and succeed against one's own past performance in a given span of time,
- compete with others as a team or individually,
- try to accomplish something unique,
- develop one's skills through long term involvement.

225) lectures, finite laboratory sessions, tutorials, computer assisted learning, programmed learning.

226) or goals which involve competition with standards of excellence, quaintly turned into the acronym 'AIMs'.

All this highlights the goal directed, future oriented nature of human beings. A need for achievement should not be viewed as a personal characteristic which will automatically lead to a pattern of antisocial behaviour based on a wish to dominate and exert absolute power. A well developed need for achievement is a characteristic of a mentally well balanced person.

A key demand of Alschuler's team, the removal of comparative targets, has been achieved to a considerable extent. Although the writer had to fight each year for the CIM marks to be adopted without recourse to 'normalisation' this became an accepted practice since it was possible to show that the students' commitment and performance improved substantially once they realised and put trust in a marking scheme which attempted to set absolute standards[227]. The quality of the documentation provided, for example, increased in absolute terms from year to year, partly because of the availability of more powerful (software) tools, but mostly because of a will to do better. It can thus be confirmed that Alschuler's preferred type of assessment repeated here, has been adopted for the course, with considerable success:

2) NSA or Non zero Sum Assessment (furthering the setting of achievement goals): the overall sum of marks is higher or lower depending on the sum of all individual's performances. Obstacles tend to be personal and environmental.

As mentioned in section 6.3.1, Alschuler et al.'s guidelines and checklists can be used to analyse the provision of learning opportunities and the development of motives. The 'six steps to success', provide an additional framework:

1) Get Attention: focus students on what is happening here and now (dramatic settings).
2) Create Experiences: students must vividly experience thoughts, actions and feelings comprising the motive.
3) Conceptualise: to clarify the motive students must conceptualise and 'label' elements of the motive.
4) Relate: test the relevance of the motive by relating it to the person's own values, feelings, demands of life.
5) Apply: use several real goal setting situations to stabilise the motive.
6) Internalise: progressively withdraw external support while maintaining its voluntary use and satisfaction.

The writer feels that it would not be productive to analyse further the links between the organisation of the CIM course and the six points listed above - the connection is self-evident. Suffice it to mention that (6) is satisfied by modifying staff behaviour in the task reviews and in the gradual reduction of supervision over between the start and end of an iteration of the course. The reader may wish to refer back to section 6.3.3 which offered a list of methods for promoting students' motivation for achievement. Alschuler and his colleagues emphasise the importance of group and team based work, clearly a key element of the CIM approach.

17.3.4 Learning about Qualification

Tasks on the CIM course are substantial and require faculties and knowledge which are neither taught during the preceding years of the two academic programmes nor can they be

227) As explained elsewhere, this practice had to be abandoned in 1994 when the students' mutual assessment returned marks which could not be accepted, for a number of reasons.

acquired as a result of industrial training. The course encourages students to identify individual and team training requirements, arrange their own training, when needed, and to demand resources for this purpose. In many cases this has to be sought from outside the department since there are no suitably qualified members of staff. This is thus a real situation in line with Thorndike's view of reality, described in section 5.6.2.1.

17.4 People: Staff as Members of BrunelCIM - Attitudes and Performance the Effect of Unconventional Teaching Methods on Staff

As discussed in sections 6.4.1 and 6.4.2, the role of staff in motivating students to perform well is very important and requires particular qualities of the people involved. This has been expressed well by Alschuler et al:

> "Teachers' expectations tend to become self-fulfilling. The teacher's own attention, involvement, and hopes can be contagious." [Alschuler, 1970]

In the present section the discussion of the issue of staff involvement will include a few theoretical comments, general observations and a brief discussion of the effectiveness of the particular tool used to manage the CIM course, the non-executive board.

17.4.1 Benefits and Risks of New Methods

Although it may appear from the whole of the preceding section that the members of staff responsible for CIM or involved in the process, could simply sit back, relax and enjoy the inventiveness and commitment of the students, nothing could be further from the truth. This was especially true for the writer who had to run the course on a day-to-day basis. Maintaining a good working atmosphere for the students involved much in terms of communications activity, from advertising visiting lectures, updating the timetable, through to responding to urgent e-mail containing exciting new ideas or calls for help (see appendices Q and S). It included fighting for funds and new equipment, developing understanding amongst other staff members for the different approach used, handling orders as well as negotiating with the chief technician. The student members of the course also expected him to take part in extra-curricular activities.

While Alschuler et al's comment applies to all teaching and learning situations it is of particular relevance in situations where new methods are being tried out and where success hinges on extracting substantially more commitment from students than would normally be the case. Members of academic staff tend to welcome the use of unconventional teaching methods since they expect to draw benefit in one or more of the following areas:

- social prestige from being perceived as progressive,
- academic prestige linked to the publication of results,
- enhanced reputation with the students,
- improved performance of the students in assessment,
- reduced time commitment.

At the same time, however, there are a number of factors which may hinder the introduction of new teaching approaches, all of which were observed on the CIM course to a greater or lesser extent. The principal objections are the following:

- increased time commitment,
- increased cost of provision,

- change in course content,
- accreditation issues with engineering institutions,
- fear of loss of control in a less structured teaching situation,
- concern with equitable distribution of work.

The educational environment in the United Kingdom is, in general, far more open to experiments and to the introduction of new approaches than the more rigidly regulated and controlled environment in Germany where a course redesign may need up to 10 years to reach the statute book [personal communication, D. Brandt, Technical University of Aachen]. France has recently become more open to innovation in teaching in engineering, a consequence of the radical restructuring of French industry [personal communication, J.C. Gentina, Ecole Centrale Lille].

17.4.2 Resource Issues on Practice Based Courses

Staff in the Department of M&ES feel that there are many areas where straightforward technological training is useful, for example, on an EA1 course, but training cannot replace a process in which students develop their very own approach to engineering tasks. In an age of low cost expansion of higher education, the CIM course, and similarly product study and artefact study, are activities which can only be justified because they are the key elements in the process of 'forming' broad based practical engineers. The courses are educational in nature since they do not equip students with ready made tools relevant to particular technologies but with the ability to identify and shape their own tools[228].

Unfortunately, this teaching of, in essence, understanding, attitude and values, requires substantial resources, contrary to the expectations of Gibbs [1993] and the EPC [EPC 3, 1991]. This is not simply because of the ever increasing complexity of the topics but is forced on Universities as a result of the changes in students' backgrounds: science subjects and the associated skills are no longer well represented in schools. It can be expected, therefore, that staff input, particularly in the areas of development of understanding and student motivation, will need to increase rather than reduce if standards are to be maintained.

However, it is the author's experience that an approach which promises less formal teaching and either more practice based learning or more 'reading for a degree' is espoused fervently by some academic staff, in the expectation that it will lead to reduced work-loads. It is likely that this misconception stems from the relatively narrow, conventional definition of teaching, characterised by the notion of "contact hours" in lectures, laboratory sessions and tutorials, many of which are seen as a burden because of their regularity. There is relatively little recognition in academic circles that informal learning and less structured approaches require, in fact, more academic input if they are to result in an enhanced 'product'. This is in line with the view of academic managers, especially those in the "traditional" universities in Germany, France and England, who feel that "chalk and talk" result in the most efficient use of resources.

Staff involvement in the artefact study (section 9.3.1) is very high, both in terms of time and intellectual input. At first sight, the product study (section 9.3.2) may appear to offer a "low cost alternative" since it requires the presence of but few members of staff. However, the learning effect, especially as regards the important issue of engineering understanding, is much more shallow since students spend most of their time learning from each other. Future

228) training, by contrast, is designed to provide skills and knowledge directly applicable to a working situation. Since concepts and theoretical constructs are not part of the package, the results of training can become out of date very quickly.

development of the courses will need to increase the time available to students enabling them to study products and artefacts more in-depth, thus maintaining pressure.

The CIM course, at first sight, might appear to offer an opportunity for achieving high quality learning, with limited implications for resource use. In contrast to traditional lectures, where each hour will require between 5 and 10 hours of preparation effort by the member of staff, it is difficult to identify a ratio of preparation hours to activity hours, perhaps excepting the preparation of the brief for each year of the programme which involves approximately 3 weeks of staff FTEs (Full Time Equivalent units). Most of this time is devoted to discussing the new overall direction, the individual tasks and the financial implications of buying new equipment etc. Writing the brief to be sent out to students itself is a task which is accomplished over a number of years, a successive refinement process. Many of the ensuing clerical tasks can be handled by secretarial staff. However, the ongoing process of motivation must be carried out by an academic member of staff. By contrast, 'conventional teaching' can minimise resource use, once a course has been written: in many cases it will be possible to repeat material unchanged for several years. Project based teaching very often requires new material and new working situations every year and is therefore more resource intensive.

From the start of the academic year, staff support for the student team engaged on the CIM project must be available far beyond the number of time tabled hours, especially for the crucial first few weeks when the senior coordinators are still finding the right management approaches. At the same time it will be necessary to arrange the programme of guest lecturers and industrial visits while solving technical problems. Once the initial build up phase is completed in an iteration, the period of the first task reviews with its increased student contact time will already have arrived.

The high investment in staff hours, culminating in the severely time-constrained marking of the group reports, together with the cost of maintaining a high quality laboratory area for the simultaneous use of up to 40 students, places a very heavy burden on any Department wishing to run such a course. Investment in equipment can be particularly onerous and must be planned well so as not to overconstrain the students - or inhibit the changes necessary between years. All the same, the experience of the last eight years has shown that the concept can work well, paradoxically perhaps due to the high pressure present throughout, for staff and students. A strong awareness of and commitment to teamwork must be created early on if real-life project based learning is not to result in frustration for some members of staff and students. It is essential that staff be trained in new teaching approaches to avoid the situation where 'freedom to learn' results in the type of free-wheeling by students decried by Klein (see section 4.4.2).

17.4.3 Motivational Issues

A key task on the CIM course was the motivation of academic staff and the management of their input. Initially the author felt that it was adequate to arrange a set of support lectures and that any other input from academics would occur on an informal basis since the students were expected to be aware of the expertise of individual members of staff. As it happened, this was not the case. Students failed to define their requests for input in a form which allowed members of staff to respond easily, the knowledge of staff's areas of specialisation was, in fact, not well developed and members of staff were in no way pro-active. As course-organiser the author tended to be present very frequently and was frequently considered to be a 'fount of all knowledge' - a difficult and time consuming role which he could not always satisfy. In general, students would be very independent though and develop their own contacts to solve problems where no expertise was available amongst the 'consultant experts' within the Department.

The author had to develop two tools which assisted in the process of eliciting input from other members of staff: the task review process and regular scheduled seminars on topics which had been recognised as problem areas relevant to groups of students rather than individuals (e.g., computing workshops, see chapter 14). Even so it proved impossible to integrate one member of staff in the day to day operation, although he was nominally part of the team running the course. He had "more important things on his agenda" and would simply fail to turn up to scheduled events - "it is the students who are running the show, after all", was the explanation. While this may sound negative it is in no way a reflection of the atmosphere of the course: both students and staff benefitted from working on challenging tasks where progress was tangible from year to year, where attitudes changed and aptitudes could be identified in a free and safe environment (see also section 7.4.2).

17.4.4 Involvement of other Staff

Technician staff's attitudes to the practice based learning approach were always highly polarised. There were technicians who would be horrified by the intimation that students could handle practical projects and operate machine tools even though they knew full well that all the students had undertaken their EA1 training (a period of workshop skills training carried out in sponsoring companies' workshops or in technical colleges). There was, at the other extreme, a technician who would quite happily turn up on a Saturday or of an evening if a deadline loomed and if he felt that his assistance could be useful. For the students the involvement of technicians was very important since they acted as teachers and assessors at the practical technical level, the "this might work if you change it a little bit in this way..." approach.

An important, but initially mismanaged, resource was the chief technician who resented the intrusion of students into his domain, especially so since they would at times take on tasks normally reserved for 'his' technicians. Until he saw some of the results achieved by the students, about three years into the course's development, he was not supportive, obstructing, for example, the use of laboratory facilities out of hours or even during the 'technicians tea break'. He had to be convinced, by the students and the writer, that practice based learning was a valid approach - even if something designed and built in one academic year had to be pulled apart the following year.

Without substantial and effective support from secretarial and clerical staff a course of this kind could not have been organised since it requires a great deal of paperwork which has to be prepared to a professional standard - if it is to act as a motivating tool. Even though much of this could be dispensed with once electronic means of communication amongst the members of the CIM course had been established, assistance from the secretarial staff became even more important since the students needed help with creating high quality leaflets and documentations, necessary for the CIM conference and links with other organisations. Clerical effort was also essential in producing summary sheets of skills etc.

17.4.5 The Non-Executive Board of BCIM

Wilhelm Hill [1994] is quoted in section 3.5 in connection with the decisions on size and structure of working groups and teams. His observations were made with particular reference to the size of non-executive management boards for which he quoted extremes of three and thirty members. While he strongly advocates the former he accepts one of the arguments for the latter, namely, the use of the board to establish links with other enterprises and public bodies. In terms of effectiveness he states clearly that a large board will, in general, perform much less well than a small board meeting frequently. Most companies with large boards acknowledge this assessment implicitly by arranging for a core group of the board members to meet more regularly and to be more involved in the running of the company.

In the first year of BCIM there was already a non-executive board with five members, three of whom would be found on every board until 1992/93. This board was supposed to meet regularly, but it soon proved to be too big - it was virtually impossible to arrange times which were convenient for all members. From the following year the board's size was reduced to four members all of whom nominally had a very substantial interest in manufacturing systems and their evolution. Unfortunately one of the four was not adequately motivated and had to be dropped from the team after two iterations. With only three members[229] the board could function on the basis of frequent but informal meetings and there was little need for coordination: all members of the board were permanently involved in the work carried out by BCIM members and were therefore immediately aware of any potential problems.

Beyond the non-executive board there existed, from the beginning, a body of engineering and management consultants. These were recruited from among members of staff from the Department, the University, Industry and Henley, the Management College. Members of BCIM were encouraged to contact consultants whenever they felt that this was appropriate. The consultants thus acted just like an extended management board giving students new links and access to information not easily located otherwise. The internal consultants could claim some credit against their teaching load while external ones were paid for a small proportion of their contribution.

17.5 Organisation and Technology

Although people issues are of the greatest importance, organisation and technology aspects of the course were never ignored. Practice Based Learning can only be successful if the organisational structure is appropriate for the task in hand and if the necessary tools are provided at the right time and of the right quality. The conventional hierarchical structure used for the first iteration of the course was demonstrably not suited to the task while the matrix approach to project management worked well, although some modifications were necessary every year. Matrix structures are very demanding from the management point of view but they tend to provide opportunities for people with different skills and personalities, from the extrovert to the "Tüftler" working on her or his own. On the CIM course this management model allows students to learn more about their own skills - although awareness of this does not seem to be very strong (see Table 38 below).

Throughout this dissertation, technology issues have not played a major role. This is not a reflection on the role of technology on the course, but rather a conscious decision of the author to concentrate on human and organisational issues. It can never be the role of a university education (as opposed to technical training) to equip students fully with the latest technological skills, rather, they must learn to adopt and acquire these skills themselves at

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229) This team was quite ideal in its composition since most of the skills and knowledge involved in developing a computer integrated (manufacturing) system were represented. The disciplines covered by the non-executive team were as follows:
member 1: robot control and modelling, machining processes and materials science, manufacturing models.
member 2: computer programming (assembler to C++), software aspects of data communication and networks.
member 3: mechanical and electronic hardware development, human factors and management.

a later date - and on a continuous basis. This choice was accepted by the respondent of script 2 in appendix S.2 who states clearly that today the technology of CIM does not yet exist - engineers must therefore be educated to create it, together with all the organisational and human interfaces. They must aspire to attain this goal adopting a human centred approach.

17.6 A Survey of Former Students' Views and other Opinions

A discussion with Dietrich Brandt of the Technical University of Aachen had prompted the writer to develop the analysis presented in Table 30 to Table 37. The realisation that information on students' perception of the CIM approach should be gathered was another important outcome of the conversation, held at a crucial time for this dissertation. It led to the decision to conduct a structured interview, combined with a follow up questionnaire. The target audience for this was a selection of graduates who had taken part in the CIM course. Most of the potential respondents were suggested by the writer to represent a cross-section of the course in terms of degree result, interest in course, gender and origin (SEP or BME). The unusual choice of holding an in-depth interview before distributing a far less detailed questionnaire was determined by the need to obtain information which was not influenced by personal allegiances.

The interviews were carried out by a postgraduate at Brunel since the writer felt that he would not be able to elicit information in an objective manner since his close involvement in the course, perceived as total identification by the former students, would lead to results which would not be even remotely representative or objective. However, the writer prepared a detailed script, to be found in appendix S.1, for the researcher who had himself participated in the CIM course. The independent interviewer attempted to contact 25 former students and succeeded in holding 17 interviews whose results are summarised in some detail in appendix S.2. Sections in the replies which refer to the CIM course questions are highlighted with double lines while "spontaneous" comments are marked with single lines alongside the text.

It is important to note that the telephone interview was designed to start as a general attitude survey about BME or, respectively, SEP. Questions (1) to (6) were designed to extract unsolicited information about the CIM course by first making the respondents comfortable (questions 1-3) and then asking a question (4) about the course as a whole. Interestingly, even question (1), concerning the respondent' overall view of the studies at Brunel, yielded useful information in 1 mention of the usefulness of CIM, 1 each of that of project and teamwork, and 2 references to the benefits of practical work. Questions (2) and (3) related to aspects of the present occupation of the interviewee and to the perceived value of the university education in this. The pattern of responses to question (4), requiring a choice of four courses from the syllabus of the complete programme followed, is important since 5 of the 17 respondents stated that CIM had been the course bringing most benefit over all the years of their programme of study. The question concerning enjoyment (4b) brought a disappointing response for the CIM course (only 1 mention) while the results for project oriented work were very positive with 7 responses! Predictably CIM, even in retrospect, was seen as the most time-consuming option by 7 respondents. CIM was not perceived as difficult though. The results for (5), a similar question centred on the final year, are substantially different with 6 of the 17 respondents describing CIM as the most beneficial option and 7 rating it as the most enjoyable. 11 people rating it as the most time consuming option was no real surprise while the 2 responses referring to its difficulty were unexpected.

The responses to questions (7) to (11) addressing CIM on its own provide a great deal of information. However, this is in a form which does not lend itself to statistical analysis: the researcher followed the detailed script of appendix S.1 but allowed the interviewees as much freedom as they wished in responding. Some of the questions were very open-ended and the responses accordingly diverse. The relatively small number of interviews would have devalued any attempt at a statistical analysis. Many comments would require substantial discussion which is beyond the scope of this dissertation. Suffice it to say that the overall picture reflects the responses analysed in the previous paragraph and that there are many useful suggestions for the modification of the CIM course and the academic programmes as a whole. A recurring criticism is the still insufficient level of realism of the situation. The reader is referred to appendix S.2 for a fuller appreciation of the outcome of the telephone survey.

The telephone interviews were supplemented by a questionnaire based survey whose results are summarised in Table 38. The survey also formed part of the review process undertaken for this dissertation. It was also carried out by the research student on behalf of the writer, to ensure complete confidentiality. Graduates were sent a survey form immediately after having been interviewed by telephone and would be asked to return it by facsimile with

Part of Survey:	Assessment of Importance of Skill to Career			Contribution to the Acquisition and Adoption of the Skills											
				Entire Programme			Programme Year 1			Final Year Project			CIM Course		
Skills	Range[A]	Mean	St.Dev.	H[B]	M	L	H	M	L	H	M	L	H	M	L
Problem Solving	1-5	2.08	1.44	7	5	0	2	7	4	6	5	1	8	3	1
Written Expression	1-8	2.91	2.27	9	1	1	3	7	2	9	2	1	2	5	5
Spoken Expression	1-8	2.08	1.89	6	6	0	4	7	2	1	5	7	2	7	4
Team Work	1-4	2.38	1.08	5	6	1	1	8	4	3	1	9	8	5	0
Management	1-7	2.30	1.74	1	8	3	0	4	9	0	4	9	5	6	2
Time Planning	1-11	2.62	2.68	3	8	1	2	5	6	5	6	2	3	3	3
Relating to Others	1-4	1.12	0.92	5	5	2	0	10	3	2	3	8	7	4	1
Self Evaluation	1-8	3.33	2.06	3	8	1	1	4	8	7	5	1	3	4	6
Information Retrieval	1-12	3.67	3.10	6	6	0	9	3	2	7	4	2	1	6	6
Evaluation	1-7	3.30	1.85	0	4	8	0	2	11	0	5	8	4	6	3
Computing	1-9	3.00	2.25	6	6	0	2	8	3	6	2	5	4	3	5
Programming	2-10	4.09	2.32	6	5	1	4	5	4	7	1	5	5	4	6
Electronics	2-5	3.11	0.88	1	8	3	2	7	4	2	2	9	0	6	7
Mechanical	1-13	4.09	3.63	2	7	3	3	8	2	1	2	10	0	7	6
Electrical	2-5	3.20	0.87	1	6	5	1	9	3	0	2	10	0	6	7

Notes: A) Graduates were asked to rate the skills in order of their importance for professional engineering work. A range of 2-5 would indicate that none of the respondents rated the skill as of top importance although it was rated highly. A low mean score would indicate a more important skill,
B) Graduates were asked to rate the contribution of a programme element in terms of its contribution to acquiring the particular skill. Choices were H = High, M = Medium, L = Low. Numbers indicated responses in category.

Table 38 Results of a Survey of Graduates of BME and SEP who had been Participants in one of the Iterations of the CIM Course

minimal delay so as to get a picture which was not modified by reflection or later discussion with former university colleagues. The original of the questionnaire is reproduced in appendix S.3. Any responses arriving late were discarded. Although 17 interviews had been carried out, only 13 completed questionnaires were received on time. Unfortunately, this number does not allow a rigorous analysis. All the same, it has been possible to draw some conclusions.

For Table 38 the list of skills has been re-arranged and the skills relating to the CIM approach have been grouped. The skills relevant to CIM and Advanced Manufacturing Environments are highlighted by shading in the first column of the table. The range is similar to the list of transferable skills of Table 14. Response rates to individual questions ranged from 9 to 13 answers. The rating of the importance of individual skills for the present post of the respondent received the lowest number of returns. The respondents were asked to grade the skills on a 15 point scale, equivalent to the number of skills listed. An important skill would be rated 1 while a less important one would be classed as 10. In the event, only values 1-13 were used. Means below 3 are highlighted, indicating that a skill was perceived as important by most respondents - in all cases the standard deviation was small, a sign of agreement.

Respondents were asked to assess how much the degree programme, the first year, the final year and the CIM course had each contributed to the acquisition or adoption of the different skills. They were simply given a choice of High, Medium and Low. The sum of responses differs from skill to skill and between groups of columns since not all respondents replied to all questions. In the "contribution" columns all the cells scoring 6 or more responses are highlighted, arbitrarily taken as a level reflecting a strong opinion of the particular group of respondents.

The undergraduate programmes as a whole performed very well in this analysis, scoring either high or medium in all relevant areas, especially with respect to the spectrum of transferable skills for which the CIM course had been designed. Not surprisingly, the contribution of year 1 is strongest in the technical skills. The project presents the most interesting picture: a highly polarised assessment between very poor and very high scores, with a particularly poor performance in the area of transferable skills. The assessment of the CIM course is more balanced, although the contribution to the adoption of some of the skills is accepted as being very high. Surprising are the low scores with respect to technical skills although this assessment should be set against the views on year 1 of the programmes: quite clearly, graduates perceive that these skills must be taught at the beginning. This in itself is a vindication of the design of the CIM approach as an integration tool.

Three individual students' views on CIM are appended in section S.4. Two of these reflect the views of postgraduates while one was written by one of the managers on the first iteration of the course. It would have been interesting to compare the results of the interviews, survey and "testimonials" with the routine student feedback results on the courses, however, these were not available to the writer. It may be possible to undertake a comparison at a later date.

17.7 Overall Review

Several lessons may be learnt from this discussion: when designing a practice based learning environment it is important to share out management roles, at the very least, to divorce the role of client from that of overall manager and both from the role of assessor. The use of manipulation, even with the best intentions, should be minimised since it can lead to uncontrollable situations. The tutors charged with facilitating learning in such an environment must decide at the beginning whether they operate as observers in an arms length relationship to the senior coordinators, with the overarching objective of a fair assessment, or whether they wish to become overt participant observers, in a position to monitor and support the learning processes much more closely. Tutors should be trained to handle supervision at a professional level because the strain on students given management responsibilities can be very substantial.

Although based on a longer term plan, the development of the CIM course, to some extent, proceeded on an ad-hoc basis and was initially technology dominated. In the expectation of the Head of Department of M&ES, students were simply being asked to conduct a large, open ended laboratory experiment. Even the team charged with developing the CIM course did not suspect that the management of an activity of the scale proposed would require more than the most basic knowledge and skills in terms of organisational leadership. As a result, they did not undertake a study of the field of human resource management before launching the course. The tools and techniques described in this dissertation were therefore introduced or developed as dictated by necessity.

In reviewing the achievements of the Brunel CIM company it has become apparent that many of the management and human resource approaches developed by the students and staff involved in the course over the years relate very closely to theories and methods, old and new, which are familiar in different professional domains, but not necessarily in engineering. The tools of supervision and participant observation, for example, are not used by engineers but were practised naturally on the course. It has now been possible to place these approaches in their contexts and it can be stated that in most cases the implementations of the concepts were successful and in line with the views of the original inventors. Revisiting the two statements made at the beginning of this dissertation we can rephrase as follows:

> **Company structures and employees' capabilities can be brought in line with the needs of companies. Novel educational approaches must be at the heart of change programmes.**
>
> **CIM and Advanced Manufacturing Technologies can only bring results if people involved in the implementation of new systems have been educated and trained to cope with change and to adopt life long learning.**

The role of engineers has changed in response to today's advanced manufacturing environments and educational approaches must reflect this - without jettisoning the good elements of more conventional approaches.

18 Conclusion

18.1 General Observations

According to Pittenger and Gooding [1971]: "Teaching is the facilitation of perceptual differentiation or a change in meaning. Teaching is not a direct act. One cannot hand a perception to another person or cause one to occur... It must be remembered that what is learned is a function of need. Need, in turn, is what is perceived as maintaining and enhancing to the self." The question for the teacher is [ibid.]: "How can I help students perceive personal meaning of the subject (see it as related in some way to their lives)?"

In this thesis the author has tried to show how a practice based learning environment can be designed and built which satisfies a wide range of requirements, from responding to the needs of students to taking into account the different and sometimes conflicting demands of engineering institutions, future employers, teachers and educational institutions. Finniston's and Parnaby's comments, quoted in section 2.5.1, were of particular importance to the author who tried to follow these through in the context of 'thin sandwich' programmes. This design process had to involve the choice of suitable organisational structures, the right mix of technologies and the search for suitable teaching methods. Learning content had to be selected so as not to conflict with the content of the overall curricula while acting as focal points for integration. The assessment of students also had to be considered at every stage of the process since the course takes up a substantial proportion of the time available (approximately 20%) in the final year.

Many constraints had to be respected in creating a structure which could be used to transfer a great deal of content and to teach and apply a number of faculties. The structure had to allow students to modify some of their qualities[230)] if they were inclined to do this. Perhaps the most important requirement though was that of creating a course which is meaningful in the context of the curricula of which it forms a part. It must also take into account the needs of the future employers.

By the start of the course students have completed three years of BME or SEP and will have acquired a broad based manufacturing and general engineering background covering:

- fundamental theoretical subjects (mathematics, mechanics, electronics),
- advanced technical topics (systems design, simulation, information engineering),
- management studies (organisation, accountancy, law) and
- understanding of processes and problems of the type encountered in industry, as a result of 15 to 18 months of industrial training.

The main role of the CIM course in the curriculum is thus one of providing an environment for integration and consolidation of earlier learning, complemented by the subsidiary, but nonetheless important, role of offering an opportunity for making mistakes in a supportive situation where problems can be analysed and assessed openly.

In a broad assessment, most of the objectives[231)] were achieved, as shown in chapter 17. One ambition which could not be realised though, unfortunately, was that of emulating the example of the polytechnic founded by the Mondragon group of cooperatives, that is, the establishment of a university based commercial manufacturing operation [Oakeshott, 1978]. Although several near-commercial products were developed, such as the remote learning interface, the appraisal procedure, a multitasking scheduler, and interfaces for the MRPII

230) refer to section 5.5.2 for the definitions of qualities, faculties and content.

231) whether part of the original aims or the successively modified objectives.

system and the shop-floor scheduling system, the interest in maintaining and enhancing the manufacturing facility was in the provision of a testing ground for applying software and hardware concepts and, more importantly, a real life environment for acquiring the capabilities for managing advanced manufacturing technology and large projects.

A number of teaching and motivation tools were developed in the process of creating and enhancing the course. These were tested extensively with large groups of students and have generally been proved to be appropriate and effective although some tools, one of which is described in section 12.2.2, had to be dropped or altered. The involvement of highly qualified experts and teachers in a course of this nature was shown to be essential: students ask questions and expect answers which go well beyond the scope of a conventional lecture course.

The latest two iterations[232] of the course have been managed not by the writer but by another member of staff whose previous involvement in the CIM course was, at first, that of a student on the MSc AMS version of the course, and later that of a consultant. He was never a member of the 'non-executive board', charged with the day to day operation of the course. Although he made minor changes to the organisation of the course the overall structure and content remained the same. This indicates that the concept is workable and person independent.

18.2 Key Characteristics of a Practice Based Learning Approach

It may be useful to summarise the most significant findings of the research undertaken in the context of developing and managing a course for enhancing undergraduates' and postgraduates' performance in designing and operating advanced manufacturing environments:

- work in advanced manufacturing is, almost by definition, team-based project work. The preparation for assuming a professional role must therefore be group and team work oriented involvement in large projects,
- the learning environment must be as close to a real life business situation as possible. Simulation and modelling, introducing artificial constraints and theoretical opportunities ("imagine having £ 10,000 at your disposal"), are not adequate solutions,
- any task set for a team must have real deliverables which are reviewed by experts not involved in the process,
- a learning environment which is intended to develop engineers who will be able to work in challenging and difficult situations must present a large number of stimuli (situational patterns) to which students are exposed over a substantial amount of time to optimise adoption of the right faculties and qualities (see section 5.6.2.6),
- leaders or managers should be elected by the members of the team using a voting process which will assure acceptability and cohesion as illustrated in section 14.6,
- the learning cycle or spiral adopted should comprise at least the elements of 'do' (and 'consolidate'), 'question', 'reflect', 'theorise' and 'apply' as postulated in section 7.4.1.
- the reward and assessment systems must be well designed and should always be of the non-zero-sum type if more than minimal commitment is expected of students,

232) latest revisions to this dissertations took place in summer 1995, following conclusion of the 1994/95 iteration of the course. However, it was impossible to include data from the large group of this year.

- a strong and committed staff team is essential. It must be led by people who hold a stake in the success of the innovative approaches (teaching must have rewards),

The points and observations listed form a good foundation for successful operation of non-conventional teaching environments, but the list cannot be considered complete or sufficient for every situation. However, the practical application has shown that most are essential ingredients. In the context of the CIM course they have allowed the development of an approach which satisfies many of the requirements postulated for the forming of good engineers, able to handle people issues as well as leading edge technology.

18.3 Transferability and Further Work

The British higher education system has changed from an elite system to a mass higher education system over the period during which the work was undertaken which forms the basis of this dissertation. Resources, financial and human, have been reduced in real terms and, even more critically, in per capita terms. Staff:student rations have moved from 1:11 to 1:20 or worse, while the emphasis on research as the only measure of academic excellence militates against the development of innovative learning and teaching approaches. It is therefore unlikely that approaches identical to the CIM model will flourish elsewhere, even though the prototype has been successfully transferred to a new team and continues to attract substantial support at Brunel. However, the paradigm of practice based learning is expected to be transferable to other situations and subject areas.

An exact replica of the CIM approach involving very large teams (between 30 and 50 students) with many task teams (each having between 4 and 8 members) may well only be possible on degree programmes which include a very large element of industrial experience, that is, sandwich programmes. Students lacking the experience of working in an industrial concern or business environment would probably not be able to cope with the managerial complexity and uncertainty of a large project but may well be able to handle the type of real-life projects described in sections 13.4.3 and 13.4.4, but with management and assessment structures similar to those piloted on the Brunel CIM course. Elements of the method could be employed in other contexts. The mutual assessment, appraisal and counselling process or the organisation of industrially orientated conferences and formal academic debates could fit into many different engineering and non-engineering curricula.

While the quality of the CIM experience is high from a student's point of view, the cost per FTE (full time equivalent) is considerable since the approach requires technical and managerial support of a high standard. It would be very difficult to replicate the approach with student numbers higher than about 50. There are indications though that the funding councils are moving towards some highly selective support of resource intensive innovative education, e.g., the EngD and Industrial PhD programmes, both firmly rooted in "real" world engineering situations.

The current team involved in the CIM course, and researchers elsewhere might wish to address the following issues in more detail:

- students on BME and SEP participate in some psychometric testing as part of the selection process. The data gathered could be used to conduct an input-output assessment of the programmes and their elements, especially reflecting on the impact of CIM. Two teams of CIM members have already started such studies to optimise the roles of people on the course,
- a follow-up study comparing the attitudes to life-long learning of graduates of BME and SEP who did or did not participate in the CIM experience,

- a study of the feasibility of introducing practice based learning into module based teaching.
- development and implementation of a similar environment in the final year of a full-time degree programme, both as an exact replica and by modifying it to take into account the lack of industrial experience,
- an investigation of the boundaries between educational simulation, experiential learning and practice based learning may yield interesting results,
- a fuller analysis of the mutual assessment process including interview with former and present participants to assess the validity and fairness (the survey reported in section 17.6 could only "scratch the surface"),
- the role of technology in engineering education should receive more attention: is it desirable to integrate involvement with modern technologies into degree programmes or should this be left to industrial training?
- the issue of training versus education on engineering courses at universities would still benefit from further study.

There are many more areas worth investigating, some of which have been touched upon during the work on this dissertation. However, it could never be an objective of the author to write a definitive analysis of educational theory and practice as applied to engineering education for advanced manufacturing environments. He hopes, that his contribution will encourage others to develop their own approaches to practice based learning and to the stimulation of students' interest in life long learning. Finally, with E.C. Tolman [quoted from Hergenhahn, 1988] the writer would like to state:

"In the end, the only sure criterion is to have fun. And I have had fun."

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21 Glossary of Terms and Abbreviations

Some of the explanations found below contain specific definitions put forward by the author in the absence of clear dictionary statements (dictionary definition=dd). These are marked thus: (*)

Ability: (dd) sufficient power, capacity to do something; (*) natural or conferred option or possibility to achieve something.

Advanced Manufacturing Environment (AME)*: defined by the author as a manufacturing situation where advanced manufacturing technologies and methods are being used.

Advanced Manufacturing Method: (*) defined by the author as the application of the approaches of control engineering (e.g., the laws of feedback) and of MSE to the management of operations in a manufacturing plant.

Advanced Manufacturing Technology: (*) defined by the author as a technical system whose output is not solely determined by the effort of an individual operator and the machine tool(s) allocated to him or her.

Affect: (dd) in psychology: feeling, emotion, desire, especially as leading to action.

Appraise: (dd) value or fix price for, estimate. Look ahead, plan, on basis of past performance and future achievable goals. Refer to section 15.3.2 for details.

Aptitude: natural propensity or talent for something, ability to acquire a particular skill.

Assess: (dd) estimate magnitude and value of something. Backward looking, 'objective', often involving numbers. Judge a person on the basis of objectives and respective achievements. Refer to section 15.3.1 for details.

Assessment: formative - gives students feedback on their performance and on potential grades

normative - indicates to students and assessors whether their approach has been successful

summative - affects the final grade which a student achieves for a course.

Authority: (dd) power or right to enforce obedience; (*) power, whose source is made legitimate through recognition and acceptance, but possibly only as the result of official backing, that is, delegated power [Handy, 1985; author].

Autonomy: freedom to determine aspects of personal destiny. Freedom to take decisions in the workplace. Semiautonomous work groups have limited freedom to manage their work.

Brunel CIM Company (BCIM): designation of the physical and organisational implementation of the teaching environment which is described in this dissertation. Made to resemble a real company but not yet as far advanced as the production side of the technical college of the Mondragon region of Spain [Oakeshott, 1978].

Cognis: sum of the core and domain specific abilities of a professional person, needed to operate on a knowledge base [Macleod, 1992(1+2)]. (*) the rational domain of knowledge.

Competence: (*) ability of a person in relation to an activity [Macleod, 1992], (perfect) subconscious knowledge of rules. Related to Performance.

Competency: ability to do, ability for a task (meaning nominally identical to Competence).

Computer Integrated Manufacturing: (*) the application of computers to link and control all aspects of manufacturing operation in an enterprise and, where applicable, between enterprises in a linked network of suppliers and customers

Faculty: competence for any special kind of action, power inherent in the body or mind as a result of training or education (see 5.5.2.3).

Formation: formation refers to the package of education and training which leads to chartered engineer status.

Gnosis: (*) the spiritual domain of knowledge.

Industry: (*) in the context of this thesis the term 'industry' is taken to mean any place where a graduate or student undertakes paid work. It can thus refer to an academic establishment where she or he works as a researcher after graduation. In other words, it is any place where the results of learning may be applied.

Influence: according to Handy [1985] the use of power to modify somebody else's attitude, behaviour or objectives.

Intuis: ability of a professional person to operate beyond the existing knowledge base [Macleod, 1992(2)].

Job of Work: (*) limited task in the context of paid work, with a beginning and end, requiring a finite time for its completion. Hence, 'jobbing shop'.

Judging: (*) term used by the author to cover both assessment and appraisal and any other method of measuring and predicting a person's performance.

Knowledge: (dd) knowing, familiarity acquired by experience person's range of information, theoretical or/and practical understanding, the sum of what is known.

Manipulate: (dd) handle, treat, esp. with skill; manage a person, property by dextrous use (esp. unfair) of influence.

Manipulation: "any learning experience or intervention which can only be done once to a student or a set of students" must be outlawed as manipulation [T. Borton and G. Weinstein quoted by Alschuler et al., 1970].

Matrix Organisation: management structure suited to organisations with flat hierarchies where people allocated to a particular task or project are also part of function or discipline oriented peer groups established to enhance operational performance.

MSE: Manufacturing Systems Engineering is the engineering discipline which was created to ensure the professional design, implementation and management of manufacturing systems (Parnaby: "an integrated combination of processes, machine systems, people, organizational structures, information flows, control systems and computers whose purpose is to achieve economic product manufacture and internationally competitive performance.").

NVQ: National Vocational Qualification as awarded by the CNVQ, Council for NVQ. These exist at a number of levels and had been supposed to replace most of the plethora of awards defined by different bodies. NVQ exist from the level of an RSA certificate to degree level.

Observation: overt/covert participant observation refers to two social sciences techniques for studying the behaviour of groups of people. In both cases the observer is integrated in the group but in the covert case the observer plays a role and the group is not aware that they are being observed.

Ownership: (*) a combination of managerial freedom and responsibility in project work which can be delegated to individuals.

Performance: potentially imperfect application of the rules in a practical situation. Related to competence.

Power (1): (dd) ability to do or act, particular faculty of body or mind to do something, active property; (*)pl. in this thesis sometimes used to embrace both 'faculties' and 'qualities' where one of the more colloquial used terms is not appropriate, e.g., skill, knowledge etc., powers tend to be used actively (see 5.5.2.3).

Power (2): (dd) influence, authority, personal, political, social ascendancy over something; (*) resource required to influence another person [Handy,1985].

Quality: (dd) faculty, skill, accomplishment, characteristic trait, mental or moral attribute; (*) pl. sum of aptitudes, attitudes, values and emotions of individuals affecting their performance in work and life (see 5.5.2.2), usually present naturally but open to modification.

Responsibility

Simulation and Gaming: teaching method involving the creation of situations which mimic reality and which allow learners to test out behaviour in near real life environment. Games are often more accurately scripted and more limited in scope than simulations.

Supervision: monitoring of performance and provision of support for resolving problems; in social work and project management contexts: highly structured method of providing support for individuals working in groups and for the group as a whole. Can only be effective if the provider is outside the group and not integrated in the hierarchy of the organisation.

Teacher: (*)person in charge of a learning situation, designer of learning situations, transmitter of knowledge and concepts. NOT an instructor.

Technis: sum of the core and domain specific abilities of a professional person, needed to operate with an existing knowledge base [Macleod, 1992(1+2)].

Abbreviations

AMT Advanced Manufacturing Technology

AME Advanced Manufacturing Environment

AMS Advanced Manufacturing Systems

BME Brunel Manufacturing Engineering Programme

CIM Computer Integrated Manufacturing

GNP Gross National Product

MSE Manufacturing Systems Engineering

POT People, Organisation, Technology

SEP Special Engineering Programme

A Appendix: Engineering Professors' Conference

A.1 Components of Capability and Learning

Table 39, reproduced here from [EPC 1, 1989] is used to summarise the teaching and learning analysis of engineering education undertaken by the Working Party on Quality in Engineering Education of the Engineering Professors' Conference and presented by Professor

Quality Parameter → Type of Learning ↓	Resources	Process	Assessment of Outcome
Knowledge	Provide information in best way: lectures, databases, videos, books	Show relevance of information to engineering. Teach simple study skills. Use discovery methods where appropriate	Test for recall by questioning
Skills	Provide facilities appropriate to the skills being learnt: labs, problem classes, computers, group projects	Instruct and demonstrate the skills and make opportunities for practice - often, but not necessarily supervised.	Set tasks that require the exercise of the skills.
Understanding	Provide a rich educational environment: lectures, computers, library, tutorials, coffee bar, VCR's, problem classes, electronic mail etc, further training for staff.	Focus teaching on concepts. Encourage students to use as many facilities as they can to help grasp new concepts. Set projects. Add problem solving to all laboratory experiments.	Set new tasks that require understanding, not just skills and memory, for their completion: projects, open ended questions, correcting other people's errors, designing, explaining etc.
Attitudes and Values, Personal Qualities	Provide congenial surroundings and good quality teachers and teaching methods. Provide outlets for personal projects, provide newspapers, discussion groups, external contacts.	Motivate where necessary: in lectures and visits, by example, by teaching 'Learning to Learn', by setting challenges that can be met successfully, etc.	By personal contact, by the effort exerted, by the extent to which challenges are welcomed, by the questions asked, by breadth of outlook, by enthusiasm.

Table 39 Educational Taxonomy of the EPC

J.J. Sparkes in the first occasional Paper of the Conference [EPC 1, 1989]. This table was used as a starting point for the discussion of the capabilities of engineers in section 5.5.2. Although it proved to be somewhat problematic, it was very helpful in stimulating thought.

A.2 Suggestions for the Design of Learning from the EPC

In their 1993 occasional paper No. 6, 'Developments in First Degree Courses in Engineering', the working group of the EPC give "some examples of how conventional teaching methods can be adapted to different educational aims. Most courses have multiple aims and therefore need to include a combination of teaching methods.

The learning of knowledge

Acquiring knowledge is a great deal easier to do if the information makes sense and is 'memorable'. The best presentation of information depends on both the nature of the information and the aptitudes of the students. Discovery learning is usually successful with 'doers' but it is time consuming and may not be so successful with others. 'Verbalisers' prefer classes or independent study ... getting students to investigate case studies is a useful way of making learning active and the knowledge relevant and more memorable. Frequent testing and simple study skills can reinforce the process of remembering.

The learning of skills

Skills of all kinds are taught by instruction and demonstration and are learnt by practice - with error-correction where needed. Instruction and demonstration enable people to know how to do things; only practice enables people to do them well themselves ...

Acquiring understanding

There are two parts to this: (i) grasping the concepts on which understanding depends and (ii) learning to apply them in various situations. Acquiring understanding is therefore usually an iterative process between these two aspects of it ...

Acquiring know-how

Know-how is the expertise acquired from the accumulation of successful experience of problem solving in a well defined field. Much of the teaching of know-how must therefore be problem-based and resource-based, on problems for which the route to successful solutions already exists (e.g., in data sheets, manuals, codes of practice, text books) ...

Learning how to integrate knowledge, skills and understanding

Problem solving projects such as design projects are essential for the exercise of integrative thinking; and since such thinking is a complex skill it needs, like any other skill, to be taught and practised. One final year project (as is common in present day degrees) is not really sufficient. For BEng degrees mini-projects and design exercises are needed throughout the course, for example as part of normal laboratory work ..." [EPC 6, 1993].

A.3 Capabilities of Teaching Methods

Table 40 has been taken from Appendix A of EPC 6 [1993] and is self explanatory apart from the abbreviations CBT and CBI, computer based training and instruction. Key elements which are missing from the table are the different forms of assessment.

The capabilities of different teaching methods as regards the extent to which they help students with different kinds of learning

Type of teaching	Potential for the learning of									
	Knowledge	(instruction)	Memorable (demon-stration)	Skills (practice)	(instruction)	Complex (demon-stration)	Skills (practice)	Know-How	Under standing	Motivation
Lectures	HIGH	HIGH	HIGH	0	Low	MEDIUM	0	MEDIUM	Usually low	HIGH
Remedial Tutorials	HIGH	HIGH	HIGH	MEDIUM	HIGH	HIGH	HIGH	HIGH	Low	MEDIUM
Tutorial Classes	HIGH	HIGH	HIGH	HIGH	HIGH	HIGH	MEDIUM	Low	MEDIUM	MEDIUM
Small-group working	Low	Low	Low	MEDIUM	HIGH	HIGH	HIGH	HIGH	MEDIUM	HIGH
Problem classes	Low	HIGH	HIGH	HIGH	Low	Low	MEDIUM	MEDIUM	MEDIUM	MEDIUM
CBT/CBI	MEDIUM	HIGH	HIGH	HIGH	Low	Low	0	MEDIUM	Low	HIGH*
Computer simulations	Low	HIGH	HIGH	HIGH	Low	Low	0	HIGH	HIGH	HIGH
Laboratories A	MEDIUM	HIGH	MEDIUM	HIGH	Low	Low	Low	MEDIUM	Low	Low
Laboratories B	MEDIUM	HIGH	HIGH	HIGH	Low	Low	HIGH	HIGH	HIGH	HIGH
Peer Tutoring	HIGH	HIGH	HIGH	HIGH	MEDIUM	MEDIUM	MEDIUM	MEDIUM	MEDIUM	HIGH
Projects	HIGH	Low	Low	HIGH	HIGH	Low	HIGH	HIGH	Variable	HIGH
Video Tapes	HIGH	HIGH	HIGH	0	HIGH	HIGH	0	MEDIUM	MEDIUM	MEDIUM
Audio-vision	MEDIUM	HIGH	HIGH	Low	Low	Low	0	Low	HIGH	HIGH
Educational text books	HIGH	HIGH	MEDIUM	Low	Low	MEDIUM	0	Low	MEDIUM	Low
Comprehensive text bks	HIGH	MEDIUM	Low	Low	0	MEDIUM	0	HIGH	MEDIUM	Low
Formative assignments	Low	HIGH	Low	HIGH	HIGH	Low	HIGH	HIGH	HIGH	MEDIUM

Table 40 Capabilities of Teaching Methods [from EPC6]

B Appendix: Project Management after Daenzer & Huber [1992]

1. Functional Dimension (WHAT)

Project Start-Up (Preparation Tasks)

(These activities may be necessary for each new phase of a project. Starred activities are initially planned coarsely and subsequently refined)

agree project aims (objectives, budget, timing etc)

appoint project manager and free resources

define project organisation (internal and within hierarchy)

arrange staffing of project group and decision teams

develop object (task) structure*

define project structure and task elements*

structure project sequencing*

plan project activities (timing, costs, staffing)*

arrange information and documentation system for customer, participants and users*

Project Continuation (Support Tasks)

arrange tasks, activities and responsibilities on an ad hoc basis

project control and management (timing, duties, costs, plan and initiate corrective measures)

co-ordination and internal management

co-ordination and external or hierarchical reporting

recording and transmission of ideas and results

resolving of disputes

prepare and initiate decisions

take decisions

Project Conclusion (Completion Tasks)

implementation and handover organisation

review and revision where necessary

training, instruction, completion of documentation

settling of account

internal review of whole project

All these activities apply to all of sequential, simultaneous and concurrent engineering - only the timing differs; and thus the complexity of the management process.

2. Institutional Dimension (WHERE)

Includes the project organisation and its links with the business organisation as a whole.

selection of the optimal organisational model

integration of the project organisation in the business hierarchy freedom and authority of the project manager

definition of the necessary decision, consultation and support mechanisms, their institutional and personnel implications

3. Staffing Dimension (WHO)

The organisation by itself cannot carry out a project. It is therefore essential to define correctly the task and personal profiles of the project manager, team members and other personnel associated with the project

4. Psychological Dimension

Primarily a people factor but closely linked to organisational matters. The aims, approaches, methods and processes must be accepted, supported and enhanced by the people working in the organisation.

5. Instrumental Dimension (HOW - TOOLS)

This concerns the 'crafts' aspects of the project. The choice of the right tools to manage the processes, e.g., planning and control tools (graphs etc), moderation techniques, management of meetings, defining of aims, assessment, presentation, deciding, structuring and many others.

In real life the dimensions are closely interwoven: the project manager, for instance, is both a person and an institution, she satisfies functions and should use appropriate tools and techniques. The formal structure given is thus only useful for analytical purposes.

C Appendix: Transaction based Teaching and Learning

Pittenger and Gooding are self-confessed field theorists and belong to the Gestalt school of psychology. In their 'Learning Theory in Educational Practice' they discuss three levels of the teaching dilemma: educational philosophy, learning theory and educational practice. Table 41 provides an overview of their classification of philosophies of education which is largely self-explanatory although it may be useful to extract the characteristics of the three philosophies:

	Concepts	Traditional	Technological	Transactional
MAN	Potential	ability to know truth	Comprehension of natural law	capacity for social interaction
	Morality	consistency with truth	harmony with scientific truth	synonymous with social maturity
	Response Made	contemplation of reality	complex mechanical reasoning	social interaction
SOCIETY	Structure	stabilised institutions	evolving towards a natural state	dynamic process
	Authority	assigned roles	competency in science	social endorsement
	Mobility	controlled and restricted	reward for approved behaviour	horizontal movement toward complex relationships
	Communication	prescribed	structured process	shared social experience
	Responsibility	predetermined code	function of social role	participatory involvement and growth
	Ethics	ends justify means	social ends justify relevant means	relevant means for tentative ends
EDUCATION	Objectives	knowledge of truth	discovery and application of natural law	personal and societal growth
	Goal determination	accord with truth	obedience to natural law	transactional relevance
	Content Criteria	reflection of absolutes	congruence with objective reality	opportunity for personal-social growth
	Social Function	perpetuate stable society	experimental refinement of society	enrichment of self and society
	Learner's Role	active acceptance	reception of knowledge	responsible participation

Table 41 An Overview of Educational Philosophies

traditional or classical education should help us rediscover and preserve the timeless values in a contemporary society and should prepare learners to find and fulfil their prescribed role and station in a stable society;

technological, scientific or positivistic education should contribute to the improvement of our society through best practice in science and philosophy and should prepare learners to find and fulfil roles and stations for themselves within the limits of their ability to contribute to such an improving society;

transactive or interactive education should promote an improving society, whose goals and techniques are re-evaluated continually, and should prepare learners to find and fulfil their changing relationships within a growing (in the psychological sense) society.

'Horizontal movement toward complex relationships' indicates a negation of classical views of promotion: people define themselves through enlarging the scope and depth of their social relationships and a hierarchical move would only indicate that fewer people are needed with the relevant skills than elsewhere in an organisation. 'Relevant means for tentative ends' is the most difficult attribute of the transactional philosophy: "Personal-social ends are dynamic processes incapable of becoming fixed and unchangeable. Ends grow from the behaviour of people as expressions of their daily involvement in life. Ends can be stated only as the purposes for daily life and not as specific attainable products or completed states" [quoted from Pittenger and Gooding, 1971].

Pittenger and Gooding reject Skinner and Thorndike (and thus all behaviourists), accept Gestalt and are happiest with the phenomenologists who have no interest whatsoever in elementist considerations. They discuss these the learning theories in terms of motivation, learning, facilitation, capacity, transfer and retention. While the details of this are of no interest their general principles of educational practice are useful and reproduced here in Table 42. Of significance in this table is the demands which the Field Model places on the student: a coordinate transaction can only happen if the teacher transfers her or his interpretation of the information to the students who must interpret it in their own manner.

Activity	Associative Model	Field Theory Model
Grading	effective motivator if objectively derived and impartially distributed	administrative procedure unrelated to perceptual learning
Pacing	inherent structure of knowledge presented at rate appropriate for the learner	interactive thrust of concerned educator and involved learner
Testing	measurement or indication of success of transmission of information	inter-personal assessment by instructor and student of goal validity and approximation
Student Participation	responsive acceptance of professional direction	assumption of initiative and responsibility for personal involvement
Teacher-Learner Planning	search for inherent structure of content and method	a coordinate transaction
Discipline	a behavioural response to proper management of variables in the education programme	function of personal identification and involvement in self relevant processes

Table 42 General Principles of Educational Practice

D Appendix: A Discussion of Purpose

D.1 Theoretical Background[233)]

In science, man is a machine; or, if he is not, then he is nothing at all [Needham]. In industry managers often perceive their workforce merely as highly skilled and flexible robots, accepting, perhaps, that human beings can only work a limited number of hours at a time and may not be one hundred per cent reliable. This view of the human as a machine has developed over the last three hundred years, as a result of the refinement of biological and biochemical knowledge about the human body.

A mechanistic view of "man" is being presented to students at all levels of the education process. Until the 1940s this concerned just the physical properties of the human body but cybernetics research and expert systems work have instilled in most Western people the certainty that it will be possible, in the very near future, to predict all human behaviour in terms of causality. Scientists and technologists will assert that a combination of causes will have a particular effect which, together with effects from other cause combinations, will result in further deterministic cause effect relationships. Although not every link in the chain can be defined at present, there exists a strong belief that at some point it will be feasible to do so. Vitalists, however, maintain that causal explanations are not enough in biology and that systems which involve human activity require in addition, for their explanation, a reference to purpose. This could be, at the most basic level, the preservation of the species.

Paraphrasing Rosenbrock we can either accept what he calls the 'causal myth', which stipulates that 'man is a machine' in the sense that every feature of his behaviour can be described in causal terms: *Since anything which can be described in this way can in principle be done by a computer, it becomes hard, if not impossible, to say that any behaviour shown by man cannot also be shown by a computer* or we can adopt the 'purposive myth' which asserts that 'man is a machine' *in the sense that every aspect of his behaviour arises from an ultimate purpose... Human ingenuity can incorporate some parts of a human purpose in a computer. But it exists there as a subordinate to an ultimate purpose very different from that of the human being. At some point therefore, human and computer behaviour will always diverge. The difference of view between the causal and purposive myths stems ultimately from the fact that the former builds up the world from simple, self-sufficient entities, while the second begins from the opposite extreme, from the universal purpose.*

The tendency of this discussion is not to suggest that computers should appear less practically useful when we accept the purposive myth. They give us the opportunity to free ourselves from much routine intellectual work, as an earlier stage of mechanisation freed us from much physical labour... When they do not interact with people, the limited human purpose which can be incorporated in them can be adequate, and need offer no problem... But where computers and human beings must interact, the purposive myth suggests that computers must be subordinate to men and women... As the surrounding environment changes, the policy derived from the purpose will also change and at some point the policy generated by the computer will differ from that which would be generated by the human organism. Unless the computer is subordinate to human judgement, those who interact with it will find themselves helplessly watching as it pursues the consequences of its error. [Rosenbrock, 1990]

As outlined by Oborne et al. [1993] Paul Branton prefers, in a similar manner, a purposive explanation of an action, in terms of anticipation and decision making, to a deterministic causal explanation, couched in terms of events which have already occurred. He also argues

233) any text shown in italics is a direct quotation from the source being discussed.

that moral considerations are an intrinsic part of the purpose in human work. Stress, for example, can be interpreted as the moral reaction of the responsible operator who realises that the standard of his or her performance has fallen or is being compromised. Managers too have to follow moral imperatives in that they must design work places which ensure the health and safety of workers and which are appropriate to them as human beings.

D.2 Context of Manufacturing

It is the purpose of the manager running a manufacturing plant to produce at the right time the goods demanded by customers, with the lowest possible demand on resources of all kinds. In an ideal world she would achieve this by devising a schedule taking into account all constraints which could then be followed sequentially by staff controlling the machines. However, in the real world there are disturbances, such as "blow holes" in injection moulded parts, which result in delays. The manager thus needs to develop a policy which will allow people and systems to adapt the schedule to changed circumstances, remaining as true to the original purpose as possible. While the schedule must be applied purely as a function of time the policy, when implemented by people, can respond to a changing environment.

In a straightforward manufacturing situation a policy could thus be defined as groups and sequences of cause/effect relationships which can be captured in their entirety and translated into computer programs. By following the policy the computer would be able to run the system in such a way as to make it perform to schedule as closely as possible. However, in a more complex situation it will be necessary for the manager to motivate people to develop policies based on their own commitment to the common purpose, that is, ensuring that the company improves its competitive performance. We could state that people have an innate sense of what it means 'to have purpose' and are therefore in a position to adopt a purpose provided they are shown the need to act accordingly.

D.3 The Dimensions of Anthropocentric Systems

There have been many attempts to define the ideal environment for people working in computer integrated production systems some of which are quoted in the thesis elsewhere. One of the 'well advertised' approaches is that of anthropocentric systems design. The notes provide a resume of a substantial document by Cooley, Brödner, Kidd et al in [Brandt, 1991]. The authors define the requirements on the design of an anthropocentric system in terms of the following three dimensions:

D.3.1 First Dimension: The Workplace.

The individual worker and his or her work environment and workplace form a human-machine system. It must be possible for the people, users, to use the technological system - a demand which is not as unnecessary as it may appear. Many technical systems are designed by engineers or analysts who have not investigated the needs or capabilities of the intended users.

Some of the standard requirements on the design of the workplace are:

- the health of the users has to be protected,
- mental and physical stress are to be avoided,
- people should develop themselves further through their work and should experience challenges, motivation, success and satisfaction.

People want to fulfil meaningful and rewarding tasks [Brandt, 1991].

D.3.2 Second Dimension: Work Organisation

An anthropocentric work organisation is characterised by groups of workers co-operating on the same task. They work in well defined and comprehensive environments, the latter adjective referring to the provision of all technical and organisational tools needed for the successful operation in their task. New technologies should be integrated to provide learning opportunities. The expectations of workers, for example, demand for higher wages to take into account better qualifications, must be handled with sensitivity.

The work organisation should lead to the development of social skills and competencies and must prevent unequal work distribution.

D.3.3 Third Dimension: Organisational Networks of Groups of People within Companies or across Companies

A characteristic of modern working environments is the linking up of people between organisations, usually on the basis of groups with similar interests. This phenomenon has existed in certain fields, such as specialised domains of medicine, for a long time, but it is becoming particularly evident in the informal networks of computer systems staff. The networks are slowly spreading to other groups of 'professional' staff, such as consultant engineers and experts of all kinds. In some universities students are even taught how to develop their own networks. The approach advocated by Brandt et al. goes much further though since it advocates the involvement of staff at all levels of organisations in the networking process.

D.4 Anthropocentric Systems and POT

It is possible to draw parallels between the anthropocentric systems approach and the people, organisation and technology approach:

People refers to the dimension of the workplace: the individual employee and his or her workplace,

Organisation refers to the dimensions of group work and networks,

Technology refers to all three dimensions. It leads to defining different kinds of technology applicable to the three dimensions.

The three aspects of technology supporting the dimensions of anthropocentric systems design are:

the technology of the workplace defines and is defined by the man-machine system,

the technology of group work defines and is defined by the arrangement of work stations and support systems,

the technology of networks defines and is defined by the information and communication systems.

Like many other authors, Cooley, Brödner and Kidd do not offer recipes but 'yardsticks' by which system design ideas can be assessed for their potential effect.

E Appendix: The Objectives Set by BCIM for the Academic Year 1992/93

The following set of objectives and the outline of the CIM course were developed by the senior coordinators of that year in conjunction with the author. The latter has edited the document and added some sub-titles.

E.1 1992/1993 BCIM Mission Statement

The following mission statement was created by the strategy task team together with the senior coordinators and other task leaders. It was agreed at a 'hilites meeting' where the representative of the non-executive board gave his approval.

> "To create an understanding of, and to establish a fully-functional Computer Integrated Manufacturing Cell for the purpose of further research and development into this area, and to promote an awareness of Computer Integrated Manufacture within educational and industrial establishments."

This mission reflects very strongly the links to the outside world which this team intended to establish, an initiative which was successful since it led to the first Brunel CIM conference, the first CIM debate at Cambridge and the Partnership award.

E.2 The Overall Objectives of BCIM for 1992/1993

From the mission statement, five overall objectives can be formed to cover the important main areas:-

The Functional Objective:

> "To work towards a fully functional Computer Integrated Manufacturing Organisation, covering all aspects of the company from the manufacturing cell to the cell support systems and the business functions."

The Image Objective:

> "To further promote BCIM and an awareness of the general concept of Computer Integrated Manufacturing, in both educational and industrial establishments."

The Information Objective:

> "To develop and maintain strong, effective and open communication and information channels, in all areas of the organisation."

The People Objective:

> "To encourage and enhance successful team building, team working and team development under a human-centred approach, to a set of clear and defined objectives, and within a distinct organisational structure."

The Financial Objective:

> "The main function of BCIM is as an educational process. However, through the experience and knowledge gained, goods and services are available to provide additional revenue to support the project."

The objectives served as the decision basis for leaders and teams whenever there were conflicts of interest. They had been drawn up and agreed by about week eight of the course.

E.3 The Company Structure

BCIM operates under a matrix company structure. These structures have proved to be most successful in engineering development type organisations, such as our own. BCIM has been established as a two-dimensional matrix, these dimensions being:-

- The skill groups, and
- The task teams

The skill groups are collections of engineers with similar expertise backgrounds or interests, and act like functional departments. Their role is to provide a pool of knowledge and resources for a particular area for the company, and to ensure that all work of a particular type is carried out in a consistent and standard manner. At present, there are six groups in operation in BCIM:

- Computing (hardware, software and applications)
- Electrical and Electronics
- Mechanical Design
- Machine Tools
- Quality and Inspection
- Documentation and Project Management

The task or project teams are sets of engineers with an appropriate variety of these skills, which are grouped together in order to complete a particular project or solve a certain problem. At present, there are seven tasks under way within BCIM:

- Task 1: Cell Controller - OS/2 Installation and Communication System
- Task 2: Cell Controller - Scheduling System
- Task 3: Machining Sub-Cell
- Task 4: Materials Handling Sub-Cell
- Task 5: Fishnet Communication System
- Task 6: ACIT and Fourth Shift (MRPII) Implementation
- Task 7: BCIM Business Strategy

Each skill group and task team has an allocated leader.

The Engineers operate within the 'cells' of the matrix, being involved in several task teams and using their particular skills within them. The work undertaken within BCIM is largely based around the task teams. However, the matrix structure is maintained to ensure formal communication between the skill and task teams and the commonality of procedures, the sharing of knowledge and expertise and the retaining and maintaining of standardisation between the task teams, which can best be achieved by cross-task skill groups.

E.4 The Role of the Senior Coordinators

BCIM is run on a day-to-day basis by two senior coordinators. Their functions include:

- Planning, organising and coordinating the CIM project overall.
- Establishing the CIM organisation and project administration.
- Coordinating the project tasks and skill areas.
- Setting task and skill group objectives and monitoring their progress.

- Maintaining communication and focus between the task and skill groups.
- Coordinating the assessment procedure.
- Approving equipment procurement.
- Liaising regularly with the Non-Executive Board of BCIM.
- Assisting in disputes and helping out with general problems.
- Reporting the progress made to all CIM members and staff regularly.
- Ensuring the CIM project runs as smoothly as possible.

E.5 What is BCIM?

BCIM - the Brunel Computer Integrated Manufacturing Company Project, founded in 1987, is a final year option offered to students in the Department of Manufacturing and Engineering Systems and exchange students from European Universities.

The aim of the project is to provide the students and supporting staff with a teaching and research platform for the development and application of CIM. Students from all disciplines of engineering, with extensive and varied industrial experience, work together within the company to solve problems within the Brunel CIM cell.

The Brunel CIM cell has as its practical focus the development of an integrated manufacturing facility for the production of small machined parts, including a manufacturing cell and associated design and business functions.

This has provided an excellent learning experience for individuals to gain a greater knowledge of CIM in practice, whilst developing CIM technology for use in industry.

The course is 100% continually assessed, combining project work with written assignments. The weighting between final group reports, the mutual assessments made of engineers' work and written assignments is determined, within reason, by the participating students (CIM members or CIM engineers).

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F Appendix: Sample CIM Timetable (1988/89)

Schedule of Time Use for BME 4 and SEP 4 CIM Course — 20 March In:

Mondays 13.00 - 14.00 Tuesdays 11.00 - 13.00 Wednesdays 11.00 - 14.00 Thursdays 17.00 - 18.00

		Monday	Tuesday #		Wednesday			Thursday
Rooms		TA200	LC210/BLADE	LC062/BLADE	LC263/BLADE	LC263/BLADE	BLADE	BLADE
Wk	Begins	13.00-14.00	11.00-12.00	12.00-13.00	11.00-12.00	12.00-13.00	13.00-14.00	17.00-18.00
1	30.09	-------	-------	-------	S(FS)	S(FS)		
2	7.10	-------	GMO	GMO	CIM91 in Birmingham to 18.00			
3	14.10	-------	MDP	MDP	S(FS)	MDP	mdp	
4	21.10	MB0(*)	GMI	MDP	MDP	MDP	mdp	
5	28.10	MB1	L(PB)	MDP	MDP	MDP	mdp	mdp
6	4.11	MB2	System Test "As Is"		L(JMD)	L(JMD)	TR1	mdp
7	11.11	MB3	S(FS)PE/MDP	TR2/MDP	Visit to AM Graphics Slough/MDP			mdp
8	18.11	MB4	TR3+5/MDP	TR4+6/MDP	L(CH)	TR7/PPE	PPE	mdp
9	25.11	MB5	L(CH)/MDP	S(JE)/MDP	MDP	MDP	mdp	mdp
10	2.12	MB6	L(CH)/MDP	MDP	L(JMD)/MDP	S(PB)/MDP	mdp	mdp
11	9.12	MB7	S(JE)	S(JE)	L(HANCKE)	S(HANCKE)	mdp	mdp
				HOLIDAY	13.12.91 - 6.1.92			
		7.1.1992:	Hand In Date for Individual Interim Reports					
14	6.1	MB8	MDP	MDP	TR7+6/MDP	MDP	TR3/mdp	TR5/mdp
15	13.1	MB9	L(EVANS)	L(EVANS)	TR4/MDP	TRBSG/MDP	mdp	mdp
16	20.1	MB10	TR1+2	MDP	L(HINDE)/mdp	L(HINDE)/mdp	mdp	mdp
17	27.1	MB11	S(PB)/MDP	L(JA)/MDP	MDP	MDP	mdp	mdp
18	3.2	MB12	S(PB)/MDP	MDP	L(BW)/mdp	L(BW)/mdp	mdp	mdp
19	10.2	MB13	S(PB)/MDP	MDP	HCCIM(FS)	HCCIM(FS)	mdp	mdp
20	17.2	MB14	MDP	MDP	L	S	mdp	mdp
21	24.2	MB15	TR1+6/MDP	TR2/MDP	TR3+7/MDPP	TR4+5/MDP	mdp	mdp
22	2.3	MB16	MDP	MDP	L(COOLEY)	S(COOLEY)	mdp	mdp
23	9.3	MB17	First Combined Test		Second Combined Test		mdp	mdp
24	16.3	MB18	S(FS)PPE	PPE/MDP	PPE/MDP	MDP	mdp	mdp
25	23.3	MB19	S(FS)PE	PE	L(PARKINSON)	S(PARKINSON)	mdp	mdp
				HOLIDAYS	27.3.92 - 27.4.92			

30 27.4 — 27.4.1992: Hand In Date for Group Development Reports
29.4.1992: Hand in Date for Assignments
01.5.1992: Hand in Date for Instruction Manuals + User Guides
31 4.5 — Group Presentations in Lab: Timetable + Format to be announced (Full Week)
32 11.5 — ASS ASS ASS ASS (Full Week)
33 18.5 — Exams
34 25.5 — Exams
35 1.6 — Preparation for Project Presentation Day
36 8.6 — Week of Project Presentation Day

	Tasks	Skills
R Pollard	2,4,6,7	electrical, machine tools, craft, mechanical des.
S Cook	1,3,5	computing (hard & soft) documentation, project plan: accounts

Notes and Abbreviations

ASS	Assessors' Meeting
L	Lecture
S	Seminar
PE	Performance Evaluation (PPE = Preparation of PE)
MDP	Manufacturing Design and Practice = Project Time
mdp	Laboratory - BLADE - and staff available for groups wishing to work
MBn	Management Board Meeting (including non-executive members)
TRn	Task Review for Group n; with PB/RJG or FS, always in parallel.
JA:	Jo Au L: Process Monitoring (General Overview, Sensors, Analysis Techniques)
PB:	Peter Broomhead; S: Software Seminars for "User" Groups
RJG:	Robert J. Grieve; L: Engineering Aspects of Flexible Manufacturing
CH:	Chris Hudson; L: Communication Systems and Local Area Networks
FS:	Felix Schmid; L: Discrete Control of Linear Systems + Problem Solving S: Organisation of Co
BW:	Bin Wu; L: Computer Aided Manufacturing Systems Design
ANO:	Invited Lecturers, not finalised
#	Double Option Only
GMn	Group Meeting (all course members)
*	Tuesday 22.10.91
JMD	Janet McDonnell; L: Database Design and Use

Planned Guest Lectures:

COOLEY	Human Centred CIM Theory
EVANS	Developing a CIM Strategy
HANCKE	Human Centred CIM Practic
HINDE	CAPP + TAGUCHI
PARKINSON	Tools for CIM at IBM

G Appendix: Results of Mutual Assessment for CIM 1988/89

This appendix is based on the summary document on the mutual assessment prepared by the 'executives' of the CIM course, academic year 1988/89. All the information presented in this section was made publicly available towards the end of the CIM course iteration and could therefore be included here without the need for 'hiding' the names of the people involved.

G.1 Task Managers' assessment of L. Burns and A. Morgan (Executives)

This protocol was prepared by the 'chief executives' and annotated by the staff member responsible for CIM (*,&,@). For the chief executives it covers the following areas:

A: Planning and Organisation
A1: Policy Making
A2: Management Controlling and Monitoring
A3: Financial Control
A4: Literature Control
A5: Conduct of Meetings
B: Leadership
B1: Direction
B2: Delegation
B3: Motivation
C: Co-ordination and Liaison
C1: Between Executives and Non-Executives
C2: Between Executives Themselves
C3: Between Executives and CIM Team
C4: Between (Inter-) Groups
D: Communication Skills
D1: Verbal
D2: Written
E: Consultancy

General Advice
* Indicates critical remark
& Indicates uneven split
@ Indicates unfounded critical remark

Gp	A1	A2	A3	A4	A5	B1	B2	B3	C1	C2	C3	C4	D1	D2	E	M
1	9	7*	7	6	6@	9	6*	10	8	8	5	7	6	7@	6*	71
2	6	7	7	6	8	7	7	8	7	7	8	6	8	8	6	70
3	6	9	8	7	9*	8	8	10	8	9	7	7	9	8	-	80
4	6	5	7	6	7	6	6	7	8	8	6	5	6	7	7	65
5	9	7&	9	9	10	8*	10	9	8	10	-	8*	9	8	8*	87
6	7	6*	6	6	7	6	7	5*	6	8	7	5*	7	7	6	64
7	6	7	5	8	7	6	7	5	6	7	6	5	8	8	5	64
8	8	6	7	7*	8	7	6*	8	8	7	9	6	8	9	8	75
9	8.	8	9	6	7	8*	-	7*	8	8	7	6	9	9	7	76
10	7	8	8	7	9	8	9	8	8	8	7*	8	8	7*	7	78
11	7	6	-	-	9	6	6	8	7	-	7	5	8	8	6	69
12	8	7	7	6	7	7	6	7	7	6	7	7	8	9	6	70
13	8.5	7.5	8	8.5	9	8	8	9	8	8	7	7*	8.5	8.5	7.5	81
14	7	6	8	8	8	7	7*	8	8	9	8	7	9	8	8	77
	73	69	74	70	79	72	71	73	75	79	70	63	80	80	67	73
	>	>	>	>	73	>	>	72	>	>	>	72	>	80	67	

Text Box 5 Assessment of Executives by Task Managers

G.2 Assessment of Chief Executives by Members of Academic Staff

L. Burns

FS: Communication Skills ok. Usually manages to appear very optimistic and carries along the crowd. Good motivator. Sometimes a bit slow in getting to the point. Uses male/female stereotyping advantages a touch too much. Making butties is good but should not be a show of womanly virtues. Tries to guarantee success through perfection (+). Keeps track of what is going on. Wants to be liked by everybody but still exert substantial control (-). Pretends (?) to lack confidence in her own abilities, to get reinforcement? Leadership qualities ok. Must be careful not to be derogatory about people whilst asserting that this is not the intention.

Andy Morgan

FS: Communication problems are quite evident. Nonchalant pessimism does not tend to motivate people. Throwaway remarks sound off hand but inhibit people all the same. Technical leadership ok but more control should have been exercised over key groups at critical times. Manner of speaking irritated me quite a lot. Management is not about getting up people's noses. Scheduling of events was good, the relatively minor overrun would not have mattered in an industrial context. Technical competence was questioned by some groups, this was, I believe, unfair criticism. Put into a similar situation in the future, it might be advisable to mug up on one particular aspect, in this case it could have been the network hardware. People's perception of the manager could have been improved by taking on some tasks during working sessions. "Actively standing about" is often not welcome. On the whole a good performance showing lots of dedication.

G.3 Specific Remarks on running of Course

No formal method of discussing work involving more than one group re boundary areas.

Managing a peer group is difficult and made directive action problematic.

Problem between group 7 and Felix? (Duncan Abbott).

Groups should not each have been allowed to write their own initialisation software.

Chief executives only nominally in control?

Lack of a proper job definition. Felix note!

Equipment delays were a great problem.

G.4 Assessment of Managers by Executives and Task Group Members

Assessment of Task Group Members by Managers

Required Characteristics for Managers
- 1A: Planning and Organisation
- 1B: Leadership
- 1C: Delegation
- 1D: Communication Skills
- 1E: Motivation
- 1F: Problem Solving Skills

Required Characteristics for Task Members are all different
First Line: Manager by executives
Next Lines: Manager by group members (with initials)
Next Lines: Group members by manager

Grp	Names		A	B	C	D	E	F	M	Tot
1	Clive Buesnel		8	9	8	7	6	8	77	
		SB	10	9	10	6	8	8	85	
		DN	9	9	7	7	8	10	83	82?
	Steve Bowen		10	8	9	5	9	9		83
	David Nyland		10	8	8	6	9	8*		82

Grp	Names		A	B	C	D	E	F	M	Tot
2	Martin Boyce		10	8	8	10	8	9	88	
		RT	10	7	9	10	8	8	86	
		ND	9	8	7	8	10	6	80	85
	Roger Teagle		10	8	8	9	9			90
	Nicola Dane		8	7	8	9	9			82

We would all like to extend thanks to Steve Bowen and Matthew Hickman for their help and to all groups we've inconvenienced during testing.

Grp	Names		A	B	C	D	E	F	M	Tot
3	Nick King		8	8	8	7	9	6	82	
		MH								
		TH	7	8	8	8	9	6	77	n.a.
	Matthew Hickman		8	10	9	10	8	10		91
	Tim Holloway		6	9	7	7	7	8		73

Grp	Names		A	B	C	D	E	F	M	Tot
4	Susan Wilby		5	5	6	5	6	6	55	
		QD	8	6	7	7	7	7	70	
		JR	8	5	9	6	7	8	77?	
		MW	7	5	6	6	7	6	62	66?
	Quiliang Dai		7	7	8	5				67
	Jacinta Rebello		7	7	7	8	7			72?
	Michael Warren		7	7	6	6	5			62?

Grp	Names		A	B	C	D	E	F	M	Tot
5	Alexei Gaylard		10	8	9	10	9	8	90?	
		AP	9	9*	9	10	9*	9*	92?	
		AV	10	8*	10	9	8*	10	95?	92?
		JW	9	8	9	10	9	8*	88	92?
	Alex Penney		10	10	9	10	9	9		95?
	Andrew Vautier		10	8.5	9	9	10	9		92?
	Jonathan Watt		9	9	9	8	9	8		87?

Group thanks Chris Hitchen

Grp	Names		A	B	C	D	E	F	M	Tot
6	Gareth Hodgson		6*	6*	6	7*	5*		60?	
		RJ	7	6	7	8	6	7	68?	
		HM	5	5	7	6	4	9	60	63?
	Roland Jones		8	8	8	6*	7	9		75
	Harvey Maylor		7	5	5	6	5	4		53

Grp	Names		A	B	C	D	E	F	M	Tot
7	Duncan Abbott		6*	6*	7	6*	5*	8	63	
		KH	6	6*	9*	7*	5	8	68	
		GS	8	6*	9	5	4	8*	66	66?
	Kevin Hilton		8	7	6	4	7	6		63
	Gary Swift		5	8	6	6	7*	7*		65?

Grp	Names		A	B	C	D	E	F	M	Tot
8	Kate Hackwell		8	8	8	8	8	9	82	
		ST	8	7	8	7	7	7	73	
		YH	8*	9*	8*	9	7	8*	82?	79
	Sarah Thompson		8	8	8	8	8	8		80
	Yvonne Hallaways		7*	8	8*	7*	8*	8		77?

Grp	Names		A	B	C	D	E	F	M	Tot
9	Carolyn Simpson		6	7	7	6	7	7	68	
		SN	7*	9*	9	8	8	8	82	
		RT	7	9	9	9	8	8	83	78?
	Stefan Nahajski		10	9	8	8	9	7		85?
	Rhodri Thomas		10	9	8	8*	8	7		83?

Grp	Names		A	B	C	D	E	F	M	Tot
10	Phil Horton		9	9	9	9	10	10	93	
		MC	9	8	9	8	9	10	88	
		JM	8	10	8	9	9	10	90	90
	Mark Collison		8	7	9	8	7	8		78
	Jim McLaren		9	9	8	8	9	8		85

Grp	Names		A	B	C	D	E	F	M	Tot
11	Chris Wood		7	6	8	5	5	8	65	
		AE	7	6*	8	5.5	5	8.5	66	
		IA	7	6	8.5	5	5	9	67	66
	Andrew Evans		5.5	6	7	6	6	7.5		63
	Ian Anderton		6	5.5	6	9	6	5.5		63

Grp	Names		A	B	C	D	E	F	M	Tot
12	Surubhi Agarwal		?	?	?	?	?	?	?	?
		FM	8	7*	6	8	7*	7	72	
		JD	8	6	8*	9	8	7	77	??
	Fiona Mackay		7*	9	6	8*	8	8		77?
	Joanne Deacon		8	7	8	8	9	9		82?

Grp	Names		A	B	C	D	E	F	G	M	Tot
13	Simon Parkinson		8	8	8	8	9	8		82	
		NO1	10	10	7	10	10			94	
		NO2	8	7	9	6	9	8.5		79	
		BT	9	8	8	7	9	8		82	84
	Nigel Over		8	8	8	7*	7*	7*	9		77?
	Ben Tilley		8*	7.5	8	8	7.5	8*	9		68

SP "Nigel appears to enjoy working on his own but sometimes to the point of being aloof from the other members of the project. Nigel does have the tendency to become very focused on certain tasks forgetting that other tasks are of equal importance to the overall success of the task, and does not like criticism even when it may be prudent to consider somebody else's point of view. When things are not working out he occasionally becomes quite negative and should thus try to keep a more positive frame of mind."

Grp	Names		A	B	C	D	E	F	M	Tot
14	Jim Hyde		8	7*	8	8	7	9	78	
		AB	6	6	9	6	8	8	72	
		MT	6	6	8	8	7	7	70	73
	Arabella Bijlani		5	6	5	6	5	4		52
	Mark Tait		6	7	8	6	8	7		70

H Appendix: Opinions about Potential Leaders (1989/90)

H.1 Opinions of David Hoffman on BME[234] 17 August 1989

"NB, CF, DR, PR & MC is the team that needs to be split up, last year's case study was a disaster. NB is a very hard worker, produces work of excellent quality, he ought to be given another opportunity to run a group, intellectually he is not first class, but he has plenty of enthusiasm, having had one failure he is now perhaps capable of leadership. CF worked very hard and worked well for NF, he is loyal and conscientious. DR and PR will work well but they are not leaders and also they wear blinkers so the effectiveness of what they do is limited by the powers of co-ordination of others in their group. CF is a passenger, he is quite content for others to do the planning, administration and work. AW has very good potential in several roles: as an administrator, an ideas man and a team-worker - I recommend him. MY works well, a plodder, will respond to good leadership, not technically very capable, but is conscientious. SH is a bit of a smart-alec, probably would a team very capably, it would be nice to separate him from DH and SN for once in the course. These three are usually in the same house and so prefer to work together as a group, one disadvantage is that a fourth member would necessarily be excluded from their "magic circle". SN doesn't seem to have a lot to offer, DH is more capable but he also is weak technically. AK thinks he is jack-of-the-lads: potentially a trouble maker unless you give him responsibility, he is not outstanding but probably would to well if demands are made of him. His friend CK is a good team worker, not leadership potential, technical ability and judgement fair only. IL can work well either as an ideas man or as a group leader, he is technically very good and would contribute to groups irrespective of group composition or leadership. KO is comparable to IL, she would make a better coordinator than IL. IL is maybe a better boss because his self-confidence is quiet but never lacking. KM is a capable team worker, she depends on someone else being superior, technically good. SD is a little boy lost, he will contribute, i.e., conscientious but not a leader and not technically very good. IG has unknown potential for leadership, I rate him one of the best in the group, maybe the best, technically very good. FB seems to be quite capable, I bet she would be very successful as a team leader or coordinator, she is brave, technically good also. AP won't excel but won't cause problems. DA has a motivation problem, he is not at all lazy, but his perception of the world and himself is defective and prevents him delivering the goods. ME and EN are pleasant make-weights, but they can be depended upon to work, and the quality of what they do is about average. PH is not outstanding, but if there were less talent in the year we might describe him as having high levels of leadership and technical ability, he is certainly above average. There is far too much dead wood in this year and this will make the organisation of CIM fairly difficult. PC is not a person I would like to depend on, he is interested in giving the minimum, which is a pity because he is below average in talent and so ought to contribute all he has. BH is hard working but not inspired or inspiring. AL must get up the nose of many students and staff but he can work and the quality is fair. PC, BH, AL, JG, RC and MR need to be spread around, none of them have got much to offer and several of them would be content to be passengers."

H.2 Opinions of Chris Ellis on SEP 20 August 1989

"PS doesn't appear very bright, but did very well in exams. Heading for good 2.1. Has done some reasonable year 3 project work - good on ideas, but didn't really follow them through very effectively. Not by nature a leader, but gets on well with others. Bit on the quiet diffident side, but a grafter. MF: rather quiet, but pretty determined with a wry sense of humour. Bright - 2.1 certain. Not a natural leader, but his training officer reckons he is learning to push himself to

---

234) rewritten to disguise the students' identities but otherwise not changed.

the front a bit more. Good year 3 project work spoilt by lousy report. MA: very bright - will get a first. Super piece of electronics project work, but always seems to me to be a bit of a loner - perhaps not by choice - lacks interpersonal skills? AH: bright, good exam results and good year 3 project. Candidate for a first. Gets on well with fellow students. Could be a good leader, sometimes seems a bit pushy - balanced by sometimes seeming a bit laid back!! JM: quite bright, inclined to be a bit lazy. Rather quiet and not a natural leader. I suspect she has sometimes taken a bit of a back seat and gone for an "easy" ride in some group work in past. On the other hand I have seen her graft and be quite assertive when well motivated."

H.3 Review of Outcomes

The comments by members of staff were only used at the very beginning to gain an idea of the suitability of individual students for "management" roles. They were not used to moderate any assessment and were not referred to once the course had started. The results shown below can therefore be accepted as offering a true opportunity for comparing staff generated quality assessments with the course results. In the table the comments made by course tutors have been summarised and complemented by the writer. The entries in bold typeface indicate a marked difference between the mark of the mutual assessment and that of the course overall. The mutual assessment mark contributes approximately 20% of the overall mark and a substantial difference between the two marks (here taken to be five points between the normalised columns) would indicate some factor worth highlighting:

MA: concentrated on contributions to the group work and neglected individual work which was marked on an individual basis. Also applies to PS.

NB: let down the teams in which he was working during a crucial period.

SD: was buoyed up by individual work and the contributions from reports to which he had not contributed a great deal.

ME: had arguments with a senior coordinator who failed to act professionally.

MF: a student unsuited to group work. Also applies to JS.

AH: similar behaviour to that of MA but greater intellectual input.

SN: a straightforward student who developed good management skills which were recognised in the mutual assessment.

AW: the mutual assessment mark was a clear indication of poor performance.

The staff assessment of individuals was in most cases reasonably accurate - a reflection of the good rapport built up between students and staff over the three year of course duration prior to the CIM course.

Notes for Table: An "L" in the POS column indicates a management role, "SC" stands for Senior Coordinator. MM is the mark for the management contribution as awarded by the course staff, MA is the result of the mutual assessment and OM the overall CIM mark. M is the CIM mark calculated by omitting the contribution from the mutual assessment. The columns marked with an asterisc are the equivalent marks "normalised" around 55%. All marks are rounded and this may cause some slight inaccuracies.

H.4 Overview of Results

Name	Summary Assessment	POS	MM	MA	OM	MA*)	OM*)	R*)
DA	problematic, lacks motivation[235]			80	60	64	51	48
MA	**very bright, loner[236]**			**85**	**75**	**64**	**59**	**58**
FB	capable, technically good	L	75	79	70	59	55	54
NB	**hard working but not bright**			**58**	**63**	**43**	**50**	**52**
MC	committed, hard working[237]			80	73	60	58	58
PC	poor and idle			78	71	58	56	56
RC	passenger			74	69	55	55	54
SD	**helpless but conscientious**			**62**	**69**	**46**	**55**	**57**
ME	**dependable and average**			**74**	**76**	**55**	**60**	**62**
CF	hard working passenger(?)	L	45	68	63	51	50	50
MF	**quiet, not a leader type person**			**52**	**61**	**39**	**48**	**51**
IG	one of the best in the group	L	70	82	73	61	58	57
JG	useless			66	66	49	53	54
AH	**very bright and sociable**			**88**	**73**	**66**	**58**	**55**
BH	useless			77	67	58	54	52
DH	reasonable but technically weak			67	68	50	54	55
PH	not outstanding, technically ok			73	66	55	53	52
SH	smart-alec, but good leader	L	70	75	75	56	59	60
AK	potential trouble-maker	L	60	73	66	55	52	52
CK	good team worker, fair quality			64	65	48	52	53
AL	useless			73	67	55	53	53
IL	excellent, technically strong	L	75	83	72	62	58	56
JM	quite bright, but laid back	L	40	65	66	49	53	54
KM	capable team worker	L	65	74	71	55	56	57
EN	dependable and average	L	65	75	72	56	57	57
SN	**technically weak**			**86**	**69**	**64**	**55**	**52**
KO	good leadership potential	SC	80	80[239]	74	60	59	59
AP	not great but ok	L	65	78	71	58	57	56
DR	works well, no leader			65	67	49	53	55
MR	useless			69	66	52	53	53
PR	works well, no leader			68	68	51	54	55
JS	**idle, but intelligent student[237]**			**65**	**68**	**49**	**54**	**55**
PS	**good, but no follow through[236]**			**88**	**76**	**66**	**61**	**59**
AW	**potentially excellent student[238]**	**SC**	**55**	**55[239]**	**65**	**41**	**51**	**54**
AY	technically excellent student[237]			85	76	64	60	59
MY	plodder, not technically capable			78	69	58	55	54
	Average of Marks			73	69	55	55	55

235) failed to hand in a major report - in line with comments!

236) MA and PS formed a practically symbiotic team which would have warranted a case study of its own, space permitting. PS produced the ideas while MA ensured that they were followed through and tested properly. As a team better than an IBM development crew!

237) characterisation by the writer of the thesis since no other input was received.

238) was made a senior coordinator whose story is told in the case study in section 13.2.3.

239) "mutual assessment" mark by member of staff responsible for course.

I Appendix: Supporting Documentation for Assessment Processes

I.1 Introduction to the Appraisal Interview (1991/92)

THE APPRAISAL INTERVIEW

AN INTRODUCTION

At its simplest the appraisal interview is a planned discussion between boss and subordinate to review how the subordinate has carried out his job since the last appraisal.

Appraisal interviews should not become a "tell" situation by managers, a secret report, another name for a discipline interview, or an attack on personalities/a character assassination.

In CIM we will use it as a method of reviewing the members' progress in the project. Although we shall not be continuing the project groups beyond the final appraisal it is important that we discuss problems and aim to detect the course so mistakes can be avoided in our future careers.

This guide to the appraisal interview is intended to be read by all members, certain sections are aimed directly at the person conducting the interview - the manager, as opposed to the person being interviewed - the interviewee.

PREPARATION BY THE MANAGER

It is important that you appreciate the need for an interview, if you are still unclear of its aims after reading this document, either of your coordinators will be happy to discuss the purpose of the exercise with you. Your level of enthusiasm will automatically indicate to the interviewee, the worth of the interview.

Preparation is all important. You would resent being interviewed by someone who apparently knows nothing of your work. To avoid frustrating your interviewee complete these tasks prior to the interview. The coordinators, though not happy, would prefer that you cancel the interview, than attempt to bluff your way through it.

Examine the original objectives
Read assessment forms
Consult task leaders

The manager must aim to measure a person's performance rather than personality. To make the appraisal realistic and objective you must relate it to facts. This emphasises the need to keep objectives and assessment forms concise, clear and up to date.

Prior to the interview, reviewing the data you have collected helps you to concentrate your mind on the individual and the facts rather than subjective opinions.

The coordinators will aid you by ensuring that there is allocated a sufficiently long time slot for the interview, and that both the manager and interviewee are notified well in advance. An official time, rather than a snatched half hour in between lectures, sets the tone for an objective and formal discussion.

Mentally you should not need to psyche yourself up but you do need to be aware of your mood, you may not give a fair interview following being aggravated. The coordinators will try to spread your time so as to avoid endless appraisals in one day, without the whole process dragging on over weeks.

The mood will be affected by the location which is preferably distinct from the working environment. The coordinators will seek a suitable room and avoid the barrier of a desk.

HOW AM I DOING?

The interviewee is unlikely to view the exercise with total disinterest as we are all naturally curious to see how our performance is rated.

The interviewee will expect the opportunity to state his views, and receive a fair hearing. He will frequently criticise his own performance before your comments. He is not in court to hear a verdict and will want to discuss his views, perhaps disagreeing and stating his reasons for disagreement. You should be aware of factors that have impeded his performance. It may be your attitude or actions that are criticised - if fair you should accept criticism.

He will expect to receive praise where he has deserved it. You should aim to comment on good performance rather than leave the interviewee to "show off" his achievements.

Particularly with the mock interviews, unless totally demoralised, the interviewee will also want to look to the future - himself and the whole project.

SO HOW DO YOU CONDUCT AN APPRAISAL INTERVIEW?

It is worth discussing the mental state of the interviewee as he approaches the interview. Confident young engineers we may be, but we all suffer trepidation at the thought of our well-concealed defects being detected." Fear causes different reactions in people, and you should consider your approach to the individual based on prior knowledge of his likely reaction - nervousness, aggression, hostility, acquiescence, resentment etc.

Appraisal is the measurement of an individual's performance against the background of the objectives. Your interviewee has questions to ask, and you need to obtain answers and his views. This requires a dialogue.

SO HOW DO YOU ACHIEVE DISCUSSION?

Assuming all the correct preparations have been made, how do you actually get the interview moving? It is worth restating the objectives at the start, and indicating the way the interview will be conducted, with approximate times.

Initially the appraisal document should not be consulted. It is merely a record of the interview. Following its format will stifle free discussion, and could alter the interviewee's performance.

In classic interview style you will progress better by starting with open-ended questions, to avoid yes/no answers, and promote discussion. Typical types of question:-

What was the most interesting task you had to do this year?
What was the most successful area in the past year?
What areas could have been better handled?
What were the most difficult tasks this year?

As you will have gathered, the idea is to get the interviewee to assess their performance before you state your views. You need to probe some of the answers given, cutting through the generalities to assess what they are really saying. Useful questions are:-

How do you mean?
Why do you think that was so?
I am not sure I grasped what you are saying, can you explain it again?
Give my more detail on what you think were the reasons.

The vital factor in this part of the interview is that you listen. Not passively but actively interpreting what you hear to detect the feeling behind the phrases.

You can pick up on these sentiments with comments like:-

You sound anxious about this?
That job appeared to give you real satisfaction, would you be interested in doing more work in that field?

These open-ended questions should get the employee to discuss the key areas of his job. Turning to the appraisal form, you should now be able to move through the questions:

ACHIEVEMENT LEVEL, ATTRIBUTE, CONSIDERATIONS AND UNRESOLVED DIFFERENCES

You should not complete the overall mark in front of the interviewee. These marks will remain confidential until after coordinators and departmental staff have reviewed all appraisal documents.

It is important that the performance assessment reflects the information gained during the interview, and that both parties are able to relate the assessments to the facts. Be prepared to discuss points where the interviewee wishes to clarify the validity of the comment. Do not respond to his disagreements with disagreements, this will lead only to futile arguments. It is vital that:-

He understands the reason behind your view.
He is given the opportunity to explain his disagreement.
If the disagreement is emotional, can it be overcome with reassurance?
If your view appears to be unfounded you may need to change it.
If you are certain that as a manager you are being fair and have heard his views, your assessment stands and he records his disagreement in the appropriate section.

CONCLUDING THE INTERVIEW

At the end of the interview you summarise the main points made, reinforce praise for work well done, go over the points for improvement and restate any actions to be taken. Make sure you end the interview on a positive note of encouragement. The interviewee should leave the interview with a clear mental picture of the situation. Handling the interview in this way you will achieve a satisfactory and positive dialogue.

AND FINALLY...

In the five to ten minutes following the interview, whilst all is fresh in your mind:-

Allocate your final percentage mark on the basis of what you learnt during the interview. It is the mark which will be examined by the reviewers. Feel at ease to move from your original impression of the interviewee's performance.

PREPARATION BY INTERVIEWEE

Hopefully you will have understood the need for the appraisal interview in the overall assessment of the CIM course. The coordinators will be happy to discuss with you any aspects of the appraisal. It is also worth reading the sections on how the manager will be preparing and conducting the interview, so that you are prepared and can understand what he is trying to achieve. It will help you if you consider the following questions in advance of the interview:-

What particular parts of the job interest you most?
What parts interest you least?
How do you feel you have carried out the main tasks you are responsible for?
Which tasks could have been performed more effectively and how?
What, if any, were the reasons preventing you from being more effective in those areas?
What tasks do you feel you have performed particularly well and why?
What areas, if any, were/are unclear in the project?
How has the project helped you in your overall training?

NOTES

PREPARATION

Ensure that you have read and understood the assessment forms completed for the assessed person. Any queries should be clarified at this stage.

MARKS should be allocated on a scale of one to ten.

ONE being low
TEN " high

ACHIEVEMENTS

Summarise the results achieved by the interviewee, as compared with those expected of him e.g. objectives set.

REVIEW OF PERSONAL ACHIEVEMENTS

From the list of qualities to be assessed, select the six that are most appropriate in measuring this person's performance. You may wish to weight the qualities based on your knowledge of their importance, indicate weightings as a multiplication factor eg x1.5.

CASE A - Include at least CASE A qualities.
CASE B - Include at least CASE B qualities.
CASE C - Include at least CASE C qualities.

Based on the assessment forms completed, rate the individual's performance against these qualities. Illustrate with examples.

DISCUSSION

During this period the conversation should be of a general nature, the assessor should aim to complete the following section based on mutual understanding. Should conflict remain over a point, do not dwell. In the case of an unresolved difference of view, the manager should complete this section and the interviewee can state their views in the later section provided.

CONCLUSION

You should not allocate an overall mark in front of the interviewee, you should complete this section later

	CASE A	CASE B	CASE C
Manager	skill group leader	coordinator	departmental staff
Interviewee	worker	skill group leader	coordinator

G U I D E

T O

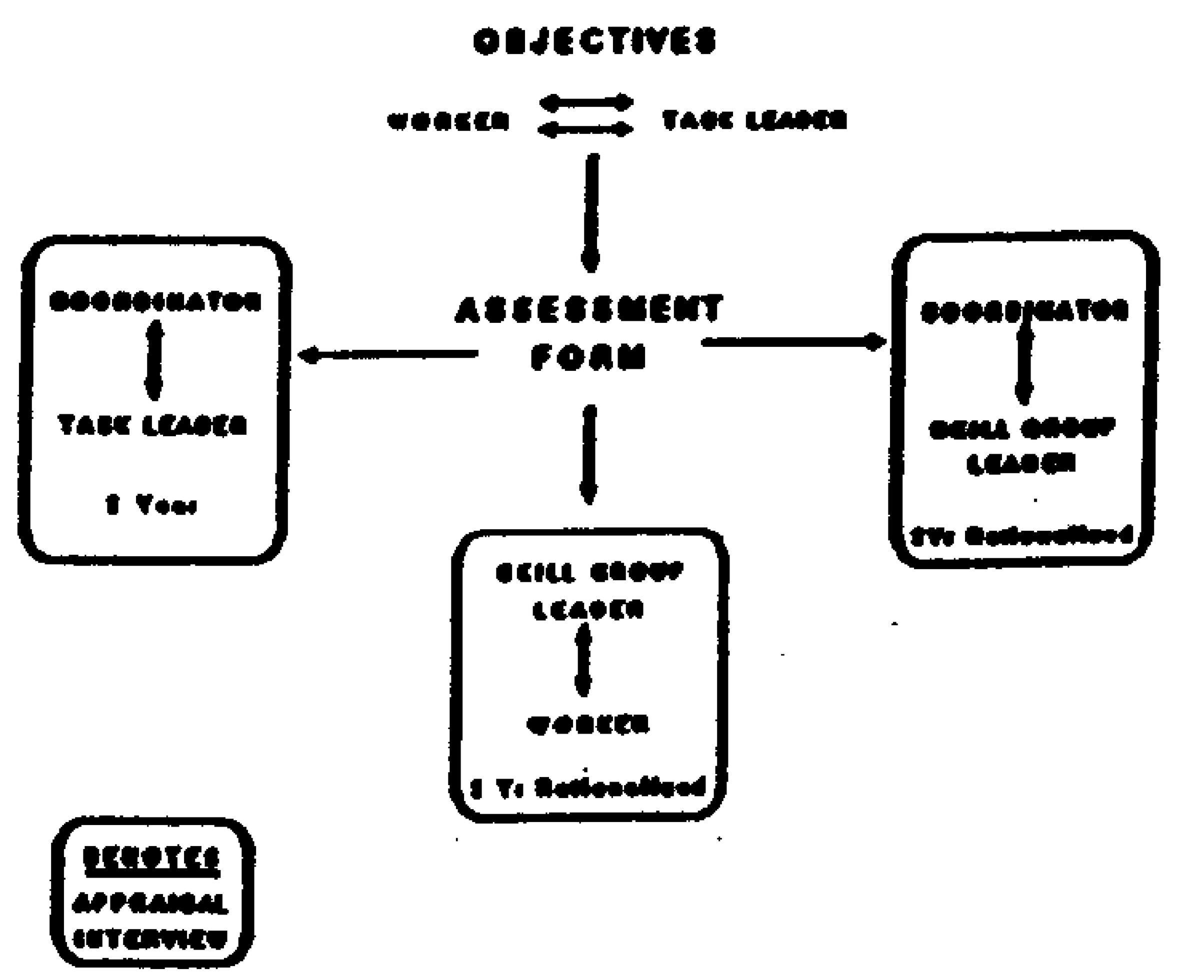
A S S E S S M E N T

DESIGNED FOR THE CIM COURSE 89-90.

CONTENTS

DON'T PANIC!

The guide to assessment may appear very daunting as you first flick through it, but it's just a development of the plan Keith and Andy introduced to you earlier in the term. Remember the objectives are agreed between the worker and the task leader and these form the basis of the Assessment Forms (to be completed at least every two months).



The Assessment Forms are the basis for the appraisal interviews. A practice one is scheduled for the end of term, and the final one, where the marks are allocated will take place at the end of the project.

Keith and Andy are working on a timetable for the first interviews, in the meantime, clear half an hour or so and sit down and read this through. Any problems don't hesitate to contact us.

Keith and Andy

ASSESSMENT FORM TO EVALUATE CONTRIBUTIONS.

A formal discussion will take place between the worker and task leader associated with:- The completion / termination of a project.
- When an objective is met.
- Or two months after the last form was completed.

This two way discussion aims to produce a mutually understood assessment of each person's contribution. It should be directed to agree facts, not to allocate marks. It is the responsibility of the task leader to ensure the discussion is held, and the completed assessment forms returned to the skill group leader, no later than two weeks after the working relationship is terminated.

Prior to the discussion both parties should prepare thoroughly, identifying aspects for discussion and questions to be raised. It may be useful to complete the assessment form in pencil.

ASSESSMENT OF WORKER.
PART A. TO BE COMPLETED BY THE TASK LEADER.
As a worker joins your project you should meet with him to discuss the objective. The objective should be that detailed to the skill group leader, at this point you should clear up any ambiguities. The two parties should sign that they believe they share an understanding of the objective.

Key elements in the task that you will be looking to assess may be identified at this stage.
For Example:
A worker's objective may be to examine the feasibility of a computer aided process planning system, recommending the most appropriate package available, and installing it in the CIM cell.
Key elements in the task might be to successfully liaise with members in two other tasks; report his findings to the other members of his group so they may encompass the package in their overall design; enlist the cooperation of departmental staff in successfully modifying the package to our specific needs etc.
These key elements can be developed through the assessment period.
AFTER THE INITIAL DISCUSSION THE FORM IS RETAINED BY THE TASK LEADER.

PART B. TO BE COMPLETED BY THE TASK LEADER.
This section assesses how well the worker met their objective. Comments on performance should be entered. Reasons for any unsatisfactory performance should be analysed and stated in this section.

PART C. TO BE COMPLETED BY THE TASK LEADER.
This section is an analysis of the workers contribution through personal skills. The Skills List gives a brief description of these skills. It is accepted that not all workers will require all these skills.

ASSESSMENT OF LEADER.
This form is to be completed by the worker and openly discussed with the task leader.
The leader is not assessed against an objective but against his personal qualities. Brief outlines of the skills are in the Skills List.

ACKNOWLEDGEMENT
With all sections completed both parties should sign to say that the form has been discussed and is a true reflection of the leader's and worker's contribution.

SKILL LIST

CASE A SKILLS

1. ACADEMIC ABILITY
   This is an assessment of the worker's demonstrated technical ability and contributions, and his analysis of the problems. The scope of such input may exceed the boundaries of the brief.

2. PRACTICAL ABILITY
   Practical ability is the person's ability to apply his theoretical knowledge to the problem in hand. It also reflects the methodology chosen to tackle the problem.

3. COORDINATION
   How well did the person align his task to the task and overall CIM objectives? This should reflect how well the person communicated within and between the groups.

4. COOPERATION
   How well did the person fit into the team? Did he cooperate and help solve problems outside of his objective? Did other members of the group have a high regard for him?

5. COMMITMENT
   Was the person committed to achieving the objective set? This could be displayed in his attendance at meetings, producing work on time. Was he decisive? Were his actions pro-active or reactive?

6. PROFESSIONALISM
   Did the person conduct himself in a professional manner?

CASE B SKILLS

7. PLANNING AND ORGANISATION
   Was the leader aware of progress made and problems encountered through the project? Did your objectives fit into the overall task? Were the objectives realistic given the time scale? Were you well integrated into the established group?

8. LEADERSHIP
   Did the leader perform the role of a motivating force within the group? He should display an ability to direct the group, and accept responsibility, which coupled with high confidence should maintain the momentum in the project.

9. DELEGATION
   Although the leader must take responsibility for the task, he should delegate responsibility, as well as chores to group members. Consider when your task was allocated to you, how much freedom and responsibility was also allocated?

10. COMMUNICATION
    Verbal and written communication should keep you aware of events in the group and within the overall CIM project. Consider the frequency and quality of this communication. Meetings can also be an effective method of communication. How well were group meetings chaired? Were they necessary? Did the correct people attend?

11. PROBLEM SOLVING SKILLS
How effective was the leader in times of trouble? How well were problems resolved? Did the leader use his understanding of individual workers position to resolve conflicts and ambiguities?

<u>CASE C SKILLS</u>

12. ORGANISATION AND PLANNING
How well did the coordinator plan ahead? Did he consider all aspects of an event? When arranging meetings were they well prepared? Were the correct people present? Was suitable documentation available?

13. AWARENESS
This should be a measure of the level of awareness that the coordinator had of the status of the project. It reflects his contact with the project personnel, and his understanding of the problems encountered.

14. INTERPERSONAL SKILLS
The coordinators should have displayed high personal qualities. They should have been approachable to all project personnel, and displayed an interest in everybody's triumphs and tribulations.

15. PROBLEM SOLVING.
How effective was the coordinator in times of trouble? How well were problems resolved? Did the coordinator use his understanding of individual's positions to resolve conflicts and ambiguities?

	CASE A	CASE B	CASE C
manager	skill group leader	coordinator	departmental staff
interviewee	worker	skill group leader	coordinator

3.2.

ASSESSMENT OF WORKER

WORKER	
TASK LEADER	TASK
SKILL GROUP LEADER	SKILL GROUP
DATE ON	HOURS
DATE OFF	

A OBJECTIVE

SIGNED WORKER ____________
LEADER ____________

B KEY ELEMENTS	LEVEL OF ACHIEVEMENT

SAMPLE

IN UNDER 30 WORDS DESCRIBE
HOW WELL THE INITIAL OBJECTIVES WERE MET

4.1

C ATTRIBUTE	PERFORMANCE ASSESSMENT
1. Academic Ability	High Low
2. Practical Ability	High Low
3. Coordination	High Low
4. Cooperation	High Low
5. Commitment	High Low
6. Professionalism	High Low

SAMPLE

4.2

ASSESSMENT OF TASK LEADER

WORKER	DATE ON
TASK LEADER	DATE OFF
TASK	

ATTRIBUTE	PERFORMANCE ASSESSMENT
1. Planning and Organisation	High Low
2. Leadership	High Low
3. Delegation	High Low
4. Communication	High Low
5. Problem solving skills	High Low

SAMPLE

WE THE UNDERSIGNED HAVING COMPLETED
THE ABOVE ASSESSMENT
HAVE FULLY DISCUSSED THE POINTS IT RAISES

WORKER ____________
TASK LEADER ____________

4.3

THE APPRAISAL INTERVIEW

AN INTRODUCTION

At it simplest the appraisal interview is a planned discussion between boss and subordinate to review how the subordinate has carried out his job since the last appraisal.

Appraisal interviews should not become a "tell" situation by managers, a secret report, another name for a discipline interview, or an attack on personalities / a character assassination.

In CIM we will use it as a method of reviewing the members' progress in the project. Although we shall not be continuing in the project groups beyond the final appraisal it is important that we discuss problems and aim to detect the source so as mistakes can be avoided in our future careers.

This guide to the appraisal interview is intended to be read by all members, certain sections are aimed directly at the person conducting the interview - the manager, as opposed to the person being interviewed - the interviewee.

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It is important that you appreciate the need for an interview, if you are still unclear of its aims after reading this document, either of your coordinators will be happy to discuss the purpose of the exercise with you. Your level of enthusiasm will automatically indicate to the interviewee, the worth of the interview.

Preparation is all important. You would resent being interviewed by someone who apparently knows nothing of your work. To avoid frustrating your interviewee complete these tasks prior to the interview. The coordinators, though not happy, would prefer that you cancel the interview, than attempt to bluff your way through it.

- Examine the original objectives
- Read assessment forms
- Consult task leaders.

The manager must aim to measure a person's performance rather than personality. To make the appraisal realistic and objective you must relate it to facts. This emphasises the need to keep objectives and assessment forms concise, clear and up to date.

Prior to the interview, reviewing the data you have collected helps you to concentrate your mind on the individual and the facts rather than subjective opinions.

You should now complete the first two sections of the appraisal document in pencil. You may wish to alter comments after discussion. The mark allocated should be entered in pen and not altered. This will allow the coordinators / departmental staff reviewing the data to see if there was a successful understanding, of the interviewee's actions, gained during the interview.

The coordinators will aid you by ensuring that there is allocated a sufficiently long time slot for the interview, and that both the manager and interviewee are notified well in advance. An official time, rather than a snatched half hour in between lectures, sets the tone for an objective and formal discussion.

Mentally you shouldn't need to psyche yourself up but, you do need to be aware of your mood, you may not give a fair interview following being aggravated. The coordinators will try to spread your time so as to avoid endless appraisals in one day, without the whole process dragging on over weeks.

S·1

The mood will be affected by the location which is preferably distinct from the working environment. The coordinators will seek a suitable room and avoid the barrier of a desk.

HOW AM I DOING?
The interviewee is unlikely to view the exercise with total disinterest as we are all naturally curious to see how our performance is rated.

The interviewee will expect the opportunity to state his views, and receive a fair hearing. He will frequently criticise his own performance before your comments. He is not in court to hear a verdict and will want to discuss his views, perhaps disagreeing and stating his reasons for disagreement. You should be aware of factors that have impeded his performance. It may be your attitude or actions that are criticised - if fair you should accept criticism.

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Particularly with the mock interviews, unless totally demoralised, the interviewee will also want to look to the future - himself and the whole project.

SO HOW DO YOU CONDUCT AN APPRAISAL INTERVIEW?
It is worth discussing the mental state of the interviewee as he approaches the interview. Confident young engineers we may be, but we all suffer trepidation at the thought of our well-concealed defects being detected. Fear causes different reactions in people, and you should consider your approach to the individual based on prior knowledge of his likely reaction - nervousness, aggression, hostility, acquiescence, resentment etc.

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Assuming all the correct preparations have been made, how do you actually get the interview moving? It is worth restating the objectives at the start, and indicating the way the interview will be conducted, with approximate times.

Initially the appraisal document should not be consulted. It is merely a record of the interview. Following its format will stifle free discussion, and could alter the interviewee's performance.

In classic interview style you will progress better by starting with open-ended questions, to avoid yes/no answers, and promote discussion.
Typical types of questions:-

- What was the most interesting task you had to do this year?
- What was the most successful area in the past year?
- What areas could have been better handled?
- What were the most difficult tasks this year?

As you will have gathered, the idea is to get the interviewee to assess their performance before you state your views. You need to probe some of the answers given, cutting through the generalities to assess what they are really saying.
Useful questions are:-

- How do you mean?
- Why do you think that was so?
- I'm not sure I grasped what your saying, can you explain it again?
- Give me more detail on what you think were the reasons.

The vital factor in this part of the interview is that you listen. Not passively but actively interpreting what you hear to detect the feeling behind the phrase.

S·2

You can pick up on these sentiments with comments like:-

- You sound anxious about this?
- That job appeared to give you real satisfaction, would you be interested in doing more work in that field?

These open-ended questions should get the employee to discuss the key areas of his job. Turning to the appraisal form, you should now be able to move through the questions, modifying answers where necessary and completing the questions not yet answered.

You should not complete the overall mark in front of the interviewee. These marks will remain confidential until after coordinators and departmental staff have reviewed all appraisal documents.

It is important that the performance assessment reflects the information gained during the interview, and that both parties are able to relate the assessments to the facts. Be prepared to discuss points where the interviewee wishes to clarify the validity of the comment or mark. Don't respond to his disagreements with disagreements, this will lead only to futile arguments. It is vital that:-

- He understands the reason behind your view.
- He is given the opportunity to explain his disagreement.
- If the disagreement is emotional, can it be overcome with reassurance?
- If your view appears to be unfounded you may need to change it.
- If you are certain that as a manager you are being fair and have heard his views, your assessment stands and he records his disagreement in the appropriate section.

CONCLUDING THE INTERVIEW.
At the end of the interview you summarise the main points made, reinforce praise for work well done, go over the points for improvement and restate any actions to be taken. Make sure you end the interview on a positive note of encouragement. The interviewee should leave the interview with a clear mental picture of the situation. Handling the interview in this way you will achieve a satisfactory and positive dialogue.

AND FINALLY...
In the five to ten minutes following the interview, whilst all is fresh in your mind:-

Allocate your final appraisal mark on the basis of what you learnt during the interview. It is this mark which will be examined by the reviewers. Feel at ease to move from your original impression of the interviewee's performance, but remember the validity of the original assessment documents, written by people on the job who were best placed to see the abilities and personal skills of the interviewee!

PREPARATION BY INTERVIEWEE.
Hopefully you will have understood the need for the appraisal interview in the overall assessment of the CIM course. The coordinators will be happy to discuss with you any aspects of the appraisal. It is also worth reading the sections on how the manager will be preparing and conducting the interview, so that you are prepared and can understand what he is trying to achieve. It will help you if you consider the following questions in advance of the interview:-

- What particular parts of the job interest you most?
- What parts interest you least?
- How do you feel you have carried out the main tasks you are responsible for?
- Which tasks could have been performed more effectively and how?
- What, if any, were the reasons preventing you from being more effective in these areas?
- What tasks do you feel you have performed particularly well and why?
- What areas, if any, were/are unclear in the project?
- How has the project helped you in your overall training?

S·3

NOTES

PREPARATION
Ensure that you have read and understood the assessment forms completed for the assessed person. Any queries should be clarified at this stage.
MARKS should be allocated on a scale of one to ten.

ONE being low
TEN " high

ACHIEVEMENTS
Summarise the results achieved by the interviewee, as compared to those expected of him eg objectives set.

REVIEW OF PERSONAL ACHIEVEMENTS.
From the list of qualities to be assessed, select the six that are most appropriate in assessing this person's performance. You may wish to weight the qualities based on your knowledge of their importance, indicate weightings as a multiplication factor eg x1.5

CASE A - Include at least CASE A qualities.
CASE B - Include at least CASE B qualities.
CASE C - Include at least CASE C qualities.

Based on the assessment forms completed, rate the individuals performance against these qualities. Illustrate with examples.

DISCUSSION
During this period the conversation should be of a general nature, the assessor should aim to complete the following section based on mutual understanding. Should conflict remain over a point, do not dwell. In the case of an unresolved difference of view, the manager should complete this section and the interviewee can state their views in the later section provided.

CONCLUSION
You should not allocate an overall mark in front of the interviewee you should complete this section later.

	CASE A	CASE B	CASE C
manager	skill group leader	coordinator	departmental staff
interviewee	worker	skill group leader	coordinator

6.

ASSESSMENT FORM

MANAGER NAME | CASE A B C*

INTERVIEWEE NAME

DATE OF INTERVIEW | FINAL/INTERMEDIATE INTERVIEW* | (*Delete as appropriate)

SECTION 1 PREPARATION

SECTION 2 ACHIEVEMENTS

OBJECTIVES	ACHIEVEMENTS	MARK

SAMPLE

MARK on basis of achievements against objectives: %

7·1

SECTION 3 PERSONAL ACHIEVEMENTS

QUALITIES	EXAMPLES	MARK WEIGHTING

SAMPLE

MARK on basis of preparation %

SECTION 4 DISCUSSION

SECTION 5 APPRAISAL

Describe in about 50 words the interviewee's overall performance.

How does the interviewee intend improving his abilities and professional/interpersonal skills?

continued on next page

7·2

Is there any (confidential) information which should be taken into account when judging the interviewee's effectiveness?

CASE B/C ONLY
Were there any interpersonal problems within the group that should be considered when judging the manager's effectiveness?

SECTION 6 UNRESOLVED DIFFERENCES

TO BE COMPLETED BY THE INTERVIEWEE
This section allows you to discuss any points which you and your manager were unable to agree upon. Please state your view here.

SAMPLE

SECTION 7 CONCLUSION

TO BE COMPLETED AFTER THE INTERVIEW

MARK
on basis of PREPARATION/ ASSESSMENT FORMS %
having completed INTERVIEW %
agreed by coordinators/ departmental staff %

SECTION 7 REFERENCE ONLY

Please help in the development of future appraisal procedures. Your answer to these questions will not be analysed until the assessment procedure is complete and marks allocated

	Circle the most appropriate
Do you feel that your overall performance was aided by feedback from the assessment forms?	YES NO
How frequently should assessment forms be completed?	more same less
Do you feel your performance at today's interview was aided by participating in the mock interview?	YES NO
Are you satisfied with the amount of information provided as a guide to the assessment procedure?	more same less

Have you further comments to make on the assessment procedure:

7·3

J Appendix: Complete Set of Marks (1990/91)

Assessment for CIM Course 1990/91
Amalgamation of Marks for Students from BME and SEP

Name of Student	BME = 1	DO = 1	CIM Mark	T-Leader	S-Leader	Interm R	Mutual A	Performance Task 1		
								Task No	Overll G	Overll I
Weighting Factor	SEP = 0	SO = 0		is = 1	is = 1	0.75	1.50		1.00	2.00
Barker, Jamie	1	1	70	0	0	55	73	T11	80	80
Bayley, David	1	1	69	0	0	62	71	T8	70	70
Berry, Nick	0	1	68	0	0	64	72	T3	68	63
Bhasin, Raj	1	1	74	1	0	80	80	T9	70	70
Bright-Thomas, Pa	0	0	71	0	1	75	69	T1/2	77	75
Commyns, Ian	1	1	67	0	0	60	73	T1/2	77	68
Dudley, Martin	1	1	68	0	0	67	67	T9	70	70
Ede, Clifford	0	1	72	1	0	74	74	T7	75	75
Gibbs, Nick	1	1	68	1	0	70	76	T6	60	70
Graves, Nick	0	1	69	0	0	65	72	T1/2	77	75
Hardy, Teresa	1	1	66	1	0	64	68	SC	68	75
Harris, Louis	1	1	63	0	0	66	68	T5	58	55
Harrison, John (Sa	1	1	71	1	0	76	73	SC	68	78
Hemington, Angel	1	1	61	0	0	67	66	T5	58	50
Heslop, Tim	1	1	72	1	0	61	80	T1/2	77	78
Ifould, Alan	1	1	72	0	1	72	80	T3	68	90
Michael, Suzie	1	1	67	0	0	72	65	T9	70	70
Middleton, James	1	1	60	0	1	56	68	T6	60	70
Power, Richard	1	1	69	1	0	67	72	T8	70	59
Price, Anthony	1	1	64	0	1	70	75	T8	70	70
Price, Michael	1	1	67	0	0	60	67	T4	80	70
Price, Paul	0	1	75	1	0	80	77	T4	80	80
Rene, Michael	1	1	69	0	0	59	70	T4	80	45
Richardson, Darre	1	1	68	1	0	69	76	T5	58	55
Richmond, Damia	1	1	65	0	1	58	68	T6	60	65
Sargeant, Ken	0	1	74	1	0	68	78	T11	80	80
Seed, Rachel	1	1	71	1	0	62	75	T10	75	70
Sibson, James	1	1	71	1	0	69	76	T3	68	58
Simpson, Jon	1	1	73	0	1	69	72	T11	80	80
Spaul, Michelle	1	1	68	0	0	63	74	T10	75	65
Stiles, Matthew	1	1	70	1	0	60	76	T1/2	77	78
Tyler, Jon	1	1	69	0	1	70	70	T7	75	50
Wallis, Paul	0	1	70	1	0	72	70	SC	68	58
Woodrow, Ian	0	1	69	0	1	74	73	T7	75	70
Averages			68.9			66.9	72.4		71.2	68.7
Standard Deviations			3.44			6.37	4.09		7.02	10.03

J Appendix: Complete Set of Marks (1990/91)

							Performance Task 2			
Presentn	Tech. Q.	Tsk Mgmt	Attitude	Achieved	Manager	Av. Task	Task No	Overll G	Overll I	Presentn
1.00	2.00	2.00	1.00	2.00	3.00 [1]	1.00		1.00	2.00	1.00
80	80	80	80	80		80.0	T3	68	65	59
60	75	70	80	75		71.8	T11	80	80	80
59	69	50	70	75		64.6	T4	80	70	73
60	73	70	80	78	55	68.4	T10	75	65	65
70	78	65	70	90	72	75.4	T6	60	70	60
70	78	65	70	90		74.5	T7	75	65	70
60	73	70	80	78		72.0	T4	80	50	73
70	85	55	80	80	70	73.2				
60	57	50	60	65	64	61.1	T9	70	70	60
70	78	65	70	90		75.7	T6	60	65	60
65	65	70	75	80	71	71.5				
50	60	60	54	63		58.0	T6	60	60	60
65	65	70	75	80	75	72.8				
50	60	60	54	63		57.1				
70	78	65	70	90	65	73.9				
59	69	50	70	75	100	72.1	T6	60	80	60
60	73	70	80	78		72.0	T6	60	60	60
60	57	50	60	65	50	59.5	T7	75	40	70
60	75	70	80	75	50	65.6	T3	68	80	59
60	75	70	80	75	50	70.0	T5	58	63	50
73	70	64	70	75		71.0	T7	75	50	70
73	70	64	64	75	80	73.9				
60	60	64	70	75		63.5	T9	70	55	60
50	60	60	54	63	52	56.7	T4	80	60	73
60	57	50	60	65	65	59.9	T10	75	65	65
80	80	80	80	80	78	79.6	T1/2	77	75	70
65	75	70	80	75	60	70.0	T9	70	70	60
59	69	50	70	75	50	60.8	T7	75	50	70
80	80	80	80	80	55	77.9				
65	75	70	80	75		71.8	T9	70	70	60
70	78	65	70	90	80	77.1	T5	58	63	50
70	85	55	80	80	55	68.3	T1/2	77	60	70
65	65	70	75	80	60	66.7	T7	75	70	70
70	85	55	80	80	65	72.5	T5	58	65	50
64.6	71.5	63.9	72.1	76.9	64.6	69.4		70.0	64.3	64.0
7.73	8.32	8.80	8.46	7.65	12.56	6.46		7.73	9.47	7.54

J Appendix: Complete Set of Marks (1990/91)

					Performance Task 3					
Tech. Q.	Tsk Mgmt	Attitude	Achieved	Av. Task	Task No	Overll G	Overll I	Presentn	Tech. Q.	Tsk Mgmt
2.00	2.00	1.00	2.00	0.70		1.00	2.00	1.00	2.00	2.00
69	50	70	75	65.0						
80	80	80	80	80.0						
70	64	64	75	70.5						
75	70	80	75	71.8	T3	68	80	59	69	50
57	60	60	65	62.2						
85	55	80	80	72.3						
70	64	64	75	66.8	T8	70	60	60	75	70
					T3	68	70	59	69	50
73	70	80	78	72.0	T10	75	65	65	75	70
57	50	60	65	59.5						
57	50	60	65	58.5	T11	80	80	80	80	80
					T7	75	70	70	85	55
					T6	60	60	60	57	50
57	50	60	65	62.2						
57	50	60	65	58.5	T4	80	70	73	70	64
85	55	80	80	67.7						
69	50	70	75	67.7						
60	60	54	63	59.5						
85	55	80	80	69.5	T5	58	50	50	60	60
73	70	80	78	69.3	T10	75	65	65	75	70
70	64	64	75	68.6						
75	70	80	75	71.8						
78	65	70	90	75.7						
73	70	80	78	72.0	T3	68	80	59	69	50
85	55	80	80	69.5						
					T5	58	65	50	60	60
73	70	80	78	72.0	T1/2	77	80	70	78	65
60	60	54	63	59.5						
78	65	70	90	73.0	T10	75	65	65	75	70
85	55	80	80	73.2						
60	60	54	63	59.8						
71.0	60.6	70.1	74.5	67.7		70.5	68.6	63.2	71.2	61.7
9.74	8.19	9.77	7.60	5.79		7.30	8.76	8.03	7.75	9.35

J Appendix: Complete Set of Marks (1990/91)

			Performance Task 4							
Attitude	Achieved	Av. Task	Task No	Overll G	Overll I	Presentn	Tech. Q.	Tsk Mgmt	Attitude	Achieved
1.00	2.00	0.30		1.00	2.00	1.00	2.00	2.00	1.00	2.00
70	75	67.7								
80	75	70.0								
70	75	65.9								
80	75	71.8								
80	80	80.0								
80	80	73.2								
60	65	58.5								
64	75	70.5								
54	63	57.1	T11	80	80	80	80	70	70	70
80	75	71.8								
70	75	67.7	T11	80	80	80	80	80	80	70
54	63	59.8								
70	90	76.6								
80	75	71.8								
70.9	74.4	68.8		80.0	80.0	80.0	80.0	75.0	75.0	70.0
9.40	6.85	6.39		0.00	0.00	0.00	0.00	5.00	5.00	0.00

J Appendix: Complete Set of Marks (1990/91)

	Staff Assessment							
Av. Task	Average	Assig 1	Assig 2	Rpt T 1	Rpt T 2	Rpt T 3	Rpt T 4	Rpt Ave
0.30	1.25	1.00	1.00	1.00	0.70	0.30	0.30	1.75
	73.8	70	65	77	75			76
	75.2	75	52	67	77			71
	67.0	62	55	75	85			79
	69.5	65	69	80	75	67		76
	70.0	67		80	62			73
	73.6	50	64	80	65			74
	69.9	60	58	80	85	67		80
	71.5	85	65	65		75		67
	66.5	67	55	62	80	75		70
	69.0	60	70	80	62			73
	71.5	58	57	70				70
	61.5	63	60	55	62	77		61
	72.8	65	67	70				70
	60.8	55	65	55		65		57
	70.3	66	68	80		62		76
	68.0	69	70	75	62			70
	67.1	63	60	80	62	85		74
	62.9	59	40	62	65			63
	66.5	68	60	75	75			75
	65.7	58	48	67	55			62
75.5	69.3	65	59	85	65	55	77	74
	73.9	60	70	85				85
	66.7	70	57	85	80	75		82
	61.6	67	65	55	85			67
	64.8	68	56	62	75			67
	78.0	68	68	77	80			78
78.2	71.4	68	66	75	80	75	77	77
	64.4	68	75	75	65			71
	73.7	80	72	77		55		72
	72.6	53	58	75	80	80		78
	69.8	65	75	80	55			70
	70.5	65	67	65	80	75		72
	69.4	67	71	72	65			69
	67.3	85	60	65	55			61
76.8	69.0	65.7	62.6	72.6	70.8	70.6	77.0	71.8
1.36	4.05	7.54	7.68	8.59	9.67	8.67	0.00	6.13

CIM NEWS

Issue 4 29th November 1989

EDITORIAL

Well then CIM NEWS is brought to you this week by a pair of gibbering wrecks. Why ? I hear you scream. "Because," I'll reply, "We got in here on Friday morning to find Issue 4 consisted of two blank lines. Fortunately some kind, good, loving person had backed the disk up and we only lost about half of it." Anyway, everyone lived happily ever after in that green and pleasant land of their dreams - the BLADE lab. And the moral is..never volunteer to edit CIM news. Oh by the way could people put their names on articles. (NUS number, course & address non-obligatory)

TASK A3 - LATHE

No amusing jokes or funny stories, just a straight forward update of progress made by task group A3.

The previously corrupted "floppy" containing part programs and communications programmes has been debugged by "the king of software" Mike Carden and is currently being investigated/interrogated by Amin.

A successful part program has been written for the pawn, although this is stored on the lathes magnetic cassette, not by the PC. A king program already exists, stored on the previously mentioned floppy.

What next? The PC and lathe controller are to be connected and their method of communication investigated. Once the design of the work holding device has been finalised we can also look at the pneumatic chuck and assess its suitability.

Apologies to all those who've done lots of work but have not been mentioned!

Andy Lynch

TASK A4 (ROBOTS) - STATUS REPORT

The robot team have had some good news in the last couple of weeks. Firstly there was a swift sortie into the transfer market to secure the signatures of Nigel Bolton as Machine Tools expert and Paul Hodgson as an Electrical Engineering expert. There was also a brief period where Fran Bowker left the group in exchange for Chris Kyle. But Fran has come back with her tail between her legs literally begging to rejoin the group. The group is now at full strength with 9 members.

After suffering setbacks in the first few weeks of the project, where neither robot was working properly, a mixture of Unimation engineers and Mark Aylott have worked well this week to fix all the apparent problems. We are now ready to start programming.

The design of the compliant gripper has been a slow process, but luckily an MSc student has come up with the goods.

Full steam ahead

Andy Proud.

TECHNICIAN FOR BLADE

On Monday, 2.12.89, Brian Shaw takes up his new position as a BLADE technician. He is a man of many skills and abilities, mainly in the mechanical area. He should prove to be a great asset to anybody working in the CIM area. Requests for Brian Shaw's assistance should be channelled through Mr E Cittern, the Chief Technician. The development will be unstoppable now!

Regards,

Felix

ASSESSMENTS
Report Format

The assessment procedures have been reviewed. It is now proposed that the whole course be marked on the following basis :-

	BME	SEP
Interim report(individual)	75	75
Mutual assessment	150	150
Final report (group)	175	175
Group presentations	125	125
Assignments (individual)	200	100
Total	725	625

It has been revised to incorporate the importance of the final report and the assessment procedures. If there are any desperate queries or complaints please come and see me in flat 147 or leave a note in the BME pigeonholes.

Interim Report

The interim report should be handed in by January 12th 1990. It should be a concise document, detailing your work within the CIM cell. It needs to contain information about the work you have carried out towards your tasks goals. It should be no longer than three pages long, and may contain diagrams.

Final Report

The final report is a group effort. It has two main aims:
* to detail the work carried out by the project group.
* to instruct the following year on how to use the CIM cell and to provide recommendations for next years projects.

Three documents are needed:-

i) REPORT. This should contain information about the task under the following headings:-

1) Summary - an overview of the project report

2) Introduction - a brief overview of the project task, similar to that required for the quality manual.

3) A 'Methods' Section - This section should include all work carried out, perhaps divided into sub-tasks, but it is up to the group to decide on how to format this section. Reference can be made to as many appendices as required.

4) Conclusions - This section should bring together all the work carried out , and define how much of the initial task brief was achieved. It could also contain a brief description of how your area of the CIM cell operates.

5) Recommendations - A more detailed analysis of tasks not completed, which the project team feels should be, and any other areas not addressed this year which should be considered next year.

ii) CIM MANUAL. This document should detail how to use the equipment and/or software you have implemented; a kind of user's guide. Hopefully we can draw up some form of standard format for these later in the year.

iii) SUMMARY. This final report can be lifted straight from the larger group report. It should contain only the summary, the conclusions and the recommendations. It will be used purely as a source of information for the following year, to give them an overview of the CIM cell to date, without having to wade through complete reports.

If you feel anything has been overlooked or you could improve the current system then please let me know and we will try and work something out. Together we can triumph over CIM !!!

Miranda Clarke

TASK Reviews Phase One Complete:

PHEW!!

Peter x 2, Bob, Felix and Bin Who, with the help of many task workers appearing in many different roles and guises, have just completed phase one of the task reviews. This proved to be a very fruitful and rewarding experience for the members of staff involved. Although involved mainly in the B-task reviews I feel that I have gained a good impression of the overall work which is going into the CIM cell and its brainwave. Software to follow later, or so Peter B insists.

My general impression is: WELL DONE and LET'S KEEP MOVING! Most if not all people seem to be happy with what they are doing and, what's more, they know what they are going to do. The structure, albeit complex, seems to be working O.K. but creates lots of work for project engineers....

As a result of holding task review B4 I have been asked to define a new task B6, which deals with the operator interface. This is a fairly small task (aren't they all?):

Task Description B6

The manufacturing cell will be supervised by one or several operators who are responsible for supplying the cell with raw material, sort out problems and occasionally assist with decisions such as whether semi-finished goods should be scrapped. A PC based interface should be developed to inform the operator about necessary interventions in the cell's running. The software should communicate with tasks A1 and B4. Any action having been carried out is signalled to the management system by an operator input. If assistance were required to solve a particular problem it could be imagined that the operator would be given a list of current orders with problems flagged.

Well folks, this is it for now. Good luck!

Felix

P.S. I loved the guide to assessment. I wish I was being appraised in this form!

ANDY WILCOX'S PIECE

Budgets

Thanks are expressed to the project leaders who so reliably compiled their anticipated requirements in order for us to agree budgets with Felix, our eternal friend with the money.

In his sober, but excited state after Chris Hinde's CAPP lecture he provisionally agreed that the shoestring is of sufficient length to support the needs you've all requested. Indeed there is the possibility of a little extra for which I'm sure we can find a use without becoming extravagant [What about a party? - ED].

So you can all start spending in accordance with the guidelines detailed in issue three of this informative periodical.

Assessment Procedure

The first publication from Kath's wordprocessor, the Assessment Procedure, is nearing completion and has been proofread in part by our literal idiot, Steve Harrington. He had no problems with the content so we hope to have it out to you by today, but if it has not been issued, please bear with the printroom and watch the CIM notice board.

If its length prevents you from reaching the relevant section may I take this opportunity to remind the skill group leaders that the bright yellow cards are in the CIM library, and are waiting for some black scribbly inputs. If these could be completed soon it would be appreciated, as we must set up the Christmas appraisals on the basis of this information.

Felix has approved CIM Budget!

The draft CIM budget as detailed below has been approved by Felix on behalf of the CIM steering group, that is, Bob and Peter. He is anxious to ensure that work can progress (relatively unhindered by bureaucracy but he would like to be kept informed of developments! He is particularly interested in the Mill Chucking and Clamping Device: he hopes that there is a good idea in the making.

CIM BUDGET REQUESTS

Task & Item	Value	Estimate	In House	Source of Funds
A1 - Jo Miller				
RS232 Cabling				
A2 - Chris Foreman				
Macro-Programming	£500			
Chuck/Clamping Device	£700	✔		
B3 - I George BSI Handbook	£ 40	✔		Dept acquisition
A3 - Andy Kay				
A4 - Andy Proud				
Warning Beacons 2 off	£ 50	✔		RS catalogue
Puma Robot Gripper 2 off	£200	✔	✔	
Fanuc Robot Gripper 2 off	£200	✔	✔	
Robot Servicing	£ 70	✔		Dept. funds
Miscellaneous items	£100	✔		
A5 - Ian Lewis				
Updated drive system for work I/p - O/p device	£ 35			
Material for securing device on translift buggy	£ 20	✔		
Materials for parts storage buffers	£ 30	✔		
Electrical devices for parts detection	£ 25	✔		
Devices to update safety circuit	£ 40	✔		
Steve Harrison				
Work handling collars & nuts 10 off	£250			
Block and Spanner	£ 50			
			£600 extras	
			£1910	

Approved by Felix Schmid

A Rumour !!!

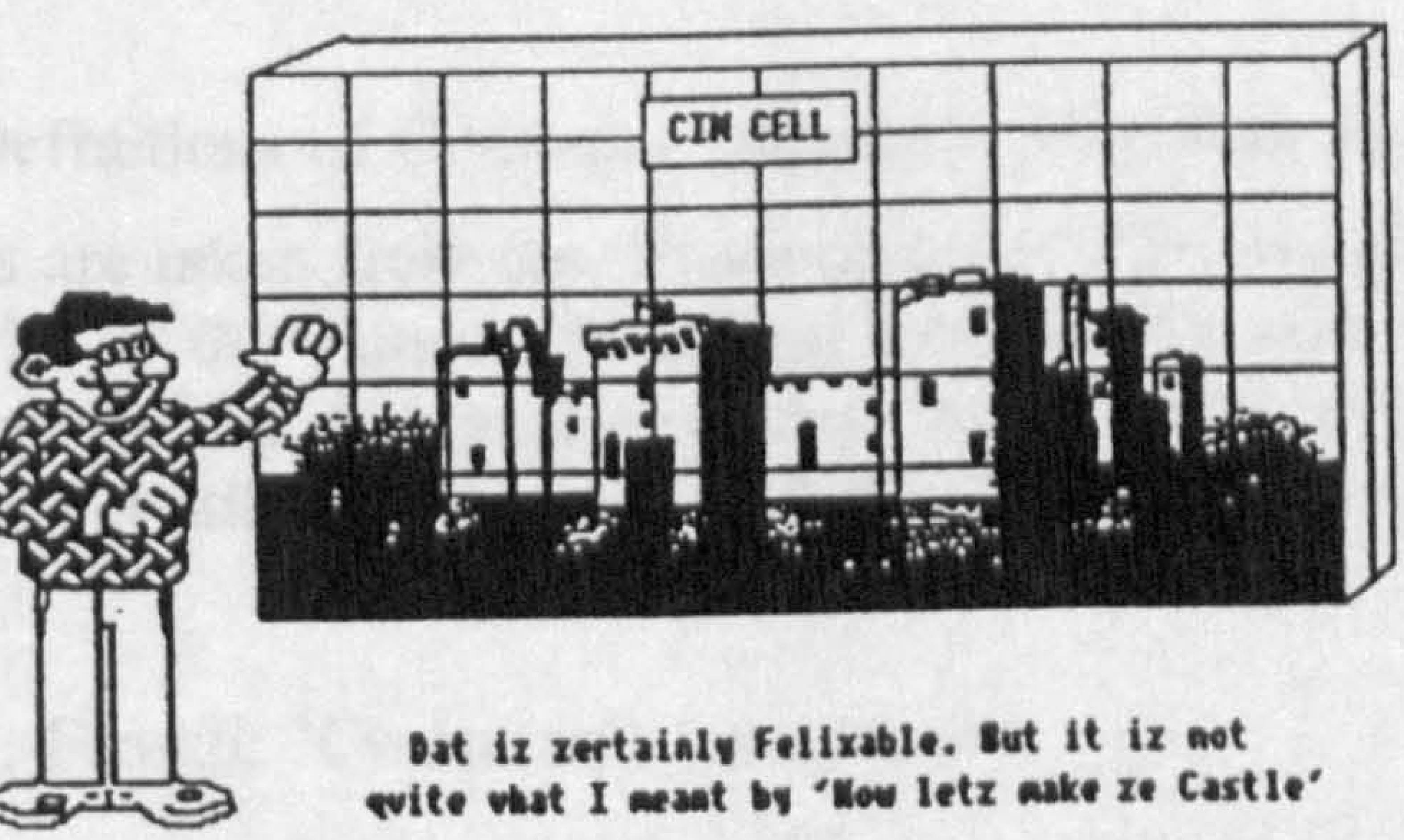
It has been rumoured that finances may be available to subsidise a CIM company Christmas party in the exclusive settings of Lord Felix's concrete tower. As yet nothing has been confirmed, but it is my guess that it will take place in the final week of term. The lord himself has refused to comment as yet, but his butler Peter Broomhead is all for the idea if free refreshment is to be laid on.

Keep The CIM Cell Tidy

Anybody who has had cause to enter the BLADE lab will surely have noticed the new tidy working environment. A great many thanks and CIM points to Ian Lewis for this very worthwhile contribution and lets keep it this way !!

OBITUARY

It is with great regret that we mourn the passing of that creature beloved of all CIMers and CIMmettes, the meeting animal. Much in evidence early in the year, this creature was not able to evolve and was forced into virtual extinction by that much more versatile, adaptable beast - the anonymous note in the pigeonhole.



Dat iz zertainly Felixable. But it iz not quite what I meant by 'Now letz make ze Castle'

L Appendix: Sources and Quotations

L.1 The National Conference on Engineering Education and Training - Extracts from the Report

The NCEET was held in 1980 (5-16 Oct 1980) as a forum of industry, academic institutions and government and listed, amongst others, Prince Charles as a speaker. The following are excerpts from the report document:

2.53 The System should include an extended and improved engineering first degree honours course, for those adjudged capable of achieving a high academic standard and its application in practice, followed by a period of structured postgraduate training and experience in a working environment. Elements in this programme will include:

(i) preparation for mainstream engineering work with an emphasis on the application and management of the best current knowledge and expertise;

(ii) recognition of the underlying economics and social contribution of engineering and importance of the design, production and marketing functions;

(iii) understanding engineering practice and application within an engineering environment.

2.56 ... Personal qualities should include motivation towards and commitment to engineering.

2.58 The course should also include a substantially greater input of engineering practice as well as consideration of the importance of money, manpower and marketing on the role of the engineer. There should be close consultation between the teaching institution and employers in designing courses, and the greatest possible degree of interaction between them during the course. This should extend as necessary to the provision by industry of non-teaching resources for the proper coverage of EA1 and EA2. In addition, the importance of the ability to be able to communicate - both orally and in writing - should not be overlooked.

L.2 Quotes and Definitions of Computer Integrated Manufacturing

The following quotations are taken from the 'Proceedings of The Symposium on Education for the Manufacturing World of the Future, Series on Technology and Social Priorities of the National Academy of Engineering, National Academy Press, Washington, 1985'. Although this is a somewhat "dated" text it still carries many useful messages and lessons.

L.2.1 Robert A. Frosch: 'Chairman's Introduction'

With the focus of business attention on fiscal and management areas, the art and science of manufacturing engineering have been allowed to decay, and companies have not recognized manufacturing engineering skills as high-priority ones to be highly rewarded. Rather, manufacturing has increasingly become a place to demonstrate only "managerial" skills, with more rewards given for these than for technical competence, skill, and ingenuity in the technical tasks of manufacturing.

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In the discussions of several working groups, as well as in the speeches and panel discussion, conflicts arose regarding the idea of theory and the matter of the reality of the manufacturing floor. It was stated that experience, not theory, is the key to solving problems, and yet a grounding in fundamentals is extremely important.

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Nonengineering problems concern the need to put the engineering side of manufacturing in an overall business context, so that engineering choices make economic sense and relate properly to social questions of health, environment, and the position and relationships of labor, management, and machines. Both speakers and discussants pointed out that a purely technical education in the traditional engineering sense is insufficient for a manufacturing engineer, since so much of his or her effort deals with the business and social systems making the manufacturing system work.

L.2.2 J.F. Shea: 'The Changing Face of U.S. Manufacturing' - What is possible

In many areas of engineering, one can evaluate how close a design - for example, for a combustion cycle, an amplifier, or a structure - comes to a theoretical limit. There is no such theoretical basis, however, for producibility of a design and achievable quality levels. Companies tend to set standards based on past performance of similar products and whatever they know about domestic competition. From that point of view, cost reductions or quality improvements of a few percent can seem like major accomplishments.

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It is conceivable that early in the next century computer-controlled flexible manufacturing systems will produce virtually all of the material goods required by society, except those with high artistic content.

The companies that master this transition will gain nearly unassailable positions in the world market through their ability to produce quality products tailored to special customer requirements on a very short lead time. As the examples cited above indicate, however, a major portion of the gains to be achieved can be realized today, not in the twenty-first century, with existing technology. One approach, well established in Japanese firms and successfully employed by several American companies to improve quality and productivity while reducing lot sizes, is the "just-in-time" production concept.

L.2.3 F.D. Brummett: 'The U.S. Manufacturing Engineer: Practice, Profile, and Needs'

Some say that management is basically the same regardless of what is being managed, but this is not true of engineering management. The best-qualified engineering managers are those who combine both technical and management skills, since they must understand and apply engineering principles while they organize projects and direct people. They are uniquely qualified for managing either technical functions in any enterprise or broader functions (such as marketing or top management) in a high-technology enterprise. Unfortunately, many engineers do not realize what an important asset their engineering background is in pursuing a management career.

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To pursue a productive and enduring career in this era of revolutionary industrial change, the manufacturing engineer must be versatile and have knowledge of and experience in the many manufacturing operations.

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After working in manufacturing, however, highly qualified engineers often transfer into nonengineering or nonmanufacturing classifications that offer salary increases or other rewards. Manufacturers must recognize the loss they suffer when an experienced manufacturing engineer leaves the production function because there is no salary or promotion incentive to stay in that classification. Many times an individual would prefer to work in engineering, but he or she has *found that moving up the promotional ladder requires a shift to a new type of work or a move into management.*

The underlying concept of structuring a full career path provides a good example of an alternate way of creating a major resource of competent engineers and managers. Recently, a new professional classification, "advanced manufacturing engineers", has been implemented in large companies such as General Electric, General Motors, Ford, and Caterpillar. This classification encompasses major responsibilities in research, design, project management, and manufacturing management and can help retain and reward outstanding engineers who might otherwise move into sales, finance, or other service areas.

L.2.4 Robert M. Anderson, jr: 'Lifelong Effectiveness of Engineers'

The concept of "effectiveness" involves knowing and being able to do many different things. Furthermore, the things that determine whether someone is effective will change as they advance in their career and as the technical requirements of their work change. Employee and employer share the responsibility for achieving and maintaining effectiveness in engineering. This is not a one-time task; it is a continuing process that merges professional development and technical education to keep up to date with new theories, processes, products and industries.

L.2.5 Callahan

Systems can only be designed by people who understand the technologies and equipment they are dealing with, and these individuals are manufacturing engineers. However, these same manufacturing engineers, who come from all disciplines, must be taught additional skills and be capable of functioning in a manufacturing rather than a laboratory environment. In semiconductor manufacturing, engineers need exposure to that part of the manufacturing discipline dealing with flow optimization.

Why is this taught in the business school anyway? Manufacturing engineers must be taught how to model and optimize flows, how to manage inventory,and most important, how to manage people. Direct labor operators are an enormous source of problem-solving information and often have many years of experience. Probably very few of the top engineers in my company, or in many companies, have ever taken a single course in any of these subjects, so we must try to broaden the training for our engineering students to touch on these and other subjects.

L.2.6 Skinner, W.: 'Panel Discussion on Corporate Attitudes'

Ultimately, we should see manufacturing people at the top again in reasonable proportions, but this requires further breadth and conceptual skills from manufacturing managers, attributes which are now the exception and not the rule. Meanwhile, the initiative for new manufacturing technology must come from manufacturing management because corporate attitudes at top levels often reflect technological illiteracy.

So we have an educational dilemma. Paradoxically, manufacturing managers need to acquire financial skills and learn to think in a competitive and strategic mode as effective top managers to, while top managers need the technological competence and confidence derived from experience and training in production. Until each acquires the other's strength, their own individual strengths become in fact a corporate weakness, for in their work together they mutually debilitate and frustrate. Meanwhile, our industrial malaise goes on.

L.2.7 Working Groups - Issues and Recommendation

Undergraduate students have a critical need for knowledge of manufacturing processes and process selection criteria, with emphasis on the process in the context of the overall manufacturing system.

Undergraduate students have a critical need for implementation training beyond design problem solving, with special emphasis on producibility.

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All manufacturing students have a critical need for "people" skills, especially leadership and communication. Often missing in a conventional engineering education, these skills are probably best developed through project courses - that is, group projects in which students learn to accommodate one another, to cooperate, to subdivide problems, and to schedule.

......

There is a faculty gap in integrative (i.e. process, design, and systems) and cross-disciplinary problem solving and a lack of focus on faculty development in these areas.

M Appendix: Copy of the CIM Introduction 1992/93

BU-CIM-751-A4-W34-92/93

C I M C O U R S E SESSION 1992/93

Further Development of a Computer Integrated Flexible Manufacturing Facility

Management and Design Project Option for BME Year 4 and a Single or Double Option for SEP Year 4

(A combination of lectures, tutorials and practical work)

(1) Introduction and Project History

The 4th year course in computer integrated manufacturing (CIM) was first introduced for the academic session of 1987/88. It has come of age! Twenty eight BME and SEP students took part in the first year. This was an experimental year although a substantial amount of work was carried out on the implementation of a flexible manufacturing cell for the production of small machined parts. During this introductory period management concepts, assessment procedures and marking schemes were evaluated. At the same time the BLADE laboratory was re-modelled to accommodate the machine tools and computers. It was shown that a large project of the nature described later on in this document can be managed successfully by students.

In the academic session of 1988/89 over forty students formed what became known as the CIM company. It was decided to change the cell arrangement in order to be more in line with current industrial practice. This meant, unfortunately, that some of the previous year's work needed to be undone. The system became, however, much more realistic and useable. Progress was hampered though by the large number of computers used in the control of the cell which rendered testing the system a herculean task.

In the academic session of 1989/90 the CIM group had 36 members. Building, to some extent, on the work carried out in the previous year the team concentrated on workpiece handling and computer communications. The group used the existing layout of the cell but introduced workpiece holders and the necessary grippers and clamping devices. This was a successful step since it rationalised the machine tool - workpiece interface. The group also changed the computer network from PC-Net to a star RS232 system and introduced a more structured approach to software development. Although the team laid the foundations for the computer based business system for the cell and the CIM company this was not integrated with the system hardware.

The major contributions of the 1990/91 CIM group were in the areas of software development for communications, business systems installation and hardware reliability improvements. The management of the CIM company again decided on a very simple but diverse range of products to be manufactured by the flexible facility, chess-pieces. The decision was taken on the basis that the capability of the machine tools and robots had not been fully assessed. Such an assessment was carried out and results are available.

In 1991/92 CIM was run as an option for both BME and SEP students for the first time. Twenty seven students from Brunel, 3 students from Poland and a lecturer from Czechoslovakia took part in the project and achieved a great deal in improving the physical environment of the cell, in writing better and more reliable software and in establishing the CIM company. They did a great job in advertising Brunel's CIM capabilities and attracted the first sales of CIM company products in summer 1992. The success of this team allowed us to apply for funding from SERC's ACME directorate - and we have been successful. CIM 1992/93 will, therefore, be able to integrate some new equipment into the cell, namely, a robot and possibly a new lathe. Peter Broomhead has identified new software systems which will make the system more controllable once they are implemented.

As for last year a reasonable target for this year is the manufacture of components of limited complexity but to good standards of quality and reliability, controlled by computers with human support, from order through to finished product.

The CIM course is designed as a double option for both BME and SEP students although there are some single option opportunities. Students who choose to have the course counted as a single option do not need to attend the lecture element and are freed of some associated essay work. Since the practical work is assessed in an industry standard way there is no difficulty in accommodating two levels of commitment.

(2) Overall Concept and Control Philosophy

The system is centred on a Translift transporter system and uses a variety of small machine tools, industrial robots , handling and inspection equipment. The vehicle is plc controlled and serves a number of load/unload stations distributed around the periphery of the Translift track. The stations are associated with machine tools, buffers and cleaning stations, etc. The control of the manufacturing cell is based on a Distributed Processing Model (DPM), that is, a number of IBM-PC class machines are networked in a star configuration with one central machine assuming the role of overall cell controller. Each of the distributed nodes on the network is responsible for the control and monitoring of one or more individual cell elements, where a typical element is a robot or machine tool. A new development is the use of sub-cell controllers. The central controller synchronises and controls the flow of information to and from the nodes according to the manufacturing schedule for a given component. Component scheduling within the cell is based on an Earliest Due Date (EDD) rule, this rule establishes the precedence and hence the flow of components through the cell. A maximum of 10 components may be accommodated in the cell at any one time.

The cell control computer is linked, via a high speed ethernet connection, to a factory and shop floor planning system, designed using a human centred approach, which in turn is linked to an MRP(II) system. The whole system should use an anthropocentric approach to the design of software and hardware.

It has been suggested that our facility could be a prototype for the future subcontract machine shop capable of competitive tendering via direct computer links to its customers.

(3) **Scope of Task Orientated Project**

CNC machines (robots, mill, lathe, co-ordinate measuring machine Translift-Track and plc's) have been acquired by the department over recent years in a purposeful fashion. As a result of feedback from the first group of students, for example, we ordered a new and more powerful milling machine. It is the intention that machines to be purchased in the future will also be chosen according to two criteria: Machine tools should be small enough to fit into the concept of precision manufacturing and must be of an industrially acceptable standard (currently not satisfied by just one machine since we are able to replace the FANUC robot by a better materials handling system).

The work in the BLADE laboratory is, as far as possible, closely related to the industrial environment which will be experienced by graduates on leaving university. It is thus an extension of the Manufacturing Design and Practice course in years one to three which is largely restricted to the use of individual machine tools and stand alone computing facilities.

The purpose of the fourth year "laboratory project" is the further development of the computer integrated flexible system for the manufacture of small machined components and of the associated company management systems. The system is configured around a transport system and encompasses a variety of 'desktop' machine tools, robots, handling and inspection equipment. Control of the system relies on an IBM PS/2 computer which communicates with production equipment either through the intermediary of IBM PC computer system units or directly via RS232 communication links. Inter-computer links are effected using RS232 at the lower level. Links to the University's campus network, remote terminals and business/management software use Ethernet/Token Ring at a higher level. The systems are based on the ISO seven layer model.

Computers are used to carry out all the functions necessary in a manufacturing company, such as order taking, order processing, planning (including parts explosion and materials requirements), accounting, cash flow analysis and forecasting. It is hoped that in 1991/92 the systems will be linked up successfully for data interchange and feedback, using a networked database and computer supported documentation.

Information generated by CAD systems is converted into codes acceptable to production equipment using CAM software, currently MASTER-CAM, acquired in 1991. Numerical control data for the range of components to be produced on the system is then down-loaded to the equipment controllers or the IBM PC system units. A separate bus system to distribute data files to nodes on the star network has been developed to a prototype stage in 90/91 and will need to be completed this year. It is a low cost tool with substantial data transmission capability. The supervisory IBM PS/2 is responsible for scheduling the desired mix of parts through the different operation sequences to be performed on the various machine tools. It will have a special operator interface to allow on-line trouble-shooting of scheduling problems. The manufacturing schedule is generated by the Fourth Shift package of which a new version has been bought for 1992/93. It is then adapted using ACiT.

The CIM activity is timetabled for three hours per week, of which one hour is set aside for a series of lectures, and contributes a substantial number of marks to the final degree. The management expect that members/students will work on their tasks for 3-4 hours per week, with a limit of about 5 hours per week.

(4) **Background Information**

(4.1) **Hardware**

The system to be set up will be controlled in its entirety by computers. The following processors will be available for these tasks:

1 off IBM PS/2 Model 80 Large Screen (CAD/CAM work)

1 off IBM PS/2 Model 80 equipped with a RIC card (System Controller)

1 off IBM XT Type Computer (Operator Interface)

1 off IBM 286 Computer (Inspection Controller)

4 off IBM PS/2 Model 35 (AT Bus for Machine Tool Control)

1 off CHUM Processor Z80, DIN (Transporter Control)) To be replaced by digital

1 off CHUM Processor Z80, rack (Pallet Handling)) I/O cards or the "Fishnet"

Additionally available, as development tools, are

2 off IBM compatible computers

These machines will also be used on other projects and will be allocated to the CIM laboratory on a part-time basis. A number of single board computers have been built to facilitate machine tool data links for DNC, bypassing the RS232 star network. These will use "FIELD-BUS", a multi drop system using differential two wire operation for which a prototype exists. This system is now at the preproduction level and provides many powerful control functions.

The following robots are currently available:

1 off large FANUC Robot Type S (Replacement pending)

1 off UNIMATE PUMA 500 Robot (Loading and Inspection)

1 off Mitsubishi Robot (not necessarily required)

All robots are equipped with their own intelligent or semi-intelligent controllers, linked to the controlling computers via RS232 or parallel interface lines. Orientation devices for parts control and buffers exist in several locations throughout the cell. Ancillary equipment, such as powered transfer slides, can be made available.

Several machine tools are allocated to the project, including:

1 off Triac FANUC Milling Machine with automatic tool change

1 off Triac Milling Machine (if required)

1 off Denford Easiturn with numerically controlled tool post (Replacement pending)

1 off Co-ordinate Measuring Machine KEMCO

1 off Parts Washing Station

Components are transported between loading, machining/inspection and assembly stations on the TransLift track, using a small vehicle controlled by micro-processor. The vehicle travelling on the track is equipped with a fixture for carrying workpiece holders.

(4.2) Software and Communication Links

It is assumed that CIM workers will have achieved a reasonable level of competence in programming in a high level language by the time they reach the final year of the course.

Since most of the tasks involve, in one form or another, communications with other computers or equipment controllers using standard interfaces it would seem appropriate to write the software in a language which is well supported. Software for driving the RS232 network at the PC end as well as the scheduling software is thus written in the C language. Exception handling and error checking routines and procedures have been developed for both the PC and PS/2 ends.

The programming languages adopted for the software development on the project are C and C++. The C++ language was developed by AT & T's Bell labs in 1983. It is a hybrid language that provides a fusion of object-orientated programming (OOP) functionality with the features of the traditional and efficiently structured C programming language. The need for a standard language in which to implement cell control software has grown in importance in recent years. The present practice of developing bespoke software solutions is both expensive and inefficient in time and resource. Moreover, many of the high-level languages currently used to implement the requirements of manufacturing systems lack the necessary language constructs, such as data abstraction and inheritance, that facilitate the implementation and administration of large-scale programming projects such as cell control. Existing software is compatible with C++.

A large number of computers (8) are connected to the PS/2 using RS232 on one side and to machine tool controllers via RS232 links on the other. Thus, computers tend to be used almost like RS232 plugs. In order to reduce the level of complexity in the system's structure it is intended that each of a smaller number of computers, communicating with each other via RS232, controls 1 to 3 machine tools, robots etc. using an RS232 sub-star system. Task 3 will need to apply this approach which has been tentatively used for the machining sub-cell.

A form of transmission error detection and handling has already been introduced and may require improvement. Software and, more specifically, communications integrity tests will need to be carried out at an early stage of this year's work.

The following software packages (and others) will be available:

Quattro (spreadsheet)

Word Perfect (word processing)

Fourth Shift (MRP II package)

MASTERCAM (CAD/CAM package)

dBase 3 (database package)

ACiT (scheduling software package)

Super Project Plus (project management software)

Compilers as required

Computer Vision Personal Designer

Integration of some of these packages with each other has been achieved but full systems control will require substantial efforts. See the software and communications diagrams for details of the system, to be issued at the start of term.

(5) Management Structure

The project management board consists of five non-executive members, including the department's chief technician and two "full-time" senior coordinators.

The non-executive board members appoint and, if necessary, remove from office the senior coordinator(s). They select the project task managers in consultation with the coordinators. This is a change from the experimental arrangement where the chief executives were selected by their management colleagues. As a result of suggestions the posts of senior coordinator will no longer be linked to the managing of tasks.

(5.1) **Matrix Structure**

The CIM company is a medium sized management consultancy practice with a clear target and budget. All the same, it must count as a relatively large organisation which carries out a very substantial multi-disciplinary project in a short time frame. The constraints on the project team, in terms of time, labour and motivation, are going to become more and more apparent as the work progresses. It is, therefore, essential that a good management structure exist within the company.

The work during the first two (operating) periods of the CIM company was organised in a conventional hierarchical project management structure. This official structure was adequate for the substantially "hard" technological tasks in hand although a secondary informal structure emerged during the course of the year which guaranteed good communication between groups (particularly with respect to the Local Area Network and the safety system).

A matrix management structure was adopted for the academic year 1989/90. This proved to be successful despite some teething troubles (meetingitis was rife during term 1).

As explained on tutorial day we should like to retain a simplified matrix structure for the course 1992/93. The matrix is again to be formed from the intersections of skills and multidisciplinary tasks. However, there will be smaller numbers of both task groups and skills, resulting in a simpler and more effective structure. Skill groups assemble people who are good at a particular task or people who are willing to learn fast. Skill group leaders should be able to be members of a task team while at the same time being prepared to assist with problems in any other task. Project task leaders should concentrate on managing the team (and themselves), not necessarily on solving technical detail problems. But there is certainly no hard and fast rule about this.

The system can only work well if everybody tries to keep things relatively simple... Regular meetings need to be held between the project task leaders and their teams as well as between the leaders themselves. Skill group leaders must find ways of ensuring common technical standards in their area of competence.

Matrix organisation is a management structure which tries to put into place the information exchange links which, in an ordinary hierarchical structure, develop only slowly on an informal basis. In the case of the CIM project we hope to ensure that people do not start to "tunnel" away from the target. We expect to use the human resource more effectively, e.g., if three groups use the same computer one software person may be able to deal with most problems.

(5.2) **Responsibilities**

In 1989/90 each of the two senior coordinators was responsible for half the project (technical and business respectively). This was not a full success. Last year the three senior coordinators were jointly responsible for the whole of the project. This arrangement worked well and should continue this year although there will only be two coordinators involved. They must assume control for planning and for financial matters. It is expected that they will ensure a common high standard of documentation and that they will be involved with the assessment procedure. Computing tools may be used to assist the project management tasks but this could only happen under the supervision of the coordinators. Coordinators may also get involved in practical work, as engineers.

The project task leaders are each responsible for assembling the teams of 2-4 engineers to carry out the first task they have chosen. The composition of the team may vary as a function of time, individual tasks may be completed and new tasks taken on. This must happen in a consultation process which should continue throughout the project period. The non-executive board members will be pleased to assist in these processes.

The full management board meets at least monthly to discuss progress with the projects. Meetings will be advertised and project task leaders should be available to brief the board on their activities. It is suggested that project task leaders meet on a bi-weekly basis, or whenever necessary.

The management board considers equipment bids and acts as a liaison forum between the different teams. Attendance by all ensures that the project stays within budget. Equipment procurement is to be channelled through Peter Broomhead/Mr. E. Cittern.

Senior coordinators are specifically in charge of referring any requests for technician support to Mr. E. Cittern. These should always be accompanied by drawings or sketches.

Information as collected from record cards and other sources will be available shortly before the start of term and should allow the selection of team leaders to proceed rapidly. Figure 1 shows the areas of responsibility in the project.

Figure 1. Management Structure for CIM Project (1992/93)

NON EXECUTIVE MANAGEMENT BOARD:

P. Broomhead

E.H. Cittern, Chief Technician

R.J. Grieve

F. Schmid

Senior Coordinators:

Provisional List of Project Task Leaders

Documentation Skill Group (Leader)

Electrical and Electronic Skill Group (Leader)

Machine Tool and Mechanical Skill Group

Software Skill Group

CONSULTANTS:

J Au	Mechanics and Computing
P Broomhead	Computing
C Butler	Metrology and Inspection
B O'Connor	Electronics, Analogue
R Duggan	Machine Tool Control
A Findlay	Networking of Computers
R Grieve	Robotics and Computing
B Griffiths	Chip Removal Operations and Materials
C Hudson	Computing an Digital Electronics
G Mullineux	CAD and CAM
J Powell	Management
P Race	Manufacturing Strategy
M Sarhadi	Electronic Control and Automation
F Schmid	Control and Electronics, Interfacing
B Wu	Systems Modelling and Simulation

(6) **Development Tasks**

The following is a list of the tasks which need to be undertaken and completed during the 1992/93 CIM course. Each task is allocated to a team, in the first instance on a basis of 'first come, first served', although the management reserves the right of restricting the freedom of choice. A large proportion of the tasks revolve around implementation of links between processors.

Task 1 Improvement of the communications protocol for the LAN based on a star RS232 network using the PS/2 (running under OS/2 and using a RIC card) for all the systems in the cell. Complete implementation of the Ethernet interface and possible replacement of the RIC card with an RS232 multiport card. Design of the operator front end and the links to higher level management computer systems. Development of a campus network based CIM database and management system.

Task 2 Design and implementation of the task management system for the supervisory processor (IBM PS/2 Model 80). Design of scheduling software and software for controlled shut-down and start-up of the cell. Implementation of the Routing Definition Language (RDL) and the Master Routing File (MRF) concepts. Safety system improvement. Liaison with all other groups to ensure compatible software and brainware.

Task 3 Improvement of the machining subsystem of the cell involving the design of the hardware and software for the Triac Fanuc mill, the Easyturn lathe and the Fanuc robot. The group may find that they also have to integrate the simpler Triac mill into the system since calculations carried out in 1989/90 showed that the mill was one of the bottlenecks in the cell. Full implementation of the sub-cell controller.

Development of the CAD/CAM/machine tool links. Provision of post-processors and modelling of the machining process. Computer assisted production of process plans and appropriate database management.

This is a large task which involves work from the design of compliant devices right through to the application of multitasking software using an AT type computer. Single board micro-processors can be used as RS232 interface managers and digital i/o devices.

Task 4 Design and implementation of materials handling and inspection within the cell. This work involves equipping the pallet conveyor and other system components with sensors, development of a combined control system for the pallet conveyor (for raw material and finished product handling), the loading and unloading robot and for the Translift truck. All these components should be controlled from one computer or a plc, itself in turn managed by the master computer. Positive detection of the presence of parts in any location must be possible. The work of this group has been made easier as a result of the use of workpiece holders. Some further robot gripper design work will be required.

Design and implementation of a manufacturing inspection system using robotic presentation of parts and computer controlled gauging of parts on a co-ordinate measuring machine. Quality control on the basis of sensor equipped go/no go gauges may also be considered by this team.

Task 5 Work associated with the use of single chip and single board microcomputers for control and communications within a cell, under Chris Hudson. Full implementation of the "Fishnet" to distribute NC data and collect statistical information building on the successful pilot phase of 1991/92.

Task 6 Materials Resource Planning and Accounts development. This task is mainly concerned with the implementation of the Fourth Shift MRP II programme.

Cell planning and scheduling using ACiT and introduction of SPC to the company's operation. This work must take into account "human factors" in terms of task definition and operator interfaces.

Task 7 Business Systems Development and remote site (EDI) manufacturing control.

As is apparent from the list, the project attempts to address some of the problems of scheduling, production and strategic planning. We are also concerned though with developing hardware and low level software at the front end of the system. It is expected that this year's CIM team will turn the flexible manufacturing system into a reliable, user friendly plant supporting all the business functions. "Dummy" cells may be introduced to simulate a complete manufacturing unit. A demonstration of the full working system is planned for Spring 1993.

(7) Support and Links to Theoretical Studies

Lectures and tutorials about aspects of CIM implementation will be presented by members of staff of the department and outside experts. Topics covered will include 'higher level' integration of manufacturing with computers, strategic planning, process simulation and plant simulation. Talks about MAP (manufacturing automation protocol), safety, CAM and project organisation will make useful inputs, on a practical level, to the solving of problems arising out of the tasks and to cover areas relevant in industry.

Lectures and seminars on more specialised topics will be arranged on 'request'. It should also be possible to arrange visits to the IBM CIM facility at Havant, Sandvik at Halesowen and other appropriate installations such as the Department of Trade and Industry AMT bus. Early submission of requests would be useful.

A software project management course may be held at the beginning of the winter term. This would be an intensive course with about six hours of lectures and structured team based learning.

(8) Documentation

It is expected that engineers use lab-books or another easily structured method of keeping records. Project task leaders are responsible for ensuring that their staff attempt to maintain adequate documentation but the leaders will not be blamed for bad quality (unless it's their own documentation, of course!).

It is suggested that any literature references be filed in a standard format, common to all groups. This can be done on a computer or using standardised filing cards. The latter method would appear to be easier to implement. Eventually, the project will result in the establishment of a reasonable bibliography.

The CIM team of the 1991/92 period established good and successful procedures for the storing and retrieval of commonly used information based on the work carried out by the 1989/90 and 1990/91 teams. Their documentation is exemplary in terms of the creation of an overall structure and general adherence to this. It is important that existing documentation is maintained in good and complete order.

It is the responsibility of the senior coordinators to set up and monitor the bibliographical data collection exercise.

Each team member, leader and coordinator will submit an individual interim report on their own work in week one of term 2. At the beginning of term 3 each project team will submit a user's guide for their part of the system and a summary report of the work undertaken during the final year (also refer to section on marking). Project task leaders are responsible for the team generated user reports on their tasks. They should ensure that each team member contributes adequately to this work. Since some team members may well be working in other areas this is clearly an incentive for keeping all documentation up to date.

(9) Assessment and Marking

Overall responsibility for marking and appraisal of the projects rests , as a matter of course, with the non-executive members of the management board. As far as possible though, the board will rely on the assessments of their engineering staff submitted by team leaders and on the feedback from engineers about their managers. This appraisal system is modelled on the structure used by a major UK computer manufacturer.

(9.1) General Marking Scheme

The assessment of the CIM course is based on a substantial number of pieces of written work, some produced individually, others produced in groups. Part of the assessment is based on interviews with groups, held by staff members about four times in the course of the year, and a final part is made up from a peer group assessment system.

Pending discussions at a meeting of all the CIM members the following marking scheme will be adopted for the CIM course. The marks are to cover the whole of the CIM course, that is, lecture course and laboratory work.

	Double Option	**Single Option**
Interim Report (Individual)	75	75
Assessment Procedure (Mutual)	150	150
Final Report (Group)	175	175
Presentations and Feedback Sessions (Group)	125	125
Assignments (best two of three)	200	100
Total of marks	725	625

The total of marks out of 725 or 625 will be computed to become a figure out of the respective number of marks allocated to the course as a whole. The mark will be computed in line with the choice of a single or double option.

Final group reports should reach staff in the week starting 26.4.1993.

It is apparent from the above that great trust will be placed on the maturity and honesty of students. It is hoped that this will be vindicated by the results of the assessments outlined below.

(9.2) Performance Assessment of Engineers

At the start of term, or the start of a project task, each of the leaders must set out individually, with their staff, the objectives to be achieved over the next six months. Objectives may stem from the task itself or from the 'Guide to Assessments' to be published by the senior coordinators.

At Christmas, at the end of the spring term and at the end of a project task, the leader will assess the engineer against the objectives, some of which may have changed at that stage. She/he will discuss the outcome with the job-holder.

A draft assessment form will be distributed at the start of term. The task leader may add an overall grade to the form. At the beginning of summer term a training and development form will be produced by the leader in consultation with the staff engineer.

(9.3) **Performance Assessment of Project Leaders**

Non-executive members of the board are charged with the appraisal of leaders. Reviews similar to those described above are held with the task leaders. The board members will take into account for their assessments the comments on the feedback sheets (copy attached) filled in by the respective staff engineers.

(9.4) **Report Requirements**

Each individual in the group produces an interim report on an aspect of the project which is of special relevance to him/her. This report is handed in after Christmas and may later form part of the group's report.

Subject to further discussions with senior coordinators and the documentation skill group each project group jointly produces a CIM report document as follows:

(1) Summary document (for an executive)

(2) Technical report outlining achievements and problem areas including recommendations for future work in the format of a report to a technical director. This is to include, as applicable, full development protocols, use-of-time records, list of unsolved problems etc. (ca 2,500 words).

(3) User manual and application notes in the form of a set of appendices. Size as required. Marking will be based on the quality of the complete document. Quality of actual work is assessed separately as above.

Reports will be marked by JA, PB, RJG, PR, MS, FS, in line with a common marking directive. This scheme will be a guide-line and staff members may change the allocation of marks to suit more accurately the reports submitted.

Marks may be modified as the result of discussions, on an individual bases, with one or two staff members, after conclusion of the project. This discussion may be directed at establishing what an engineer has learnt from her/his involvement in the task.

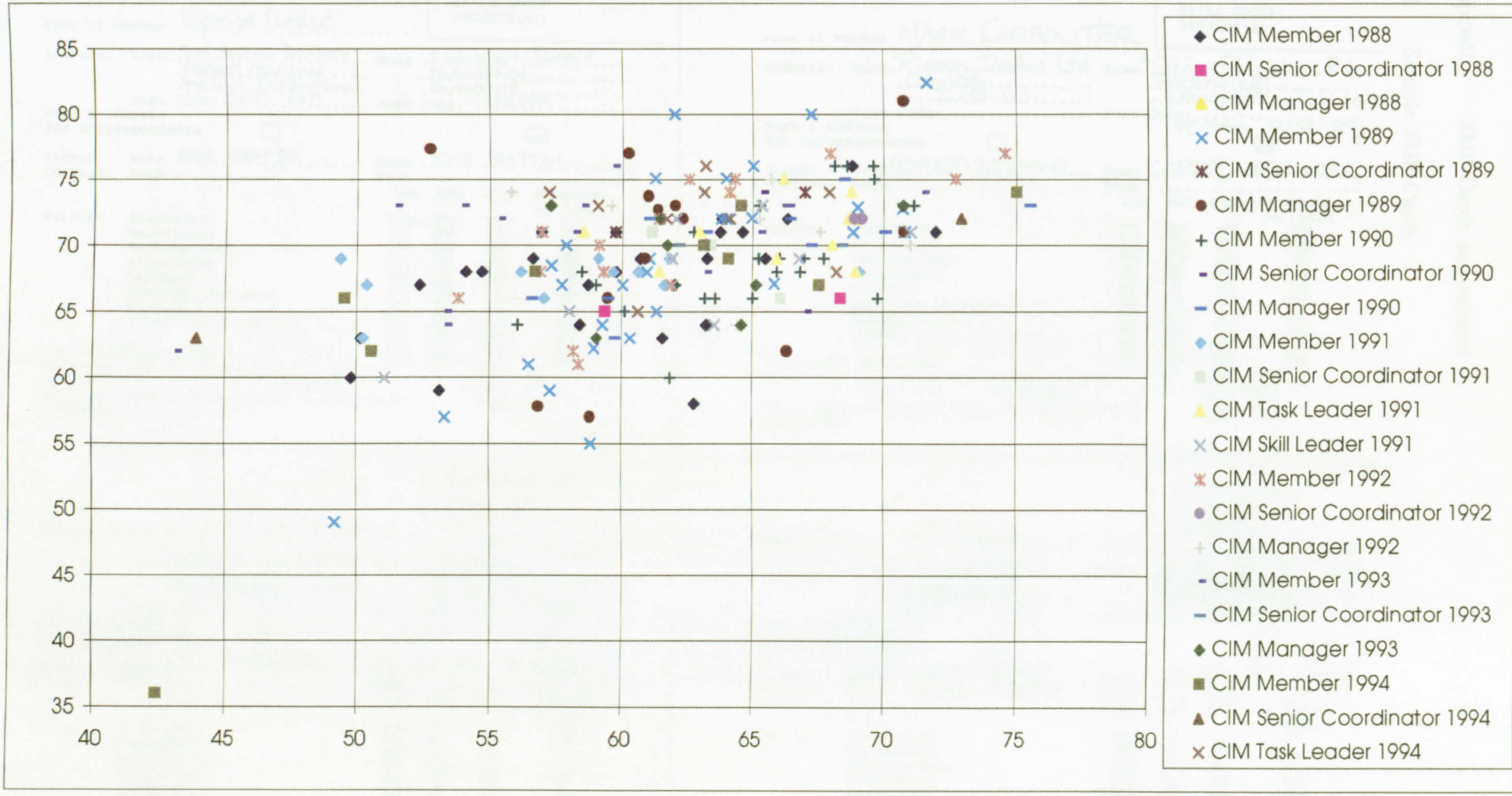
All students must take part in the CIM course presentations which will be held, on a group basis, in the summer term. Two members of academic staff will review with the students their contribution to the success or failure of their team's task. These vivas last between 30 and 40 minutes.

(10) **Project Timetable** (CIM Weeks)

1992-10-05 Start of Term	:	Document read and understood. Declarations of interest!
1992-11-16 (Week 7)	:	Budgets Fixed
1992-12-14 (Week 11)	:	Appraisal Forms Completed (Round 1)
1993-01-11 (Week 12)	:	Hand in Date for Interim Report

1993-03-03 (Week 20)	:	Completion of Hardware/Software Work
1993-03-22 (Weeks 21/2)	:	Period for initial System Trials?
1993-03-26 (End of Week 22)	:	Appraisal Forms Completed (Round 2)
1993-04-30 (Week 24)	:	Submission of Development Report
1993-05-07 (Week 25)	:	Submission of User Documents & Report
1993-05-17 (Week 27)	:	Presentations and Feedback Sessions

N Appendix: Overview of all Marks on CIM



Overview of all Marks on CIM as a Function of the Roles in BCIM (1988-1994)

O Appendix: Skill-Cards and Returns

O.1 Sample Skill Cards

FOR OFFICE USE
SKILL GROUP:
PROJECT(S):

Name of Worker MARK CARPENTER

Address: Work. Plessey Radar Ltd, Cowes, I.O.W. Home Glencroft, New Rd, Porchfield, Newport, I.O.W.*

Post Code: .... Post Code: *(From 3/8/89)

Mark X Address for correspondence ☐ ☒

Phone: Work (0983) 202440... Home (0983) 822400
Contact: Work .... Home

low med high Prepared to learn

Skills: Electrical
Mechanical
Machine Tool
Accounting
Software
Computer Hardware
Documentation
Others ....

Leadership Abilities
Would you like to manage a (skill group Yes (No)
(project Yes (No)
Would you like to be a senior coordinator (Yes) No
Interests:

FOR OFFICE USE
SKILL GROUP:
PROJECT(S):

Name of Worker Rob Cockhill

Address: Work. Dowty Grp Services, Arle Court, Cheltenham Home Flat 2, Promises Wst, 50 Park Place, Cheltenham, Glos

Post Code: .... Post Code: GL50 2RA

Mark X Address for correspondence ☐ ☒

Phone: Work ... 0242 533469 ... Home ... 0242 584546
Contact: Work ... 0242 533325 ... Home

low med high Prepared to learn

Skills: Electrical
Mechanical
Machine Tool
Accounting
Software
Computer Hardware
Documentation
Others ... Prod. management, Man^t. systems

Leadership Abilities
Would you like to manage a (skill group Yes No
(project Yes No
Would you like to be a senior coordinator Organising Yes No
Interests: Looking to use admin/production/skills - not too hot on technical sides of things

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FOR OFFICE USE
SKILL GROUP:
PROJECT(S):

Name of Worker Hilanda Clarke

Address: Work. Fuel Systems Division, Product Assurance, Arle Lane, Cheltenham. Home S. Whitehall Terrace, Shrewsbury, Shropshire

Post Code: GL51 0TP ... Post Code: SY2 5AA

Mark X Address for correspondence ☐ ☑

Phone: Work 0242 533490 ... Home 0743 247721
Contact: Work .... Home

low med high Prepared to learn

Skills: Electrical
Mechanical
Machine Tool
Accounting
Software
Computer Hardware
Documentation
Others ..... Quality ?

Leadership Abilities
Would you like to manage a (skill group Yes No
(project Yes No
Would you like to be a senior coordinator Yes No ?
Interests:

FOR OFFICE USE
SKILL GROUP:
PROJECT(S):

Name of Worker CHRISTOPHER FOREMAN

Address: Work. DOWTY GROUP SERVICES, ARLE COURT, CHELTENHAM, GLOS. Home 55A NEW STREET, CHELTENHAM, GLOS.

Post Code: .... Post Code: GL50 3LU

Mark X Address for correspondence ☐ ☑

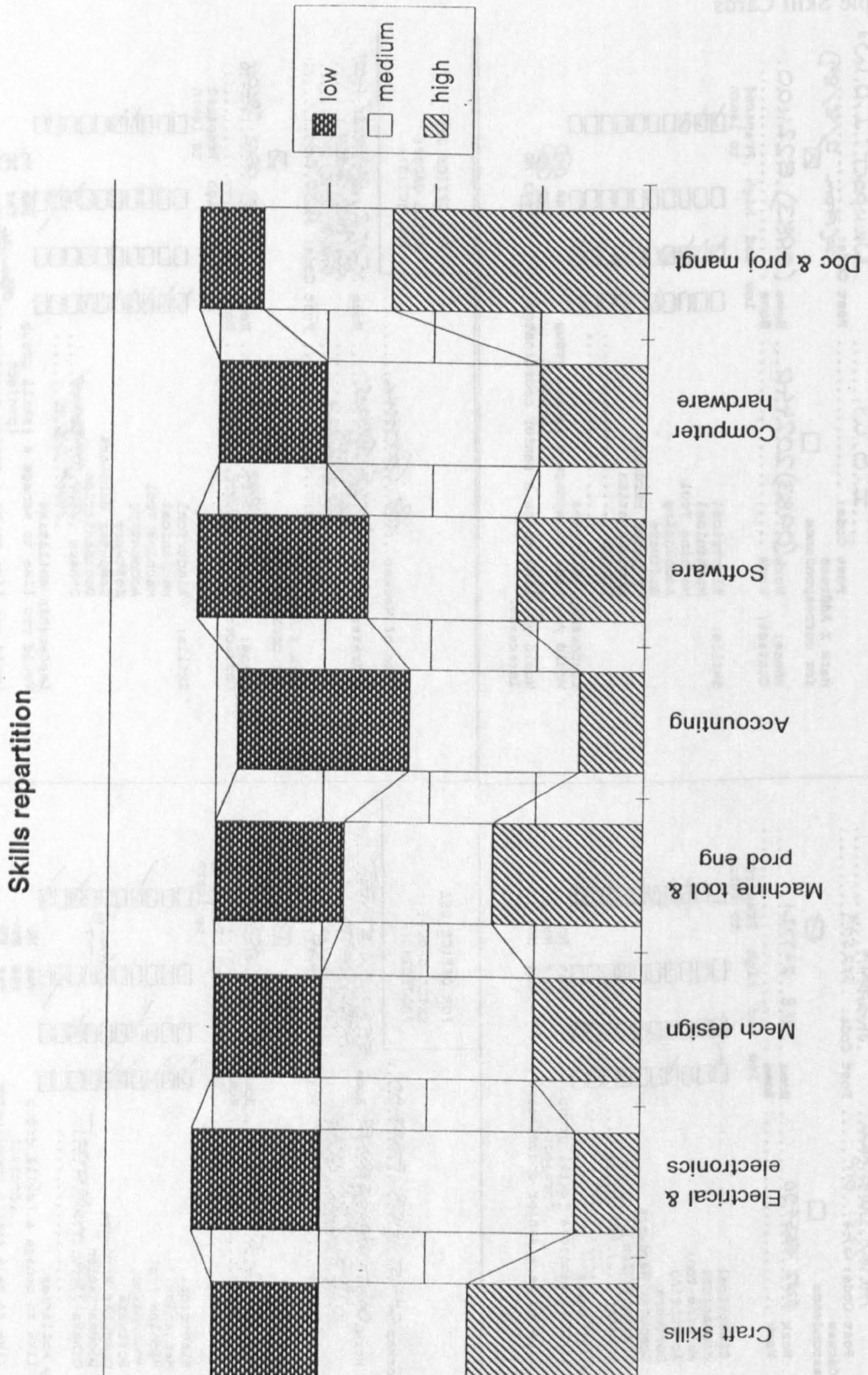
Phone: Work 0242 533164 ... Home 0242 30636
Contact: Work .... Home

low med high Prepared to learn

Skills: Electrical
Mechanical
Machine Tool
Accounting
Software
Computer Hardware (Commercial only)
Documentation
Others PROD. MANAGEMENT.

Leadership Abilities
Would you like to manage a (skill group Yes No
(project Yes No
Would you like to be a senior coordinator Yes No
Interests: NOT VERY KEEN ON HIGHLY TECHNICAL SUBJECTS BUT I'M QUITE GOOD AT THE MORE BROAD BASED SUBJECTS.

O.2 Skill Repartition for 1994



P Appendix: Programme of the Brunel CIM Conference

BRUNEL UNIVERSITY

COMPUTER INTEGRATED MANUFACTURING CONFERENCE

Organised by the BRUNEL CIM COMPANY - BCIM

Friday, 26 February 1995

Conference Centre, Brunel University

09.15 Welcome by the Vice-Chancellor of Brunel University, Prof M.J. Sterling

09.30 Prof. Bob Gibbon, Key-Note Address on 'The Impact of Advanced Manufacturing Technologies'

10.00 Dr. Steve Owswianka (Department of Trade and Industry): 'Funding for AMTs and DTI Support for Cooperative Work'

10.30 Coffee

10.45 **Session 1A:** Computer Systems and Management Systems

Eric Woodcock (BAeCAM) on 'Design Philosophies for Production Management Systems'

Andrew Tunswell (Coopers and Lybrand): 'Software and Hardware Management'

Mike Beer (Fraser Nash): 'Shop Floor Tools'

Session 1B: Industrial Users of Systems

Prof. Bob Gibbon (John Crane UK Ltd): 'Minimal Systems Work Better'

Dr. P. Warbley (Edwards High Vacuum): 'Industrial Experience'

Graham Carter (Unilever Research): 'Advanced Research Tools'

11.45 Coffee and Discussion

12.00 **Session 2A**: Education and Training for AMTs

Mike Gregory (University of Cambridge): 'Technology and Management Challenges for Engineers and Scientists'

Felix Schmid (Brunel University): 'Skills for Advanced Manufacturing Environments'

Ray Shaw (Fulcrum Developments): 'Changing People's Mindsets'

Session 2B: Company and People

Dr. Steve Evans (CIM Institute, Cranfield Institute of Technology): 'CIM and Company Strategy Development'

Prof. J. Smith (University of Sunderland): To be announced

Andrew Ainger (Human Centred Systems): 'Place the Human in the Centre'

13.15 Lunch

14.15 Informal Discussion on Appropriate Advanced Manufacturing Technologies and CIM

15.15 Demonstration of the Brunel University Manufacturing Installation and associated Planning and Control Systems (guided tour with talks by the 4th Year CIM Team)

Enquiries and Registrations should be addressed to the BCIM Team, c/o the Department of Manufacturing and Engineering Systems, Brunel University, Uxbridge, UB8 3PH.

Mail for Jean-Noel Ezingeard — Wed, 26 Jan 1994 16:46:08 +0000 (GMT) — Page 1 — (1)

From: [redacted] <em90asd@brunel.ac.uk>
To: em90ssv@brunel.ac.uk, bm90niw@brunel.ac.uk
Subject: Mechanical Skill Group
Date: Wed, 26 Jan 1994 16:46:08 +0000 (GMT)

G1 Chepstow Hall

26th January 1994

It is with no regret that I am resigning from the post of Mechanical Skill Group Leader. the 'extra' work that it has emcompassed in addition to the two tasks that I am involved in has been at no additional reward to myself

Indeed, at the mutual assessment appraisal, I believed that my marks would have been higher if I had not been holding that post. This, I see, is a ridiculous situation at any time in a degree course, let alone my final year.

I have attempted to lead the Mechanical Skill Group, in a relaxed manner, allowing the Task Leaders to get on with the work that they have identified for their task group. As a result, meetings are never fully attended, and communication of objectives and general information back to myself sparse.

The action that I am taking is effective immediately, and it will allow me to spend more time on my task activities.

[redacted]

Mechanical Skill Group

Mail for Jean-Noel Ezingeard — Thu, 27 Jan 94 17:23:51 GMT — Page 1 — (2)

From: [redacted] <em90ssv@brunel.ac.uk>
To: jean-noel.ezingeard@brunel.ac.uk
Subject: relaxation
Date: Thu, 27 Jan 94 17:23:51 GMT

Jean-Noel,

[redacted] and I have asked [redacted] to come and see us tonight before the Quazar trip. We have four points to jput which we will give him a written copy of and copy to yourself.

He is avoiding us on the flimseyest kof excuses (the words wriggly and worm spring to mind) and we have seriously considered having the RAG hit squad kidnap him kand tie him to a chair in the common room. Can you lend us your spot-lamp?

Current Chaos aside, it has been suggested that you might referee the football match tomorrow afternoon, would you, or would rather be involved in some other way (we need someone to cut up the half time oranges).

RSVP,
[redacted]

Mail for Jean-Noel Ezingeard — Fri, 28 Jan 1994 09:12:57 +0000 (GMT) — Page 1 — (3)

From: [redacted] <em90asd@brunel.ac.uk>
To: Jean-Noel.Ezingeard (Jean-Noel Ezingeard)@brunel.ac.uk
Subject: My decision
Date: Fri, 28 Jan 1994 09:12:57 +0000 (GMT)

Having just walked out of a meeting with [redacted] & [redacted], where I was being treated like a child who is unable to make the right decision, I feel compelled to write to you.

My decision to quit as Mechanical Skill Group Leader was made for a number of reasons, some directly relating to CIM, and some personal. I feel that I have given enough reason on the organisational issues for the personal reasons to be left personal.

When I started the CIM course, I was unaware of exactly how the Mutual Assessment worked. It had appeared to work in the past, so I put my faith in it. I did not expect the assessment to be based on personal feelings and subjective attributes - at least not to the extent that it is. I firmly believe that I should be mainly assessed on the content of my work, rather than whether I please everyone or not.

The role of Mechanical Skill Group Leader has meant a degree of extra work, over and above the usual CIM call of two tasks. Where is the benefit from this ? I have plenty enough to do this year which will earn me marks, and/or aid my personal development, without taking on extra roles which do nothing for me.

The meeting that I have just walked out of was an insult. I was treated as though I could not be trusted to make up my own mind. [redacted] insisted that he explained each of the "misconceptions" in my letter, however, this was only his view, and my views are clearly different. This tactic having failed, I was then faced with threats of being marked down because of my decision. It seems that I get marked down if I put in the work, and if I don't, so its quite clear which one I will chose. When Nigel decided, against my wishes to read through each area on the assessment form despite my saying that it was not necessary, nor desired, I left. I felt justified in doing so. The meeting was clearly arranged to force me to change my mind through threats, and intimidation, and I resent that.

Personally, I wish that this had come out sooner in the term. But my workload prevented that. However, I will stand by my decision, and accept any of the consequences that Shankar believes will follow.

The Senior Coordinators need to get on with the job of finding a replacement, whether temporary of permanent, rather than waste time hassling me to change my mind.

Mail for Jean-Noel Ezingeard — Thu, 27 Jan 94 18:10:54 GMT — Page 1 — (4)

From: [redacted] <em90ssv@brunel.ac.uk>
To: em90asd@brunel.ac.uk
Date: Thu, 27 Jan 94 18:10:54 GMT

----- Begin Included Message -----

[redacted],

It is in your best interests, and those of the organisation that you come to see us before Quasar tonight.

[redacted] and myself will both make kourselves available between six thirty and seven fortyfive tonight at Nigel's room. [redacted] is prepared to drive you down to Uxbridge in time for Quasar at eight.

This meeting will not take more than fifteen minutes.
I have an outstanding commitment for seven thirty five, so if you can make it before seven fifteen (or as early as possible in fact) it would be appreciated.

Michael Alderson

Task 7: (TE) — CIM conference evaluation and implementation — 85%
Link into year 3 for overlap
CIM promotion in university and industry
CIM social organisation — 5%

Task 3: (TE) — Cell layout design for optimum operation — 15%
Planned involvement with MasterCam + cell modelling.

Skill Group: — dissemination of task 7 results
documentation SG not yet active.

Good description of task 7 work, including justification. Clear reasoning for work and links with other institution. Cambridge link important.

Excellent detail on Task 3 decisions. Lack of an overall introduction.

73

Mark Behling

Task 2: (TL) — Task management system. Identification of current state and progress difficult. Clear statement of who does what. Are four parts the absolute limit? Why are Petri nets difficult? MRP and assembly graphs. How was the redistribution of responsibilities (for sensing etc) decided? New data structure.
Safety system and ACIT link. Start up/shut down procedure.

Task 1: (TE) — Cell communication protocol. DDCMP chosen and reasoning given.

You relish in sweeping statements which are occasionally flawed. You attempt to lay blame before you can be blamed ..... The report would have benefitted from proof reading! Quite a lot. But report is complete although an overview of DDCMP would have been useful for me.

63

Lara Bilton (glandular fever)

Task 6: (TE) — Currently no contribution due to lack of training and familiarity

Documentation SG: — no activity yet apart from two policy decisions

Task 7: — Development of focused business strategy +

(TE) — team selection brain storming planned with Peter Race. Team selection as main area of responsibility. Matrix structure not very much in evidence – more training needed, especially in team selection.

I am very interested in the approach used to evaluate the social/psychological aspects of CIM. An early discussion might be appropriate. How much is linked to your project? An OK report but of necessity a trifle thin. Could have done with proof reading!

55

Wendy Bourne

Allocated to Documentation, Computing, Mech. Design and Machine Tools group – but no particular objectives set.

Task 3: (TE) — Study of current robot operation, evaluation of possible replacement of FANUC by Puma. Brief changed to re-programming of FANUC robot. Difficult transition.

Task 4: (TE) — Materials and inspection using PUMA robot.
Good analysis of work necessary. Useful documentation excerpts but Buggy 1 + 2 not quite clear – do you intend to split the associated positions when both "holes" available?

Task 6: (TE) — SPC associated work with short run SPC.
Information a bit sketchy but good direction!

An appropriate and well presented report although a bit superficial in some areas. Did you re-read it? SPC work could continue with Swiss students ...

68

Philip Davenport

Task 6 — Fourth Shift, ACIT etc — 60%

Task 7 — Business System and Strategy — 20%
Leader Documentation and Project Management Skill Group — 20%

Task 6 — Computer repair (battery), support of installation of 4th Shift. Participation in 4th Shift Training Day at suppliers, in charge of getting 4th Shift up and running, re-entering data from last year, re-coding of all parts and development of new bill of material.

Task 7 — Business Systems development for transition to a profit generating company, discussions with Gibbon and Gregory at Cambridge. Ideas about data testing software and solving CIM related problems

In industry seem useful. The two strategy meetings in the spring term were very useful.

Skills Documentation and Project Management Skill Groups: CIM library and improvement of the CIM working area. What about transparent covers for PC keyboards, is this happening? Display of CIM strategy objectives is excellent. Good choice of events to be documented, problems with project management since it was not recognised at the beginning that all groups should use the same system.
A well prepared, clear and concise report.

68

<u>Steve Ede</u>

Task 5: (TL) Leader and task engineer on flshnet task. Management of task overall and involvement in hardware design and lower level software. Difficult project start due to poor documentation and incomplete hardware. Component selection and circuit design.

Task 1: (TE) Design of front end software for the cell controller/team 2 task).

An excellent report with useful appendices. Well written and a 'good read'. A few quibbles relating to the English, as noted in text. I agree with your criticism as regards attendance at meetings. I would like to be more involved. Should I attend 'highlights' meetings?

75

<u>Donna Edwards</u>

Task 3: (TE) Study of robot changeover from FANUC to PUMA. Layout design for machining sub-cell. Good choice of solution. Pushpart mechanism and lathe door automation.

Task 4: (TE) Analysis for improvement of the buggy operation. Work piece holder support. CMM roof work.

Good comments on overall course - especially on need to inform year 3 students on SEP of requirements/scope. PC/terminal in the foyer - good idea.

Your suggestions for related assignments are great. Go ahead with one or two of these. Particularly the one on costing of computer provision for all 4th year students? At home? A well written report with appropriate appendices but with a very few irritating English problems.

72

<u>Matthew Heaton</u>

SC: Close collaboration with Beth W. 80%
Company establishment/formulations. Team selection work. This worked well - new approaches were used. Only two people were 'lost' from the course.
Corporate mission and identity statement. Task coordination and mile stones. Excellent idea of Christmas presentations. Communication duties well described. Hi-Lites meetings and paperless office including Gopher and e-mail.
Organisation of mutual assessment process and evaluation.

Task 2: (TE) Documentation role + software work. 20%
Job status file on cell controller for start-up and shut-down. Safety system development.

Discussion of past and future roles very good despite some poor English. Further work on assessment system necessary as well as redefinition of skill roles. The report makes an enjoyable read!

70

<u>Slawomir Golec</u>

Task 2: (TE) Analysis of Master Routing Files (MRFs) and Assembly-Graphs (AG). The examples given could have been explained a little bit better. But you give full information on the content of information being transmitted. Do you mean 8 bits = word or = byte (the latter is the correct designation).

Task 1: (TE) Connection of cell controller to University Ethernet. You were given a very difficult task here.

Overall this report is not badly written but it lacks an introduction and a conclusion. I like the joke about the WALKNET .. I have corrected some of your English. I can give you more help if you need it.

60

<u>Andrew Griffiths</u>

Task 7: (TL) Business development - setting up of work groups and ensuring an environment for creativity and imagination. Good description of approach used. Use of Belbin questionnaire. New structure seems a good idea. Good review of individual activities. Can I provide one or two questions for the survey (on education for CIM)?

S Appendix: Interview Details and Graduates' Feedback

S.1 Interview Script for Survey

INTERVIEW SCRIPT

Good morning / afternoon.
I'm from the department of Manufacturing and Engineering Systems at Brunel university. The department is currently undertaking research in order to review the courses on BME and SEP. As a graduate from the department, your name was suggested (by Felix Schmid) as a possible contact.

Would you be able to spare some time in order to participate in a quick telephone interview to help us assess and improve our courses?

1. Describe in one or two sentences, your view of the course as a whole

2. State your current job role or roles, your hierarchical position and if possible your basic salary bracket.

3. How relevant was the course to what you're doing now?

4. I am now going to ask you a set of questions relating to your experience of the entire course. You will be asked which individual course elements gave you the most benefit, the most enjoyment, the most work and then, which was most difficult.

   Which individual course element throughout the entire course gave you:
   a. Most benefit
   b. Most enjoyment
   c. Most work
   d. Most difficulty

5. The same questions are now going to be asked relating to the courses undertaken in the final year only.

   Which individual element in the final year gave you:
   a. Most benefit
   b. Most enjoyment
   c. Most work
   d. Most difficulty

6. Which single improvement would add most to the quality of the course?

We are reviewing the course provision and would like to improve the cost effectiveness of the courses. Since the CIM course is the most expensive course to run, we would like to review this course in greater detail. The following questions will therefore concentrate on this course. (It is not clear whether FS will continue to run the course).

7. a. Is the CIM course environment realistic?
   b. How could it be made more realistic?

8. How much did you learn on the CIM course?

9. How fair was the CIM course marking system?

10. a. Are the assessment and appraisal methods appropriate for CIM?
    b. Are they relevant?

11. Any Further comments on CIM?

Thank you for sparing your time to provide this information.

Do you have access to a fax machine?
Would you be prepared to fill in a very short quick response questionnaire, immediately whilst the issues concerning the course are still in your head? I would appreciate it if you could fax it straight back to the department once it is completed (fax. no. 0895 812556). If you have any queries my phone number is 0895 274000, ext. 2945.

Your fax no. is?

Script 1
Q1) Enjoyed it. Very good overall, covering of a majority of the subjects. Good grounding of knowledge covered
Q2) Manufacturing Systems Engineer, small company. Directly answerable to the manufacturing director.
Q3) Grounding in engineering was relevant, particularly relevant were the third and fourth years
Q4 a) No element in particular from all
b) Project work at the end
c) Project
d) Mechanical / Electrical engineering
Q5 a) No element in particular from all
b) Project
c) Project
d) Nothing in particular
6) More access to computers
7) Reasonably
b) nothing
8) Fair amount, particularly industrial visits. Realistic so learnt to put into practice
9) No problem
10) yes
b) yes very much so
11) Group work involved very much dependent on the composition of the groups. assessed as a group and not as individuals. would have perferred an element of individual assessment.

Script 2
Q1) Enjoyed it, enjoyed its mixture of manufacturing and engineering subjects, computing content and computing based project work
Q2) contracting analyst programmer, team member, weekly 37.5 hours ● £24
Q3) Not very
Q4 a) Tony Medland's cad / CIM cell development and J. Au's programming
b) Nigel slack's POM, and 3rd year POM
c) Mechanics and fluids
d) control
Q5 a) 4th year project (computing)
b) 4th year project (free trips back to company)
c) 4th year project
d) 3D cad modelling
6) more options, to select route through the course
7) Not totally, in the computing environment there are constraints, in reality, deadlines impede on research, availability of appropriate software is an issue, also the inter personnel relationships, in CIM this was hindered by the aim to secure marks, in industry/company the team would pull together and would not be so individualistic. In my experience no true cad/cam environment truly exists and so CIM is still on a theoretical level.
b) no real improvement possible due to cost of machines etc.
8) not as much as on more structured courses since concentrated on a particular area of CIM. This area was chosen because of ability rather than to learn something
9) no problems
10) yes
b) not totally, see Q7
11) now a programmer so not touched on CIM since Brunel, so cannot comment

Script 3
Q1) Very good. Split between work placements and university useful, not just theoretical but practical as well
Q2) Lucas - production engineer - technical projects, reporting to site technical manager
Q3) Some quite relevant Eg systems engineering, some were not relevant, Eg applied mathematics
Q4 a) manufacturing systems
b) finance
c) control systems and computing
d) control linked to c)
Q5 a) manufacturing systems
b) project
c) control
d) control
6) project based work could be improved with clearer targets. Groups tended to waste time and then hurry towards the deadline date
7) Not at all, but seemed realistic at the time
b) would require full size machine tools and greater investment to be more realistic
8) lots
9) Fair, though verbal element depended on how good at speaking in that sort of situation rather than whether knew the subject. The CIM course required C-programming which hadn't done before (a bit odd?)
10) Yes, covered various aspects
b) no, doesn't really measure up to output per unit time, not really assessed under quality, cost and delivery of output
11) no

Script 4
Q1) Hard work, seemed much harder than other engineering courses. Result - jack of all trades, master of none, enjoyable, enjoyed team work aspect
Q2) production manager, reporting to the manufacturing director. £26,500 per year
Q3) limited, helps in understanding what engineers are talking about
Q4 a) manufacturing and electronics
b) nothing stands out
c) final year project and CIM
d) mechanics
Q5 a) manufacturing and electronics
b) nothing stands out
c) CIM and final year project
d) final year project
6) decent set of lecturers all round
7) moderately
b) it was a lot of equipment just cobbled together. better if got the right equipment but then as in industry that's reliant on budgetary constraints
8) technically not a lot, learnt organisational issues and management skills
9) can't remember
10) vaguely not
b) more so than some of the other courses
11) no but can still remember the BLADE lab

Script 5
Q1) academically hard - but that's ok and happy about it. Hard to get the required information by books lectures or other sources and this was made difficult, lectures didn't teach much or give much advice on reading material
Q2) sales support engineer, reporting to manufacturing engineer services manager, approx. £20K
Q3) reasonable to low
Q4 a) operations subjects - POM and Man Strategy
b) Pom & man Strategy
c) maths
d) control
Q5 a) man Strategy
b) Manufacturing Strategy
c) final year project
d) none
6) make information sources clearer and lectures simpler
7) yes, the most realistic of the courses,
b) tie it to deadlines
8) average, not above average
9) can't say
10) fair, due to syndicate method
b) yes
11) the jump from two years of Pascal to c was a hassle. consistency would be better in this respect

Script 6

Q1) very good broad based course, good practical content, some courses not relevant Eg management based, used a lot of the engineering

Q2) Currently off seriously sick.Mechanical project engineer, food and beverage cans, answerable to the factory engineer

Q3) quite relevant, engineering very relevant

Q4 a) tasks elements (mini projects with presentations)

b) labs, I.C. engines, practical

c) tasks and labs

d) finite elements

Q5 a) CIM course, 4th year project and fluid options

b) CIM

c) CIM

d) project

6) remove some of the elements, Eg management courses Eg CDE's management of change courses, more emphasis on engineering courses

7) hard to say, where work now it is not relevant, but a lot of techniques are relevant Eg team-work. Good team learning

b) more defined objectives, reduce pressure on team leaders, need a project management job team. Still consider it to be realistic

8) quite a lot, not just technical, project process as well

9) can't remember, but hard work to get good marks, lot of individual work for team so could be let down by other team members

10) not too objective, marking system a bit woolly

b) no. industry has time scales and costs, could do very little work and get away with it

11) good team-work, frustrating due to lack of coordination, could depend on one team but if goes off at a tangent then whole group is in trouble.

Script 7

Q1) excellent basis for job

Q2) manage.ment consultant, hierarchical role of senior consultant, 30-40K bracket

Q3) very relevant in terms of principles and how to work

Q4 a) general project work - 3rd and 4th year projects

b) tasks

c) tasks

d) mechanical engineering

Q5 a) man Strategy

b) man Strategy

c) 4th year project

d) artificial intelligence

6) more space, less cramped physical location

7) yes

b) realisable goals- since integration did not occur

8) not a great deal

9) not particularly, subjective rather than objective

10) marking should be specifically small group oriented and with individuality

b) yes

11) as remember it, rather unstructured, realistic aim, but wasn't that useful since too loose.

Script 8

Q1) Liked the practical nature and the emphasis on practical things. reasonable balance, not too theoretical. liked CIM and the workshop aspect and the work/industry related activities. Did not think lecturers were very good as a whole. Would have liked more design and make projects, perhaps along the lines of being given a product and analysing how it could be manufactured. The six month placements were good

Q2) Materials handling engineer, Ford, bottom of the hierarchy, answerable to a senior engineer, approx £20k annual

Q3) Not directly relevant, but there are probably aspects which are subconciously relevant

Q4 a) CIM and CAD

b) Projects, particularly design projects

c) nothing stands out

d) control Engineering

Q5 a) CAD

b) CIM

c) Can't remember

d) Finance

6) Improve the lecturers

7) Yes

b) Don't know

8) Don't know, quite a lot

9) Not a lot of feedback, or the feedback didn't mean a lot

10) Can't remember

b) Yes, particularly with respect to project engineering, but perhaps it could include clocking on hours

11)

Script 9

Q1) Very good. Came from an engineering background, so the structure was similar to tech college and work. the group working was good, building on management experiences. Lecturers presentations left a lot to be desired in some cases though that is a personnel issue. the course content was very good and useful, some theory though has not been touched since the finals but it is a necessary background for work

Q2) Materials manager, reporting to the site operations manager who reports to the board of directors, still with sponsoring company. Earning approx £20 K

Q3) Extremely relevant, particularly the management oriented stuff, teams etc. Manufacturing stuff is relevant since in charge of loading the shop floor so a good Appreciation of shop floor activities is useful instead of as some managers do - bullshit their way through, hence get things done. some theory is not always relevant but have used materials knowledge, also systems, work systems, information systems, computer systems, procedural systems and still do some programming

Q4 a) team related elements, Eg CIM, also systems work and operations management which is beneficial for what doing now

b) Project work and programming

c) Project and CIM cell

d) maths

Q5 a) All of them

b) CIM cell

c) Project

d) None

6) Don't know

7) The physical set-up is on a small scale but realistic. the concept is way ahead of British industry

b) introduce awkward suppliers - joke, but valid. the CIM environment is very insular, not enough external influences or pressures

8) Not a lot of knowledge gained but good experience for team and communication skills- an awful lot. The latter two are being applied in current job in charge of a team etc

9) Quite well, but lot of scope for personal influence. If there is a clash of personalities then could be unfair, but personally had no problems

10) Yes, because of the way the CIM course is structured with group working etc.

b) Yes, how judged in present job. if screw up then get a hard time.

11) No

Script 10

Q1) very good, particularly the final year, very useful. Not a lot of knowledge about engineering, but about how to approach things. Hard work

Q2) Account Manager, answer to sales manager. £23K basic plus up to an extra 52% bonus

Q3) In terms of engineering, not really, but in terms of understanding industry. No specifi facts useful except telecoms

Q4 a) CIM

b) CIM

c) CIM

d) Control

Q5 a) CIM

b) CIM

c) CIM
d) Project
6) Nothing springs to mind. Not keen on project work. Could do with more spare time before exams, without the additional pressure of having to complete assignments
7) There are real and artificial elements, but yes, recognise the limitations.
b) Lacks in realism over the financial responsibility. It is unrealisitc because it involves a bunch of people that know each other, are highly motivated and same age with similar skills, knowledge etc.
8) Learnt a lot, particularly management and dealing with peiople and technical manufacturing issues. Really learnt a lot in every area
9) Limited at the top end. A lot of work deserved high marks but appeared to be restricted to 75%, if compare to other options such as mechanics which could give 80 - 90% etc
10) Yes
b) Yes
11) Excellent course, could be forward in terms of technology used. Best thing about the whole degree course

Script 11
Q1) good broad based course, generally good lecturing
Q2) Power train control engineer - a basic engineer. Basic £22K plus overtime approx £24K500
Q3) Some of it, eg Combustion, I.C. engines, thermodynamics, control
Q4 a) control
b) Dossy one, eg Marketing in the second year
c) Combustion I.C. engines
d) Thermodynamics
Q5 a) control
b) Project management
c) I.C. engines (forgot about CIM until mentionned it later then asked to change this to include CIM)
d) Control
6) Bring Healey back for management subjects etc
7) no
b) More realistic structure to the organsiation, with a hierarchy structur rather than matrix
8) Minimal
9) Dubious
10) Yes
b) Review by peers - NO. From above and feedback - YES
11) Worthwhile doing it, not for learning new stuff, but for application of stuff yes. Pressure

Script 12
Q1) Good course, broad based. Gave enough in a variety of areas to talk to people and assist in manufacturing projects. Thin sandwich structure put in good stead for industrial contacts etc
Q2) Assistant Implementation manager, reporting to Operations Director. £20 - £25 K
Q3) day to day - NO. General - YES, background in lots of things to assist in way think and approach problems
Q4 a) Computing and CIM, applications of computing in manufacturing
b) business, marketing, acounts, because a bit different
c) Projects and labs
d) electrical engineering and control
Q5 a) CIM
b) CIM
c) CIM
d) composite materials
6) More links with industry, real life people talking about industry. Include courses in cost accounting, useful for manufacturing jobs
7) As realistic as it could be, teams and projects etc.
b) No need, only difference in job is that have to have "battles" with board ofdirectors - not practical
8) Lots of technical stuff regarding computing and networks, also team working, project planning, getting project work together etc.
9) can't remember, got no grudges
10) A bit subject to personnal views rather than work gone into the project, don't know really
b) yes
11) Not really, one of the more useful courses

Script 13
Q1) Enjoyed the course, good grounding in engineering, good springboard onto higher things
Q2) Research engineer, doing engineering doctorate. Answer to supervisor, guest worker, lowest of the low. Approx £10K grant
Q3) Not very relevant, doing sort of physics ish. Measurement systems and electrical and some mechanical build projects
Q4 a) Computing courses 1st to 3rd years
b) bioengineering
c) tasks in 2nd year
d) fluid dynamics and mechanics with CC, 1st and 2nd years, especially the first year
Q5 a) CIM
b) bioengineering
c) CIM
d) CIM
6) not too sure
7) Pretty much, management etc yes, equipment no
b) The use of integrated equipment would be better, had to bodge quite a bit
8) Awful lot about about management and being able to work as a team with different people. Learnt a lot about being in charge but not a lot about the technical aspects of CIM
9) Quite fair. Liked the idea of task leaders and other people being in charge simultaneously. Mutual assessment worthwhile but requires secrecy or else can cause antipathy. But it worked well
10) Should be more assessment by lecturers, students are pleased by what done so tend to give higher marks
b) No, never have mutual peer assessment, always by boss
11) Lot of work, gain a lot. Future students should think hard over whether keen to do it, since need motivation to do it

Script 14
Q1) first two years, too much emphasis on the nitty gritty o fengineering rather than behaviour patterns etc. Learnt loads of formulae which never used after, and knew probably never would use after. Good course. Not enough tutorial support. Can't really approach some tutors Eg if tutor is a professor
Q2) Quality Engineer, sanswer to senior quality engineer. £15K
Q3) Towards the end it is very relevant. Still refer to notes especially final year. Don't refer to the engineering stuff but to skills
Q4 a) group aspects such as group tasks and projects
b) Beach Umbrella project for D. Hoffman
c) CIM project because motivated to do work, Maths courses because given lots of tutorial sheets to do
d) control engineering, but enjoyed it
Q5 a) CIM
b) CIM
c) CIM
d) Finance because boring, CIM because stretching
6) Persona; development, belbin profiles and OPQ would be useful throughoput the course with feedbak. Measuring of managment skills and communication skills. More structured
7) Course lecturers made too many assumptions over direction heading, achievement target perhaps not realistic, not realsitic when consider ability iof students
b) No one petty enough in the environment, need more spanners in the works (a bit like th ebeach umbrella project) ie it is too insular and could do with being open to external influences and the external environment
8) Loads, learnt a lot about communication
9) No because of lecturesr assumptions of where projeect should be heading, peer assessment was pretty fair
10) yes very appropriate, more helpful to have feedback comments
b) yes
11) no

Script 15
Q1) Enjoyed it, good course, some of the subjects appeared logical and obvious EG POM at the time, but when go into industry, found that nobody does it at work etc.
Q2) technical Project manager, answer to Operations director, £24K

Q3) Yes, still doing production related things. Up until 2 months ago was a production manager
Q4 a) Combination of sandwich placements and university studies, else Manufacturing strategy with N. Slack
b) Manufacturing Strategy
c) CIM
d) first year mechanical engineering
Q5 a) Manufacturing Strategy
b) Manufactruing strategy
c) CIM
d) Project, chose wrong thing
6) Had very limited options, and could only chose 2 option sin the final year. would have liked more options available throughout the whole course.
7) Yes, because the people became heated and political, which was realistic but depressing
b) Allocate teams rather than be allowed to choose them though this could be horrible for the students involved. Also because know each other well it was not realsistic
8) Not sure, a bit
9) Unfair because CIM was worth twice as much for BME as for SEP, but actual marking was fair
10) Can't remember
b) Can't remember
11) Good idea, went a bit wrong due to difference between BME and SEP marking - could be demotivating for sep memebers, the tasks whatever went to peoples heads, particularly those in charge which caused problems. It didn't really work, perhaps the fault of those in charge

Script 16

Q1) Fine, loved it. Very good, very well balanced course
Q2) Consultant @ scientific Generics, product development group, work is sometimes lab based, sometimes manufacturing study on behalf of clients to set up organisastion to make new products perhaps developed by the company. Nominally no hierarchy but have a head of skill group
Q3) Very relevant - in some of projects no, but to get job it wa svery relevant due tobroad range of knowledge etc. The engineering an dbusiness skills are particularly relevant
Q4 a) can't say
b) Manufacturing systems and grioup working elements
c) CIM. On the whole it was quite well bsalnced theroughout the course, but CIM diominated the final year, perhaps due to own motivation
d) first year fluid mechanics and thermodynamics, control
Q5 a) Quality and perhaps Manufacturing strategy
b) Not CIM. Can't say
c) CIM
d) Finance
6) Quite a lot of intense work in first year or two, could be baklanced out a bit. Too many subjects, but useful to have done them, but coul dremove subjects such as fluid mechanics and control, would be interestin gto know if anyone has actually used these subjects, if not then perhaps get rid of them
7) not really
b) set it up within a company with real deadlines and goals, but to be more realsitic it would consume much more time and other courses would suffer. Also the team leaders did not really have much real authorety so it was quite artificial and becam ea bit bitchy and personal
8) fairly little, can't remeber task. Could have learnt some leadership skills probably , but not much about CIM
9) Can't remeber how it worked. Thinks there may have been moans and groans afterwards
10) Yes
b) Assessd more on personnal performance in industry, but yes
11) no

Script 17

Q1) Broad based, problem solving course: good, benefits because of connection with industry and real life problems. A bit vocational - no broader issues or philosphies considered
Q2) Unemployed
Q3) relevant for previous job, breadth of engineering and business things useful
Q4 a) probably the 4th year project
b) can't remeber enjoying anything, but probably the 4th year project
c) tasks
d) analytical methods
Q5 a) project
b) project
c) project
d) organisational change
6) include elements which look at what do as a whole, a philosophy type unit
7) some useful elemnets, but not really realistic
b) If it were a complete project, working on the whole thing to give a beter perspective of the whole thing
8) not a lot
9) use of students as managers was not useful, eg 5 people got a totally different experience of learning form the rest of the group as leaders and their marking unput was not useful - did not learn anything from the marking
10) yes useful, definite descriptive feedback
b) no
11) cim means different things to different companies. To a lot it means MRP / MRP II. perhaps separate integrated manufacturing from automation. It was a jumble of things

S.3 Questionnaire for Interviewees

PLEASE RETURN <u>IMMEDIATELY</u> BY FAX 0895 812556
FAO Roger HULL (M&ES Tower A ext: 2945)

Skills acquired on BME / SEP and on CIM course

1) Did you do : BME / SEP / CIM /

2) Your current job description : ....
Your current salary £ / FF / DM *: .... (optional)
(* delete where appropriate)

3) Please complete the " **IMPORTANCE** " column for each individual skill before assessing the contribution columns.

Skill	Importance for your work (see note)	Contribution of BME / SEP			Contribution of Year 1 of course			Contribution of Final Year Project			Contribution of CIM		
		Hi	Some	Little	Hi	Some	Little	Hi	Some	Little	Hi	Some	Little
Problem solving	.....	/	/	/	/	/	/	/	/	/	/	/	/
Evaluating one's own work	.....	/	/	/	/	/	/	/	/	/	/	/	/
Written communication and report writing	.....	/	/	/	/	/	/	/	/	/	/	/	/
Ability to work in a team	.....	/	/	/	/	/	/	/	/	/	/	/	/
Managerial skills	.....	/	/	/	/	/	/	/	/	/	/	/	/
Oral presentation	.....	/	/	/	/	/	/	/	/	/	/	/	/
Information retrieval	.....	/	/	/	/	/	/	/	/	/	/	/	/
Evaluating work of others	.....	/	/	/	/	/	/	/	/	/	/	/	/
Computing skills	.....	/	/	/	/	/	/	/	/	/	/	/	/
Programming skills	.....	/	/	/	/	/	/	/	/	/	/	/	/
Time planning	.....	/	/	/	/	/	/	/	/	/	/	/	/
Relating to other people	.....	/	/	/	/	/	/	/	/	/	/	/	/
Electronic skills	.....	/	/	/	/	/	/	/	/	/	/	/	/
Mechanical skills	.....	/	/	/	/	/	/	/	/	/	/	/	/
Electrical skills	.....	/	/	/	/	/	/	/	/	/	/	/	/

NOTE Importance column : 1 = most important, then 2,3...etc X = no relevance
Contribution columns : Indicate with a tick whether Hi, Some or Little

Thank you for taking the time to participate in the interview and to complete this questionnaire. Your cooperation is gratefully appreciated.

PLEASE RETURN <u>IMMEDIATELY</u> BY FAX 0895 812556
FAO Roger HULL (M&ES Tower A ext: 2945)

C.I.M. Course Review

I attended the CIM course as part of the Brunel Manufacturing Engineering B.Eng (Hons) degree. The course was unlike any other that was held in the university. I was in the first year of the project, and we were charged with setting up the structure of the company and generating a CIM cell to manufacture chess pieces.

From my point of view, the most useful part of the course was learning how to project manage a large group of people involved in a wide range of tasks, and achieve a deliverable at the end of the course. This was the closest that a college course came to mimicking a real life situation. In line with my later work experience, certain course members did not invest as much time, effort, and energy as others. It also highlighted the importance of all groups maintaining their schedule else the entire project is placed in jeopardy.

The course covered a wide range of aspects regarding running a company, from personnel management through finance and technical detail.

I enjoyed the course, and found it relevant to later work experience outside the University.

Ros Miller

MME 1984-1988

To: Felix Schmit

From:Simon Elliott

Date : 22 July 1994

Re:- CIM course, MSc in AMS

The course was centred around completing an automated assembly process for filling cosmetic vanity pack. This was based around one large robot and two small ones, with ancillary equipment like vibratory feeder bowls and linear vibrating tracks.

The main strength of the course is the multi-discipline skills required to complete the project, from finance, project planning to detailed system integration and programming. To be able to solve the problem within the given constraints (principally time and money), it was necessary to be able to not only solve the problem from a technical point of view, but also from a practical stand point. This led to the division of tasks between the team members and careful co-ordination of the different elements to in sure final integration went smoothly. This was achieved by first devising an overall solution and then breaking down the project into separate elements, which were then prioritised and time phased.

The weakness of the CIM concept was the amount of time people could dedicate to the project.,we were only on site formally one afternoon a week , but this could be supplemented by weekends. However, most people were not local and weekends were not often used. Also due to time constraints the work tended to go to the people with the relevant skills already. Thus if your background was in computing you would end up doing the 'c' or robot programming, etc. So although everyone was aware of all the elements involved , few people learnt a new skill in any detail. As a manager overseeing a project this would not be a problem as you would only probably need to know the main constraints, variables and the likely interface problems. But this knowledge was at a high level and until you try doing something do you get a real grasp of all the difficulties involved.

In conclusion the course offered a good background in solving a CIM project and the skills needed to solve/implement it. However the time pressure meant that a lot of detail was missed by each individual .

I hope this brief summary helps you.

Kind regards

Simon Elliott

C.I.M. Course Review

The principal areas of learning covered by the CIM course were:

1. Technical issues relating to the specific project.
2. Project management and team working.
3. Business impact of a development program.

I will cover each of these areas in turn.

1. Technical Issues

The majority of people involved in our CIM group ended up being assigned to activities that they were already experienced in, on the basis that they could contribute more. The downside of this however was that the amount of new learning was very limited, and really amounted to incremental increases.

Work tended to be very compartmentalised, and the ability to learn from exposure to work by the other members of the group was limited.

Due to the amount of time spent on site there was an imbalance in the level of work carried out by the full and part time students, with the former carrying out the bulk of the work.

There was some valuable learning in the area of interfaces. Most people on the course underestimated the amount of effort and difficulty involved in co-ordinating the "fit" of each of the individual tasks to the whole.

There was little formal teaching, or technical support from staff, in any of the technical areas of the project.

2. Project Management

The application of matrix management structures on the group was not a great success. This was in my view mainly because once most people had formed into their original teams they largely forgot about their roles as technical specialists or managers and just became part of a task team. I think that Brunel may well have learnt more in observing this than did the students. This is a situation fairly typical to the real world and the missing education was really in the area of reviewing what was happening, and responding to it.

Learning concerned areas such as:

1. The propensity to "last minuting".
2. The tendency to underestimate the level of effort required to achieve anything of quality.
3. The need for professional co-ordination of effort and activities to ensure timely completion.
4. People issues such as management, interaction of personalities, relationships and varying degrees of commitment.

Again I thought formal teaching of some concepts (i.e. Project Management, Human Issues) could have been useful, since students did not realise they didn't know enough until it was too late to research the topic and do something about it. This belated realisation could of course be considered to be valuable learning in it's own right.

3. Business Issues

Although the project was commercial, in as much as it was being carried out for a commercial organisation, on a real problem, there was little exposure to any of the commercial realities of the situation. There were no meetings with the "client", no understanding of his/her wants and requirements, and no real world emphasis.

A. D. Caffyn

Part Time MSc Course, 1988 to 1991

CIM course, Oct' 89 to June '90

S.5 List of Suggested Interview Respondents

The writer suggested to the researcher in charge of the interview and survey process, Mr. Roger Hull, that he should contact about 25 former students of the Department of M&ES who had all been part of the CIM team at some point. The writer also suggested the following core list of people to be contacted, to which the researcher added further names with the aim of getting a broader statistical spread. The preponderance of academic year 1988/89 was intentional: this had been the largest CIM group and the people were expected to have a suitable distance from the experience. 17 people were interviewed and 13 returned the questionnaire which was part of the survey.

Simon Buesnel, group leader, 1987/88
Ros Miller, executive, finance and personnel, 1987/88

Surubhi Agarwal, task manager, 1988/89
Mark Aylott, SEP, task engineer, 1988/89
Arabella Bijlani, BME, task engineer, 1988/89
Steve Bowen, task engineer, 1988/89
Martin Boyce, task engineer, 1988/89
Clive Buesnel, BME, task manager, 1988/89
Paul Strutt, SEP, task engineer and skill leader, 1988/89
Roger Teagle, task manager, 1988/89

Elaine Neely, task leader, 1989/90
Andy Wilcox, senior coordinator, 1989/90

Cécile Roussel, MSc AMS Full Time, 1989/90

Andrew Caffyn, MSc AMS Part Time, 1989/91
Simon Elliot, MSc AMS Part Time, 1989/91

Mark Behling, task leader, 1992/93
Beth Williams, senior coordinator, 1992/93

Relationships between Transferable Skills and Capabilities in Advanced Manufacturing						Skill Levels			Individual Student Project Work				Computer Integrated Manufacturing			
Domain	Transferable Skill	SNo	Quality	Faculty	Content	EN	AM	PS	Teach	Demand	Monitor	Assess	Teach	Demand	Monitor	Assess
Group Work	leadership, chairing	1aa		KH		5	4	3					ST,MC	MF,MC	TR,TW	FR,MA2
	co-operation	1ab		SL		5	5	4		WM			TG	DW,MS	GM,MA1	MA2,TR
	sub-ordination ability	1ac	AT			4	4	4	WM	WM			(TG),TR	TW	GM,TR	MA2
	team based work	1ad	AP			4	5	2					TG,(ST)	DW,PW	GM,MA1	MA2,FR
Organisational Skills	setting of objectives	1ba		KH	RL	5	5	3	WM		IP	IR,IP	MC,TR	DW,PW	TR,GM	TD,FR
	time management	1bb		SL		4	5	3	WM	DW,PW	IP	IR,IP	SA,(ST)	DW,PW	MC,TR	TD,FR
	project management	1bc		KH	SC	3	5	4	WM,IP	DW,PW	IP		(PC)	DW,PW	MC,TR	FR,[GR]
	project evaluation	1bd		SL	RL	3	5	4		PW		[TH,OE]	(PC)	FR,GR		TE,[SY]
	decision taking	1be		SL	RL	4	5	3		DW,PW	DW,PW		TR	GM,MC	TR,MA1	FR,MA2
Entrepreneurship	take initiative	1ca	AT		SC	3	4	3		DW,PW		WM	(TR)	GM,PW	MC,MA1	FR,MA2
	seize opportunities	1cb	AT		RL	2	3	3				WM	(TR)	CC,IV		MA2
Personal Skills	independence, autonomy	1da	AT	UN	SC	4	3	3		DW	WM			TW,PW	GM,MA1	MA2
	self assessment	1db	AP	UN	RL	3	4	3		DW,PW	WM		TG	IR,MA1	GR	MA2
	self confidence	1dc	AT			4	5	2		DW,PW	WM	IP,[OE]	PW	GM,MC	MF	FR,TD
Interpersonal Skills	influence	1ea		SL		3	4	2				IP,[OE]	TG,LG	MC,GM	MA1,ST	MA2
	listen, counsel	1eb		KH		2	5	3					CI,(ST)	MA1,MA2	(ST)	MA2
	motivate	1ec		SL	SC	3	5	3	WM[2]				LG	MF,LE,SE	MA1,TR	FR,TD
	negotiate	1ed		KH	RL	3	5	3	WM	DW,PW	WM	IP,[OE]		LE,TG	TR,PW	MA2
Problem Solving Skills	problem definition	2aa		KH		5	5	2		DW	WM	WM	(PC)	DW,PW	MC	FR,[GR]
	problem analysis	2ab		SL	SC	4	5	3		DW	WM	IP	(CA)	DW,PW	TR	FR
	collection of solutions	2ac	AP	RE,SL	AK	4	3	1		DW,PW		[TH]		SA	GM,TR	[GR]
	decide on solution	2ad		KH	RL	5	5	4		DW,PW		OE	SA,(ST)	MC,GM	TR	FR,[SY]
Creativity	stimulate	2ba		SL		4	4	3			WM,LA	OE		SA	GM	MA2
	develop mental models	2bb	AP	KH,UN	SC,RL	4	5	3	WM	DW	WM,LA	OE	LS,LG	DW	TR	FR,[GR]
	channel effort	2bc		SL	SC	4	5	3		DW	WM,LA	OE	TR	DW,TW	ST,LA	TR
	lateral thinking	2bd	AP	RE,SL	SC,RL	4	4	4	WM	DW,PW	WM,LA	OE	LS,LG	DW	GM,TR	TD
Practical Skills	electrical	2ca		KH	AK	4	3	4		DW,PW[1]		WM,[TH]	ST	DW,PW[1]	LA[1],PW	TD
	electronics	2cb		KH	AK	4	4	4		DW,PW[1]		WM,[TH]	WE	DW,PW[1]	LA[1],PW	TD
	mechanical	2cc		KH	AK	4	3	2		DW,PW[1]		WM,[TH]	ST	DW,PW[1]	LA[1],PW	TD
	machine tools	2cd		KH	AK	2	3	3		PW[1]		WM,[TH]	OT,ST	DW,PW[1]	LA[1],PW	TD
Information Gathering	locate info. sources	2da		SL	AK,RL	4	4	2		LR		IP		EW,DW,LR	TR,CC	EW
	extract data	2db		SL	RL	4	5	3		DW,LR		IP		EW,PW	TR,IR	IR,EW
	evaluate sources	2dc		RE, KH	SC	4	5	3		DW,PW		TH	ST	EW,DW,LR	TR,IR	IR,EW
	interpret data	2dd		RE,SL	SC,RL	4	4	3		DW,PW		IP,[TH]	LS	PW,DW	TR,IR	IR,FR
Literacy and Language	technical vocabulary	2ea		RE	AK	5	4	1		IR		[TH]		GM,MC	LS,LG	
	read purposefully	2eb		SL	SC	3	4	2		LR			HO	EW, LR	PW,TR	EW
	write simply/accurately	2ec	AP	KH		4	5	3	WM	TH		WM,[TH]	HO	IR,EW,GR	(MS),EM	EW,IR,GR
Informacy	word & data processing	2fa		SL	AK	3	3	1		TH		TH[4]		IR,EW,GR	CC	IR,[GR]
	use of software tools	2fb		KH	AK	5	4	3		DW,PW		TH[4]	CA,CB	DW,PW		TD
	electronic communication	2fc		KH	AK	3	5	4				TH[4]	CB,ST	EM,PW,DW	GM,CM	FR
	understand drawbacks	2fd		UN	RL	3	5	4		DW,PW	WM	IP,OE	LS,LG	GM,MC,TR	CC	
	use of CAD/CAM/CMM	2fe		SL	AK,SC	4	3	2	WM			TH[4]	IV,OT	DW,PW	PW	TD,[GR]
Numeracy	use of mathematics	2ga		RE,SL	SC	5	4	2		DW,PW		[TH]		PW	TE	FR,TD
	building of models	2gb		KH	RL	4	4	3		DW		[TH]	LS,LG	PW	TE	
	financial management	2gc		KH	RL	3	5	4					(ST)	SC,TW	MC,GM	
Communication	presenting information	3aa	AP	SL	RL	3	5	2		IP,OE		OE,IP		TR,FR,TD	DE,CO	DE,TD
	writing reports	3ab		KH	SC	4	5	3		TH	IR	[TH]		IR,EW,GR	MF	IR,EW,GR
	use of graphics	3ac	AP	SL	AK	4	3	3		TH				GR,TD		(EW)
	documentation management	3ad		KH		4	5	4					HO	PW	MF,SC	GR,[SY]
Teaching and Training	identify learning needs	3ba	AP,AT	UN	SC	3	4	2						GM,MC	PW,MA1	MA1/MC
	designing training	3bb		KH	RL	2	3	5						EM	GM	
	running workshops	3bc		SL		2	4	3						CB,EW	(TR)	MA2
	instructing others	3bd		SL	RL	3	5	3		IP,OE			ST	CB,EW,GM	MA1	MA2
Learning	literature search	3ca		SL	AK	4	3	1		LR		OE,[TH]		EW	EW	EW
	literature review	3cb		KH	RL	4	4	2		LR				EW	EW	EW,GR
	logbook maintenance	3cc		SL		4	5	2		DW,PW			LS,GM	GM,PW,LA	TR	

Transferable Skills and their Teaching on Individual and Group Projects (exemplified with the CIM Course).

Specific to CIM Course

- CA Computing workshop by staff
- CB Computing workshop by students
- CC CIM Conference
- CI Counselling Introduction for appraisers
- CM Course Meeting
- CO Course Organisation
- CS Counselling Session
- DE Debating Exercise
- EM Electronic Mail, e-mail workshop
- EW Essay Writing on sociotechnical or technical topics
- FR Final task Review
- GR Group (final) Report
- GM skill or task Group Meeting
- HO Hand Over (based on documentation from last year etc)
- IV Industrial Visit
- LA Laboratory Active support
- LE Leadership Election
- LG Lecture by academic Guest
- LS Lecture by member of Staff
- MA Mutual Appraisal (phases 1 and 2)
- MC Management Committee meeting (all members with a management function)
- MF Management Function (SC, SL, TL)
- MS Matrix Management Structure
- NL NewsLetter
- OT Outside Training
- PC Project engineering Course
- SA Scanco Activity
- SC[4] Senior Coordinator role
- SE Social Events
- SL[4] Skill group Leader role
- ST Small group Tuition
- SY assessment by Subsequent Year
- TG Team Games, social studies type activities
- TL[4] Task Leader role
- TR Task Review
- TW Task Worker
- WE Electronic engineering Workshop

Common to Individual Project and CIM

- DW Design Work
- IR individual Interim Report
- LR Literature Review
- PW Practical Work
- TD Tutorial, project presentation Day
- TE TEsting by discussion and interview

Specific to Individual Project

- IP Interim Presentation
- OE Oral Examination
- TH THesis
- WM Weekly (or regular) Meeting with supervisor

Qualities, Faculties and Content

- AP Aptitude
- AT Attitude
- RE Recall
- SL Skill
- KH Know How
- UN Understanding
- AK Atoms of Knowledge
- SC Schemata
- RL Relations and Links

Further Abbreviations and Codes for Table

- SNo "Skill" reference Number
- EN need in ENgineering in general
- AM need in Advanced Manufacturing engineering. Categories for EN and AM are:
  1 irrelevant
  2 not very valuable
  3 somewhat valuable
  4 valuable
  5 essential
- PS Preexisting "Skill" level:
  1 all possess skill at good level
  2 most possess skill at decent level
  3 some possess skill at decent level
  4 few possess skill at decent level
  5 hardly anybody possesses skill
- [ ] no feedback from assessment possible
- ( ) limited feedback from assessment

Short descriptions of most of the individually identifiable CIM course elements can be found in chapter 12, while the most significant innovations may be found in chapter 14, the chapter on tools for the CIM education process. Quite clearly it is impossible for every student to use all the tools, apply all the methods or experience all the processes. However, since each student is active in a number of different groups, she or he will learn at least an essential minimum about most of the skills, activities and issues addressed.

Notes:
1) applicability depends on student's project or task,
2) applies particularly to industry based projects requiring substantial effort to maintain good working relationship,
3) applies to software oriented project work,
4) these roles are (usually) mutually exclusive.

Key to Skills Acquisition Table: List of Activities on CIM and Standard Major Projects