CuDAS: An Interactive Curriculum

Combining Pedagogic Composition With Interactive Software for the Teaching of Music Technology

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Abstract

Within the framework of education of Music Technology for 16-18 year olds there exists a lack of thorough teaching and learning resources sufficient for a broad understanding of the basics of audio and electronic synthesis. This PhD submission outlines the role of the composer in the classroom in addressing this fundamental issue through the development of a curriculum containing pedagogic composition and interactive software.

There will be a discussion of the principles of pedagogic methodologies developed by various composers and of the current model of learning provided in Music Technology A-level. The programming tools used to develop the software are investigated, as well as an exploration into the current learning psychology that informed the curriculum development.

This submission consists of a written thesis that accompanies a set of compositions and a multimedia DVD, which includes the software for the CuDAS curriculum. Within this software is contained a presentation of a series of interactive tutorials alongside compositions in the form of scores, recordings and interactive exercises. There is also included written supporting documentation and sound files of techniques and recordings from contrasting genres of music history.

CONTENTS

Introduction to CuDAS

The following chapters will include an examination of the educational practice and delivery of the GCE Music Technology qualification investigated through the presentation in this thesis of a radically new curriculum that offers potential for the development in the subject areas of acoustics and electronic synthesis. This devised programme is henceforth labelled as 'CuDAS' (**Cu**rriculum for the **D**evelopment of understanding of **A**udio concepts and **S**ynthesis). The development of this curriculum has been made in order to address a perceived lack of provision in this area at GCE level, pertaining to 16-18 year olds. This thesis will uncover the current models of learning available to students at this level and investigate whether or not it is possible to introduce an alternative learning style through the pedagogy of CuDAS.

CuDAS contains three core elements; interactive computer software, specifically composed musical examples and literature written especially for the curriculum. The first two of these three elements have three sub divisional stages to them, the first being the holistic whole, the second a precise deconstruction and the third a working and understood material for the development of the student's own creativity. It is intended to discover whether or not it is possible to achieve the purpose of creating a whole and complete educational experience that can be precisely deconstructed into a series of steps and then built back up again into a creative opportunity through the process of the CuDAS curriculum.

One of the key issues in this work is the relationship of the artist as educator and the investment of my own creativity through composition into the educational instruction of the material in the syllabus. The inclusion of works specifically composed to aid the instructional learning of the students undertaking the CuDAS curriculum is central to its success and informs the decision processes throughout the devised prospectus. CuDAS is designed to be a complete one-term course, studied as part of the wider Music Technology A-level subject. It is intended to run for two hours a week over the duration of one academic term, totalling 20 hours of education over the course of 10 weeks from January to March.

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This work will be investigated through the context of GCE Music Technology with specific relation to the areas of study within this course related to the introduction of the principles of acoustics and the history of electronic composition. Chapter 1 will discuss the current provision of this subject and examine whether the current teaching and learning of the theory of the basics of audio in acoustic and electronic music displays a tendency to remain underdeveloped. I strongly believe that it is not sufficient to learn the key concepts of these areas through the use of pre-determined learning that is currently experienced in software environments that do little to provide an understanding or a deep-seated knowledge of the principles of the subject matter. Rather, the argument is made for exploratory learning that promotes the study beyond that of a particular software package on a relatively superficial level. It is my intention to show that the current provision is not befitting of the GCE level of examination and hinders progression and development in the subject area. It will be seen whether there is indeed a lack of provision in the development of these areas for students at this level and the question will be posed as to whether or not such students are therefore hindered in their knowledge base in this area and subsequent advancement into Higher Education Music Technology courses.

There is a recommendation at the end of Chapter 1 to investigate the DVD submitted alongside this thesis. Using '*Appendix 1 - CuDAS Examined*', the reader is given the opportunity to gain a thorough understanding of the software and processes behind its development, thus aiding in a greater understanding of the remainder of the research that follows. This begins with the importance of current contemporary educational theory in specific relation to the CuDAS project as addressed in Chapter 2, where the use of different intelligences is discussed in detail. The importance of the brain in developmental learning and the education philosophy that has developed out of recent research into this area are discussed in detail. There then follows a detailed examination into the development of these areas into the CuDAS curriculum, asking the question of whether current Learning Style Analysis based educational philosophies are relevant in application to this level of learning or whether alternative considerations need to be applied.

Chapter 3 will look at the role of the professional composer in education, examining the impact that has been made on the field of learning by non-educationalists in this way. There has been a small and yet hugely influential literature of works composed and creative techniques developed specifically for pedagogic purposes. Three highly distinguished composers' principles, methods and works for pedagogic purposes will be examined with the aim of highlighting the importance of work in this field. Questions will be posed as to the validity of their methods and some of the wider philosophical and didactic impacts their work has had on the musical education of students in the United Kingdom and beyond.

This PhD examines in part to what extent my own work can be used for pedagogical purposes in relation to the seminal composers in the field and in Chapter 4 there is presented an alternative approach to pedagogy specifically related to the area of education that runs through the entirety of this research. This will form a scrutiny of the veracity of the potential of pedagogic composition in Year 12 and 13 in British schools of the specific subject area chosen. There will be an assessment of the relevance of the composers discussed in the previous chapter, as well as posing the question as to whether their work can be adapted and extended into a wider context of musical education, specifically in relation to the CuDAS curriculum.

The principal programming tool that is used to offer a developed educational curriculum that addresses these issues will be Cycling 74's software Max/MSP. In Chapter 5 the history and working of this programme are discussed alongside an investigation into the pedagogic potential of this software, looking at current practice and areas of interest relating to the CuDAS curriculum. It will be seen whether Max/MSP is an appropriate tool for allowing the possibility of educating through performing functions in electronic composition that the programme was not necessarily designed for, or that at very least pre-date the computer music age. The topics to be studied in this way are to include the four focus areas of Representations of Waveforms, Spatialisation, Subtractive Synthesis and Additive Synthesis.

The outcomes of these processes will be discussed in Chapter 6, where test cases of students undertaking this curriculum will be presented for discussion, posing the questions of whether or not CuDAS is capable of delivering success and achievability in the desired areas from both the perspective of the educator and the educated. The students' feedback on their own perception of the learning process will be discussed to discover whether or not the software benefits their understanding of the learning areas presented in CuDAS as well as an investigation into how the presentation of materials in the CuDAS model was received. It is my contention that CuDAS offers a strong educationally principled learning experience and the validity of this claim will be uncovered and disseminated. This will be followed by a summary that will revisit the key areas of the thesis and discuss the success of CuDAS and what has been learned through the process of the CuDAS delivery.

There then follows a series of appendices in written and electronic form. The first of these provides a detailed investigation into the Tutorial Topics, Max/MSP patches and compositions that form the body of the CuDAS Curriculum. The processes behind the materials are examined in depth, showing how the literature for the tutorial topics was devised and written, alongside the processes involved in the conception and programming of the patches to support this material. It will also be shown how the compositions were created in order to deconstruct the written musical material into learning chapters in order to provide the students with the opportunity to reconstruct the material into a compositional process.

The other appendices include the literature used for supporting material, results based analysis, multimedia file indexes and surveys and questionnaires. Alongside this is presented a DVD containing the multimedia as well as the CuDAS interactive software in its entirety.

Chapter 1 The CuDAS Curriculum in Context

1.1 The GCE Music Technology Context

Music Technology as a GCE A-level subject emerged out of a desire to offer learning in an area that was previously not receiving any provision. The study of popular music in traditional Music GCE was extremely limited and the areas of development of technology and electronic music were not covered at all. As students began to express a desire to learn about such things, fuelled in part by the acceptance of these subject areas at HE level, the acknowledgement of the validity of Music Technology as a separate area of study was established. It has been ratified as a GCE subject by the QCA since 1995 and has in this time been offered by only one examination board – the Pearson Company owned Edexcel.

The fact that only one company offers this branch of study is unlike most other GCE subjects where a variety of examination boards compete for entrants from across the country. It could be argued that this has had both positive and negative effects on the development of the subject. Being the sole provider of the subject area maintains a healthy state of not needing to compromise on curriculum content or structure. This generates a strong sense of identity for the subject without the need to argue validity for topics and content. Whilst content and delivery remain consistent throughout the UK[1], leading to a greater unity amongst teachers and students graduating from the course, there are also concerns that the lack of competition can be problematic. There is no fuelling of the progression of development that such competition produces. This lack of a need to change can also be frustrating to the teacher as there is nowhere to turn for alternatives. In other subjects the ability to swap to a different examination board offers the freedom of choice. This is a choice that is frequently taken in the teaching profession.[2] However, with no alternatives on offer, the specification edicts can at times feel a little dictatorial.

As part of the wider GCE unit structure alterations for the majority of subjects in 2007, the GCE Music Technology syllabus as devised and presented by Edexcel received a major overhaul. The previous incarnation of the subject had been part of the Curriculum 2000 development, and as such there were areas where the structure and content of the course needed to be reviewed and updated. The duplication of MIDI sequencing, arranging, recording, composing and scoring tasks that peppered both the AS and A2 level unit configuration were structurally cumbersome, as was the more general curriculum content of an over-reliance on MIDI sequence techniques and skills and an under-reliance on advanced audio manipulation and signal processing.

The fact that the 'technology' part of the qualification had moved on due to the continuing developments in the world of digital sampling and synthesis is addressed in the new specification itself, where on page one, under the heading of 'Key Features' can be found the subheading of 'Embracing New Technology', with the comment that, "Music technology, like other forms of technology, advances rapidly. This new and revised Music Technology specification provides opportunities to embrace recent developments in the field."[3] The new and updated version of the course was first examined at AS level in May 2009 and presented to the same cohort at A2 level in June 2010.

Although the new syllabus[4] (see *fig. 1.1*, right) that was presented in document form appeared to be a slimmed down edition of the previous version of the course, the actual reduction was very slight, showing a lessening in volume from 26,905 words to a comparatively similar 26,369. The impression or reduction was due partly to the change in course content, but also to a slim-lining of presentation. The new syllabus was far easier to navigate, much more attractive on the eye and generally more useful as a reference manual for the teacher. Approaching a 137-page document for information on the delivery of an altered course, when teaching at this level is pressured to have the answers at the fingertips at all times, can be a daunting experience. It became clear, however, that the thorough and descriptive text none-the-less outlined the nature and requirements of the course in a clear and succinct manner. Split into 6 sections (Specification at a Glance – Specification Overview – Music Technology Unit Content – Assessment and Additional Information – Resources, Support and Training – Appendices), the document has clearly been designed with clarity of information and ease of use in mind. There is no doubt that it is a publication that is entirely fit for purpose.

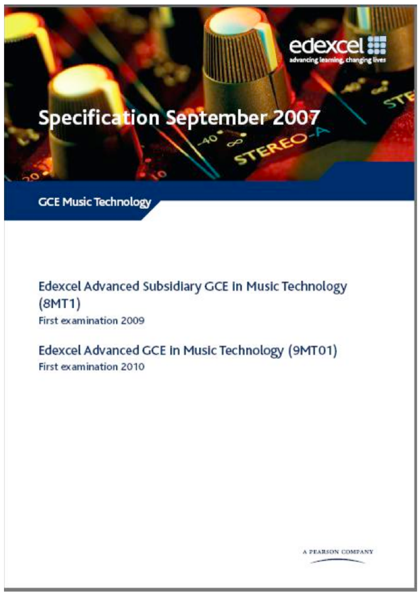


Fig. 1.1 The Edexcel GCE Specification, 2007

Edexcel can also be seen to take responsibility for teachers and students alike in the devising of the GCE course and the provision of support for the delivery of the subject. It is a firmly held belief from personal experience that they are particularly strong in delivering in this area. The mechanisms in place are highly effective and they make clear their intentions and the range of support that is available. As well as the statement in the syllabus that "Edexcel aims to provide the most comprehensive support for our qualifications,"[5] the URL for the subject specific website is provided[6], offering further information about the wide-ranging levels of support available to a practitioner of the subject. This dedicated website [see *fig. 1.2*] not only contains a full downloadable version of the syllabus, it also contains a notice board, a list of upcoming training events and materials for the practical running of the course. There are also various resources pages containing downloadable PDFs of past exams, mark schemes, examiners' reports, sample assessment materials and tutor support materials.

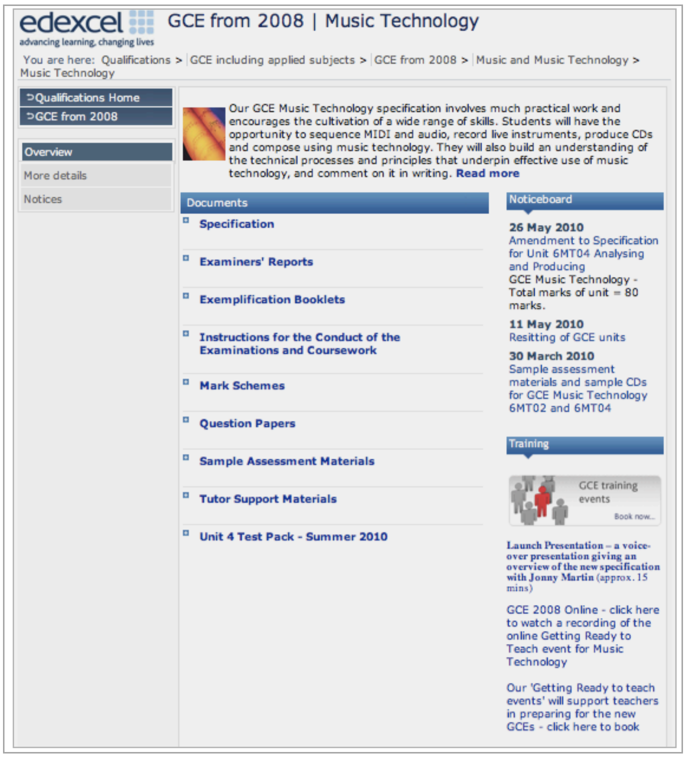


Fig. 1.2 The front-page of the Edexcel GCE Music Technology website

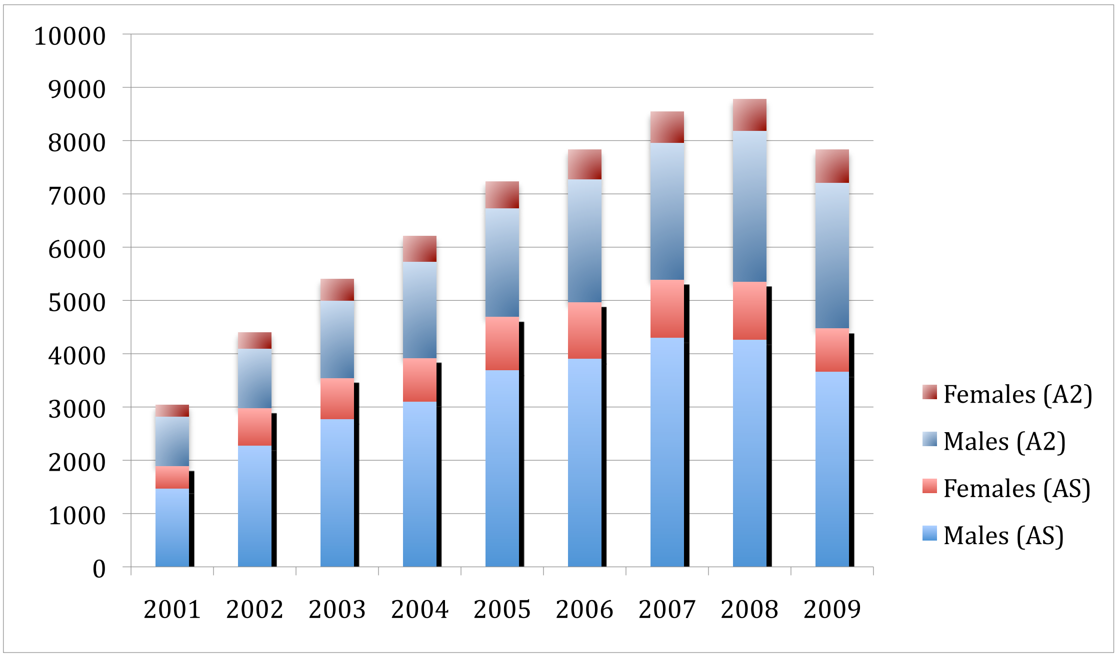
The presentation of this website is clear and informative. It is well laid out, avoiding an over-cluttering of information. It also has a cohesive appearance that ties in with other Edexcel webpages. All of the subareas meet the needs of the teacher and organiser of the course and personal experience has found that if visiting this online resource for a specific reason, the desired materials are easily located and up to date and accurate. As well as these online resources, Edexcel has recently set up its 'Ask the Examiner' initiative. This service provides an email contact directly to chief examiners who will then answer any questions that may have arisen in the delivery of the course and that need answering. This is an excellent source of information and having used the service on more than one occasion, empirical insight can confirm that the responses are sent promptly and that their content is well informed and helpful.

Alongside these needs, the potential route into HE is also addressed, where the number of Creative and Applied Music Technology courses and the number of students enrolled on them have grown exponentially over recent years[7]. As the syllabus states, GCE in Music Technology has been widely accepted by higher education providers and this Music Technology Advanced GCE will continue to provide valuable experience and preparation for students aiming for HE in the subject."[8] The progression from HE into employment is also mentioned, all of which underlines the value and the validity of the course and the work that has gone into implementing it.

The very nature of GCE delivery makes course content an issue of intense and often impassioned debate. There will always be discussions amongst teachers and senior examiners alike that will provide scope for ample deliberations as to the merits of this particular coursework task, or that specific examination topic. It is important to deal with the content that is supplied, however, rather than admonishing the devisors of the content. That a Music Technology course includes elements of sequencing and subsequent mixing and production of MIDI and audio, alongside the need to record live instruments, produce CDs and compose using technology, is entirely appropriate. The syllabus makes it clear that the course is intended to fulfil the need of creative musicians interested in more contemporary popular music forms rather than those of traditional Music GCE that deals with the western classical tradition.

This is clearly reflected in the popularity of the course, with the number of students sitting the examination increasing dramatically over the initial years of its inclusion as a GCE subject. They built from 3041 entrants in 2001 and have recently been seen to plateau at 8779 entrants in 2008. This is a number that corresponds interestingly with the numbers taking the Edexcel GCE in Music, the 'traditional' western classical music course, which can be seen to be slowing in its growth rate over the same period. Like all A-levels during this time there were more candidates sitting examinations due to drives in educational reform at Further Education level for 16-18 year olds by the British government of the time. However, whereas the numbers in Music Technology increased by a staggering 374%, numbers in the music course increased a mere 19%, from 8063 to 9598 candidates, in line with other subject areas.[9] This indicates that the Music Technology course was not taking its cohort from the Music traditional source, but rather adding considerably to the numbers that were continuing their studies in music at FE level. The course and syllabus therefore clearly present an area that is of interest to the 16-18 year old learners, and as such the uptake in numbers enrolling on the course is substantial and so the syllabus can be deemed to be a major success story in the musical education of those at GCE level. This discovery is reflected in centre K, one of two centres where CuDAS was presented, where since its introduction in 2004, Music Technology has consistently had more students enrolled on the course than Music Traditional, where numbers have remained constant.

However, on analysing the statistics in more detail some interesting issues are raised. First let us consider the number of candidates who present themselves for examination. This is represented in the graph below [*fig. 1.3*], where number of candidates are split into the male and female components of both the AS and A2 qualifications for each of the years from 2001 until 2009.[10]



DATA SERIES					
Year	**Males (AS)**	**Females (AS)**	**Males (A2)**	**Females (A2)**	**Total**
2001	1475	421	923	222	**3041**
2002	2281	702	1119	301	**4403**
2003	2775	773	1452	398	**5398**
2004	3104	819	1806	484	**6213**
2005	3691	1008	2037	498	**7234**
2006	3909	1063	2308	547	**7827**
2007	4302	1090	2568	586	**8546**
2008	4267	1090	2828	594	**8779**
2009	3663	817	2730	616	**7826**

Fig. 1.3 Graph showing the number of candidates sitting the Edexcel GCE Music Technology examination since 2001

This graph highlights some very interesting areas in the GCE Music technology subject area. The first of these is that there are clearly far more males taking the qualification than females. This is perhaps inline with the way technology in general is approached in this country. The exam board does little to address this issue, which suggests it feels that this is the status quo and so cannot be altered. It could be argued that this is a national stereotype that will take years until the barriers perceived in such areas are finally broken down. After all, this is certainly not reflected in the results where, for example, at A2 level in 2009 males achieved only 0.3% more A-B grades than females and 0.9% more grade Us.[11] It is also interesting to note on this topic that this is in direct opposition to the norm of Music as a traditional GCE, where there have always been more female candidates than male.

What is also highly significant is that the numbers taking the subject rose very sharply over the first few years of the inception of the Curriculum 2000 version of the course. Numbers increased almost threefold between 2001 and 2008. Having reached this number the amount of candidates then drops again sharply in 2009. This is of such significance because it is only in the AS year group that the numbers drop and it was 2009 that marked the first year of the new syllabus. It would appear that a great many candidates and centres were put off by the changes that were made. It is important to note that until the figures for 2010 are published it will be hard to know if this is a one-off blip or a consistent trend. There could be other more significant factors that occurred in general education that have not been outlined. However, the number of total candidates sitting all GCEs that year was not inconsistent with previous years. Therefore it seems to have been this subject that was particularly affected. The statistics for the 2010 cohort are awaited with eagerness to answer this question.

1.2 The GCE Music Technology Curriculum

The Edexcel syllabus in its entirety is divided into three clear Areas of Study (generally referred to in the specification as AoS) that "underpin the whole specification"[12]. These are labelled as follows;

AoS1: The Principles and Practice of Music Technology, which focuses on the study and skill development of MIDI sequencing, audio production and recording techniques. The practical coursework element contained within the course falls into this AoS and as such it is studied in both the first AS year and into the second A2 year of the course. This content makes up 70% of the marks available at AS-level and 60% at A2-level.

AoS2: Popular Music styles since 1910 is only studied in the AS year and includes a study of the major styles and genres of the last 100 years of popular music, from the early developments of jazz and blues through to the contemporary commercial, club and underground music scenes. Alongside this, students are required to develop their musical theory as well as their understanding of technical language. Two of these genres are studied as special focus works and the whole AoS is presented as a written examination, making up 30% of the total marks available in the AS qualification.

AoS3: The Development of Technology-based Music is studied in the second year of GCE for the full A2 qualification. It focuses on developing understanding about the influence technology has had on music in the last 100 years. This area covers the development of electronic instruments, with particular reference to the guitar and synthesiser as well as drum machines, decks and early electronic instruments such as the theremin. The development of recording technology is also included in this area, as is the work of key producers and albums, as well as contemporary electronic classical music. This AoS is assessed through a written examination alongside a practical examination that relates more to AoS1.

These AoSs are then applied across the 4-unit structure of the full A-level. Units 1 and 2 are taken at AS-level and units 3 and 4 make up the A2 part of the course. Units 1 and 3 are made up of externally assessed practical projects and units 2 and 4 are assessed through written examination. There is also a practical element to the examination in unit 4. This can be understood more clearly by referring to the table below [*fig. 1.4*]. Within this structure are placed the individual tasks. When one looks at these in slightly more detail it is clear to see the care and attention that has been made to ensure a wide range of music technology skills and principles are learned and that the development of knowledge in the subject is appropriate, challenging and of relevance to current trends.

AS Music Technology			
Unit 6MT01 – Music Technology Portfolio 1			
Task 1a	Sequenced Realised Performance	Coursework (controlled conditions)	20%
Task 1b	Multi-track Recording		20%
Task 1c	Creative Sequenced Arrangement		20%
Logbook		Q.9 & 10 assessed	10%
Unit 6MT02 – Listening and Analysing			
Task 2	Examination	1 hour 45 minutes	30%
A2 Music Technology			
Unit 6MT03 – Music Technology Portfolio 2			
Task 3a	Sequenced Realised Performance with Audio Overdubs	Coursework (controlled conditions)	20%
Task 3b	Multi-track Recording		20%
Task 3c	Composition		20%
Unit 6MT04 – Analysing and Producing			
Task 4	Examination (written and practical)	2 hours	40%

Fig. 1.4 The Edexcel GCE Music Technology assessment structure

Although the expectations in terms of tasks and assessment are very thorough, little is made in terms of the expectations of the practicalities of running the course. Rooming and equipment remain untouched areas and no practical guidelines as to how work is to be monitored, implemented or supervised are offered. Upon further analysis of this course content and structure, it could be argued that one of the major drawbacks that the current model produces is that teaching time is limited by the structure of the course itself. The weighting towards coursework and practical tasks leads to teaching time that has to be given up in order for the students to achieve to their full potential in this area. The coursework (Units 6MT01 and 6MT03) has to be undertaken under 'controlled conditions'. 60 hours per year are given over to the completion of these externally assessed tasks. This essentially means that the work the students undertake must be completed in the presence of the teacher. Naturally this means at the centre rather than in the students homes and given that teachers will have other class and extra-curricular commitments during the day, the only realistic time for the offering of the 60-hour provision is in class time. Given that the coursework makes up 60% of the total marks available throughout the course, this is considerably the largest area of the subject. Assuming that on average a GCE class receives 5 hours tuition per week and that there are 28 teaching weeks before the coursework deadline set each year in mid-May, nearly 45% of the first two terms is taken up with practical work. This leaves relatively little time to teach the skills needed to achieve the outcome of the coursework tasks and as a result even less time to cover the other areas of study.

This lack of teaching time then becomes a serious issue when one considers the content of AoS1. It is a vast area, including jazz as well as pop and rock and although the syllabus states that, "Students are not expected to study every type of popular music in detail," it continues to remark that they are to acquire knowledge of "the main musical and cultural characteristics of the major styles and trends of the past 100 years."[13] If this part of the course is to be tackled with any aim at achieving this outcome, much focused study needs to be placed in this area. This is relatively easy to achieve, given the vast wealth of literature and multi-media resources that exist for the teaching of these areas. However, the time needed to cover these genres in adequate depth could be argued to be undermined by the 60 hours lost to controlled conditions. Unit 6MT02 is worth 30% of the overall marks available at AS, which is more than half as much again than is on offer for any singular coursework task, each of which are worth 20%. The examination for this unit was set as May 20th in 2010. This left only 3 working days from the coursework submission date to the examination date. This is a precedent that has been replicated in the 2011 series, where the examination date of May16th is one day after coursework submission. This in turn means that all learning for this unit has to run concurrently with the coursework tasks. It only takes a cursory glance at the hours available in the course to realise that if 60 are used on coursework, 80 hours are left for the teaching of skill based acquisition and the whole of the examination unit. It is a firm belief of the writer that there is a strong imbalance here.

Given that AoS3 is worth as many marks at A2 level as AoS1 is at AS, it should therefore logically be approached with the same fervour and detail as AoS1. However, the descriptions in the syllabus are far less detailed and do not appear to be as cohesive. It is perhaps for this reason that this area does indeed tend to get neglected by teachers. In addition to this, unit 6MT04 is worth 40% of the marks available at A2, an increase from the AS examined tasks. There is an underlying issue in GCE Music Technology at present where too many classes are focusing on coursework as, combined, the tasks provide such a large proportion of the marks. This leaves the examination topics underdeveloped and teaching and learning in these areas is therefore compromised.

Furthermore, when looking at the suggested learning material for AoS3 there is a troubling inclusion of the phrase, "Study might include…"[14] The suggested learning material for AoS1 and AoS2 are succinctly but clearly laid out. The material of AoS3 appears to be similarly approached, but as an educator with a need to plan a course and develop learning materials, the word *might* is not one that inspires confidence. It suggests that either the material listed may or may not be included in an examination topic. If it is not to be included, then further to this the syllabus could be argued to be a little casual in its clarity of areas of study as no direct alternatives are offered. It is almost as if the specification is admitting that this is too large an area to tackle and so it cannot list all of the areas that could come up when this AoS is examined.

Perhaps the most pertinent of the areas of concern are raised when questions of differentiation are considered. As Tomlinson comments, there is clearly a link between "effective standards-based instruction and differentiation. Curriculum tells us *what* to teach: Differentiation tells us *how*."[15] Although Edexcel clearly shows various mark schemes that allow the broadest range of marks across the qualification, there is no clear distinction made between the varying degrees of talent and ability in the documentation. Indeed, although clearly viewable as a philosophy of key importance in current education writing and planning, differentiation is a word that is entirely absent from the specification, appearing on not one occasion. This area is discussed further in Chapter 2.

Indeed, the fundamental ability of the students, and the very likely scenario that not all will be equally gifted or talented at the required tasks, is not mentioned. There is no outline of whether the ability to read and write traditional music notation is required. Although the tasks suggest that, while useful, this ability is not essential, no guidance is offered to cope with the obvious disadvantage posed to the student who, for example, possesses very little in the way of keyboard skills or one who is not literate in the fundamentals of music theory. It soon becomes apparent that the 60 hour limit set for the controlled conditions would seem to be far more of a daunting task if every note in a sequence has to be step-inputted with a mouse than if simply played in through a MIDI controller. The disadvantaged student should not simply be ignored and whilst admission onto the correct course for the individual is to be encouraged, none-the-less the issue remains intact. If a student wishes to progress into HE in a music technology qualification where sequencing skills may not need to be developed further, if used at all, then the course can be seen to be discriminatory.

The syllabus is also rather vague when it comes to differentiation and development of the more advanced student, and given that the course sells itself as providing a route into the world of HE Music Technology, it is therefore surprising that not more is suggested as to which parts of the course, or indeed studies that would extend beyond it, would be necessary to make this a successful transition. It is in relation to this area that it is essential to introduce some key concepts of analogue and digital audio prior to a student's move into Higher Education. As a teacher of technology-based composition within the HE framework, personal experience has shown a common occurrence of the student with no concept of this critical area. For university lecturers, course devisers and curriculum specialists, this can prove to be surprising, frustrating and disheartening. The development of the students' skill level in software-based sequencer applications such as Logic or Cubase is usually relatively advanced due to the increasing availability of such programmes in terms of budget, marketing for public consumption and also, rather negatively, through the growing community of internet piracy making such software free to any computer owner. Some students may even have a keenly developed understanding of live audio recording within both a close-mic studio and ambient location context through their own interest in popular music and the production techniques of such genres contained within such an all encompassing bracket. However, in the example of such students as these, the basics of acoustics from both a physical and crucially a musical perspective are likely to remain severely underdeveloped.

It is directly as a consequence of these issues and concerns that CuDAS, the new programme under discussion, was designed. The development of the software was made in order to facilitate a more comprehensive learning experience for students undertaking the A2 part of the course and as such needing to study AoS3 and sit the examination presented in unit 6MT04. Further to this, it is also designed to feed into all areas of the A2 curriculum presented by Edexcel, theoretical and practical alike. It is a strong contention that an understanding of acoustics is essential for all units of the A2 course. This is formed from the opinion that knowledge of *why* must always accompany a perception of *how* in any practical environment to enable informed and cohesive creative choices.

1.3 Devising a Curriculum Model for CuDAS

CuDAS does not set out to be a model that radically alters the structure of education in this subject area. Ginnis is keen to point out that the devising of a curriculum should not "…set out to redesign the education system, desirable though that might be."[16] Rather, CuDAS considers the practice and structures of the current model in order to take teaching and learning in a new direction. In order to achieve the building of a curriculum that could be successful in this area it was first necessary to look at the underlying philosophical principles that are true of all curricula and learn from the progress made in the understanding of this field in order to apply these findings to the development of CuDAS. It is important to keep in mind at all times what the educational value of the attempted outcome is. In the case of CuDAS the need for the building of this curriculum came from a very strong desire to improve provisions and learning in a very focused area of learning as discussed above [Chapter 1.1]. This was critical to the success of the model as it lent a clear and identifiable aim to the decision-making process during the planning process. This cannot be undervalued in importance, for as Steen comments, "The best curriculum is one that reflects a specific situation."[17]

Having decided on a very targeted area of learning, it was then essential to address the key areas of consideration for the forming of a new curriculum to begin with. Only in this way would it be possible to achieve the aim of the project, which can be neatly summarised by

Clarke when he says, "The challenge is how to devise a curriculum that will help students to develop technical understanding and to do so in a way that is seen as creatively relevant and stimulating."[18]

These areas were largely three-fold. Firstly, it was deemed necessary to address the students' needs in the area of audio concepts and synthesis that were not being catered for under the current model of classroom teaching. Alongside this was the parallel notion of involving the students in the learning, ensuring frequent student contributions and control over the learning process and therefore keeping the student at the centre of any learning and teaching that developed. The second area of consideration related to the choosing of materials that would be best suited to addressing the first area. Having already worked with Max/MSP as a graphic interface and real-time audio processor it was deemed that this was an excellent source of educational value that was currently not being used at this level of education. The third area was focused on how to structure the learning into clear areas of study that could be subdivided into lessons.

It is important to any curriculum design to keep these areas of consideration at the forefront of any developmental learning. If one simply addresses the topics with no clear planning the lessons are likely to become unfocused and generate an unsatisfactory outcome, no matter how good the intentions. As Steen puts it, "Knowing music involves the interaction of many factors – not just a sequence of learning tasks – a curriculum that is most useful will reflect a thought process that considers all of them."[19] She extends this thought into a simple model that is worth considering in the planning of a curriculum [see *fig. 1.5*] [20].

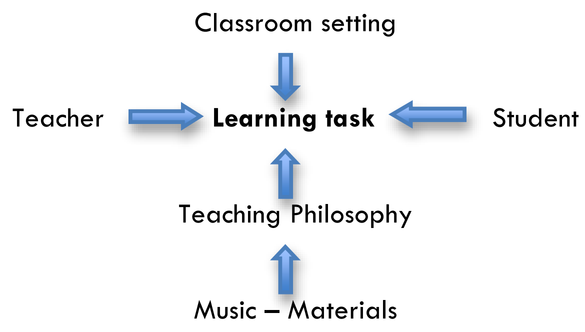


Fig. 1.5 Steens' curriculum plan

One can see from this model that there are two Influential factors in the planning of the curriculum that have not yet been addressed. The first of these is the learning environment, by which is meant the room, the resources and the school setting. CuDAS has been presented in two quite different locations. One, centre T, was a purpose built computer lab equipped with a suite of OSX i-macs intended for Undergraduate and Postgraduate study at a music conservatoire but being operated by students attending a Saturday school. The equipment was of first-rate quality and the learners were musically advanced. However, the delivery of the course was pressured due to its constriction into 3 hours of learning once a week.

By contrast, centre K was a school setting with a room of Windows XP computers intended for learning at all levels from year 9 to year 13 (ages 13-18) in multiple music subject areas. The learning time was spread out over 5 hours a week with teaching contact on 4 days allowing more time for exploration around the examination tasks, but the musicality of the students was not as advanced leading to more pressure in these aforementioned tasks. These contrasting factors needed to be taken into account in the initial planning of the curriculum. As the work progressed, the desire to make CuDAS accessible to all students regardless of classroom situation and ability began to inform the devising of the curriculum. The dual-platform nature of the materials and the accessibility of the learning materials that were created as a result of this thought process are discussed in greater detail in Chapters 2, 4 and 6.

The second influential factor was the inclusion of the teacher as informing the learning process. That CuDAS was designed in order to be self-disseminated had a large bearing on what materials were included and in which direction the teaching and learning progressed in the curriculum. This is not only a natural and inevitable process, but also a desirable one, Steen commenting, "The best curriculum is the one *you* plan and review for *your* students in *your* school."[21] This planning then informs the teaching that is involved and as a result makes it stronger, more communicative and more successful educationally. This is a view shared by Steen when she says, "Teaching from your own sequence of objectives is guaranteed to be more rewarding for both your students and yourself."[22] During the teaching of CuDAS it became apparent that the ability to have the curriculum builder present in the room was incredibly valuable to the students. They showed a natural enthusiasm to learn more about how the materials were devised and created and could ask more questions directly related to the learning topics with confidence and assurance. This point was specifically made in one of the feedback surveys included in the results-based analysis of Appendix 3.[23]

Having developed the philosophy behind the development CuDAS, it was also necessary to focus on specifics of content. There was a need to ensure that both concepts and skills were developed alongside one another. In terms of concepts, these were broken down into the four tutorials which each contained five subdivisions, allowing for a total of 20 concepts in all. The utmost care and attention was applied to ensure both the development of knowledge but also a maintaining of relevance to the wider curriculum of GCE Music Technology. It was necessary to ensure at all times that the student was aware of both *what* they were learning, but also *why* they were learning it. This important factor is one that Steen is keen to point out; "Materials chosen for making conscious the new concept must be selected carefully so that it is easy for the teacher and the child to identify what is being learned."[24]

However, the need to focus on skills was also of critical importance. Turning to Steen once more, her comment that "Both concepts and skills must be learned before musical independence can be achieved"[25] is erudite and contains much truth. A student who has a skill-based approach to a subject has every opportunity of displaying and developing his or her understanding as well as his or her knowledge. The skills involved in CuDAS also follow a sequential pattern. There are relatively few operational facilities in the early tutorials. A MIDI controller, a few toggle on/off switches and some faders are all that is made present. However, by the end of the fourth tutorial there are a great many more options for controlling sound, including EQ parameters, ADSR envelopes and various other types of sliders and controls. This ensures a gradual development of skills in using the functions of Max/MSP as well as the skills needed in order to bring about the topic of the concept in question, this allowing a gradual and progressive learning that ultimately enhances both knowledge and skill-based practices.

Having designed and implemented the curriculum, the work is ongoing, as it remains important to continually review and update the material contained within the structure. After all, "A curriculum is a tool, not a dictator of what you teach."[26] Alongside this runs the concurrent notion of being flexible with the material that is delivered. Naturally this is easily adhered to in the development of the interactive software, as the tutorial patches can be easily reprogrammed and edited. Presented with this thesis is a version of CuDAS, which, although complete, may still be adjusted and fine-tuned according to the needs of the students and the delivery of the course.

Although a preferred and organised timescale is intended for the delivery of the CuDAS curriculum, it is none-the-less important to retain the freedom to allow a topic to develop for longer than intended if it is proving to be inspirational to the learners. In such a case it would be entirely appropriate to spend longer than the given time per topic. In that way it allows for the organic flowering of knowledge of a topic rather than cutting the investigation dead just as the interest levels are rising. Evidence of this can be seen in the Appendix 4 videos, where classes showing the teaching of CuDAS in action highlight how one needs to be flexible with time management of delivery of concepts and topics.[27] It is these factors that ensure one follows the sage words of Steen when she says, "A curriculum should never be static, but instead a lively process of decision making that responds to changes in instruction and continually mirrors the highest possible music objectives for your students."[28]

At this point in the thesis it is recommended that the reader explore the CuDAS software provided on the accompanying DVD. This should be worked through whilst referring to the text in Appendix 1 - CuDAS Examined. This will offer the reader the greatest opportunity to understand the contextual placement of the remainder of the research presented.

Chapter 2 The Psychology of Learning in Relation to CuDAS

Having decided on a curriculum model and the tools best equipped to bring about the fruition of this programme of study, it was also important to consider current educational philosophy and the psychology of learning to ensure that the most productive learning environment was created when developing the compositions and interactive tools within the CuDAS software. The need to constantly seek to improve one's teaching methodology and develop a broader sense of understanding of the needs of the student is a key area of curriculum development and delivery. Although this is a field that seems to have sprung up over the last decade due to its adoption into the mainstream politically and socially charged educational debate, is in actual fact something that has long been relevant to educators. A huge amount of research now exists within this framework, both in print and in cyberspace and many schools have dedicated curriculum support departments. It is therefore now increasingly easy for the teacher to gain access to a vast array of resources, be it research literature, online theses or published books, all of which can enable a greater understanding of this growing and, at least in the eyes of modern teaching philosophy, increasingly important area. For these reasons alone the area is highly significant to the work of CuDAS and as such needs to be investigated thoroughly.

2.1 Brain-Based Research

Understanding the functionality of the brain is key to implementing strategies for the development of educational techniques. Blakemore and Frith, two of the UK's leading experts in this area of research, make the comment that, "Only by understanding how the brain acquires and lays down information and skills will we be able to reach the limits of its capacity to learn."[29] However, this area has only recently been adopted into the mainstream educational thought. This is partly due to the complex nature of the study. "There is currently very little material about the relevance of brain research to education that is readily accessible to the nonspecialist."[30] However, recent interactions between the two fields of education and brain science have taken place. In 1999 the British government introduced the 'Early Learning Goals', dividing those in the field in to two camps; those who thought the measures were unnecessary and went too far and those who felt they were underdeveloped and did not go far enough. As with all areas of education, one soon learns that there is very little room for sitting on the fence. A year later, in 2000, the Parliamentary Office of Science and Technology (POST), a body charged with the task of providing the House of Commons and House of Lords with up-to-date and current thinking in these areas, commissioned research into what they termed as 'Early Years Education', broadly defined as being from the ages of 0-6 years. There have also been recent publications in this field that specifically target this area and argue for the further development of brain-based research and the need to encourage the growth of this area into the world of education planning and consideration. Just one example of this literature is the aforementioned Blakemore and Frith, who make it plain that their aim in publication is to demonstrate how "research on the brain and learning could influence the way we think about teaching."[31]

In order to understand the importance of brain-based research, it is helpful to have at least a very basic working knowledge of the brain. This is arguably as far as we can venture whatever our intentions, as those in the field concede that, "The brain is one of the most complex systems in the universe, and although we are starting to learn a great deal about it, we are still a long way from understanding exactly how it all works."[32] Indeed, there exists argument with those in the field that we may not even be able to link the knowledge we have to the implementation of educational strategies with any meaningful effect. "Many neuroscientists question whether we know enough about the developing brain to link that understanding directly to instruction and educational practice."[33] However, it is possible to clearly see how the progress in research into the developing brain has influenced the thinking on this subject.

Early research into how the environment influences the development of the neurons in the brain showed that there were critical periods in the development of the brain. This was clearly shown in the1960s by Wiesel and Huber with their experiments on cats, whereby their sight was inhibited for a pre-determined period of time. Without stimulation, the areas of the brain for the development of the function of sight in the covered eye were repressed and remained underdeveloped. It was discovered that if the blindfolds were then removed, the brain was able to mend itself to a fully functioning state, albeit only before a critical cut off point, at which point the area of the brain concerned would effectively have ceased to function at all and sight would be lost forever. Further research on cats and monkeys in the 1970s showed that the brain's capacity to catch up in this manner was due to the ability of it to form new connections between neurons in its post-natal existence. By the time Wiesel and Huber had been awarded the Nobel Prize in Physiology or Medicine in 1981 for their work in this field, the impact on educational psychology had been realised. These discoveries clearly pointed to the argument that the brain develops due to stimulation and that therefore an enriched environment would provide it with a greater chance of developing to its full potential.

Further research undertaken by Greenough on rats showed that those provided with wheels, ladders and other rats to socialise with performed far better in tasks such as working through mazes compared to rats deprived of such stimuli. Indeed, on further investigation it was shown that the areas of the brain that control sensory perception were up to 25% more developed. In contemporary thinking it is now accepted that these findings can also be applied to the human brain. "It is a scientific fact that sensory areas of the brain can develop only when the environment contains a variety of sensory stimuli – visual stimuli, textures, and sounds."[34] This leads to the conclusion that the brain develops in a two-fold manner. The first is through nature – the specific genes of the parents that influence development in pre-natal growth. The second is through nurture – the environment in which the brain receives exposure to developmental stimuli. Blakemore and Frith underline the need for this to be taken into account when considering how to plan the educational provision for children; "We believe [there is no] argument for a *selective* educational focus only on children's earliest years."[35]

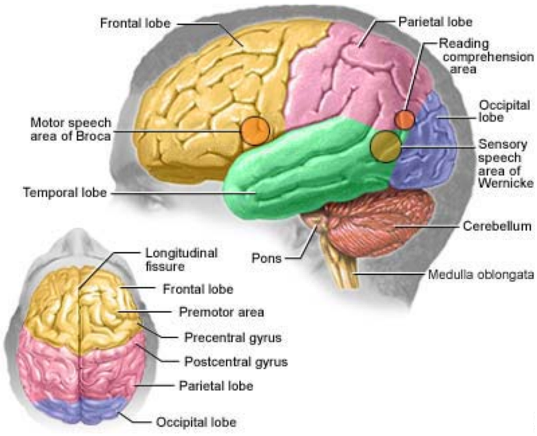


Fig. 2.1 Mapping of the human brain

These studies into brain functions have particular relevance into educational work relating to music. Lauren Stewart conducting research in London in 2003 showed how the fluent reading of music activates the Parietal Lobe, shown in the clear mapping of the different areas of the brain as displayed in *fig. 2.1*. This area of the brain also controls the function of spatial awareness in both time and space. It is also used in the computing of mathematical tasks. When one also considers how the Auditory Cortex, located next to the ears close to the surface on either side of the brain, is stimulated when playing music, it is clear that in this field the brain is pushed to a higher state of function. Christo Pantev, working in Munster in Germany, recently produced research that has shown that the Auditory Cortex can be up to 25% larger in highly skilled musicians. The impact in this field does not stop there. Thomas Elbert showed in Konstanz, Germany that the Sensorimotor Cortex, located at the top of the brain, was much more developed in musicians, particularly violinists. This area of the brain is used for the control of fingertips. As with all motor functions, those on one side of the body are controlled by the opposite side of the brain. It quickly becomes apparent that playing a musical instrument will stimulate a huge proportion of the brain in differing ways. It is therefore not surprising that a recent study in the US showed piano playing to be one of the ten tasks that used the most areas of the brain simultaneously.

2.2 Learning Styles and Experiential Learning

The notion that as individuals we each have an identifiable learning pattern unique to our own brain functions is not new. Ivan Pavlov, with his famous experiment with dogs, bells and the response of salivation, showed as early the 1890s that learning could be *implicit* as well as *explicit*. That is to say, explicit learning can be seen to be conscious learning, encompassing the notion of awareness of being educated. Attending a class, making notes, reading a textbook or participating in a workshop are all examples of this. Implicit learning, in contrast, happens subconsciously. As in the case of Pavlov's dogs, the learning takes place unknown to the conscious analytical progress of our own minds. Learning styles often attempt to cross the boundaries between these two types of learning and any educational instruction can therefore be determined in terms of value by how well it enables this to happen. As Blakemore and Frith comment, "Knowing how or when to make rules explicit is … an important determinant factor of effective teaching."[36]

Despite an increasingly growing inclusion into curricular learning and teaching methodology over the last three decades, the adoption of such thinking into the classroom on an everyday level remains an underdeveloped area. While it is true that PGCE students will have access to this material and may even be encouraged to adopt it, there is no time in the courses offered to focus directly on brain-based learning.[37] The reality of added pressures an NQT faces when tackling a first post combined with a lack of reinforcement of these guidelines and concepts in educational institutions often determine that this area is overlooked. This is a troubling conundrum that worries a great many educational theorists, including Ginnis in his excellent and informative book, 'The Teacher's Toolkit'. His comment that there remains "a great deal of confusion in Britain between ability, behaviour and learning style"[38] is succinct and to the point. That there are students still admonished for a lack of skill in certain areas without delving into the psychology of why this certain student might be underperforming highlights the need educational practitioners and researches see as essential to develop our understanding of individual learning styles.

That learning styles exist as a notion and that they are so radically different from each other highlights the need to address each of the senses in the delivery of material. Students learn in a variety of different combinations, amalgamations and strengths of Visual, Auditory and Kinaesthetic, commonly referred to as the V-A-K model of learning. It is universally agreed upon that one area of sense will generally be stronger than another to some degree in all students. Bandler and Grinder, the American developers of the Neuro-Linguistic Programmers, were one of the first to develop this idea in the 1970s. They and others have developed the notion that "the dominant sense creates the preferred channel for receiving and processing material and is consequently the most efficient and default way of learning."[39] Many tests and surveys have been carried out over the years, most returning statistics that show the preference for any particular group will be split by approximate thirds, with perhaps a slight preference for Kinaesthetic learning, albeit by a mere few percent (see Ginnis, 2002).

Naturally this is crucial for all subjects, but this can be seen to be especially relevant in music. The *Visual* of notation and of communicating with fellow musicians combines with the *Kinaesthetic* of the physicality of the instrument and of shaping and using the body effectively to produce the sound. These then in turn work together and alongside the *Auditory* result that is the music itself. Clearly a multi-sensory approach that is so crucial to music making is a learning strategy that could be usefully developed and applied throughout curricula and yet, certainly in the field of music, it can be argued that this is an underdeveloped area. There is a distinct lack of practice methodology and of literature on this subject, which, considering its importance, is puzzling.

Given the proven recognised results in literature for and by educators of adopting this multi-sensory model it tends to be abandoned in the classroom in favour of the solely *Auditory* category, the 'talk' part of the often clichéd 'chalk-and-talk' technique of teaching. This is recognisable as being the listening and discussion parts of a classroom experience, be it from teacher or peer, or indeed an audio recording. It also extends to include inner-dialogue; the sense of talking oneself through a problem which, although a far rarer way of learning, exists none-the-less. *Visual* learning (the 'chalk' part of the above cliché) includes the reading of text, watching video material or analysis through graphics and PowerPoint or slide projections. It also includes visualisation through imagination.

When it comes to *Kinaesthetic* learning, it is harder to define specific areas of styles due to the variety of labels that are covered by and therefore included in this category, a reason why learners who prefer this category remain unaccounted for, an argument developed by Ginnis. He argues that it is far easier to deliver material in the reading-writing-listening model than the making-active-doing form and that far too great a number of teachers and educators rely on not only what is easy, but also what is known to them. They continue to implement the cycle of learning that they themselves received.

This work on learning styles was developed further by the work of David Kolb and Roger Fry and their research on experiential learning. Working together in America in the mid 1970s, Kolb and Fry developed a four-pronged circular model of learning that involved the elements of concrete experience, observational experience, abstract conceptual development and exploration in new circumstances. In simpler terms these areas can be generalised as doing, observing, thinking and planning, as outlined in *fig. 2.2*.

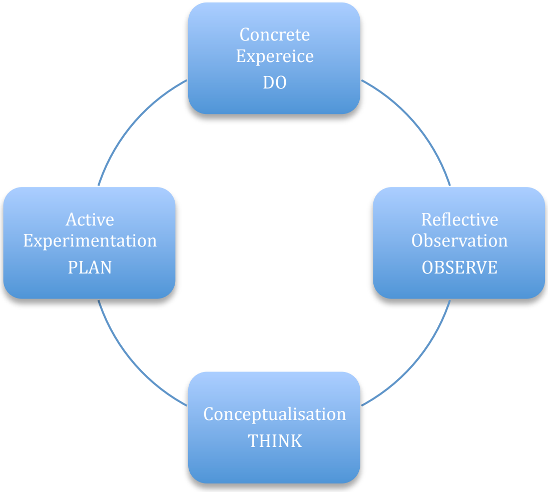


Fig. 2.2 *The Kolb learning cycle*

This model is intended to run as a continuous circle and as such is designed in order to be accessed at any one of the four points, although it is then necessary to adhere to the order of sequence presented. It is, however, conceded by Kolb that focusing on one particular strand may lead to more focused understanding of the processes involved and an ability to anticipate future experience. For educators this is an essential skill as it leads to an ability to transfer key learning strategies to alternative situations with the knowledge of what to expect as an outcome. As Smith says, this avoids "difficulties about the transferability of their [the students'] learning to other settings and situations."[40] If applied in full, the cycle has the potential to enhance learning through the acquisition of comprehension through kinaesthetic exploits. As Kolb himself puts it, "Learning is the process whereby knowledge is created through the transformation of experience."[41]

The learning cycle was then extended into four main types of learning styles which Kolb labelled as being 'convergers', 'divergers' 'assimilators' and 'accommodators'. The first of these groups learn more effectively when focusing on a specifically outlined problem in an emotionally detached manner. Divergers, in contrast, have a strong imagination when approaching learning and are as a result stronger at conceptualising ideas and observing. Assimilators are particularly strong at reflective observation and as such tend to be effective at the creation of theoretical principles. Those in the last group, the accommodators, learn most effectively through the act of doing and so perform strongly when presented with practical tasks.

The work of Kolb and Fry has continued to have a major influence on the development of education strategies and as such can now be found on the syllabus of a great many Undergraduate educational courses throughout America as well as in Britain. This interest has been created in part due to the assimilation of such techniques in the education profession more generally. As Mark Smith comments, "There has been a growing literature around experiential learning and this is indicative of greater attention to this area by practitioners,"[42] and it is for these reasons that it is a commonly held view that, "The model provides an excellent framework for planning teaching and learning activities."[43]

Study in the field of learning styles has subsequently been developed and expanded by a great many researchers and it is in this area that the work of Barbara Prashing comes to the fore. She devotes an entire chapter of her book 'Learning Styles and Personalised Teaching' to the need to develop beyond the standard V-A-K and into V-A-T-K learning. She defines a clear difference between *Tactile* and *Kinaesthetic* in education. In many alternative models these tend to get placed together, such as in Jonathan O'Brien's book 'Lightening Learning'. Their significance is still recognised; "It is important to realise that you can and should try to use as many senses as you can. It doubles or trebles your learning ability!"[44] And yet Prahsing argues that *Tactile* learning and *Kinaesthetic* learning are independent of one another and as such should be approached in different ways. The former infers the hands-on touching and manipulating of objects, whereas the latter refers to the pattern of learning that encompasses the development through experimental action. It includes the idea that at first the results might not be as expected but that working through the problem to a satisfactory answer or outcome is where the actual learning process is contained.

Since the creation and subsequent development of Prashing's Learning Style Analysis (LSA) assessment instruments in the early 1990s, a great many students have been shown to have benefitted from the alternative learning styles made available to suit their needs. Available as a short 30-minute questionnaire aimed at respective age-groups[45], the results can be startling as to the clarity with how each individual in a classroom learns, and also as to how the whole group responds to differing teaching methods and conditions. It is very easy to dismiss learning styles as an invalid framework, frequently being "discredited, misinterpreted and dismissed as a concept in academic literature."[46] The pyramid of 49 elements across the six layers of Learning Styles [see *fig. 2.3*, below] enable specific targeting to enable educational improvement targeted at the individual or group. As well as benefits for students with learning difficulties such as dyslexia, dyspraxia or ADHD, students who just seem a little restless or under achievers can be targeted with specific learning actions that can transform their academic output.

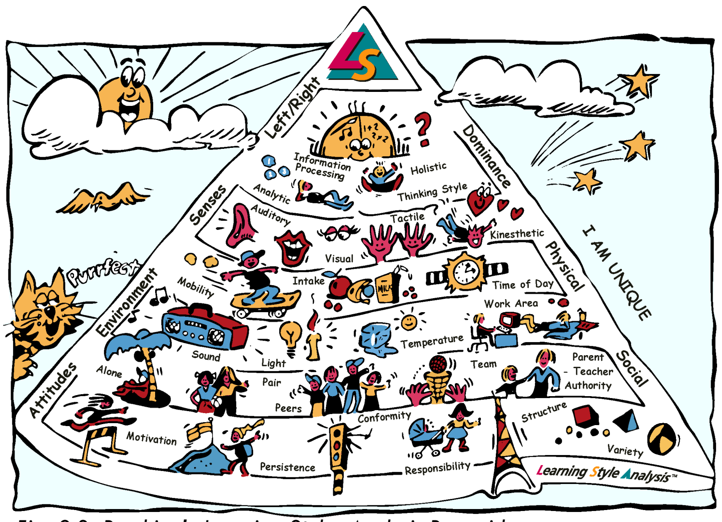


Fig. 2.3 Prashing's Learning Styles Analysis Pyramid

2.3 Problematic Areas Within Learning Styles

Prashing believes that the LSA profiles must be used to place students into subgroups in order that they learn well together. She goes as far as to say that this is a 'golden rule' as "they will be able to relate to each other's learning because they have the same sensory needs."[47] However, the examples that she gives are all of junior students and classes. With phrases such as "these pupils would not normally work or play together"[48] alongside images of Primary School class lists subdivided into their sensory preferences, the importance of this method for GCE students is diminished and as a consequence undermined. Indeed, the pyramid that underlies her entire philosophy of education seems to me to be aimed at appealing to the younger learner, with the inclusions of bright, smiling suns and playful cats.

Prashing is not alone in this; a great many of the resources and books that centre on the learning strategy area of education are targeted towards the younger pupil. Indeed, a great deal of educational psychology is aimed at younger children. As the work of CuDAS is aimed at the adolescent this needs to be taken into account and investigated further. It would appear that it is an assumed understanding that early childhood is the key time of a child's life in terms of their development of educational practice and that any habits that are formed, for good or for bad, are done so in the primary stage of schooling. References to pubescent learners or indeed to students reaching the end of puberty and still actively involved in education, as is the case for many GCE students, are hard to find in literature. As excellent and as valuable as Ginnis's book is as a reference for improving one's teaching, the lesson plans and class ideas are fundamentally aimed at the pre-GCE learner. The illustrations underline this, and while Ginnis and others would argue that these techniques and ideas are aimed at all, it remains still clear in the text that the initial devising of these materials was made with the younger pupil in mind.

There is a long-established assumption in the field of brain development that the major changes occur are almost entirely centred in the early years of childhood. Blakemore and Frith note that study beyond this field into the domain of the teenage brain remains an underdeveloped area. "There has been surprisingly little empirical research on the development of cognitive skills and the brain during puberty and adolescence."[49] This would seem strange as much is clearly changing in the body during adolescence. Emotional reactions and responses are also drastically altered and Blakemore and Frith therefore logically conclude that alongside this, "much is changing in the … brain during puberty."[50]

There are some clear reasons why this area of research remains underdeveloped. The most inhibitive of these was purely scientific, in that the ability to undertake such study was only very recently made possible through the use of Magnetic Resonance Imaging (MRI), which produces high quality images of the living brain, but is only a very recent invention, certainly in terms of the history of the study in this field. Damadian, Goldsmith and Minkoff did not publish the first images of human study using this technique until 1977. Prior to this, brain research was conducted entirely on animals in the 1950s and human corpses in the 1960s and 70s. This form of post-mortem study did not enable the ability to study the brain over a period of development, nor offer the chance to see it 'in action', responding to tasks and challenges. Today we are fortunate to be in an age where "recent advances in technology have provided an amazing tool for neuroscientists to discover more about how the brain functions."[51]

Another reason that little is known in this field is due to the fact that it was not an area deemed worthy of study until relatively recently. "The notion that the brain continues to develop after childhood is relatively new."[52] Research conducted in the late 1960s showed that although the volume of brain tissue remains stable throughout the life of the brain, the inner workings of the connections between neurons do not remain constant. It was discovered that there was an increase of *white matter* in the frontal cortex of the adult brain when compared with that of a pre-pubescent child. This white matter, so called due to the insulating layer of myelin on the axon fibres that connect neurons that appears white under a microscope contrasting with the otherwise grey appearance of the brain, aids in the increase in speed of electrical impulses between neurons. This discovery led to the further work of Huttenlocher, who concluded that there is a "large decrease in the density of synapses in the frontal cortex after puberty."[53] In all other places of the brain this happens just after birth and in early childhood. Subsequent MRI scans have enabled the clear demonstration of "major changes in the frontal cortex throughout adolescence."[54]

This is of particular interest when one considers the primary functions of the frontal cortex, which include attention, decision-making and the ability to perform multiple tasks at once, all areas that Blakemore and Frith logically conclude "might improve during adolescence."[55] It is for this reason that the importance of study of the adolescent brain in relation to education is essential. "It is equally important to know about brain development during adolescence for teaching and learning in the classroom."[56] As Blakemore and Frith comment, if one is to heed the evidence of recent research into brain development that shows the brain "naturally undergoes large waves of development well into the teens,"[57] then education of teenagers is not only important in itself but the specific approach to skills learned at this level of schooling need to be considered. As they say themselves; "The research on brain development during adolescence shows that secondary and tertiary education are vital."[58] Furthermore, they go as far as to suggest that these education principles be as detailed as to include targets such as the "strengthening of internal control, self paced learning, critical evaluation of transmitted knowledge, and meta-study skills."[59]

There is also a further sub-issue raised in this notion of age-related learning style material that extends to all studies in this field. It is unclear as to whether the assumption that a learning style identified for an individual pupil is one that will remain with that learner for the rest of their life, inside and outside of formal education. It could be argued that given the highly complex nature of physiological and psychological brain development, it is highly likely that as we age, our learning preferences may develop beyond any initial assessment we may provide in our infancy. Therefore, it would be both logical and prurient to identify key ages at which to aim an analysis of learning styles and a timescale of how often these processes should be reviewed. These remain unaddressed areas and therefore LSA models do nothing to address these unanswered questions. The issue continues to grow in complexity when one also considers the distinct and likely possibility that not every learner will respond with the same brain functions and preferences in all subject areas. A highly kinaesthetic sports learner may find himself or herself with a much stronger auditory learning style in a maths lesson. In terms of music this will have dramatic implications when one considers the need for multisensory learning as discussed above.

As well as these fundamental problems in stance that affect the LSA model, Prashing also follows a highly prescriptive ordering of learning, starting with the LSA preference, using the secondary preference for revision and only working through the non-preference models once the content is understood fully in order to aid with flexibility of learning. The comment that, "Nobody should have to learn new and/or difficult material through their non-preferences – it often makes learning impossible!"[60] sits uncomfortably as a prescriptive model for older students that might actually promote what is attempted to be avoided – the inhibiting nature of modern learning. Teaching and learning should not only be about adhering to the comfort zone, of either student or educator. In fact, it could be argued that there is great merit in taking this to the natural conclusion and promoting the opposite tendency, thus encouraging the neurological functions that would otherwise remain underdeveloped and lacking in functionality.

There are other key elements of the Prashing LSA model that sit uncomfortably within the wider context of lesson planning and teaching. It soon becomes apparent that there are several of the six areas contained within the pyramid that as a teacher in a wider school context it is not necessarily possible to have any control over. The classroom for those undertaking CuDAS will usually take the form of a keyboard lab designed specifically for the implementation of Music Technology. Centres running the GCE Music Technology course may find, however, that the space is shared across the year groups, from 12 to 18 year olds in a variety of curricula. Addressing area 4 (environment) as an example, altering temperature may well prove very hard. The recent successful departmental bid for, and installation of, a cooling and heating fan has enabled one of the centres where CuDAS was implemented to address this area, but the requirement in Prashing's pyramid to offer formal and informal areas as well as the monitoring of light levels are not able to be practically implemented. Given that the majority of work in areas of this nature takes place at a computer workstation with the use of headphones, the notion of communal sound in the learning strategy is clearly not appropriate.

The nature of the rooming will also have dramatic repercussions on the third area, that of the physical needs of the students. The complex timetabling issues in a school environment do not allow for differing strategies. This is reflected in the learning that will continue at HE level, where a lecture on a given topic may only happen once a week at the same time for the whole academic year. Therefore it is with no certainty that a variety of lessons can be spread across the hours of the day. Referring again to the nature of a fixed workstation environment, it is also clear that addressing students' differing needs in mobility is not something that is relevant to the software-based application of learning. It could also be argued that allowing drinks and nibbles could be an unnecessary hazard to any electrical set up and as a result is not something that can effectively be worked into a sequencing lab-space, especially in today's heightened tension concerning the contamination and spreading of the Norovirus, HCN1 and other airborne infections passed on through physical proximity and contact. A great many teachers will have witnessed the installation of alcohol-based cleaners in classrooms where IT equipment is shared. Logically it makes sense to also outlaw the consumption of food or drinks in such an area.

2.4 Learning Preference Models in Relation to CuDAS

Having discussed Prashing's conclusions on learning styles and her definition of a V-A-T-K model through her learning style pyramid in some detail, it is interesting to note the relevance her outline has had on the planning and delivery of CuDAS. Below follows an analysis of where Prashing's table conforms or otherwise with the CuDAS model of compositionally based teaching methods that have been devised for the GCE Music Technology course.

The **LSA** assesses 49 individual elements in the following **six areas**, which are represented as layers of the pyramid. The first four of these layers can be described as **biologically/genetically** determined and the last two **conditioned** or **learned**:[61]	
Area/Subgroup	**Evidence in CuDAS**
LEFT/RIGHT BRAIN DOMINANCE	
Sequential brain processing strategies	The ability to learn through a progression of stages is clear in CuDAS, whilst the ability to retain factual information and ideology of subject matter in a systematic manner is presented throughout the learning process.
Simultaneous brain processing strategies	Intuitive connections between differing strands of learning are made possible by approaching the tutorials in a non-sequential way, allowing for the creative leaps associated in this type of learning, where the end target is reached with seemingly no obvious route to the end cause.
Reflective thinking styles	The tangents and imagination that go into the creativity of the CuDAS model are indicative of the personal connections required by reflective learners. The use of images, sound and movement also contribute greatly.
Impulsive thinking styles	The practical activities are structured with step-by-step guidance in hands on learning.
Analytic learning styles	The ability to work alone with structured worksheets allows the student to think things through, working towards structured academic research.
Holistic/global learning styles	The ability to attain knowledge through self-discovery (a '*work it out for yourself*' approach) and trial and error is represented in the CuDAS model in many stages and at many levels.
SENSORY MODALITIES	
Auditory (hearing, talking, inner dialogue)	Initial CuDAS information lectures and class discussions as well as software.
Visual (reading, seeing, visualising)	Notes to accompany CuDAS project as well as software.
Tactile (manipulating, touching)	Control of Max/MSP patches as developed through tutorials. An interactive SmartBoard was also used to realise the full tactile potential of CuDAS.
Kinaesthetic (doing, feeling)	Learning through development of CuDAS tutorials and personalised creative input as well as use of a SmartBoard.
PHYSICAL NEEDS	

Mobility (moving or being stationary)	Fixed workstations in a Sequencing Lab environment leads to stationary learning only.
Intake (eating, nibbling, drinking, chewing, etc)	Electrical equipment forbids the taking of water into the Sequencing Lab work area on Health and Safety grounds.
Time of day preferences (personal bio-rhythm)	Lessons are pre-determined in a fixed timetable cycle. Any independent work relies on a light timetable (at A2 level this would not include a student taking 4 subjects which is a common occurrence), an ability to work at a level where supervision is not necessarily a requirement and also the free periods a pre-determined timetable may account for. Given the nature of Controlled Conditions [see Chapter 1.2], this is unlikely to be practical.
ENVIRONMENT	
Sound (needing music/sound or wanting it quiet)	Not possible during work due to the use of headphones. Also impractical in areas of 'lecture' style due to demonstrations of audio examples.
Light (needing bright or dim lighting)	Lighting is a pre-determined and a fixed feature.
Temperature (needing cool or warm)	Heating of school is pre-determined and a fixed feature, however, in centre K the installation of a cooling and heating fan was made to control temperature.
Work area (wanting formal or informal/comfortable design)	Layout of Sequencing Lab is not adjustable due to the large amount of wires and cabling. Uniformity is also a requirement due to shifting nature of classes and curricular using the space. The sharing of rooms and resources by students and possibly teachers in advanced levels of education makes this area impractical. The teaching space is not usually predetermined to belong to any one group, pre-GCSE, GCSE and GCE levels all sharing materials, resources and rooming and as such making changes to suit the learning needs of one particular group is not possible. Achievable alterations included changing the hard-backed plastic 'school' chairs to swivel office chairs with adjustable height and back support, redecorating the room and altering the layout of the computer lab to enable a more conducive study atmosphere and work ethic.
SOCIAL GROUPINGS	
Working alone	Workstations and tutorials are designed primarily for singular use.
Working in a pair	Collaborations are fairly easily arranged within pairs. Larger groups become more problematic due to the nature of personal control of the

	programme being of a singular nature, but creativity is possible in any combination of numbers
Working with peers	See above.
Working in a team	This becomes much harder to define in the CuDAS model, although it can be argued that the class as a whole can learn during this process as a team through the use of aural analysis, creativity, critical thinking and discussion.
Authority (wanting to learn with a teacher or a parent)	Provided by the teacher as well as by the help notes, supporting material documents and green pop-up boxes that accompany the tutorials.
ATTITUDES	
Motivation (internally or externally motivated)	Evident in the progression of learning and understanding through the creative process
Persistence (high, fluctuating, or low)	The CuDAS tutorial patches require high persistence levels to create something with musicality, which is in turn mirrored by the low persistence needed for the factual understanding and visual representations of the supporting material.
Conformity (conforming or non-conforming/rebellious)	Ability to forge one's own path through the creative process, as well as to dip into and out of each tutorial as required in a non-sequential manner.
Structure (being self-directed or needing directions, guidance from others)	Manipulating the tutorial patches can be undertaken with or without teacher led guidance. The supporting material enables those happy with a 'manual' based learning preference, whilst not necessarily being overtly required for those that like to 'get their hands dirty', taking a 'do now, learn later' approach.
Variety (needing routine or changes/variety)	The very nature of the CuDAS project escapes routine learning in the GCE Music Technology syllabus whilst retaining the possibility of being delivered in a variety of differing methods that conform or otherwise to normal teaching practices.

Despite the concerns within the learning style philosophy of education as raised in Chapter 2.3, it is clear to see from the above table that there remains the possibility of positive outcomes through heeding the approaches directly in the planning and delivery of CuDAS. It is an undeniable obligation to our students to attempt such developments in our teaching. Once they are adopted into our care for the development of their minds, intellects and skills, we must take our responsibilities to heart and offer as informative, rewarding and developed a learning path as possible. This is particularly true at the GCE level, where students are about to make the transition into the adult world and are settling into working methods that will stay with them for the rest of their lives. At this level of learning it is therefore essential to offer alternative teaching styles. That this view is shared by others is essential to the success of the CuDAS model of learning. Prashing comments that "although the multisensory instructional approach needs more preparation and greater teaching skills, it's the only way of keeping students engaged in the learning process, especially when curriculum content is difficult."[62] This is a position that is not at odds with O'Brien's observations that "we learn through all our senses so you can't leave any out. The best way to learn is using them all."[63]

Having understood the implications of the development of learning styles within the educational process, it becomes essential to implement such knowledge into the planning and delivery of CuDAS. This can be seen on a great many levels, both generically and specifically targeted. The emphasis placed on Kinaesthetic learning, inferring the hands-on touching and manipulating of objects, can clearly be seen throughout the CuDAS process. This is made possible through the application of the interactive Max/MSP tutorial patches, designed to be used by the students as learning material. Not only are they physical in nature, requiring the turning-on of bangs and movement of objects to produce results, but at the core of the exercises is the notion that at first the audio results might not be as expected and that only by working through the problem to a satisfactory answer or outcome can one access the hub of where the actual learning process is contained. The tutorial patches encompass this ideology in their need to be *manipulated* in order to work. The very notion of the CuDAS function is to manipulate and synthesise sound, which in turn can only be achieved through the physical manipulation of the tutorial patches.

Through the use of Max/MSP, which in itself is a highly kinaesthetic environment, there is a deliberate avoidance of the notion of 'one click and it's done'. As discussed further in Chapter 5.4, this model is far too frequently the norm for sequencer programmes such as Cubase and Logic. Any sense of creativity through manipulation is reduced by the inclusion of presets and instantaneous actions by single clicks from the mouse. This can most clearly be seen in the application by music technology students of spatialisation. This area is arguably the most complicated practical aspect of the recording tasks that student's need to achieve to access the full range of marks available to them through the mark scheme. It is also one of the more difficult concepts to fully understand. Even when knowledge of theory and practical application are applied, it still remains one of the most challenging of fields in which to be produce creative and consistent work whilst retaining a sense of purpose as defined by examination guidelines. As a result, in a vast number of cases that personal experience as a teacher and examiner in this area have shown, it can be seen that students will too often resort to 'presets' loaded with the software application.

This lack of creativity and development of understanding is often made due to the ease of such a choice. It can be regarded as the path of least effort, leading to a concerning lack of comprehension that is required to really understand the topic. For this reason, the CuDAS tutorials have been designed to require far more analysis, thought progression and understanding of the key audio concepts in order to achieve the same results as the 'one-click' presets of sequencer software. They are resources to *advance* learning, rather than to 'spoon-feed' the pupil. The avoidance of providing so much information to the student that they no longer need to think for themselves is one of the main areas of learning that underpins CuDAS. In addition, it can be seen that the CuDAS tutorials also reach beyond what a sequencer can achieve, thus increasing the possibility for learning. This can only be a positive step towards improved learning in this field, but also allows the reaching beyond the opportunities for music making that exist in other software formats. The physicality required to support learning is essential, rather than the giving of fact or direct knowledge in the more commonly used *Visual-Auditory-Kinaesthetic* (V-A-K) model.

Despite the importance of the Kinaesthetic learning preference, as previously touched upon there has been shown to be only a very slight preference of a mere few percent for this model of learning over Auditory and Visual (see Ginnis, 2002). Therefore, with no clear majority to adhere to, the CuDAS tutorials were designed to appeal democratically to students in each of the three key sensual learning structures. This was crucial for targeting individual strengths, but also in the wider knowledge that in a learning environment, all senses will work in combinations and therefore it is important to appeal to this need for a holistic learning pattern. CuDAS achieves this by allowing for the presentation of material in any single level of the V-A-T-K levels of learning or indeed all of these in any combination. That the student can learn in whichever way he or she chooses is surely where a key element of the strength of this teaching method lies.

The supporting material for the CuDAS tutorials [see *Appendix 2*] was initially delivered in both an Auditory and Visual manner. A lecture-style class was given with clear illustrations of theory and demonstrations of practical application in software as shown. Classroom discussion was involved between students and teacher in a formal and informal setting. Handouts were given for clarity and for use by the students at a later date. The design of the software paid particular attention to the visual in design, manipulating traditional Max/MSP objects to appear more user-friendly to the student [see Chapter 5.4]. A written test was devised to underline and further ensure the revision of knowledge, results and evidence of which can be seen in *Appendix 3 - Results based analysis of CuDAS*.

Through the principles of Kolb it is also possible to argue for an inclusion in curriculum planning of specific learning environments that are directly related to the four holistic stages of the Kolb model of learning discussed in Chapter 2.2. These can be identified as being embedded in the delivery of CuDAS. The C*oncrete experience* of CuDAS can be seen in the actual software and use by the student in a computer lab environment. R*eflective observation* is made through the inclusion of feedback forms and short tests, as discussed further in Chapter 6. This encourages the students to consciously consider the activity that has taken place in each of the tutorial topics of CuDAS. There is also the opportunity for *abstract conceptualization* whereby the learner is encouraged to perceive a route into creativity through the CuDAS patches and once this has been achieved *active experimentation* is partaken using CuDAS as the tool to achieve a creative end product.

Further care was taken to ensure that certain areas of learning style analyses were covered in the design of CuDAS. These included ensuring that the students were offered all possibility to improve their sense of communication regarding the subject area. At some stage this will be important, either in the GCE examination, an interview for HE or perhaps even in industry. Knowledge learned through peer observation was also important in this category. Alongside this, the students' creativity was advanced through the learning style method to ensure the continuing development of this crucial area in the Music Technology GCE. The inclusion of interactive exercises adheres to both Kolb and Prashing and as such develops the students' ability in their own composition to use the techniques covered in CuDAS. This is achieved through a certain perspective of emulation. For Blakemore and Frith this is a problematic device. They pose the rhetorical question; "Is imitation a good thing or does it stifle creativity?"[64] However, it could be argued in return that the desire to fulfil a positive role model should not be underestimated. Learning that is able to stay with the scholar for life, and that can be identified beyond *memorable* and into recognised knowledge and appreciated good practice, can lead to student-led pushing back of boundaries through inspiration received directly from the learning and from the creativity imagined as a direct result of the learning.

Other areas of targeted learning philosophy within the CuDAS curriculum include the important area of ownership, whereby the student develops the ability to initiate learning and the acquisition of skills without the need for a teacher-led authority. This independence is crucial in developing life-skills as well as instilling a value of cooperation and democracy and developing an understanding of self-expression. Motivation from the energy and positivisms that are created as a result of the enthusiasm towards the CuDAS work are also extremely valuable and likely to form in contrast to the lack of perceived ownership that permeates most A-level learning which is dictatorial in terms of the requirements for examination. The ability to raise expectations from the perspective of the student as well as that of the teacher is something that was considered, as was the area of self-esteem. While it is accepted that 'mistakes' can lead to a positive learning outcome, the student still needs to feel as if the work he or she is producing has a worth. This leads on to respect, both from a teacher-student relationship, but also a peer-to-peer relationship, which could be argued is becoming increasingly important to students in current schooling and certainly has relevance to CuDAS.

The final area that CuDAS specifically targets through learning style analysis is the area of general musicianship. Given that the subject material included in CuDAS encompasses a great many genres and techniques, it was considered important to keep in mind the realisation that the work developed retained a clear sense of musical identity, that is, the ability to identify it as a *musical* exercise at all times. CuDAS is required to achieve a stretching and developing of the students' understanding of some of the key concepts behind the fundamental basics of audio, but from a perspective that will fundamentally enhance their musicality, rather than improve their understanding of physics, computer programming or mathematics. That these areas are also covered is a bonus, but not a primary function and that these fields overlap at many points in often intriguing ways is certainly interesting and worthy of pursuing. However, it was important to retain a sense that the learning tools were developed for music students and as such the planning and development of the materials of CuDAS were required to pertain to this fact at all times.

It is also in this area that one can look with more attention at the social groupings and collaborative approach of CuDAS. It is possible to see that the participant's roles are not rigidly demarcated when implementing the learning through the software. There is a breaking down of the assumed traditional roles of teacher and learner in what Argyris and Sehon, as quoted in Hayden and Windsor, would label as a "Closed Loop interaction."[65] The planning of the material in CuDAS has attempted to avoid the notion of a directive collaboration between teacher and student in favour of a more open and spontaneous educational relationship. The operator of CuDAS has complete ownership of the resulting sound production. As a result, this avoids the traditional hierarchies developed between the composer, the creator of educational resources and the learner, offering in its place an alternative way of learning for the student, where there is neither a correct or incorrect approach to the manipulation of the patch and the learning involved. It is the notion of sharing the output of creativity that is central to this point. The patch has been created to be able to realise certain possibilities. However, the user of the patch is able to define these possibilities entirely to his or her own tastes, desires and aesthetic sensibilities. This is what Tom Armstrong recognises when he comments, "Shared conceptual and aesthetic concerns aid a successful collaboration."[66] In this instance, the collaboration between the patch creator and the patch manipulator remains an open relationship, where each feels a sense of ownership and a sense and possibility of dialogue.

This extends further into what Armstong and Steiner label as *complementarity*, meaning a sense of mutual appreciation between teacher and learner. This encourages learning and promotes excellent working relationships that increase knowledge as well as creativity. This is a point that is agued by Dobson, who says, "Most creative work comes through conversation."[67] In this case conversation is taken to mean a communicative dialogue between the two parties involved. This can still involve a journey of discovery. As Masutov, Mercer and Littleton argue, there is currently an over emphasis on agreement and an underdeveloped sense of disagreement in collaborative work. It is in the tension of conflict that dialogue and the development of thinking can sometimes be most effectively progressed. What is essential is that communication remains intact. For as Blakemore and Frith write, "Successful teaching is based on many of the same component skills as in ordinary two-way communication."[68] It is possible to recognise that these extensive philosophies have been applied to the development and implementation of the learning that CuDAS provides.

Chapter 3 The Relationship Between Composers and Pedagogy

The essence of the work on CuDAS being that of the development of an interactive learning environment through the use of pedagogic composition, questions must be asked as to the issues that relate to the educational work developed by composers entering into pedagogy and the specifics of the principles that may be brought to this area. These principles, which help to form an underlying methodology, cannot be produced in any alternative way. That is to say, the composer is central to the emergence of the thinking through the use of their own skills in the generation of musical material that defines the concepts in question. For this reason it is of importance to discuss other models of pedagogy that can be related to the principles of CuDAS itself.

3.1 The Pedagogic Principles of Zoltán Kodály

Zoltán Kodály (1882-1967) is one such composer who dedicated a large amount of his creativity into developing the music education system in his native Hungary. He was primarily concerned with the education of young children, seeking to develop the way the music curriculum ensured the social and artistic development of the child leading to the production of fully musically literate adults. This in turn, he believed, would lead to an enriched society and in turn improve the social fabric of Hungarian life. To quote Choksy; "Kodály felt deeply that it must be his mission to give back to the people of Hungary their own musical heritage and to raise the level of musical literacy."[69] In order to do this Kodály realised that he could use his own creativity as a composer to ensure music could resume its importance in the overall curriculum, an importance that would place it democratically alongside the sciences and languages. As he said himself, "Music is an indispensable part of universal human knowledge. He who lacks it has a faulty knowledge. A man without music is incomplete. So it is obvious that music should be a school subject. It is essential."[70]

Kodály combined elements from other established education approaches, such as Dalcroze and Curwen, with the study of what he deemed to be appropriate musical material, a large basis of which was the vocal folk tradition of Hungary. What is crucial in these developments is that as a composer he was able to supplement this element with specifically composed material. These compositions were influenced by his nationalist passion for the folk music of his fatherland. Hungary was, at this time, dominated by the cultural impact of the German and Austrian traditions and as an impassioned musicologist, Kodály committed himself to extensive research in the collation of his native folk music. As such, it is little surprise to note that his compositions were in turn inspired by this music and his melodic writing is heavily tinged with Hungarian folklore. This is a principle in his methodology that is always present, to a greater or lesser degree.

There are many guiding principles that can be seen in Kodály's pedagogic work and the analogous descriptions of Gillian Earl are particularly helpful in grasping these. She likens each of the main principles of the Kodály philosophy to "the spoke of a wheel, starting with music at the hub, and leading out to the ever-expanding circumference of the wheel as the understanding of the language of music increases with progress."[71] One such spoke is the notion of importance of beginning at the earliest possible age and to start with the joy of experiencing music. Although the concept is transferable to older students through to adulthood, the ages from three to seven are the most important, as are the notions of avoiding over intellectualisation of material and using the voice to assure assimilation and the concept of the inner ear.

Kodály viewed the human voice as being essential to this process of musical enlightenment for a profound pedagogic reason. He saw it as being the body's built in instrument and as such the most effective way to express ourselves musically. This is at the very core of the Kodály philosophy, as noted by Vinden when he comments, "very simply, the Kodály Concept could be summed up as the practice and belief in musicianship development through singing."[72] As Kodály himself says; "If, through the reading of music, a child has reached the stage where he is able to sing a small masterpiece in two parts with another child, he has acquired a hundred times as much music than if he had thrashed the piano from sunrise to sunset."[73] The notion that learning an instrument becomes a *skill* to be mastered rather than providing an *awareness* of musicality is a concept that repeatedly runs through Kodály's principles. He maintained that removing the necessity to be hindered by technical difficulties, as well as avoiding the over-emphasis on developing technique over the fostering of musicality, would lead to results that would be profoundly more intrinsic to the ideal of musical understanding and knowledge, thus making the voice the fastest way to reach a higher goal of developed musicianship and an ability to 'internalise' music. He also noted that the voice happens to be an excellent social leveller as it is a free instrument we all have access to. He comments; "The most simple instrument is the voice. Singing does not involve financial costs … and the only need is a competent, good teacher."[74] Kodály maintained that the principle of unaccompanied singing would lead a student to develop the skills of musical memory, intonation, harmony and the ability to develop the inner ear.

In order to address these principles, Kodály composed a great many works of various complexities for voice, the first publication specifically aimed at young children and their musical education being published in Budapest in 1941. *333 Olvasógyakorlat* (trans: 333 Exercises in Music) was accompanied two years later by *Iskolai Énekegyüjtemény* (trans: A School Collection of Songs) by Kerényi and Kodály. Both volumes contain material for voice specifically composed for the publications by Kodály. The exercises begin with songs built entirely on the major second before progressing gradually to a complete scalic tonality by the end of the volume, displaying a clear pedagogic principle of stripping down to the initial building blocks of melody. This developmental approach to learning can be seen in the following exercises, taken from *333 Exercises in Music* [see *fig. 3.1*]. The first, exercise 1, uses only the notes D and E, the tonic and supertonic of D minor. The second, number 183, taken from the middle of the volume, can be seen to build on this basic principle and makes use of the tonic, the supertonic, the subdominant and the dominant in A minor. The third example shown here is taken from the end of the volume, by which time the development of tonality has introduced a pentatonic scale in D major (exercise 326).

Fig. 3.1 Three examples from Kodály's '333 Exercises in Music'; numbers 1, 183 and 326.

A further example of the developmental learning contained within Kodály's pedagogical works contain can be seen in the 1963 publication *66 Two-Part Exercises* [see *fig. 3.2*], where he employs increasing rhythmic and tonal complexity to develop learning. The first exercise can be seen to employ basic rhythmic canonic material with minimal melodic variation that retains the basic melodic shape and line. The second, again taken from the middle of the volume, introduces inverted imitation (number 35) and greater rhythmic, time and key complexity. It has also increased in length from 8 to 12 bars. By the end of the volume, exercise 66, the length of the music has developed into a fully worked piece containing triplets, giving a compound feel to the time signature. Modulations, accidentals and counterpoint to replace canon have all been introduced. It is this introduction of musical concepts gradually leading to a full development by the end of the volume that highlights Kodály's pedagogic methodology. These two part exercises are made by a first-rate composer and integrated into an educational theory in order to enlighten and it is this that is of such key importance. They are not merely designed by an educationalist in order to achieve a certain outcome; they also contain aesthetic validity and could not exist if it were not for the role of composer in the overarching pedagogy.

Fig. 3.2 Three examples from Kodály's '66 Two-Part Exercises'; numbers 1, 35 and 66.

Naturally, what is now described generally as the 'Kodály Method' is a retrospective label to a whole area of music education development and theory. Indeed, Choksy points out that, "It is unlikely that Kodály ever thought of what was taking place … as the 'Kodály Method'," [75] a statement echoed by Kocsár's rhetorical questioning; "Did Zoltán Kodály write a book on methodology? The answer is definitely *no*."[76] However, there are clear strands of identifiable progressive educational theory present in all of Kodály's teaching, pedagogic composition, speeches and writing that ensure that his name remains at the forefront of such thinking.

3.2 The Pedagogic Principles of Carl Orff

The educational work and pedagogic principles of composer and educationalist Carl Orff (1895-1982) bear similarities to that of Kodály, notably in the way he viewed the key to musical literacy and development being in the universal concept of targeting the child from as early an age as possible. Following an extensive series of workshops in the 1920s at the Günther School for Gymnastics and Dance in Munich, '*Orff-Schulwerk. Elementare Musikübung*' was published between 1932 and 1935. What is key to this publication is that alongside the introduction into group improvisation and the playing techniques for various percussion instruments, Orff contributed several compositions intended for ensemble playing, forming the first examples of his pedagogy. Following an initial stalling caused by the opposition to the notion of improvisation in the differing ideology of the Nazi regime of the late 1930s and early 1940s, development of the method continued in 1948 with a series of Bavarian Radio broadcasts on the technique. These broadcasts contained further compositional material by Orff, amongst others, all of which contained a framework for improvisatory exploration with young children. These broadcasts form an important area of Orff's principled pedagogy as they were later published by Schott Music under the five volume title '*Orff-Schulwerk. Musik für Kinder*'.

Concerned as he was with the initial education of young children, Orff believed that development in this area should come out of a combination of musical improvisation on simple ostinati and physical movement that reflected the music making and as such remained in character with it. The use of ostinati was a reflection of the composer responding to the spirit of music making at that time in history. It places Orff's compositions very much in their historical context and shows him to be aware of current practices and trends and therefore responding to the needs and interests of his subject material. As such it is clear that the principle of this particular method of pedagogic composition is of central importance to the musical material produced, Orff himself holding the view that; "Music can grow, organically, from small motives to phrases and sections, from simple to evolving complexities."[77] [see *fig. 3.3*, below].

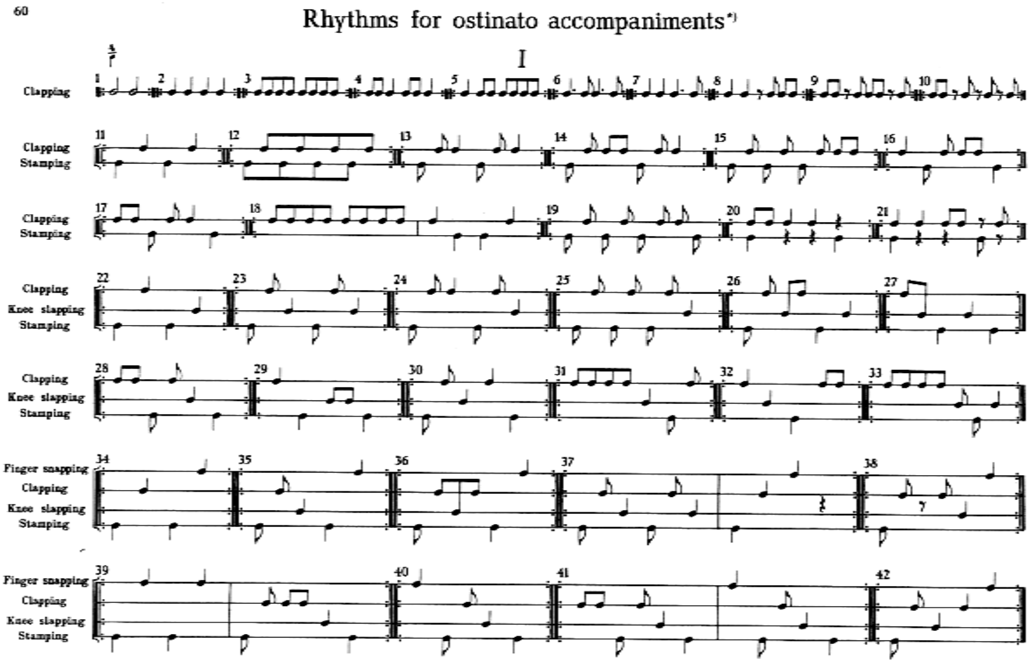


Fig. 3.3 An example of percussive ostinati from the Orff Schulwerk, Music for Children, vol. I.

A further principle in the methodology developed by Orff can be seen in the tools used to achieve the instrument ostinati. These were almost exclusively percussion instruments, both barred and untuned, as can be seen from the example above. The xylophones, metalophones and glockenspiels that were common at the time were added to with instruments made specifically for his work. These were developed from 1928 onwards in collaboration with K. Maendler, eventually leading to the setting up of 'Studio 49', which concentrated on the manufacture and distribution of Orff instruments. Modelled on African barred instruments, Orff was keen that the bars should be removable in order for the possibilities of differentiation. It was in this way that he developed a pedagogical methodology that ensured every child could participate, regardless of initial musicality or development of technical ability. Added to these instruments were the non-pitch percussion instruments mentioned earlier, as well as clapping, finger tapping, singing and chanting. What is conspicuous in its absence from the methodology is the piano. Orff was very strong in his opinions on this, writing in 1950, "The use of the piano … is to be deplored as it bars the way towards the tonal and stylistic originality of … music making."[78] The instruments that were retained in preference over pianos, accordions and mouth organs were deemed to be more cohesive and were further bound together through the inclusion in the method of dance and movement.

That the development of movement through flowing movements was expounded from the percussion instrument ostinati was a tenet that was to be retained throughout the method. Alongside this ran the key concept of improvisation, which played an underlying role. It was through the application of improvisation to both the movement and the music that the interlinking of these two disciplines was achieved, leading to a recognisable principle that was central to the work in the Orff Schulwerk. It can be seen that the specific pedagogic nature of the Orff method manifested itself in the novelty of the moment. Indeed, Orff went as far as to say, "The tuition is based in its entirety on the principle of improvisation."[79] The decision-making of improvisation was of such importance to Orff as it was here that it enabled the minds of the students to develop educationally. This was a radically alternative approach to music education at the time and as a result Orff's contribution to this area is held in great esteem, Frazee commenting that, "Carl Orff developed a different approach to pedagogy, one in which the student was presented with musical problems and expected to improvise independent solutions."[80] Throughout Orff's work there is contained the underlying principle of encouraging improvisation through movement, or as Kruger succinctly puts it, "creative music-making in non-written form."[81]

It is important to recognise in Orff's Schulwerk the particular educational principle of having a practicing artist deliver the material with which the students will learn. An example of Orff applying this argument in practice can be seen in *fig. 3.4* where he allows for the flourishing of creativity through the offering of incomplete melodies designed for realisation by the student.[82] This is a principle that can be uniquely offered by a composer working with pedagogic material as only a professional working in this way can provide material that is musically alert and full of craft.

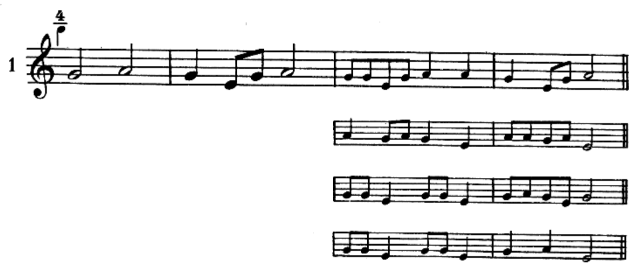


Fig. 3.4 An example from the Orff Schulwerk of the first of a series of 'melodies to be completed'.

The further one moves through volumes of *Musik für Kinder*, the more one realises that the order of material is presented as moving from the simple to the more complex. This can be seen in the nature of complexity of the rhythm, melody and modality of the material. Examples of these principles of pedagogy can be seen below [*fig. 3.5]*, in three examples taken from the beginning, middle and end of volume one of the Orff Schulwerk. The first example, exercise 1 in the *Schulwerk*, is a short melody using only the tonic and mediant. The second bar is a direct repeat of the first, so this almost 'question and answer' motif can be seen to be simplicity personified, structurally as well as harmonically and rhythmically. This piece opens out the opportunity for the key principle of developmental improvisation from the very outset. The second example is of the first of a series of speech exercises that come later in the volume. One can see the complexity of rhythm and development of material has progressed substantially, as has the nature of the presented material. However, the possibilities for improvisation remain intact, highlighted by the inclusion of the word 'examples' in the text, which suggests there are many more that are not printed below. The third example is taken from the end of the volume, where canonic material has been introduced in a full piece. Included here is only the first page of a longer piece. It is possible to now see developed instrumentation, structure, differentiation of parts and the use of ostinati and canon.

Fig. 3.5 Three examples from 'Orff Schulwerk, Music for Children, vol. I'; pages 1, 50 and 136.

Often presented separately as different topics, the way in which the two elements of rhythm and melody show elements of progression, clearly points to a tackling of developmental learning in the Orff pedagogy. As Steen argues, "The range of difficulty of parts as the book progresses implies that the players have a wide span of abilities and levels of musical perception."[83] Indeed, it is interesting that Orff intended the volumes as a universal tool to be used by all age groups rather than a specific class set. The inclusion of simpler lines therefore enables differentiation within the same lesson.

Gertrud Orff, who studied under Carl Orff and was a collaborator in the Orff-Schulwerk editions from 1949-1953, outlines four further areas of principled pedagogy in Orff. The first of these elements is that of *provocation*, meaning to stimulate and engage the student in his or her learning without resulting in the inhibiting nature of intimidation. This is clearly important to G. Orff in the pedagogical context and she comments that, "Provocation is an element in any growth process."[84] This is achieved by introducing a stimulus that has the capacity to fully captivate the learning brain of the child, one that "expands and enriches his comprehension."[85] Following on from this area is that of *gestalt*, encapsulated by the notion of the whole being more than the sum of its parts. For Orff this provides an idea of opposition and of setting up something against the moment. It provides "something one is confronted with, that one must come to terms with."[86]

The penultimate area is that of *language*, meaning literally the voice that we use to communicate through the written word and orally as well as the thoughts of our own inner voice. However, the concept extends beyond this when dealing with the notions of language being essential to our daily lives. This philosophical stance is best summed up with the phrase; "Language is as much a part of living as physical movement: it is a motion of the inner self."[87] A key attribute of Orff's pedagogic principles is that of musical language. When teaching music in the classroom, Orff believed it was essential to develop the ability to think in terms of pitch and rhythm and to foster an inner dialogue of comprehension that would aid in the problem solving required in the realisation and elaboration of his ostinato compositions.

The fourth concept is the notion of *communication* through the sharing of communal involvement. G. Orff points to the Latin root of the word, considering that its derivation of '*munus*' means both obligation or duty but also gift or offering. It is this that causes her to reflect, "Communication is made possible only by effort in a spirit of giving."[88] This has dramatic consequences on the pedagogic approach to the Orff methodology. It is clear that the initial pedagogue is in himself a giver, offering his own credo as a principled and developed method of teaching. Alongside this must be contained an offering from the participating student. This will enable the educational process of music to develop beyond the state of uninspired learning programmes that the Orff-Schulwerk strives to move beyond. In this way it can be seen to be a teaching approach that "promises that we and our students will interact as partners in making music."[89] It is essential to the practices of Orff's ideas that the classroom becomes a place of communal giving, where the student contributes towards his or her own musical development and in doing so is able to receive a greater knowledge and musicality due to the giving nature of the composer as teacher.

3.3 The Pedagogic Principles of Peter Wiegold

One of the main areas of pedagogic principles within the work of Peter Wiegold (1949-) is that of *ownership* and the way in which control ceases to belong to the individual and moves into the realm of collaboration. Following his early experiences with the conservative nature of the Western Classical Tradition in practice, the juxtaposition felt by his work with Javanese gamelan musicians in Surakarta was profound and when asked to compose a piece for the musicians, the resulting work clearly had a profound effect on his aesthetic and subsequent approach to pedagogy and composition;

> "I took the composition into the rehearsal room, and an extraordinary thing happened. It immediately ceased to be "my" piece and now belonged to everyone. They said, "Lets put this at the beginning," or "Lets add a solo here." The music naturally belonged to all present, with no hesitant, standoffish relation between composer and performers."[90]

Like Orff and Kodály before him, Wiegold uses small and simple ideas in his pedagogy to ensure a contact between composer and musicians otherwise unattainable, particularly when working with children. He uses the term 'elemental' to describe this principle and in doing so outlines a method that provides "an intelligent understanding of form and function without complications of stylistic literacy."[91] Through the use of drones, ostinati punctuation and foreground/background, Wiegold is able to transcend stylistic backgrounds and boundaries. This principle can then be extended into further areas of his pedagogical work, leading to a sharing of creativity. His aim is always towards a creation that would "belong especially to that group of people."[92] This is a principle he refers to as 'enculturing', by which he means the concept of bringing a group alive. This can clearly be seen in his description of a workshop leadership as described in his paper '*But Who Will Make Their Tea*';

> "I played a simple figure and repeated it over and over, inviting each person in turn to join in with their own. Eventually we had a fine bubbling texture. A viola was playing a striking pizzicato rhythm, so I dropped to that, then rebuilt into a Steve Reich-like web of pizzicato. I asked for a solo. The clarinetist [sic.] looked as though he'd have a go. The music calmed and became floating and spacious, I added some revolving harmonies on my keyboard, and gradually we progressed towards a swooping free improvisation. After a stillness, a new riff from the trombonist, strong and funky; add everybody in, and onto a rousing end."[93]

Wiegold further developed his pedagogic principles at the Guildhall School of Music and Drama, London, where he was Artistic Director of the Performance and Communication Skills Department from 1984-95. At this institution he ran a postgraduate course for 2½ days a week entirely carried out in workshop form, which, at the time, was a genuinely radical curriculum that included Afro-Caribbean drumming, improvisation, composition, group work and working in many diverse areas in the community. The cohort of up to 24 musicians included those from a wide spectrum of musical backgrounds, including jazz, classical, Indian, composition and performance.

The work Wiegold undertook at the Guildhall he now views as "a ten year experiment in a different kind of education."[94] The improvisation coaching and pedagogic material he provided for the workshops were undoubtedly the full realisation of his educational practices through compositional ideas. "The Guildhall was the thorough development of the pedagogy both in theory and in practice."[95] It also provided a clear model for what Wiegold sees as a principle at the foundation of his methodology, stating that, "… some core principles were clear from the start. All musicians would create as well as perform. All would develop the skills of improvisation and collaboration."[96] The work he has since refined and developed has also left him in a position of control over the direction of his collaborative work of this nature. He says that, "I am now happy to write pieces that are 95 or even 99% composed, incorporating elements of realisation or improvisation as appropriate."[97] He also realises of himself that "I now feel comfortable in my dialogue with musicians and able to incorporate their imaginations … in my own work"[98] and this has led the way towards a clearly identifiable new direction of principled pedagogy, which he labels as '*backbones*'.

Although complete pieces in their own right, backbones fundamentally contain more than the simple fragments of material presented in score format [see *fig. 3.6*]. These fragments can be seen to range between short motivic gestures of mood or texture, to longer more intricate passages of melody, rhythm or harmonic development. However, within this analytical construct they can be seen to exist on the level of principle, being concepts that contain part written and part non-written material and are therefore distinctive. What marks them out as identifiable is their nature as through-composed works around which material is weaved. As he says himself, "The idea of a backbone is something that carries the spine of the whole piece and formally realised as opposed to fragments of material to work with."[99]

Fig. 3.6 Two examples of Wiegold's backbones.

Wiegold maintains that through his methods, "…boundaries loosen and musicians feel able to reinvent their working methods, learning from increasingly wide sources."[100] In essence, these backbones are primarily concerned with carrying the "line of the piece"[101], offering a great many alternative ways of fleshing out the initial material. The substance of each of the backbones is very deliberately composed to offer specific material that leads to particular implications in terms of the meaning of the material and therefore the form of the realised performance. There is nothing intrinsically new in this concept in itself. Wiegold freely admits this himself, pointing to the role of the 'baloungang' in Javanese gamelan music as employing a similar method, or of the continuous and constant 'cantus firmus' of Renaissance polyphony. Both of these models form the spine around which everything else is spun and augmented in spontaneous arrangement. The use of the 'clave' principle in South American music can also be seen to be moulded in this method in the way in which it gives a key rhythm around which other rhythms are woven. The same could be said for the realisation of jazz charts, where the initial head and chord structures are developed by the musicians as a spontaneous and evolving art form. Indeed, when one begins to look for examples, they are visible in a great many forms of music, from the traditional melodies of Irish folk music to the figured bass of Baroque music.

In the case of Wiegold's backbones, reflected in the contrasting examples above, the key principle is the idea that the music may be realised in any number of different ways. It is merely a "… short score that holds the centre of a piece while allowing a creative response to it."[102] He avoids the use of the term 'style' in this explanation, finding this inadequate as a piece of terminology, commenting that backbones can in fact remove the nature of style altogether. As he puts it, "Backbone is a form of de-styling because it is a piece of material that you realise and it might tend towards Ligeti or Miles Davis but the point is it will find a discreet idiosyncratic realisation in the hands of the people of that day or of that creative director"[103]. By this he means that there may be a tendency according to the performers or directors of the music to move towards modal harmony or extreme textures but that "None the less it holds the centre by having some motivic or harmonic or particularly structural yoke."[104] It is this principle that is at the very heart of the pedagogic compositional process.

In the differing examples previously mentioned there are two underlying principles that feature; first that it is in these examples that the form and structure of the piece, regardless of genre, is carried. Secondly, it is in the realisation that the key to these concepts lays. The individual musicians must find a way to 'explode' the material into completion in a way that is in keeping with the original sensitivity of the presented material and that maintains a respectful angle towards the music. As Wiegold comments, it is easy for a breakdown in musical dialogue to cause a return to a 'safe' and known musical focus point that is contrary to both the pedagogic and aesthetic nature of backbones. "When it goes wrong, people can pick it up and say, *"let's do a bit of jazz"* or, *"I like minimal music so lets make it minimal"*. You do need total respect for the sensitivity of the material."[105]

Pedagogically this has two major implications. The first is that there is a freedom from stylistic norms such as rising leading notes or a jazz form that offers each player a solo one after the other. "You are not locked in stylistically and in fact the reverse – there may well be a peculiar voice that emerges with that backbone on that day with those people."[106] Indeed, neither is it therefore necessary to have a coherent and traditionally recognised group formation, such as a string quartet, or jazz group of like-minded musicians from similar backgrounds with approximate levels of ability. "You could have an idiosyncratic group of people some of which could read, some of which were not reading; some virtuosic players, some not; some professional some amateur; some young; some teachers some learners and people across cultures."[107] He describes this further;

> "A backbone … gives flexibility in terms of realisation and musical language and it gives flexibility in terms of who participates in it for what reason. You could have a six year old playing a bass drum with the best clarinettist in the country or you could do it with the National Youth Orchestra where you've got people of the same age and inclination."[108]

This idea can be extended further to realise that it is therefore possible pedagogically to realise the same material in several different ways and consequently understand the difference between genres. In this way it is possible for a backbone to lead to a juxtaposition of participants that allows those with very different experience to work simultaneously, leading to a possible further understanding because of those differences. Wiegold refers to this principle as 'modality'. He describes this terminology further in the following way;

> "Modal music adopts centres for relative reasons, tonality for fixed, absolute. Thus, I am proposing, in quite a deep way, a modal outlook. Not one without centres of attraction, but where this has relative value, and where, indeed, there may be several (relative) centres at once." [109]

To use examples Wiegold himself offers, a jazz, Stravinsky or Ligeti accentuation of the same backbone material will offer to the players the ability to recognise more in the music than is apparent at first glance. This in turn underlines the secondary pedagogic possibility available in his work with backbones as providing a medium for enabling the ability to, "Learn through contrasted realisations more general things about form and balance and line and focus."[110] Both of these pedagogic principles are clearly to the fore in the work that Wiegold is currently engaged in at Brunel University, where it can be argued that this type of approach is greatly more beneficial to the musical education of the type of undergraduate students that are enrolled at this particular institution than the approach of a conventional 19th Century music school.

The potential for new aesthetic thinking in Wiegold's work with backbones lies not necessarily in the practicalities of realisation or the ideals behind the material itself, but rather with the more holistic nature of his view of the principle that can be summed up as what he would call the '*Third Way*'. The first way deals with the concept of specific authority in music and of notated score as defined by the composer and interpreted by the conductor or performer. This denies the model of an open, flowing form and instead prescribes that of containment within a closed form that Wiegold likens to a box – one that is impossible to break away from. If the piece is to be interpreted correctly according to the composers' wishes, a strict code of conduct must be followed. This can be seen in the minutely detailed scores of Romanticism through to more modern approaches to composition. As Wiegold says, in the first way, "Everything is contained, logical and 'boundaried'."[111]

It could be argued that we are entering a post-score phase in Western Classical Music where it is no longer assumed that the score is the absolute reference for a piece of music. Rather, the notated score can on occasions seen to be obsolete and redundant. Wiegold argues that, "We are definitely at a point where the score is only one option, where for some things it is obsolete, for others it needs reworking. It's moving from an absolute position to a relative one: it's *relatively* useful for relatively important things rather than *absolutely* useful for all the important things."[112] However, Wiegold highlights the use of the score in 17th Century Rome, where performers auditioning for a chapel or church choir were held in lower esteem if they did not depart from the text. His use of this as a principle of pedagogy that we should consider in the modern age is particularly striking. The resulting liberation from the scores of old serves as an alternative example of an approach to compositional technique of today. If this is considered, Wiegold argues that creatively there is more to be gained than to be lost in the compositional process. "There are things composers do on paper that can be done no other way. There are things players can do within their instruments that are impossible to notate. The joy and the excitement is in the alchemy between those two points."[113]

If the first way is concerned with a specific authority, then the *Second Way*, as defined by Wiegold, can be recognised in the democratic freedom offered in 1960s experimental music and the sense of open space that leads to group decisions makes the final output more important than the sum of its parts. As he says himself, "The pure form of the second way is an equal group of people making equal decisions out of the specific idiosyncratic conditions of where they are."[114] This notion encourages the music created to become a twisting of discovery and of evolution rather than a blocking and denying of musical possibilities. However, this then dissolves the tension between the pre-prepared and the spontaneous or improvised that Wiegold insists is such a valuable principle in pedagogic creativity of this nature. If everything is positive, he argues, then there is left a far too diminished role for the editing process and journey of development and improvement. He comments, "There are things that composing can do that are impossible with improvisation. Formalities, proportion, exact repetitions, the sculpting of line, dialectical, critical change, 'scoring' and so on."[115]

It is with this background that it is clear to see how Wiegold approaches the principle of what he labels as the *Third Way*. It springs from the chemistry produced between the 1st and 2nd ways, which produces a line with threads of multiple results from the centre as a "convergence of the twain"[116], where tension, alchemy and play become central to the core of the music. He describes this further;

> "The third way [is], for me, like a strong line, holding the centre. It runs into the distance, it sustains movement, reminding of, evoking the essence of the movement. But it is only the centre, and you can move to and from it to infinity."[117]

The third way can be seen reflected in the way in which, for example, Miles Davis ensures the individual voice retains an importance by approaching the sound and modalities of *Bill Evans* as opposed to *a piano* as being central to the sound of their recordings together. The essence of this principle is further explored in the notion of a 'wrong' note in a backbone working. Wiegold argues that the nature of the improvised music will demand an exploration of this note, using it as a point of human contact to share and investigate the redemptive possibilities presented by it, rather than letting it hang as a mistake, commenting, "If you make a mistake and you own it, it becomes people's favourite moment. If you make a mistake and you try and hide it, it's their worst moment."[118] He develops this idea further when he says; "A mistake becomes a source of individual power and pride in a way in which the sheer humanity of the moment makes the moment greater."[119]

This allows for the embodiment rather than instruction, as Wiegold argues that written instructions for improvisation, no matter how detailed, are no alternative for human contact. This process can be seen in pedagogic realisation in the piece 'Bow-Wave'. Premiered in January 2009 by the National Youth Orchestra, the piece was played from memory and contained elements of improvisation. Pedagogically this is clearly important as the members of the orchestra were part of the scoring and provided the voices through soloing and were therefore essential to the realisation and character of the piece. The name given to the piece is a reflection of the concept of waves off a central point, as exemplified in *fig. 3.7*.

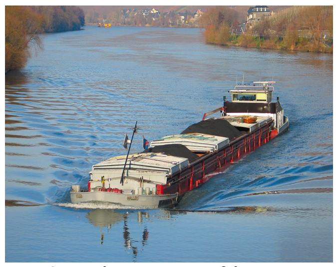


Fig. 3.7 The concept of bow-waves

This concept is clearly a reflection of the spirals motif, which in itself can be seen to be more than simply theoretical in nature. "I could point to many places in my music where this concept is used. A strong centre invites, philosophically, an infinite number of spirals which can go to infinity at which point the underlying rules may be completely transmuted."[120] It is a principle that is clearly visible in the score of the *Bow-Wave*, where one can see from the short

Fig. 3.8 An excerpt from 'Bow-Wave'

excerpt included here [*fig. 3.8*] the potential for the spirals leading to an infinity, whereby "they transform the thing beyond itself."[121] *Bow-Wave* is a clear example of this principle in process, one that contains "the idea of a single point which is very finite and *highly* specific – this massive ship at the point in which it touches the water – and then an infinite number of resultants."[122] This leads to the clarity of principle that an infinite response creates an infinite inclusivity. This inclusive literacy has major implications pedagogically, politically and socially as well as morally and musically. It is therefore in this piece that Wiegold can recognise his third way principle using the backbone method in its purest form. "*Bow-Wave* is a perfect example of the third way because the backbone is infinitely small but has huge ramifications of potential waves coming off it."[123]

Fig. 3.9 Bow-Wave *in performance, Roundhouse, London, conducted by Peter Wiegold. Note the way in which the position of conductor and musicians reinforces the metaphor of the bow of a ship.*

The moment of multiple memories explored here brings to mind the work of Luciano Berio (1925-2003), particularly the ideas employed in the Sequenzas. Indeed, one can clearly see the technique of spirals around a central point in the work 'O King'. However, in Wiegold these ideas are extended through the relationship between the composer and the performer. Wiegold is keenly aware of the psychological way in which he approaches his performers with the notions of 'positive signals'. This is enabled due to his taking on of the role of conductor as well as composer, thus highlighting his role as composer as pedagogue. An example of this is approach can be seen in the way Wiegold promotes the idea of *permission*, constantly reminding the players of the doorways available to them whilst maintaining the tone of the space of performance, retaining the atmosphere and controlling the choice of voice in relation to the animation, inspiration and input of the players at any given time. He has to work hard at this latter point. As he says himself, "There is … a very fine line between opening up imaginative space and maintaining artistic focus."[124]

These techniques can also be seen in the 2009 opera 'The End of the Line', premiered at Piccadilly Station, Manchester, again using young musicians, on this occasion drawn from the Royal Northern College of Music. The wide palette that creates an evolution into a *something* shows the triggering or de-triggering of material, considered by Wiegold to be a very important skill. The principle contained within this is the notion of using composition as a method of facilitating learning. It is this

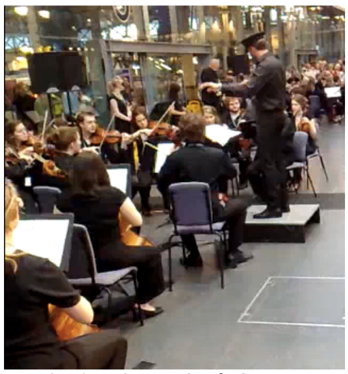


Fig. 3.10 The End of the Line *in performance, 2009*

aspect that helps to retain the tension and freshness through alternative leadership and the notion of "critical intervention"[125] in the potency of the moment. This retention of tension in the musical situation is embedded in Wiegold's third way and remains critical to the potency of the musical moment. He comments; "It is better to keep the tension, the tension between the score, the director, the players. Each can have a different, critical role. The triangle is fascinating, to have the best from pre-prepared notation, the best from creative direction, and the best from each individual player."[126] The first and third of these are self-explanatory; they are given truths in the musical situation that Wiegold generates. The second shows the importance of the area that contains material devised and fixed in rehearsal and therefore the extension of what is then left for improvisation in performance.

Wiegold has identified three alternative ways of delivering a precise instruction and therefore engaging with musicians. The first of these takes the form of traditional notation or oral instruction, where material is presented as being defined and pre-determined. The second offers the infinite possibility of offering alternatives. It is this duality of the second element that Wiegold finds particularly "…fascinating. How do you trigger someone's imagination, and also contain it in just the right way?"[127] For this reason he concedes that "it is the second that I particularly specialise in. It's very fascinating in conceptual and structural terms."[128] The third element can be seen to be the choice being opened up to the performer through the carefully managed offering up to a collaborative contribution. This third element is clearly essential to his creative imagination; "There is a very interesting moment when the player knows they have the reins. And this power and freedom folds back very well into straight repertoire."[129] This transfer of power helps to break down the restrictions of ideas between the participants, restrictions that Wiegold argues are not necessarily pre-determined if approached in the correct way; "There are no rigid boundaries among composers', conductors', and players' imaginations. One must simply find the right trigger for the right imagination at the right time."[130]

Of these three elements of instruction, it becomes clear when studying Wiegold's work that the combination of the three in practice is of most interest to his aesthetic, commenting, "It's the chemistry between the three that is most interesting."[131] He describes the three in combination in clear terms when he says, "When I'm directing, there are three kinds of instruction I can give to the players: *"do this," "do something like this," "do whatever you want."* Each is a vital part of the mix."[132] In structural terms the first and third of the three elements are philosophically very simple, made more complex by then rehearsing and developing that which is intrinsically very simple and offering an infinite number of complexities to the concept. The second element has deeper considerations in that it is not concrete and as such "is moving its tracers and point of potency."[133] One can also see the philosophy that arises from the need to use the correct person at the correct moment in a way that Wiegold labels as being for "the greater good,"[134] an element that helps to link all three constituents, as all must serve this ultimate purpose.

Wiegold's pedagogic principles are evident in both his composition work and also in his workshops and masterclasses. The importance he places on performance in his work must also be discussed. In this area he is keen to promote the final product as being a moment of union through performance. "The workshops always close with some sort of performance: the moment of no return, the moment of shared celebration."[135] This concept of 'shared celebration', and with it the principle of 'shared learning', is key to Wiegold's work as it enables a connection process that is a thread in his creative output. "Connect player to conductor to composer to student to audience. Connect traditional to new. And keep the relationships fresh by being willing to remake and remodel them."[136] In the wholeness of relating to students from experimentation through to creation through to performance, moving through the entire cycle deepens shared learning. Contained within this is an inclusion of celebration of the coming together of the work, which can be seen to be an excellent way of learning. Alongside this is the technical learning and development enabled through the need to complete and present a project. One begins to clearly understand through this process that Wiegold's pedagogy can be seen to include the encouragement of a holistic cycle of relationships in the learning process.

It is when the value of such pedagogic aspirations are realised that connections are made that enables the music to fulfil its full potential. That Wiegold's pedagogy is so largely aesthetic in this sense extends beyond the mere educational properties of Kodály and Orff and opens up a whole new perspective on what it means for a composer to instruct young musicians in their approaches to their own musical creativity and the interaction with their audiences. After all, as Wiegold states, "When audiences sense that something is alive, … daring, personal, committed, and belongs to them, they want to … identify with the story that is unfolding before them."[137]

Chapter 4 The Principles of Pedagogy Within CuDAS

4.1 The Pedagogical Genesis of CuDAS

Having investigated the nature of pedagogy in relation to composers, the principles outlined in Chapter 3 can be seen to have influenced the work on the development of CuDAS. As such, the pedagogic potential of the compositional process involved in CuDAS became a central and core theme. It soon became apparent that what was being offered was not merely a through-composed work using technology, but something that contained further depth. That which started life in a loose and free sense of creativity could not initially be labelled as a completed composition. This would be akin to one of Orff's short fragments composed as exercises for completion, which, when viewed as standalone works, could be argued to fail to develop into actual considered compositions until the method has developed and been placed in a holistic programme of study. This sense of development was in turn applied to the work on CuDAS so that it becomes a coherent curriculum, where, for example, instead of the inclusion of subtractive synthesis for purely aesthetic reasons, the inclusion of this area was merited by its place in a consistent syllabus, where it is followed by additive synthesis and proceeded by spatialisation as key areas of electronic manipulation and synthesis.

The project created as the final work was enhanced by the sum of its parts as CuDAS could be viewed alternately as a piece of software technology, a compositional tool, an enabler of creative teaching and learning, an interactive technological environment in which to gain knowledge of key topics as well as an addition to the oeuvre of pedagogic composition. Whilst it is clear that CuDAS retains the essential essence of compositions of mature expression, the resulting elements of educational theory, practice and philosophy were clearly centrally implicated in the investigation into pedagogic principles of Kodály, Orff and Wiegold. The resulting process of study and exploration, both academic and compositionally, has led to the creation of a series of writings, software tutorials, examples, studies and longer full works, all of which flow into the one central core of the CuDAS pedagogy, with the intention of offering a new and improved way of tackling Music Technology with a specific focus on that which pertains to the GCE course offered by Edexcel. The pedagogic principles discussed in this previous chapter aim to further the provision in the area of Music Technology for 16-18 year olds and the development of CuDAS has at its core the intention to end the problematic lack of provision in this area.

CuDAS was initially devised as a compositional project with the aim of generating a live-performance tool to enable the investigation of new sound worlds through the use of real-time digital audio manipulation using Cycling 74's Max/MSP programme (more information on this area can be found in Chapter 5.1). However, as the patch that was being built was developed to achieve this aim, with the gradual addition of new concepts and refining of ideas, it began to be used increasingly as an educational and teaching tool in the classroom. Primarily aimed at students taking the Edexcel GCE in Music Technology, the work on CuDAS rapidly evolved into a considered and deliberate resource for the delivery of material relating to the development of Music Technology, both in a historical context and that of the intrinsic nature of key concepts and areas within the world of acoustics and electronic synthesis. The compositional process then began to shift as the possibility of the educational potential was realised and areas of interest related to the specification presented by Edexcel and the wider curriculum of Music Technology were then specifically targeted. Finally, as previously discussed in Chapter 1.3, it reached the finished state as a curriculum presented through interactive software in 4 identifiable stages that introduced the learning of audio concepts and synthesis in electronic music, presented for two hours a week over 10 weeks of an academic term.

4.2 Targeted Areas of Pedagogy Within CuDAS

The general philosophy of learning through doing, the kinaesthetic approach, as witnessed in Orff, Kodály and Wiegold is also extremely important in CuDAS and as such forms one of the key points of principled pedagogy. As Orff says; "Tell me, I forget. Show me, I remember. Involve me, I understand."[138] There are strong echoes of this statement in the words of Wiegold when he outlines one of his principles as being that of, "Invoke, don't describe."[139] This outlines his determination to ensure learning is experiential, a reaction against the contrary learning he received in his youth. This can be seen to be the case in CuDAS as it is in the *application* of methodology that the essence of the pedagogical message lies. The important substantiation and practical application of the project is therefore something that it is important to retain through the technical language of explanation. This is a view reflected in Cecilia Vajda's book 'The Kodály way to music', where she comments, "Even the most beautifully written lectures on the subject … impress for a few minutes only. It is the practical work that matters,"[140] words that can be clearly seen in the Kodály method. The same is true for Orff, as his own comments show; "Experience first, then intellectualize."[141]

CuDAS was developed in order to address one of the main problems in the learning area of audio concepts and synthesis at GCE level. This area of concern relates to the delivery of such learning and the resources available. At present any learning on this subject is required to take place through the reading of text. Knowledge on the subject can only be learned through the reading of books and essays. As will been shown in Chapter 5.3, although there are some pedagogic tools that make use of Max/MSP in order to improve such learning and enable an interactive approach, these are not appropriate on a pedagogic or user level for the age group and learning level concerned and they can be seen to be over-complex in their choice of material for inclusion, or over analytical in their approach. This leaves published texts as the only possible resource and this is where the crux of the problem lies. The available texts are exclusively highly advanced in their presentation of subject material. They are not designed for the novice and as such are written in complex and highly technical language. Perhaps the most commonly referred to of these texts is the Curtis Roads' opus 'The Computer Music Tutorial'[142]. This is a volume of incredibly thorough research and explanation. However, it could be argued that only Chapter 1 offers any easy access and that even then the reader soon becomes very laden in advanced terminology and technical terms. This is a view that is in common with the thinking of Kirsty Beilharz, a member of the Key Centre of Design Computing and Cognition at the University of Sydney who comments that, "The most common texts on the subject (for instance Roads…) have enormous scope, and even a fraction of this amount of material would act to confuse the student."[143]

The fact that literature in this subject area can be alienating to the student can therefore be seen to be a major obstacle in the teaching and learning process. The written or spoken word is not as engaging to the student as the subject matter requires. The second-hand imparting of knowledge ceases to be of such relevance and importance when one is trying to describe what essentially amounts to an experience. It is logically more useful to impart the occurrence of listening rather than a description of the theory of the process, important though the theory is. CuDAS attempts to find a middle ground between the two states of theoretical written word and experiential learning through the constant application of this pedagogic principle. It could be argued that this is a position that must be attained in order to successfully offer a teaching and learning experience in this field. This is a view that is reflected in the work in this field by Michael Clarke, who states that, "Simply reading a book or attending a lecture can lead to study that is remote from the sound that is the key element in the discipline."[144]

A further point to note on this topic is that the mere size and weight of the Roads book is off-putting in itself, evidence of which can be found in the Learning Resource Centre at one of the examination centres that CuDAS was presented at. The statistics show that students took out the mini-books that form the 'Basic' series by Paul White over 10 times more frequently over the same two-year period.[145] The evidence suggests that 16-18 year olds find it more difficult to relate to Roads, which one could argue is aimed at an older and more educationally developed audience.

The very nature of the requirements of a student engaged in A-level education goes against the learning philosophy behind Roads, which is that of a complete course in computer music from the initial experiments with sound to the highly complex world of multifaceted algorithms. It is not necessarily designed as a manual to dip in and out of at random, nor is it a short guide to each of the topics examined. Rather, it is an in depth collection of essays that build upon each other, leading to a work as a whole. Each chapter makes references to earlier chapters and as such it becomes clear that to understand Roads, one must ideally read the whole book, a task that is asking a lot from a student who is not only still developing his or her learning ability, but also one who only studies the subject for 5 hours a week [see Chapter 1.2]. That the education system in this country encourages multiple subject learning throughout the GCE years leads to the predictability of a lack of in-depth study in any one of them. So great are the amount of tasks to cover in each area, it is only logical that students try to avoid having several large projects simultaneously progressing. It can be argued that it is far more rewarding for them to focus on first one project and then the other. This is one of the very reasons why subject leaders look for areas in the school calendar where coursework may be entered into in a focused and directed period of time that does not clash with other commitments the students may have.

In order to best understand the way in which the students undertaking the CuDAS curriculum responded to established texts in this way, each of them was given an excerpt from varying books relating to the same subject material. The texts given included Roads' 'Computer Music Tutorial', 'The Cambridge Companion to Electronic Music', edited by Collins and d'Escrivan, and Ian Johnston's work, 'Measured Tones, The Interplay of Physics and Music'. The level of understanding of each of these texts varied greatly. The students reported that the Roads was complicated and although some of the text was understood by some of the students, the vast majority of the information was not retained or realised for future use. They found the Cambridge Companion easier, although still a little muddling, and the Johnston the easiest to grasp, although still there were areas that remained lacking in comprehension. It is important to note that the texts were read in different orders by different students and so it was not simply a case of the information becoming easier to understand upon secondary and tertiary repetitions. As a result, it becomes clear that to teach this subject area from textbooks alone is not satisfactory. Presenting work in entirely this manner decreases comprehension, as witnessed in the student body in question, by going against current educational philosophy regarding learning styles and the need to differentiate according to how the brain functions when learning, as previously discussed in further detail in Chapter 2.

However, the dryness of the texts available in no way reflects the fascination that can be found in the subject matter and as such only goes to further highlight their inappropriateness for learning at this level. It is for these reasons that CuDAS offers an alternative learning strategy more in tune with both the subject material and the nature of learning at FE level. This can be seen to be a cross-fertilisation of learning provided by reading material, aural instruction, compositions and interactive software. The first of these four areas addresses the issue of density of text for this level of learning. It cannot be denied that literature is important in learning as it provides an authoritative set of truths that can be presented through a meaningful and structured argument. As mentioned, the leading published material on these topics was deemed to be too alienating to the 16-18 year old. The other viable alternative would be that of the Internet as a research based tool for the student to gather information to be processed. Generally the Internet provides a clearer and more succinct way of explaining the key features of the chosen subject areas of CuDAS. However, clear though these are, the Internet can also be highly problematic due to the nature of the ability to use it to publish uncensored and unverified material. This often leads to conflicting or false information. An obvious example of this is the material on the Wikipedia website on Subtractive Synthesis, which is unclear, lacking in focus and at times incorrect.[146]

These challenges were met through the inclusion of written material specifically formulated for CuDAS and consciously designed to appeal to the GCE learner. A large proportion of this can be seen in the supporting material that accompanies the tutorials. *Fig. 4.1* shows the location of this material in the software.

Fig. 4.1 The location for the supporting material for each of the CuDAS Tutorials, highlighted in red.

For each of the CuDAS tutorials the supporting material opens a PDF with a single click. The content of these PDFs have been designed to refrain from the use of over technical language and yet to impart as much of the essential information of the subject as possible. This has been achieved through the use of self-formulated text as well as the inclusion of self-generated images. The supporting material documents can be found in full in 'Appendix 2 – The Supporting Material for the CuDAS Tutorials' (2.1-2.4). These documents form an essential part of the process of education and learning, vital in fulfilling learning preference dialogues [see Chapter 2.2], but also giving a point of reference for the students with regard to what is essentially a relatively complicated area of study. The ability is created from them to return to the material in order to update and revise the knowledge that has been presented to them. Each of the CuDAS patches is accompanied by a document entitled, for example *Supporting Material for Tutorial 1* which develops the understanding of the topic, providing historical and musical examples and explaining the technical and scientific language involved. This material can be delivered by the teacher in any number of ways; as a handout, a lecture, a discussion, or even as work to be investigated outside of the classroom. The versatility of these documents is designed to appeal to teachers and learners together, allowing for as wide a range of teaching and learning styles as possible, whilst ensuring the curriculum is sufficiently supported to certify that the key areas of learning are covered in adequate detail and accuracy.

There is further written material in every part of the software. Each sub-area of each of the four tutorials opens a green box that outlines the necessary operating instructions and learning areas [see *fig. 4.2*, right]. On occasions the text in these boxes offer open-ended questions, as can be seen in the example shown. These offer the students a chance to question their actions when performing the tasks involved in each tutorial. They also serve to highlight the pedagogical nature of each of the processes that require manipulation programmed into CuDAS. The answers to these questions are always located in the tutorial, either through the patch itself or in the supporting material. Needless to say, it is also possible for these questions to be answered verbally by the teacher.

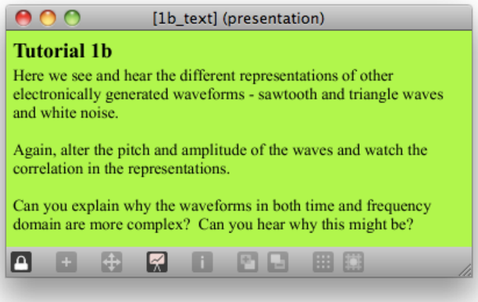
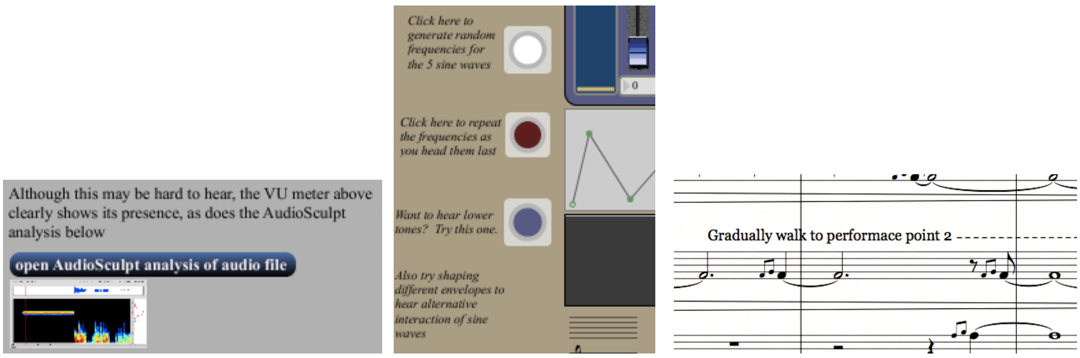


Fig 4.2 An example of a tutorial instruction pop-up window.

There are also examples of instructional and pedagogic text contained within the tutorial patches, sound file patches and composition patches that offer further learning opportunities. An instance from each of these three areas is included below [*fig. 4.3*].



a) b) c)

Fig. 4.3 Use of text within; a) the sound file patches, b) the tutorial patches, c) the composition patches

Aural instruction forms the second area of pedagogic principle in CuDAS and runs throughout the software. This area is crucial for the success of the software as it is clear that if instructing the basics of audio concepts and synthesis, one must address the sounds that are made as a result of such practices. This is a view that is also held by Clarke, who writes, "Why do we so often turn exclusively to text and visual representations when what we are really concerned about is sound?"[147] CuDAS conforms to this thinking in the way that each of the tutorials within the software functions through the manipulation of sound. Without this key factor the programme would be redundant and as such it forms the core of the whole instructional material. More can be found on the individual nature of these tutorials in Appendix 1.

Alongside each of the topics addressed through the four tutorials, there are also contained further learning resources in the area marked 'sound files' [see *fig. 4.4*, below].

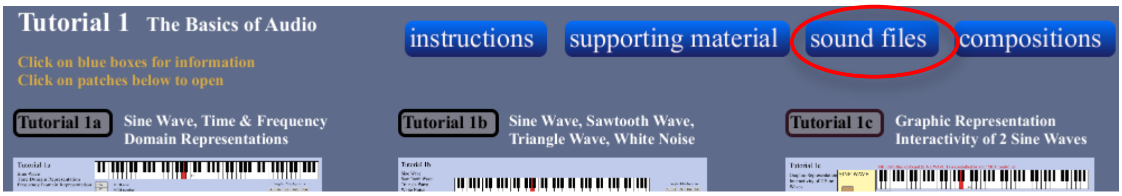


Fig. 4.4 The location for the 'sound files' for each of the CuDAS Tutorials, again highlighted in red.

As before, a single click will open a subpatch that contains various examples that have been made reference to in the written material. An example of how these 'sound file' patches appear to the user is included below [*fig. 4.5*]. These are different depending on the topic, but all have a common link in that specific examples have been created to enable the student to hear the process in question. Alongside these examples are other audio excerpts taken from recordings made of the techniques by various artists from various genres of music. These are all limited to 20 seconds in order not to infringe on copyright, as discussed further in Chapter 4.3. However, despite the limitations outlined previously, even these small inclusions aid a great deal in the understanding of the topics in question. They offer the student the chance to hear examples from throughout the history of music where such techniques are employed, thus increasing the contextual awareness of the learner whilst simultaneously contributing to a sense of relevance to the study of such fields contained within CuDAS. Their inclusion also negates the problematic nature of referring to seminal works without the learner being able to contextualise them. As Clarke notes, "Written texts may direct students to scores or CDs, but for many students this is not as stimulating as experiencing the music for themselves, especially engaging with it interactively."[148]

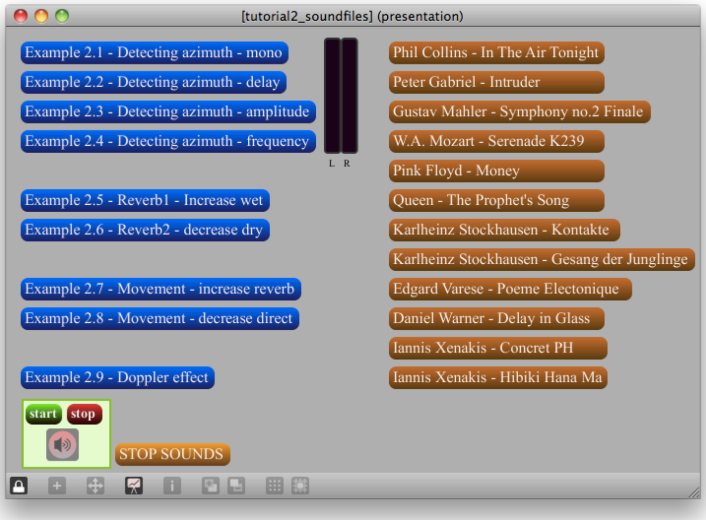


Fig 4.5 An example of the 'sound file' subpatches showing self-generated examples on the left and recorded works from various genres on the right.

There is also a strong argument to be made for the inclusion of these excerpts as a springboard for further learning, through the accessing of the CuDAS compositions or from further study outside of the CuDAS software. Such reading or listening around the subject area will serve to increase the student's ability to progress in his or her own learning through self-exploration of the music contained in these patches. As Steen remarks, "The enhanced responsibilities … leads virtually without exception to increased student motivation and to student growth."[149] The notion that making the student aware that learning more through research is not only a distinct possibility but that it is to be actively encouraged is a very important pedagogical message that is imparted at this stage and consistently runs through CuDAS.

Finally, one can see addressed the final strand of pedagogic strategy in CuDAS, which is that of an interactive learning tool. As previously mentioned, text only goes so far in the explanation of advanced audio concepts. Diagrams and labels help, but ultimately remain unmoving objects that lack the dimensionality needed to impart the necessary information. Clarke has already been cited in regard to needing to hear the sounds that accompany the text. To reiterate and to take his argument further, his belief that "Text and graphics may well have a role in analytical presentation, but only when closely allied to interaction with the sound itself,"[150] is one that holds true in the principles of pedagogy behind CuDAS. The need for a connectivity between the pupil and the learning task points to a desire for an interactive learning tool whereby the student can manipulate the data involved and in so doing both *see* and *hear* the results in a system of cause and effect. CuDAS has been programmed and designed to fulfil these needs and can be seen to be interactive on every level at every juncture within the learning process. The tutorials patches are themselves intrinsically interactive by their nature, as are the way the material of literature, sound files and compositions are presented. The reason for this approach is purely that of a pedagogic principle. This principle of interactivity or experiential learning in essence offers the opportunity to move away from the notion of working alone in a studio and returns the learning to the classroom. It also removes the traditional note taking from a lecture-style presentation or written resource and instead offers the alternative approach of exploration and interactivity with the subject matter. Wiegold notes that it is essential to realise, "The educational value of experiential learning and learning through exploration as well as definition…"[151] and indeed it is clear to see that, philosophically, his approach to this area has many reflections in the CuDAS pedagogy.

There are various other layers of pedagogic influence on the development of CuDAS. The approach to the process of patch building and composition has been targeted specifically at certain key principles of pedagogy. The first of these is the need to target a specific area of study that can be comprehensively and undeniably attained. Running alongside the notion of the physicality of doing, which enhances all pedagogic study, this intended area enables the strong model of developing certain key concepts of music. For Kodály this entails a focus on the rudiments of music and developing an understanding and appreciation of music in order for it to become a fundamental part of your being. As Choksy puts it, "Skills and concepts – the functional side of music. This is what the Kodály concept is all about."[152] Orff can also be seen to be focusing on a basic level of concepts, in his case those of integration of musical education into the standardised curriculum through movement and improvisation. In CuDAS it is also possible to recognise the targeting of certain concepts of education. The development of the key areas of understanding, notably the areas of audio concepts and synthesis with relation to the GCE Music Technology examination, form the important underlying pedagogical principle that the curriculum aid the development and understanding of the intended subject matter. Both the Kodály and Orff pedagogies deal with the efficacy of practical work and through function the development of skill based knowledge as a key concept. This principle can also be seen to have had an influence on the pedagogic design of the CuDAS curriculum.

The tools that enable the success of the pedagogy in question are also of critical importance. For Kodály these can clearly be defined as the use of the human voice through the medium of native folk song. There is a key similarity to Kodály in the way that CuDAS has been designed as a standalone piece of software. Utilising this feature of Max/MSP enables the CuDAS programme to run without the need for the purchase of any software. Therefore, like the human voice, the tools used in this pedagogic curriculum are also free and available to all, thus reducing any prohibitive factor from the cost of purchasing external software or materials. The percussion tools that Orff uses to achieve his pedagogic aims produce a further link to CuDAS in that both systems develop and create instruments specifically for the methodology. For Orff these were barred percussion instruments. For CuDAS these are a range of complex patches that enable the computer to be used as a musical instrument. It is this medium of creativity in the tools of pedagogy that links these two methodologies so closely.

As well as developing the musicality of young people, through his publications Orff also intended to provide a different approach to learning through the notion of what Kugler labels as '*building blocks*' and describes as being "small, manageable structural elements to reduce excessive demands and uncertainty in the creation of individual ideas."[153] For the Orff technique this refers to the ability to select and vary the material that would lead to imaginative teaching and learning. The level of the learner can then be taken into consideration as the material used for teaching is adapted to suit the pupil, rather than approaching the education from the opposite axis. This leads to a thorough and holistic understanding of each of the key areas of music; melody, harmony, rhythm, form, timbre and texture. The nature of small developmental learning blocks that Orff outlines in his *Schulwerk* are of particular interest to CuDAS. Initially this principle affected the software development and the way in which the Max/MSP programme requires a patch to be created entirely from the ground up, using a successive series of building blocks. Programming in this way in turn effects the learning as the approach of programming has a direct influence on the way the completed software both functions and appears. A further tangible link can also be realised through the ability in the final stages of CuDAS for the student to develop his or her own patch through the inclusion of access to unlocked and editable source code. This way of working would be new to the student, providing an alternative to the more common technological learning provided by the completed package environment of more common sequencing programmes. This is discussed in greater detail in Chapter 5.

It can also be seen that the tutorials themselves are broken down into smaller sub-patches which form a series of these more easily-accessible elements created to help with the progression of learning that avoid inhibiting creativity and that, together, combine to make a greater whole. They offer the chance to progress at a steady pace and avoid the possibility of being overwhelmed by technical programming and function language of the Max/MSP programme. This way of planning the learning follows Steen's comments that, "A sequence of musical concepts and skills becomes a tool to guide instruction in logical steps. These steps should be ordered so that achieving one objective predicts the next step."[154] It is important that the steps in question are not too large, otherwise the learning objective will fail to be achieved. The skill set needs to be fully developed before the next is introduced and both must be connected in a manageable and clear way.

This approach can be seen in all of the tutorials, but using the first as an example, one can clearly see that the building up of knowledge from sine wave to other electronically generated waves and then to audio samples as one moves through the tutorials is more easily manageable as a concept when presented over several learning blocks (see *fig. 4.6*, below). The complete tutorial would run the risk of being over complex and alienating but having seen each of the areas in isolation it is far more educationally informative.

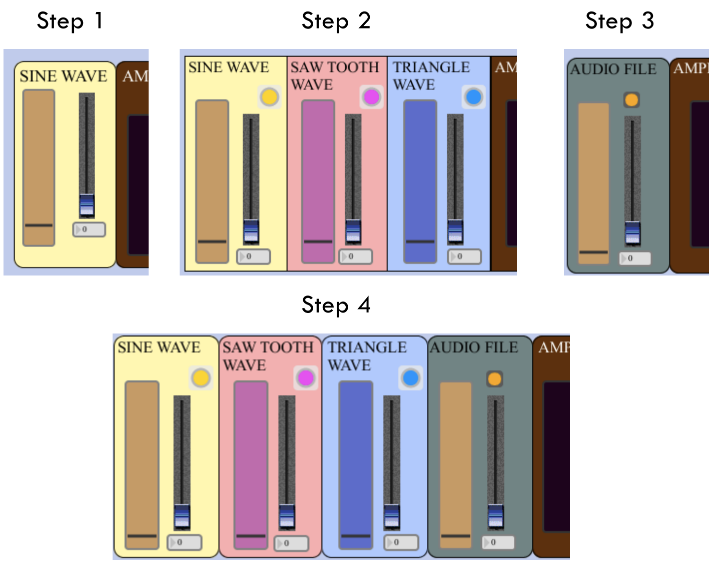


Fig. 4.6 Examples of tone generation progressively introduced in Tutorial 1.
From left to right, Tutorial 1a, Tutorial 1b, Tutorial 1e, CuDAS 1.

This approach to developmental learning also enables greater differentiation between users. This has echoes of the Orff Method's ability to involve all musicians regardless of talent or pre-developed skills. This can also be seen in CuDAS, particularly with regard to the high level of creative freedom and the ability to develop one's own choices. There are also similarities in this regard to the Wiegold method of backbones as discussed at length in the previous chapter. It can be argued that the process of a successful realisation of Wiegold's backbones lies a similarly layered approach and by building elements up stratum by stratum. He explains this himself when he comments it is more successful if one ensures an approach of "Banking everything for the next thing to appear on a solid ground."[155] He describes this further; "If you have eight people all have a go at something it may be less strong than if you get the bass line and then get the drone and then get a melodic fragment."[156] This is very much the framework that is attached to the process of CuDAS whereby a layered approach results in a stronger holistic residual learning experience.

There is further differentiation catered for with the inclusion of the 'Learn More' subpatch [see *fig. 4.7*, below]. This includes extra learning topics, further interactive exercises, web links and the chance to learn more about Max/MSP and to implement this in a practice through the 'About Max/MSP' and 'Create Your Own' subpatches. These contain basic level programming information using Max/MSP and also instructions for where the source code as a Max/MSP patch can be located and how, as a student and novice in Max/MSP, to go about the process of programming oneself. This extension of material exists in order to stretch and challenge the most able student, but also to offer the material to the slower and less obviously gifted student but one who none-the-less has a great interest in this area. In so doing it creates the possibility for this latter kind of learner to progress in a manner that is fitting of their level of interest in their own time once the main body of CuDAS has been presented. This subpatch also caters for the weakest student, or the student who perhaps has failed to assimilate all of the information presented, by offering a re-cap of the learning topics and a chance to re-examine the supporting material.

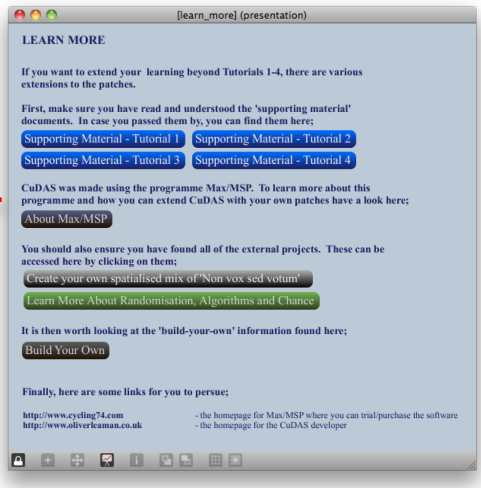


Fig. 4.7 *The 'Learn More' subpatch. Clicking on the highlighted area will open the secondary window, right.*

Alongside the development of the detailed Max/MSP patches that enable the learning of the key areas stated, the secondary area of targeted pedagogy lies within the compositions that accompany the tutorial topics. These have been specifically targeted at presenting key areas and topics that are covered within the CuDAS curriculum. The aim for each of the accompanying compositions is to provide a thorough and fully worked example of the principles of the given topic in an aesthetic context. The aim of the pieces is always to ensure that the work is not merely a demonstration, but rather a model. This is key to the pedagogic nature of the work, as a model enables a remodelling in transformation by the students whereas a demonstration merely serves its own purpose as a specific closed example. In this way they cease to become allegories or metaphors and focus instead on the substance of connection between the composed work and the tutorial topic in question. It is for this reason that the compositions that accompany the tutorials exist on at least one level as works to be manipulated and explored using the tools of the overall pedagogy, namely Max/MSP.

It can be seen that alongside the compositions that are made in this way, there are other works of acoustic composition included that explore material outside of the software Max/MSP. These are included for further interest, either on a listening level or as explorations into the properties of live acoustics and instruments. These offer the possibilities of expanded awareness rather than the central core of learning but merit their inclusion due to the very nature of the aesthetics of pedagogic composition. It is important to present a full and detailed curriculum that covers all aspects of the topics and stretches the students into thinking beyond the mundane. It is therefore logical to include material that will highlight the areas of learning. Detailed listening lists on each of the topics are included in the written supporting material for each tutorial. These contain works from throughout the historical development of electronic synthesis and techniques and as such also include works of a contemporary nature including compositions specifically aimed at this curriculum of learning.

There are various further levels of principle that shape the pedagogic approach to CuDAS. It is clear that a strong element of importance is placed on the need for the student to be creative in his or her educational training and output rather than simply learning by rote or other less dynamic methods. This is contrary to a great deal of current educational delivery as well as contemporary governmental policy where the end result is analysed through examination. This can be seen to be the case at all ages, from the governmental SATS tests through to the examinations of GCSE, AS-level and A-level. Indeed, never in the history of British education have the students sat more examinations and received more qualifications from the ages of 6 (SATS) to 18 (GCEs)[157]. This alternative approach naturally exists in places throughout educational study. The vocational aspects of any course, alongside the completion of coursework, allow for the student to be creative. However, the difference in approach to this principle behind the CuDAS pedagogy is that the key learning is undertaken through creativity. The facts are not imparted and then applied to a work in context, rather the learning is achieved through the creative manipulation of the tutorial patches and the ability to produce personalised sound as a result. In this way the curriculum drives the examination, rather than the examination driving the curriculum.

As a general principle of pedagogy it also important to consider the practicalities of course delivery and the dissemination of subject material. It is necessary to have in mind the context of the classes and how the material is to be delivered. It is therefore considered that the size of the class for the CuDAS curriculum is entirely dependant on the number of available workstations available to the group. It is intended that each child will have access to an individual DAW to enable a personalised manipulation of the patches. However, attention has been paid to the realisation that in some contexts this may not be possible due to lack of resources or over-subscription to classes. For this reason it is possible to see that the material can be worked on in pairs or trios. Stretching the learning to a group larger than this calls into question the practicalities of running a DAW. However, it can be clearly seen that group work can still be achieved through the supporting material, listening exercises and teacher or student-led discussion and feedback sessions. Despite the openness of the curriculum in this regard, there is still considered to be an optimum number of participants in the curriculum. It is suggested that 10 members of a class, each with access to their own DAW, would be most befitting of this curriculum, although greater or fewer numbers would not be substantially disruptive.

Having discussed the size and nature of classes, it is also important to consider the timescale of the curriculum. It can be seen that the Kodály and Orff have a specific ideology in relation to this matter; namely that the musical development of a human should start in infancy to enable the development through to adulthood. As Kodály says, "All reasonable pedagogy has to start from the first spontaneous utterances of the child."[158] This is a very long-term approach to pedagogy, requiring the independent methodologies to last the duration of an infant's upbringing. The nature of the CuDAS curriculum and its place within the wider GCE context has fewer long-term aims, primarily concerning itself with one academic term of the life of a 16-18 year old. This ensures a lack of disruption from other elements of the course that need to be adhered to and yet offers a prolonged approach beyond a mere workshop or singular classroom activity. This long-term approach, relative to the structure within which it finds itself, is essential to the pedagogy of CuDAS and is what stands it apart from an inspiring lecture or engaging masterclass. It offers the students a drawn-out approach to the study of this area that can then in turn be applied to any future learning and development that extends beyond the curriculum into Higher Education.

The relationship between educator and learner is a further extension to the pedagogic principles of CuDAS. It is a strongly held belief in this pedagogy that the output of work is strongly linked to the working relationship between teacher and pupil. For the purposes of

CuDAS this should be relaxed, fluid and informal aiding the discovery of new material and the possibilities open to each individual learner. In terms of current examination practices it can be argued that an emphasis is placed on imparting the same knowledge to each student and that moulding each student into a very specific template offers the greatest chance of attaining the most successful results. CuDAS has a principle contrary to this whereby the learning is centred on the needs of the individual and that it is possible for each learner to find his or her own way through the learning process. To this end, the instructor should be well informed and knowledgeable in his or her subject area whilst retaining an open interest in the discovery of new techniques and sound worlds. The technology used should not be a barrier between the two parties but rather act as a democratic leveller; enabling new and unexplored ways of communicating creative principles alongside factually based material. Further to this, CuDAS enables a bridge between the student and teacher through the application of interactive design and the combination of visual and aural to increase learning with the message of Steen to the forefront when she comments that the most productive transference and acquisition of knowledge occurs when such a model is applied; "Learning results when the teacher, student and music interact in the classroom."[159]

The methodology of using a computer as opposed to a traditional musical instrument also contributes specific pedagogic implications. The way in which a student has a different working relationship with a computer rather than with pen and paper has been a contributing factor to the presentation of all materials within each tutorial to be contained within one easily controlled application built from a larger collection of Max/MSP patches and other self-generated PDF and AIFF files. Combined with this experience is the nature of electronic music in balance with acoustic timbres that aid to break down the barriers of stylistic labelling. The two alternative timbres are dealt with in conjunction with one another to underline the principle that both are of equal interest in the study of acoustic principles and synthesis. All of this combines to further underline the development of CuDAS as a tool for the encouragement of self-learning, moving away from the authoritative lecture or teacher-led discussion.

The core subject area that is dealt with in the CuDAS curriculum is perhaps not what one might initially take as a regular area to be covered in the context of a music education. By its very nature, the area of study is that of scientific acoustic principles as opposed to the more traditional aspects of harmony, rhythm, melody and form and structure. However, these more traditional topics remain important in the musical development of the students at this level and therefore the principle of consilience is of high significance to the development of the pedagogic philosophy. The necessary concord between the advances to a topic of different scholastic subjects, notably science and music, require that this approach is undertaken in order not to differentiate between the areas, unnecessarily separating them from each other. The two are essential in the understanding of each other and therefore this approach is of very specific significance. The CuDAS curriculum largely negates the need to independently spend time learning the principles of acoustics when dealing with, say, frequency spectrum analysis. The material in Tutorial 1 can be shown to include this in a substantive and musical way with clear correlations between the two differing approaches to the field of the production of sound.

Naturally, in devising a new methodology, one must always question whether the principles come together to form the desired result. For Wiegold this was always a challenge due largely to the perception of the improvised sections of his work. It is interesting to question whether his work at the Guildhall was his own music being performed in his own way, or a specific and clearly identifiable pedagogy. In many ways these issues remained unresolved at the time as, in a sense, the creative work of that period was both of the two arguments. However, in hindsight it can be argued to be a highly effective pedagogical method because the backbone method has clear pedagogic validity as discussed in the previous chapter. It can also be argued that the same applies for the CuDAS project. The methodology extends beyond a composers' creation that is merely dipped into, where certain elements are used by others as they see fit. Rather it is designed and therefore retains the overriding strength of a shareable and transferable pedagogy through the identifiable psychology of the principles outlined. In this way it becomes possible for other teachers to use this model as a way of injecting their own creativity into the learning areas. CuDAS can be retained as it is, forming a complete and holistic curriculum, but it is also possible to see that other teachers can extend the learning to suit the situation in which they find themselves, inspiring their own students through the use of their own creativity.

4.3 Composition as Pedagogy

There is an interesting philosophical question at present as to whether the creation of the software and the complex design and building of the CuDAS patches themselves should be regarded as composition rather than sound design or programming. There is a tendency in current electronic sound generation to view the technology as the creator of the art form, particularly in installation art. Programmers are becoming increasingly keen to present their patch as the finished work, with performance of the patch being a less concrete entity. This can be seen in the examples of Wessel and particularly Coleman discussed in greater detail in Chapter 5.3. However, composition in relation to CuDAS does not follow this model and as such can be viewed as being a structured exercise or piece that is intended to have a certain effect on the curriculum at the stated point. This is to say that composition in CuDAS is used entirely and exclusively as a pedagogic tool.

One of the key areas of CuDAS that generates an innovative and stimulating curriculum is the inclusion of compositions created specifically to enhance the learning and therefore the pedagogic material of the curriculum as a whole. This material was deemed to be central to the learning for various reasons. The principle of these was the opportunity that including these works allowed for an improved philosophy of learning. It is a firm belief that students will respond positively to creative input from the teacher and in return invest more of their own productivity into the learning cycle. This is an educational argument that has been recognised by others, such as Steen who contends that, "If we model and then expect artistic responses, we discover that children can perform in expressive, musical ways."[160] This sense of expectation is more fruitfully rewarded if the student experiences the learning from a creative viewpoint from the very outset of the curriculum. They instantly obtain a sense of inclusion and as a result are more likely to participate in the creative process themselves. Steen argues this point further when she says, "Students … acquire curiosity because they are encouraged to experiment as composers do."[161]

Using compositions also help the student to realise the potential of the experiments they are completing. For this reason, each of the tutorials is accompanied by a short electronic work made entirely using the tutorial patch that it relates to. These studies, called simply CuDAS1, CuDAS2, CuDAS3 and CuDAS4, propagate a clear awareness in the student of the potential of the tutorial patches. They serve to act in dual existence as smaller pieces for the deconstruction of topic information as well as larger statements of possibility. Once students have heard the works, they are in turn inspired to create such music themselves. It is then made possible to retain the work the user creates by including a 'record' facility in the playback window. The student is therefore, through the use of composition, encouraged to develop his or her own experimentation and creativity in this field.

There are also included several larger works that offer the ability to show the potential for an aesthetic realisation of the techniques described in an acoustic environment. The aim of these pieces and the educational message they carry is that through the simple techniques learned about in CuDAS, it is possible to apply this knowledge to the art of composition and in so doing create music that is both challenging and complete. These works include the pieces 'Harmonium', 'Non Vox Sed Votum', 'SubSyn' and 'Dissimiletude'. In all of these examples it is important to note that these works have been composed specifically with the intention of imparting an educational message. In the case of 'Harmonium' this would be that it is possible to create an artistic and challenging piece of music using only notes from the harmonic series. In 'Non Vox Sed Votum' the pedagogical message is that in acoustic music the boundaries of spatialisation can be broken down and that by returning the work to the electronic domain through the ability to mix a new version, the possibilities of the learned areas of spatialisation are limited only by one's own creativity.

The inclusion of both these shorter and larger works was also made necessary by the practicalities of presenting material in the inclusive way that CuDAS promotes. The nature of copyright of full works meant that only 20-second examples of key works or examples from the canon of classical, popular and electronic works could be included in the CuDAS software. Although interesting as starting points, these brief references often do not do justice to the techniques contained within. There is an implicit suggestion that the learner should investigate these works further and in full. However, it is often the case that once out of a particular learning environment a student may well lack the motivation, desire or indeed time to carry out these tasks. Most of these electronic compositions are not freely available on streaming websites such as Last.fm or Spotify and as a result the expectation on the student to acquire and listen to all of the works would be demanding a major investment of capital. The inclusion of my own compositions ensured that the topics presented could be heard in the context of a full work that makes aesthetic use of the subject matter at hand. Further to this, composing the material explicitly for CuDAS ensures that the message of learning is direct and targeted. Using spatialisation as an example, it could be argued that the examples of the techniques available that are included from the western classical tradition only go so far. Composing with a specific educational point in mind ensures that the technique can be taken to its full conclusion, making the practice of the method more directed and therefore more convincing.

In the pedagogies discussed in Chapter 3 it is clear that the concept of the traditional notated score plays a significant role in the material developed for learning. For Orff and Kodály the score was at the very core of their methodology as it was through this medium that developmental learning could be most effectively disseminated. For both of these composers the score also offers a branching out beyond the material that is included, either from development through improvisation or through the inclusion of movement devised from the substance of notation. For Wiegold the score is of a similar significance as it offers through backbones the opportunity to generate the principles of the *third way*.

When dealing with electronic compositions of the nature found in CuDAS it is arguably commonplace for the traditional notated score to become redundant, either replaced by a graphic score or omitted altogether. This is certainly the case in a great many of the works from the genre of electronic composition included as 20-second sound file examples in CuDAS. There is a certain efficacy in this principle when applied to CuDAS as it enables the user to concentrate on the manipulation of dials and faders and as such concentrate on the *sound* output. It can be argued in this way that notation may indeed inhibit learning as it provides a distraction away from the central core of visual and aural representations of electronic waveforms. However, the score retains an educational significance even in this field of study. A great number of students that take the GCE in Music Technology have the ability to read music and will therefore respond favourably to seeing the material in notated form as it is in this form that they are used to seeing the study of music presented. Certainly this is the case for the composition 'Harmonium' where the inclusion of the notation makes the identification of the harmonic series more distinguishable [see *fig. 4.8*] and as such the inclusion of notation of the compositions included can be seen to have an important place in the pedagogy of CuDAS.

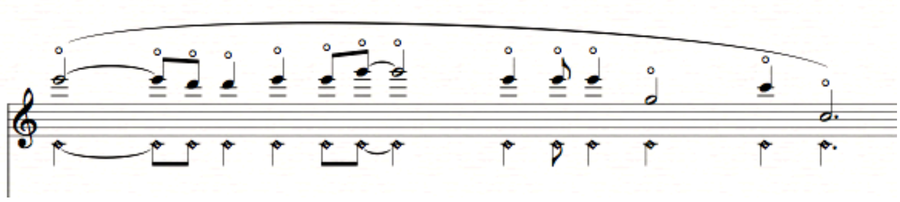


Fig. 4.8 An example from 'Harmonium' showing the clarity of identification of the harmonic series through notation in the principal flute melody.

Traditional notation is also used to aid the learning of several of the concepts covered by CuDAS. The use of the graphic notation tool in Max/MSP allows these concepts to be placed in a traditional format that the student is perhaps more familiar with. An example of this can be seen in Tutorial 4b where ring modulation is introduced. Although at this stage in the CuDAS learning the student should be familiar with frequency as a way of defining pitch, none-the-less it is still valuable to further aid the understanding through the use of notation. In this way the student can understand the effect of the synthesis through graphic representation using time and frequency domain representations and a sonogram. He or she can also hear the effect through the ability to interactively manipulate the material, but crucially also comprehend the effect by understanding the notation and therefore appreciating the musical effect in a way that will be more akin to his or her learning in music to date. An example of this principle in action is included [*fig. 4.9*] with the notational aspect highlighted in red.

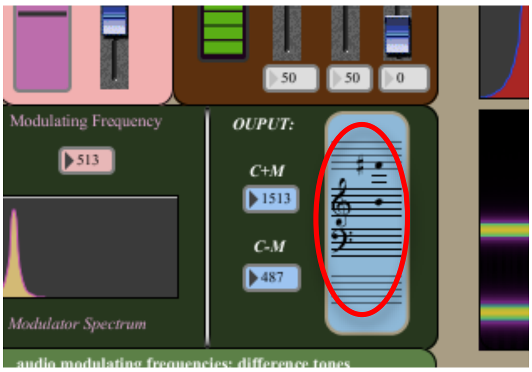


Fig. 4.9 Part of Tutorial 1d, showing notational output of RM synthesis.

However, despite the value of traditional notation, it is important to state that CuDAS is careful not to foster an over reliance on the score format. Where it is functional as part of the pedagogy it is included, but it is not included merely for the sake of it. This stance has been taken most fundamentally due to the fact that not all students enrolling on the GCE Music Technology course are fluently literate in musical notation. Despite the qualification clearly being a music course, since the new curriculum was introduced in 2008 [see Chapter 1.1], there is no requirement for the students to be able to produce scores as part of their own compositional work. Indeed it is entirely plausible for a student to achieve very highly in the course without being able to read music at all. That score reading is not essential for the qualification has been brought about largely because the type of student interested in music technology tends to come from a more popular music background where the need to read notation is reduced. Guitarists and drummers have alternative forms of notation or indeed no need for notation at all and as such these students are often weaker at reading music. Using scoring as a sole method of pedagogy would therefore be potentially alienating to such students. Neither is it true that music of this type can only be achieved through scoring. That there is the possibility for students to generate similar music and techniques with or without using scores requires the pedagogy of scoring to be discretionary. It is for these reasons that opening the available scores forms part of an option. It is possible to listen to the work without looking at the score, or to peruse the score without hearing the music. The choice is left to the learner rather than inflected upon them.

It is clear in this regard that a distinction is being made from the score as opposed to the composition. Whereas the ability to read music may lead to an interest in seeing the score, a lack of this ability will in no way undermine the pedagogic message of the compositions. It can be argued that the study of the electronic synthesis techniques covered in CuDAS leads naturally to a desire for the student to use these techniques in his or her own work. In this way one can see that the study of music leads inexorably to the logical conclusion of creativity. If this is indeed the case, then the compositions in CuDAS serve to aid this transition and successfully complete a learning cycle that will be of invaluable use to the student enrolled on the GCE Music Technology course in terms of knowledge learned, practical application of this knowledge and also improved creativity of subsequent compositional output.

Chapter 5 Cycling 74's Max/MSP as a Teaching and Learning Tool

Having discussed the principles of pedagogy and the context within which the developed interactive tool and compositions of CuDAS were made, the question must be asked as to which tools hold the most potential for the implementation of the educational work explored in the curriculum. Logic dictates that one is best served turning to computer software for the purposes of this course, as it is this area that remains the focus of practical work within the Music Technology GCE context. In order to explore the possibilities of interactivity and live sound it was therefore deemed prudent to use the programme Max/MSP to most effectively bring about the desired results as discussed in the previous two chapters due to its ability to process audio in real-time, provide graphical representation of said audio and also because of its ability to be used as a programming environment for the building of new software.

As previously mentioned in Chapter 4.1, CuDAS was initially devised as a live-performance tool to enable interaction between the performer and the patch operator. In the first instance the performer in question was either the patch operator himself or herself, or a supplementary instrumentalist. CuDAS was used in this way to present material at various performance events [see Appendix 4 – Sound File Index, as well as multimedia DVD]. It was the interest developed by the relationship and response in the triangle of performer/improviser, composer/patch operator and the possibilities created by the digital workstation itself that formed the main core of the composition. The strong elements of chance operations in the patch reflected the desire to try and create a three-way dialogue, one that would be defined in a triangle of cause and effect encapsulated in the diagram below [*fig. 5.1*].

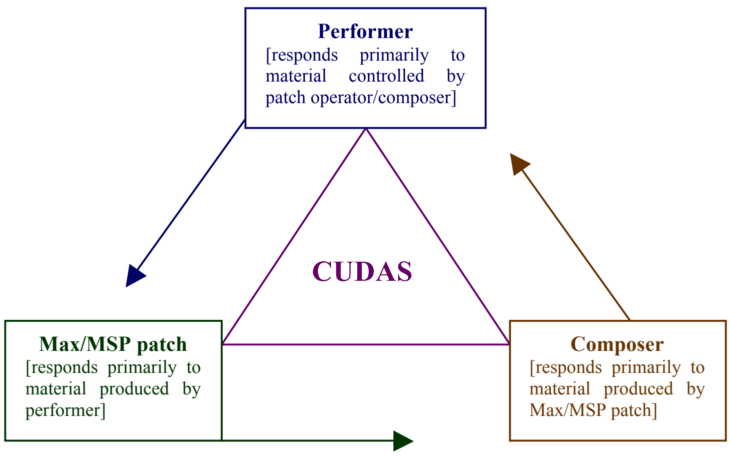


Fig. 5.1 The original concept behind CuDAS as a live performance tool

As the possibilities of this tool were explored, it became apparent that it was being used as much in the classroom as on the concert stage. It was found that students were motivated by curiosity, initially at the complex visual nature of the patch [see Appendix 1] but also importantly by the sound-world that was being produced. Using the patch in lessons started as a mere demonstration of this alternative sound-world. However, it soon became more involved as the explanations behind the individual techniques used to generate the sound manipulation were presented and explained. It was this moment that the potential for the possibility of pedagogic work through the use of both a composition and a piece of programmed software was realised.

5.1 The History of Max/MSP

In order to achieve the desired results for the live, computer-controlled and generated audio manipulation of the original CuDAS tool and then of the subsequent pedagogic work, the software used was Cycling 74's Max/MSP. This programme has become increasingly common as a graphic computer-programming environment since its creation at IRCAM, Paris in the mid 1980s. The eventual emergence of this programme from IRCAM was not a simple path. The very nature of the institution prevented initial research into the world of programming for home computers. It is important to realise that at the centre of the evolution of IRCAM lay Pierre Boulez, a composer who was fiercely against pre-programmed music in general. As David Wessel, one of the first full-time members of the IRCAM team in the late 1970s, comments, "He had a real distaste for taped music concerts- I mean, to the point where he just wouldn't tolerate it. He really wanted realtime [*sic.*] live performance … to be the key."[162]

Wessel was instrumental in convincing IRCAM to work with the new Macintosh computer, which had become available in 1984, despite hostile opposition from others at IRCAM. "The question was, should we keep these or give them back to Apple because it was considered maybe a '*cadeau enpoisone*' [*sic.*] - vulgar machines coming in, machines that people might have access to…"[163] This notion that the home computers were somehow inferior to the artistic integrity of the work at IRCAM was reflected in comments attributed to Boulez by Wessel at this time. "He said, "*Okay, look - you can keep them, but you're not going to have any money to do anything with them … There are some limitations on the resources you have, and we're not going to invest in it, so don't spend time over this.*""[164]

It was when Wessel began working with Miller S. Puckette in developing software for the Macintosh intended for use in live performance that the first seeds into Max/MSP were sown. The work they were doing increased in credibility at IRCAM and as a result they were given their own department, called the *Système Personale*. At first the work was undertaken with the

LISP (an abbreviation of List Processing) programming language. Used for artificial intelligence, it is a free-floating environment that works with parenthesis. It is possible to set a list of instructions and then give the parameters. Therefore a simple ‘2+3=?’ equation would read (+ 2 3) with the answer immediately being outputted beneath. This language can be seen in evidence in other IRCAM programmes such as Open Music (see *fig. 5.2*, right).

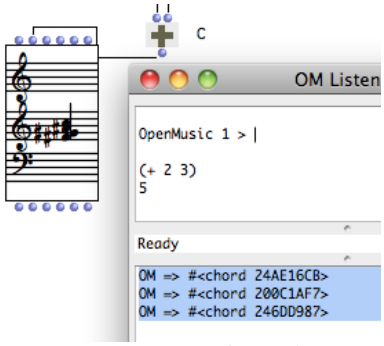


Fig 5.2 An example of LISP programming from Open Music

The problem Puckette encountered with LISP, however, was that due to the image processing nature of the language it was very slow. The initial programme, named simply ‘*Patcher*’, controlled the IRCAM machines through MIDI interfaces. When Patcher evolved into ‘*Max*’, named after Max Mathews, the pioneer of this field with his MUSIC-N developments, Puckette conceived of the programme as a MIDI controller for external sound synthesis workstations that could be used graphically and in real-time to produce interactive computer music. This development mirrors the historical context of electronic music and the move away from offline programming and batch processing to real-time sound synthesis, made possible by faster and smaller computers. These machines could be viewed as personal computers and instruments for music making for the first time. It is important to note that any computer programming prior to these developments would have involved machines that were impractical for home use due to their cost and their behemoth dimensions.

Max developed in various stages to reach the audio sample manipulator that we recognise today. The most significant of these changes occurred when Wessel invited Opcodes’s David Zicarelli to IRCAM in 1988. Puckette and Zicarelli found a common goal and as Wessel says, they “hit it off right away.”[165] This collaboration brought about the integration of DSP hardware to enable *Max/FTS* (faster than sound), the first commercial product known as *Max/Opcode* in 1990 and the release of Puckette’s *Pure Data* (PD) software, which processed audio. The latter was added to *Max* as *MSP*, commonly assumed to stand for Miller S. Puckette, but also an acronym for Max Signal Processing. This development was authored by Zicarelli which led to the current commercial distribution by his company, *Cycling ’74*. 2008 saw the release of version 5 of Max/MSP, which included further developments in the user interface and graphical display through the integration of Jitter. This was expanded upon in 2009 with the release of *Max Live*, for integration with the programme *Ableton Live*. The end result as we have it today is one of the most revolutionary programmes for digital audio manipulation. Its importance in the development of electronic music cannot be understated, Thomas Wells summing it up perfectly when he says, “To my mind, it [MSP] may even be as significant as Moog’s modular synthesizers or Pierre Schaeffer’s first musique concrete [*sic.*] pieces.”[166]

5.2 The Functioning of Max/MSP

Max/MSP is intended to be used as a dual-platform graphical patching environment, whereby it is possible, through the use of *edit* mode to link hundreds of *objects* from basic control commands such as multiplication or division, to graphic displays and audio processing (always identifiable by the inclusion of ~ at the end of the object name). The object boxes, sliders or graphic representations can be interconnected via inlets and outlets to other objects in order to build increasingly complex commands. It is also possible to develop external objects, providing a modular approach to sound synthesis. When not in *edit* mode but rather in *run* mode, the patch ceases to be modifiable, although toggles and dials can be manipulated interactively. It is these two states that make Max/MSP so appealing; it can be seen to be both a programming and a user interface, which highlights a "wonderful duality."[167] Indeed, initial reviews of the software were very open to its versatility and the endless possibilities for creativity that it opened up. In a 1991 review in Keyboard Magazine, Cater Scholz noted that "…it may not be an unforgivable exaggeration to say that MAX is limited only by your imagination."[168]

Max/MSP can be daunting to the new user at first, especially given the alternative look to the graphic display that is quite unlike the design of other music production and notation software that the student may be more familiar with. When one also considers the soon-learned realisation that the creative possibilities are unbounded it is easy to see how a student can be overwhelmed when first approaching the programme. Max/MSP does provide support in this area in the form of a series of in-depth tutorials presented in both patch and PDF format in both the full software and the download of the 30-day trial version. This material can help with the acquiring of a familiarisation of the software. Indeed it could be argued as essential to encourage initial use of the programme to centre on this documentation as contained within are a whole host of small and structured tutorials that are perhaps the best way to become familiar

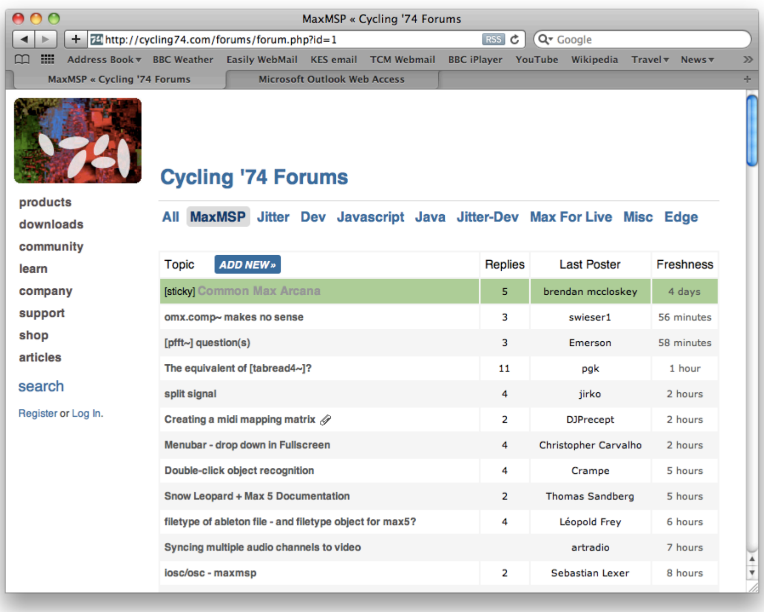


Fig. 5.3 The Cycling '74 Max/MSP Forum website

with and to learn the endless possibilities that the programme offers.

Further support to the user is available through the use of the online forum at the manufactures own website[169] [see *fig. 5.3*, above]. This forum is particularly useful as it contains informed discussions on the problematic nature of the steep learning curve of the patching environment. Alongside this, it is also possible to gain access to the online sharing of patches made possible by the 'New from Clipboard' function that will translate seemingly nonsense jargon text as found on the website into a workable and understandable patch at the click of a button. An example is included below of both text format and realised patch [*fig. 5.4*].

----------begin_max5_patcher----------
662.3ocyVssiaBCD8YxWQDu1TDl.AnppR86XUUkAbHtArQFiZZWs+601byFB
qHQa5t4gINismamyLNOuwxNgdAUau8KaeZqk0yarrTpjJr59skcI7RZArVcL
aB52zjeYuqcKN5BWo9Sa850cjR303+hj5AtNtcpoM7BDm+mJTq6rwDwU+Q2t
I4ozBJqcKf3RlhgyUwP0HBGxwTxOYnTd6MjtwTLZYX54bFsgjIOZezn4MWmH
4Mh7kxPfo+v4DpvME3zy5WuBxSOgI4Zgv9XomObPJ264DHrSzBAttkvpvxVT
S+LPuBRfkpBk82YXXQ+NmvYYHi6KQ.ijwnPnmJjlRLQ.AJbzaTYKvnzBzBfi
vTU.3JU8xlMRwtURRRZ3bQZtDxm.I4ZPeAlbdJ5KviXWP7AUdzsROYL3KtNw
f8dJTb9hvf2bxysRJ.JRgmau7lHEQKi8GWYSiAxCdUjWpBSPFE2vgR4jEJeb
GziRTcMLGMaHx0Gg.bBhC.Qgc6kyfYXDgqWHlwvrWhnDcP7Ib2UW8HlybqTE
e26e9gm+6v.jt5q2XAtqlN90Da7.l2HrZBhsF1yoYoaTnaPT6K.yVoG4W88q
cSGlwY35TXQal3Du3qatN6i72C70W8H3eh3wrWNXmgT2mBjoF0ToecAfiKaJ
UE4uRnDz25KxoPhfBKxczJn6BvZAyrXiPrupQH7dlY5MLyLgxxPLiJfJ06ES
.3pFwyVyh9+CcSfA54D7JpsMxSJ8lvQDmUT+a4ZCFXx7tWy8ZMhdCoJqDxml
7Wq0TYHa4aES96iJDUp2resl1vR6ac5eXa6X7jgp4Xx.p9z3HMsCMudutjsD
mUQE8qcg5BOZs5HeMAdzGv.eR075QN3gG3he7xl+AnmdSaO
-----------end_max5_patcher-----------

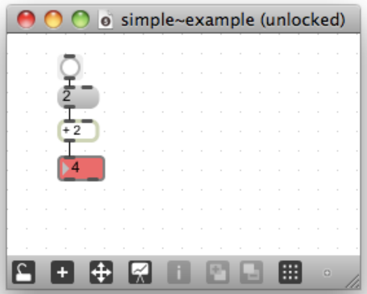


Fig. 5.4 A very simple patch in text format (left) and patching mode (right)

A further recent addition to the continuing of the success of the Max/MSP programme is the ability to remove the arguably off-putting and prohibitive sight of complicated programming by hiding away unnecessary information through the use of *Presentation Mode* in order to avoid obstructing the pedagogic message. The student is then provided with the opportunity to investigate the detailed programming in *Patching Mode* should they so wish to do so. This offers the possibility of dissemination of information to the stronger student that does not necessarily encumber those who are not as advanced in their abilities in this area. This differentiation is essential to any curriculum model as discussed in Chapters 1 and 2.

When using Max/MSP as a programming tool there is also the extremely useful function of being able to save your work as a Collective or an Application. Both of these enable the patch that has been built to run in a non-editable mode outside of the software itself. Collectives require Max/MSP runtime, a downloadable piece of free software from the Cycling '74 website. Applications run entirely as standalone software, which only needs to be authenticated by the user, in the same way as the installation of any other piece of software, in order to function. In this way, CuDAS becomes a free instrument, akin in importance of universality to the human voice for Kodåly.

5.3 Current Pedagogy using Max/MSP

We have already discussed pedagogy in connection with composers and their specific methodologies. However, it is also apposite to look at this area in relation to software development specifically for the instruction of the subject areas covered by CuDAS. Due to the file-sharing nature of the software it is possible to perform an extensive search in cyberspace and in doing so realise relatively quickly that the there remains very little pedagogical work specifically designed using the Max/MSP platform. The programming language is used primarily for studio-based or live electronic composition of an individual nature or used to teach modules about the programme itself rather than any other specific skill-based knowledge set. However, there are a few notable pedagogues involved in the use of Max/MSP. The first important contributor to this field is David Wessel.

Wessel came from an educational background having been appointed head of the pedagogy department at IRCAM in 1979. His remit as he saw it was "to be the sort of connective tissue between the scientific world and the musical world."[170] As well as working at IRCAM for a decade, where, as discussed in Chapter 5.1, he set up the department where Miller Puckette first began working on developing Max for the Macintosh platform, Wessel has also had a major influence on the way Max/MSP has been educated. In his role as Professor of Music at the University of California in Berkeley, Wessel has been responsible for the development of a number of Max/MSP-based projects, which he has subsequently made freely available. It is in his role as director of CNMAT (Center for New Music and Audio Technologies) that this work has been most noticeably disseminated.

When he first started working with the programme he immediately realised its potential; "I was really enthusiastic about it [patcher/max] and I started teaching it right away even though I didn't really have a computer lab when I came for my first year here."[171] He realised that Max would be able to appeal directly to the aesthetic principle he held that music should contain a channel of communication, or as he puts it himself, "that high degree of interactivity in music, in which people perform together and kind of have a discourse of some kind. I always thought that computers ought to be involved in something like that."[172]

Fig. 5.5 David Wessel demonstrating 'SLABS', one of his interactive instruments.

The projects Wessel has used with his classes mainly involve live, interactive performance tools.[173] He chooses to use Max/MSP for the building of such implements in the most part because, "the software has features that allow me to make new combinations of the material that I wouldn't normally think of." This leads to the ability for him to "build this whole highly interactive reactive system and work with it, evolving it as I go."[174] For Wessel, Max/MSP is clearly the perfect platform with which to achieve his aims. As he says, "Max is just the best thing. I look out there and ask what else there is and … there isn't anything."[175]

The American artist Chris Coleman is has also made a major contribution in the development of education of Max/MSP. His main contribution to the development of software has come with the design of *Maxuino*, a collaborative open source project which allows Max/MSP to communicate with the Arduino microcontroller board, enabling reading and writing of digital pins and sensors [see *fig. 5.6*]. It has proved incredibly popular for multimedia and visual artists. As he says himself, "The last major upgrade is in pretty wide use; it has had over 4500 downloads from 52 countries."[176]

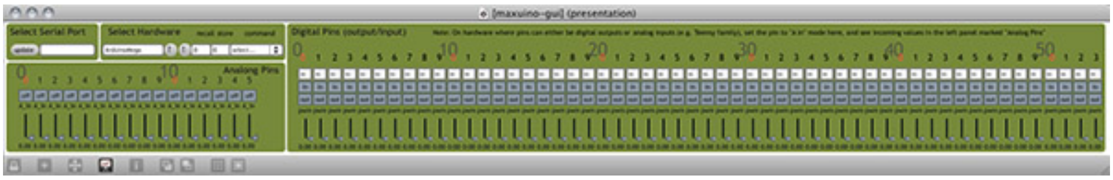


Fig. 5.6 The Maxuino user interface

What is interesting in this development is that the tool is in itself useful for educators. Coleman sates that, "I get teachers in Mexico and the Netherlands that are teaching classes with it, it's very popular in Japan."[177] Coleman himself currently teaches at Denver University and it was during the development of his teaching that he found himself using Max/MSP to aid in course implementation through the building of software tools. His reasons for doings so are clear; "If you are teaching a complex technical course in 10 weeks, you have to make things easier. And so I ended up coding a lot of different tools to make the transition into things very easy."[178] Having thought programming was not a world he wanted to inhabit, he soon found that Max/MSP altered his perspective. As he comments, "it was so easy to use it – so easy to make the necessary adjustments – and to use Max to do translations in a way that was really powerful to me."[179] He extends these thoughts further when he says, "I was introduced to the Max/MSP/Jitter world, and realized that … I could make exactly the tool I wanted, and I wouldn't have to keep messing around with these other tools that I didn't quite understand or do quite what I wanted."[180] This implies that the ease of use and final outcome were far more preferable than any alternative programming language that was available to him.

Educationally, Coleman finds that the use of Max/MSP enables him to engage students with greater ease and with far more effectiveness. As he says, "I can get a student up and running, and making beautiful things pretty much instantly. It's very powerful, and it gets them interested … really quickly."[181] It is because of this that he has witnessed the educational value of the software. He recalls an occasion where after just two days of Max/MSP instruction, he "watched someone that wasn't even a digital media student – someone that wasn't even that technically engaged – instantly pick up the mindset and understand the possibilities of what to do with it."[182] Further, he comments that generally the software provides an invaluable source of possibilities. "It's just brilliant to have a tool like Max/MSP, where you can finesse things so easily."[183]

Educationally interesting though these two examples are, Wessel and Coleman are not directly involved in the education of audio concepts and synthesis. Rather, they tend to use the software to develop interactive tools or instruments for performance art. Allied to this is the notion that Max/MSP in education tends to focus on the learning of the programme itself. The above-mentioned Cycling '74 community is an excellent source of information on the programme and from this source one can also see a large amount of educational work being undertaken *in* the field of Max/MSP, but very little *with* Max/MSP. That is to say that there are tools for increasing understanding in the use of Max/MSP through the creation of self-penned patches designed to make the learning process of the patching environment more progressive, detailed and targeted than the Tutorials provided in the documentation folder of the software. One such author is Mark Cetilia, who makes his course content and all patches that relate to it available online.[184] However, these tools, although excellent, are largely in existence to guide the student through the functionality of Max/MSP rather than using it as a pedagogic tool in itself.

There are some examples of patches freely available online which extend beyond this to make use of graphic displays to show synthesis and audio techniques. However, they are all similarly connected in that they do not offer any educationally instructive material. They are functional exercises in theoretical issues but are not designed with any pedagogic purpose and are as such limiting in their educational use. Included are two examples of this, both being patches that show graphic representations of differing wave shapes. The first, by Stefan Tiedje [see *fig. 5.7*], is made over complicated due to the showing of all patch cords and workings within the patch. This is not a criticism of the patch itself, which works very well. More it is to highlight that this particular patch is not designed to be user friendly to the beginner in this field and as such contains little of pedagogic value.

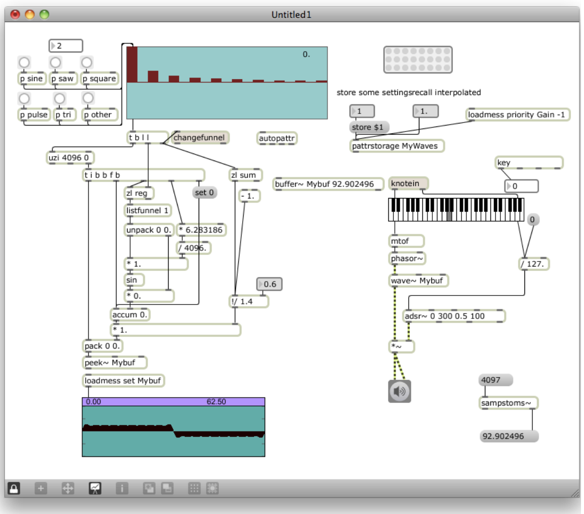


Fig. 5.7 Stefan Tieje's patch

Slightly more approachable is Chris Muir's patch 'PartialWorkshop'. This is rather similar in produced result to Tiedje's but has a far superior user interface and is as a result far more easy to use and to understand, especially to a novice. However, its educational value is limited as the differing wave shapes that are produced are at no point explained. One can also see from the screenshot in *fig. 5.8* that the values on the graphical displays have not been set to most effectively maximise the function being performed. Most of the harmonics in the triangle wave being sounded in this example are too low in amplitude to register on the harmonic domain spectrum.

Fig. 5.8 Chris Muir's 'PartialWorkshop'

One can see from all of these examples that educational projects and topics that use Max/MSP are either addressing differing subject material to CuDAS or that the pedagogic message is not consistent with the aims and needs of CuDAS. Arguably the work that comes closest to fulfilling both of these needs has been that of Michael Clarke, who over the last 18 years has been developing pedagogic software at the University of Huddersfield. During this period he has worked on four main projects, each of which has at the centre of its development the aim to offer students "the opportunity to engage with music as sound not just as text on the page, and for this engagement to be interactive."[185] Clarke approaches this interactive learning through the encouragement of creativity, commenting that the software he builds is done so, "to encourage a creative approach to the use of technology in music."[186]

The first piece of software to achieve this was developed in the early 1990s and named '*SYnthia*' (an acronym for Synthesis Instruction Aid). Although it didn't use Max/MSP as its programming language, it none-the-less represents an important stage in the development of later software and therefore plays a large role in Clarke's subsequent development of software. As a result it is important to look at it in more detail. Targeted at university music students, the software was intended to break down barriers that existed between the students and their ability to use the techniques available to them through the use of technology. Alongside this the software was designed to aid in the process of creative interaction with the technology of synthesis from a position of understanding. This would in turn lead to the students' creativity being "idiomatic and their creative invention [would] originate from the nature of the technology they were using."[187] The ultimate aim was to "bring the theory alive, make it relevant to the students' musical aspirations, and, at least in the more advanced exercises, make a link between theory and creative work."[188]

The SYnthia project dates from a time before digital technology was such a common feature of our everyday lives and as such requires what now seems like outdated technology in order to function. The programme was made with HyperCard and HyperMIDI using a Macintosh computer that interacted directly with a Yamaha SY99. This in itself is not obviously directly related to Max/MSP. However, the work Clarke undertook in this area was important for two main reasons; firstly it is an early example of pedagogic programming and although the platform used to make the software was an alternative one, many of the underlying principles apply to both. Secondly, the work that Clarke undertook on SYnthia was to have a direct influence on the way he approached the Max/MSP programming of later projects. The way in which the material was presented in four progressively structured modules with subdivided pages was retained for the programming of future research into this area. Alongside this, the graphical layout can be seen to be similar, with a combining of text, diagrams and mouse control that interact together. An example of this can be seen below (*fig. 5.9*)

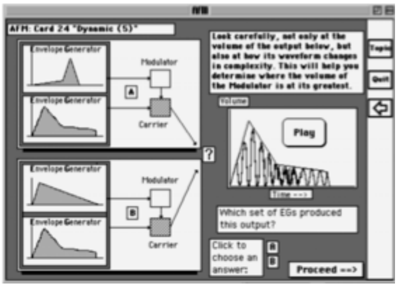


Fig. 5.9 A screenshot from SYnthia

SYnthia was used by students at Huddersfield University and in Germany, New Zealand and beyond over its lifetime of ten years, in which time Clarke noticed that, "It significantly improved their knowledge of synthesis techniques and their creative application."[189] Its success led Clarke to develop '*Calma*' (Computer Assisted Learning for Musical Awareness), which aimed to address the shortcomings of University teaching in the subject of aural. Clarke, working alongside George Pratt, attempted to enhance the curriculum in this field through the use of computer technology. There were several important factors that this work developed, including moving away from the notion of the computer workstation in isolation to include more traditional forms of aural learning. A website for the sharing of resource and creation of feedback was created and the ability to read from CD to avoid copyright and yet preserve the integrity of genuine musical examples allowed for a far more satisfactory final product.

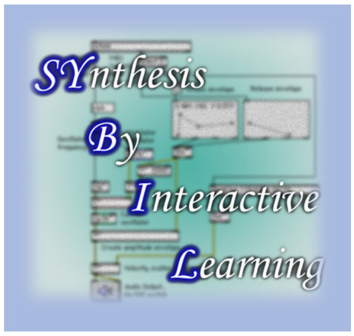


Fig. 5.10 Sybil, front page

These principles and they way in which the whole project was approached were to have their own direct input into the software that was designed to replace SYnthia. In the ten years that had elapsed since the first appearance of this software, the world of computer music technology had moved on and as a result the materials used for the instructional learning were deemed to be out of date. Clarke was aware that there was an "opening up of new possibilities for pedagogic software."[190] Alongside this, frustrations with the limitations of having to own a Yamaha SY99 in order to work the software were keenly felt and the experiences from the original project and the intervening development of Calma offered the chance to fulfil this area of learning in a more satisfactory manner that was more in tune with a new type of student more at ease with a computer workstation. Working with Ashley Watkins, Mathew Adkins and Mark Bokowiec, Clarke developed a new software package in the early 2000s labeled '*Sybil*' (Synthesis by Interactive Learning) [see *fig. 5.10*, above].

The principle difference in operation to SYnthia was that the computer itself now performed the generation of audio, eliminating the need for an external synthesizer or sound module. This was made possible by using the Max/MSP platform to programme the software. Clarke's reasons for doing this were clearly due to the ease of function and the extended possibilities available to him through the use of this programme. "Max/MSP made programming of many aspects of *Sybil* much easier than had been the case with *SYnthia*."[191] He was also attracted to the ability to 'see' as well as hear in real time the audio with the use of waveforms and spectra. Added to this was the ease with which to apply a user-friendly interface. This extended still further the interactivity of text, audio and mouse control that first featured in SYnthia. An example of how this interface looks to the user can be seen to the left [*fig. 5.11*].

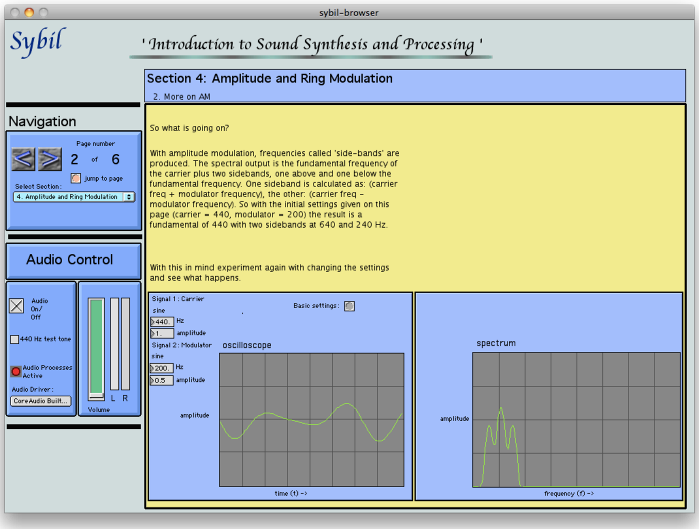


Fig. 5.11 *One of the Sybil modules, showing interaction of text, audio, mouse control and visual display*

Clarke's aim in producing Sybil was once more to appeal to the creativity in his students and increase their accessibility to the knowledge and therefore sound world of synthesis. "We wanted to link the technical and the creative, and we wanted to make the technology widely accessible to students whatever their previous technical experience."[192] Max/MSP allowed this to be achieved through its ability to be transferred and used across the platforms of Mac OS9, OSX and Windows XP. Clarke also cites the attractive nature of the ability to generate standalone collectives or applications, ensuring that "students who have their own machines can run the software without any additional cost."[193]

The use of Max/MSP for creating Sybil also allowed Clarke to develop his desire for an online community of users that he first attempted with Calma. The large number of users of Max/MSP meant that Clarke was able to encourage the use of his materials. From this extended the possibility of allowing Sybil to be extended and adapted by others. As Clarke comments, "If the source code is made available, *Sybil* can also be easily adapted or extended by anyone with knowledge of programming in Max/MSP."[194] This aim of working towards "the development of an international shared library of *Sybil* modules"[195] was further enhanced by a sub-area within the Sybil modules of a 'build-your-own' section, with detailed instructions on how to create other Sybil modules and interlink them with the main programme. It is for all of these reasons discussed that Clarke himself stated in 2006, "*Sybil* can be seen as a culmination of our research in this field to date."[196] It can also be argued that this culmination would not have been possible without the use of Max/MSP.

Since the completion of Sybil Clarke has been working with Max/MSP to generate tools in interactive aural analysis. In 2006 he developed the Sybil browser to include a thorough investigation of Jonathan Harvey's *Mortuos Plango, Vivos Voco*. The work on Calma was particularly useful in this respect as it was now possible for Clarke to include a CD playback function that could jump to precise moments of the performance and as such negate any copyright issues. Sybil was used to create a series of 15 interactive exercises that explore the synthesis techniques used in this work. This is then completed with a paradigmatic analysis of the whole work, which in itself is interactive [see *fig. 5.12*].

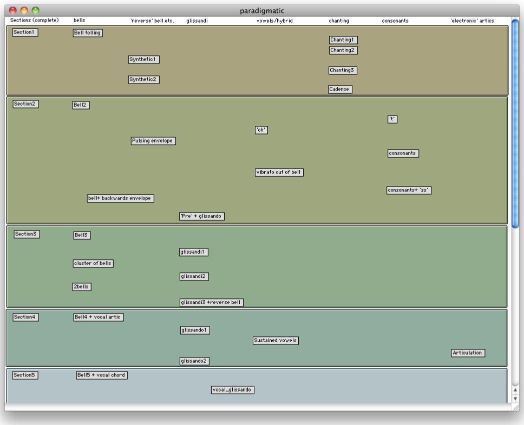


Fig. 5.12 The Paradigmatic analysis of Jonathan Harvey's Mortuos Plango, Vivos Voco

This work was then followed in 2008 by analysis of the 1987 work *Wind Chimes* by Denis Smalley. A similar approach was used but with the added possibilities made available by the adoption of *Jitter* to the Max/MSP interface. The success of these extensions can be measured in the adoption into mainstream HE teaching where this work sits as one of importance in synthesis analysis. The ease and clarity with which the topics are presented allow for an interactive pedagogic exercise of first-rate quality, which would not have been possible without the programming undertaken in Max/MSP.

Clarke continues to use Max/MSP for the development of pedagogic software. In July 2010 he previewed and demonstrated the project he had undertaken with Amanda Bayley from the University of Wolverhampton into the building of a multimedia interactive DVD generated from researching the processes of composition, rehearsal and performance of Michael Finnissy's Second String Quartet. The venture, made possible through the funding of the PALATINE (Performing Arts Learning and Teaching Innovation Network) organisation's Development Award, sought to create connections between compositional and analytical thinking as a methodology 'in action', based upon the creative and interpretative processes that evolved from Finnissy, the Kreutzer Quartet and interaction between the two. What was of particular pedagogic interest in this project was the inclusion of the software DVD, designed as an instructive tool to aid teaching and research in areas of composition, performance and analysis and that promoted interaction between these areas. The feedback received at the workshop that was held at the home institution of Huddersfield University was assimilated and then absorbed in order to contribute towards refining the final DVD which is due to be sent for free to HE institutions for the 2010-11 academic year. Once again Max/MSP forms the basis of the software and an image is included below to highlight how the user interface is clearly developed from the programme [see *fig. 5.13*].

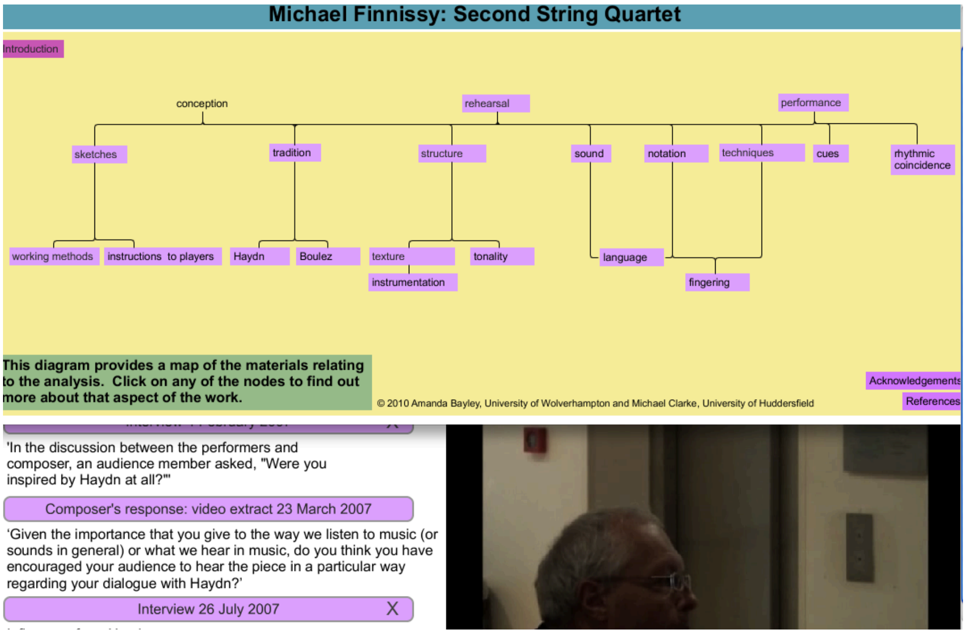


Fig. 5.13 *A screen shot of the Finnissy software, with an open sub-menu underneath the main navigational window*

The importance of the approach of Clarke to pedagogic software development can be best recognised in the awarding of European Academic Software Awards for each of the three finished software packages. This can be further recognised by the adoption into curricula outside of the home institution where the software was developed as marking considerable success in this area. That his current work on the Finnissy Quartet has yet to be completed does not prohibit this from being included in recognition of importance with the previous work. The fact that it is intended to be disseminated to Higher Education establishments across the United Kingdom shows the ambition contained within the work. It is for this reason that Clarke remains one of the only consistently interesting developers of pedagogical software in the UK. The fact that he is now consistently using Max/MSP to achieve the aims in educational and learning development is of considerable importance not only to CuDAS, but also to anyone seeking to programme and develop software with a pedagogical approach at the centre of the project.

Positive though these examples of pedagogy through the Max/MSP platform are, they remain exceptions rather than common place and all have a common strand in that they are aimed specifically at the Higher Education student. There is no literature in the UK or abroad that refers specifically to 16-18 year olds with the use of this programme. Indeed, extensive research has been undertaken that has shown the programme is not currently taught in any other GCE examination centre in the UK. Neither is the programme used as a pedagogic tool to further the education of students at this qualification level.

5.4 The Relevance of Max/MSP to the CuDAS Curriculum

Max/MSP is only one of a whole host of commercially available programmes intended for the making of or enhancement of music. Of these, most are aimed entirely at the market of what we now label quite readily as Music Technology. Some may be intended for use as notation packages, such as Sibelius or Finale. Others are marketed as creative production tools, including Cubase, Logic and Pro-Tools. However, It quickly becomes apparent as a Max/MSP user that the philosophical approach to its use can be highly valuable as an educational tool and it is this that makes it distinctive from other software packages. The basic principle that you cannot achieve an outcome in Max unless you really understand what it is that you are trying to achieve is in stark contrast to that of generic Sequencer based programmes. It is possible to use, for example, Logic's ES1 synthesiser to produce a sine tone, to oscillate that tone, to introduce FM synthesis and ADSR envelope modifications by simply pressing buttons and twirling knobs in a 'trial and error' approach to creativity. In order to construct a sine tone in Max and to develop it into some sort of additive RM or AM synthesis, it would be almost unfeasible to achieve this by accident. One would be required to understand the principles of carrier and modulating bi-polar or uni-polar signals in order to patch the correct path to the end result.

The conclusion in these two differing models of learning is that the Sequencer user will learn how to cause certain effects to produce certain results without ever developing a root understanding of how, for example, a sine wave becomes a square wave. They will learn their way around the software package in question very well without ever needing to develop a fundamental understanding of the principles of acoustics or synthesis. The Max/MSP user, on the other hand, will have a far deeper understanding of the principle that in order to understand sound synthesis, there are an element of basic tools that need to be mastered and understood alongside a generic comprehension of the software programme used.

This is not in itself a problem of the alternative programmes that one finds in computer sequencing labs in schools and colleges up and down the country. They are intended primarily as music production tools and as such offer little in the way of educational materials of the principles they put in place. This is not in the remit of their use and requirements and so cannot realistically be expected to form a major part of the software development. The positive side of this approach is that the student can and often will produce highly creative pieces of music that use a range of complicated and sophisticated techniques. The underlying problem with this approach remains, however, that the understanding behind these techniques remains lacking or underdeveloped. In Max/MSP, this equation is often reversed, in that the programme can help to provide a high level of comprehension but be very difficult to for the user to produce creative and aesthetic works of interest. When using the software Max/MSP as a beginner it can take a large investment of time before one is able to work productively and creatively. It can be argued that it is not the most intuitive of programmes, especially for those who have an education rooted in sequencer package user interfaces.

To overcome this issue CuDAS has been developed using the 'application' feature of Max/MSP as discussed in Chapter 5.2. Using the ability to save the software as a standalone programme ensures that the user is not confronted with complicated patching and the information that is critical for making the software work, but not needed for the learning task involved. In this way the emphasis can be placed on the user interface and the interactivity rather than on the need to teach how Max/MSP functions per se. This leads to a higher level of learning and comprehension from the student and as such a more effective curriculum. It also reduces the cost to the learner and the school department involved as CuDAS is designed to be freeware. It is for these reasons that the advocation that the use of the CuDAS software by all schools and by all teachers related to the GCE Music Technology subject area can be devised and it is only through the use of Max/MSP that this is made possible. It is a considered opinion that Max/MSP offers the greatest potential for the generation of standalone software of this nature and as such offers a fundamentally new approach to the dissemination of learning to the student.

Alongside this alternative approach for the learner, as a teaching tool the productivity of Max/MSP can also clearly be identified. The programme is by design highly visual, auditory and kinaesthetic, thus addressing all three of the learning styles so prevalent in current education psychology and philosophy (see Chapter 5.2 and 5.3). Effective use of the programme requires the user to physically make connections through patching in the initial stages of patch creation, alongside the requirement in any completed patch to turn dials and manipulate sliders to see as well as hear the visual effect of your work. This serves to clearly underline the useful nature of the programme as an instructional tool. The ability to generate a patch in real time in front of the learners is valuable beyond measure. It allows the students to see the creative development of material as it is discussed, rather than it being presented as a completed and dry exercise, allowing the educator to pace the topic of learning at an appropriate rate, ensuring all material is covered when and as required. It also connects educator and learner in a common exploration of development as the work unfolds on the projected screen, allowing an atmosphere of common exploration, shared and experienced by all, rather than the rather prohibitive nature of traditional sequencing packages that have all the answers predetermined and require a rather less educationally interesting approach of simply exploring until one finds what one is looking for. The creativity of initial conception is somewhat lacking in these programmes.

Max/MSP has also had a profound effect on the ability of CuDAS to be moulded specifically to specifically targeted learning areas. The ability to add materials and to adjust the programming as desired is an excellent resource when planning the pedagogic delivery of materials through software design, something that Wishart also sees the value in when he says "I like to work with my own software, because if it goes wrong, I can fix it, and if it doesn't do what I want it to do, I can extend it."[197] It was the ability to be selective that avoided the problematic nature of over complication for the targeted learning audience as discussed in regard to Clarke's *Synthia* programme [see Chapter 5.3].

One of the aims of CuDAS is to focus on the development of technology-based music as determined by AoS3 in the GCE Music Technology course, as discussed in Chapter 1.2. Within this context it is important to realise the importance that Max/MSP has had in production, live performance, composition and installation sound art. It could be argued that such is the importance of this programme to the development of electronic music that it should certainly be included as a topic for discussion, and therefore included in the resources for the subject. The common acquisition of Sibelius as a score package for this course is conceivably misguided as there is no place in the current specification that demands the production of a printed or graphic score. However, the need to explore developments in technology and investigate the world of audio manipulation suggests that the purchase of the Max/MSP software would be of far greater use to the course.

This becomes markedly true when one considers the recent integration of Max/MSP into popular music culture. Since the ability to integrate laptop computers into live performance, the software has built up such a large community of users that bands such as Aphex Twin and Radiohead are prolific users of the software in studio production and on stage. It is possible to watch Jonny Greenwood from the latter of these two bands both using the software in live performance and also discussing his reasons for approaching Max/MSP in this way on YouTube.[198] There have also been a number of high profile instances of the discussion of Max/MSP in the press, including a 2004 interview with Greenwood in the Computer Music Journal as well as a 2007 article in the New York Times by Jon Pareles.[199] It is clear from these articles that he views Max/MSP as integral to the Radiohead sound and his own creativity. As he says himself, "With Max/MSP I finally got to think about sound ... manipulation, in a much purer way... I felt that all direct contact with computers had been taken away from me, until I found Max/MSP... I could fill pages with obsessive stuff about Max/MSP."[200] Radiohead, to further highlight this point, have appeared in the AS examination in previous years and as one of the most influential and creative of recent bands must surely be included in the study of AoS1 and AoS3. As such, their techniques for sound production should also be highlighted.

Furthermore, it is likely that Music Technology students will be utilising elements of Max/MSP without realising it. The patches are often placed into other applications, distributed free or sold commercially. As a result, several of the software instruments and plug-ins found in common sequencer-based software will have been initially developed using Max/MSP. Indeed, the whole nature of developmental software has made graphic patching much more of a common feature. Mainstream commercial programmes such as Native Instruments' *Reaktor* make use of this nature of interface programmability. In addition to these points, that Max/MSP is now recognised as standard in many Higher Education establishments as well as being used in industry highlights the need to introduce students to the nature of the software that they can expect to encounter in any potential future education in this field.

The nature of Max/MSP is held in the fundamental idea that the composer creates from the smallest unit, building in small bricks until a bigger aim is achieved. This is conceptually the reverse of Sequencer based programmes such as Cubase or Logic where this would only be conceivable and therefore achievable in very basic MIDI terms. This inside-out method of learning is justification for the study of such a programme in itself, regardless of the educational value to be had from the differing principles, paradigms and psychologies required to undertake music creativity in this field. What a student is required to undertake is a more holistic approach to his or her ability to bring about creativity in the learning environment that Max/MSP proposes. In so doing, the possibilities open to the learner are greatly increased. It is possible to view the software not as an alternative to the standard sequencer but rather an addition that will enable an alternative way of learning and extend the possibilities available in CuDAS. Even in the initial stages of development this possibility was realised by its creator, Miller Puckette, who in 1988 suggested that Max was created with the intention of filling the void left by the closed system of the sequencer, saying the programme was developed "... for people who have hit the limits of the usual sequencer programs."[201] One of the limitations that Puckette refers to in this statement is the difficulty that sequencer packages have in producing effective real-time synthesis. This is an area of major concern to CuDAS, which relies on this technique to successfully deliver the tutorial topics. Max/MSP addresses this problem extremely effectively, delivering high power visual and aural amalgams instantaneously at the touch of a button or slide of a fader. Indeed, many composers have realised the potential that the programme offers in this respect, including Trevor Wishart, who comments that, "Max is most useful for real-time processing."[202]

Given that sound manipulation-based composition is increasingly expected in the GCE Music Technology syllabus, Max/MSP offers unlimited new angles in the creative process as it is far more powerful as a manipulator of digital data, enabling simultaneous, and therefore live, manipulation through the algorithmic Fast Fourier Transform analysis. It is within this power that the addition of so much audio is made available through CuDAS. Unlike other synthesis software models, the audio sample as opposed to an electronically generated tone plays a major role in the significance of the learning. This is not to say that electronic signals are abandoned in favour of samples, which is not the case, but Max/MSP allows the two to run concurrently alongside one another with no reduction in software performance or problematic CPU inefficiency. This is especially the case for the interactive composition exercises, where many samples are processed simultaneously with no adverse effects on the computer's functionality. That students can also upload their own audio material contributes significantly to the personalised learning experience of CuDAS.

The problems of user interface in patch design mentioned in Chapter 5.3 also affected the initial CuDAS patch that was designed for concert performance. Once this was taken into the classroom it became apparent that the need to 'tidy up' the workspace would be required. Although it made the patch look alien and interesting to the student, it was educationally negative in learning about the synthesis techniques employed or how to use the Max/MSP programme. The patch can be seen in its initial state below [*fig. 5.14*].

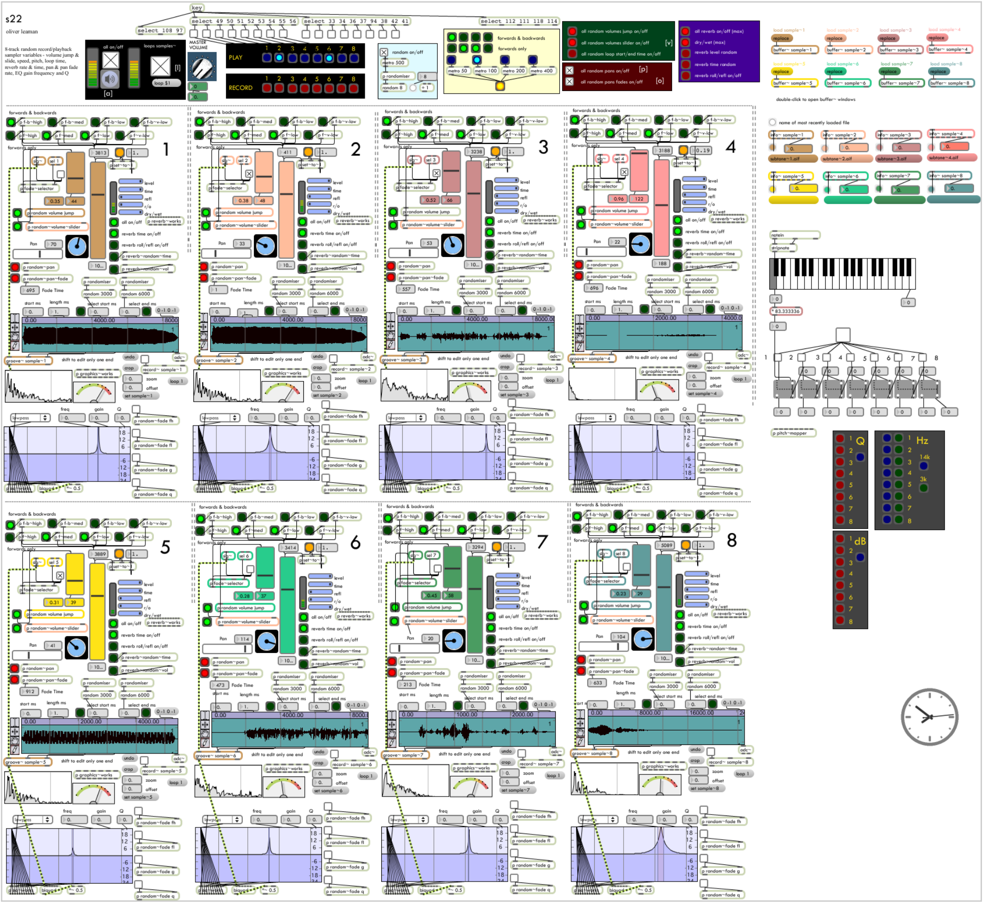


Fig. 5.14 The first CuDAS patch that was taken into the classroom, initially labelled as 'S22'

However, Max/MSP v5 has allowed for a major improvement in this area. The programme now has the ability to display real-time graphics of sound manipulation. This can be seen from the work Clarke achieved with Sybil. However, one major drawback of the Clarke model is that the user interface now looks very dated. Max/MSP enabled this to be addressed in the design and layout of CuDAS achieving a more contemporary interface that is more likely to engage a generation of 16-18 year olds that have grown up with computer graphics far in advance of what was expected when Clarke was building his model. This in turn allows CuDAS to be visually more accessible to the first time user. A great deal of care and attention has been paid to this area of programming and development of CuDAS as a finished product and this is discussed in greater detail in Appendix 1.

Chapter 6 CuDAS in Practice

The interactive, pedagogic learning tool of CuDAS has been delivered as an educational tool on three main occasions. The first of these was in a lecture format to music and physics A-level students. This experience then greatly influenced the subsequent development of the full curriculum, which in turn was delivered in two contrasting learning environments; centre K and centre T. Each of these three contrasting experiences has produced interesting results and it is therefore important to deal with each one in turn.

6.1 The Interplay of Music & Physics – a lecture

CuDAS was developed over the course of 4 years from 2006-2010. From this timescale it is possible to deduce that the initial programming was undertaken with version 4.5 of Max/MSP, using the older graphical system and arguably less user friendly patching options. The work at this early stage, as discussed earlier in this thesis, was centred on that of a live performance tool that was subsequently taken into the classroom. The patch in question in its early form can be seen in Chapter 5.4 where this development from performance tool to pedagogic curriculum is discussed in greater detail. As CuDAS developed into the curriculum that can now be recognised, it was used in various stages in the classroom environment. The initial short experiments in Music Technology lessons during the 2008-9 academic year were collated into a formulated structure and presented in June 2009 in an arts festival at a school for 12-18 year olds in Southampton in the form of a lecture entitled *The Interplay of Music and Physics*.

Fig. 6.1 The Interplay of Music & Physics lecture

The hour-long lecture on the relationship between Music and Physics was delivered to 54 A-level students at the end of their AS year in collaboration with the chief examiner of Physics A-level for the OCR examination board. The boldness of this lecture lay in the unusual approach to teaching and learning of these disparate subjects. The student audience contained a mixture of Physics A-level and Music and Music Technology A-level students. This meant that the material delivered had to appeal to both sets of students whilst remaining informative across the two varying curricula. This was achieved by keeping in mind that not all the physicists were musicians, and that not all the musicians were physicists, thus making the need to remain clear and concise in each subject. Whilst the material was relatively technically advanced, clarity of explanation of any technological or musical language was always retained and the material was presented in a light-hearted and yet serious academic fashion.

Fig. 6.2 Examples of the teaching and learning provided in the Music & Physics lecture. The photo on the left shows an explanation of the harmonic series, using students as partials. The photo on the right shows 'Harmonium' in performance.

Elements of the CuDAS project were used in this lecture, delivering a concise and condensed version of Tutorials 1, 3 and 4. Whilst the essence of the learning was the same as is currently found in the CuDAS software, it is important to note that the version used here was very much a predecessor to the full curriculum that now exists. It can as such be viewed as a prototype. The topics that were covered included the basic terminology of frequency and amplitude, chladni, the harmonic series and partials, AM and RM synthesis and lastly, difference tones. Alongside this was delivered some of the pedagogical material of CuDAS, including the compositions 'Dissimiletude' and 'Harmonium'. Both of these pieces were performed live to the students. These performances and the lecture as a whole are included on the DVD of additional materials included with this thesis.

A questionnaire was devised which was given to all students upon conclusion of the lecture in order to evaluate their perceived level of understanding and whether or not they felt the lecture and the pedagogical methods contained within had been enlightening and worthwhile. The results presented in '*Appendix 3 – Results Based Analysis of CuDAS*' show a clear pattern of positivity to this process, particularly when the results are broken down into simple positive and negative groups of feedback.

Much was learned from the experience of the lecture format. Some of this was positive. Clearly the students had reacted well to the learning process, with most saying they had found the format of the delivery more educationally stimulating than a traditional lesson. There was clearly a good reaction to the compositional material and the computer programming, with 82% of the 54 students polled responding positively to these two areas. This was extremely encouraging as it served as confirmation that the pedagogic principles behind these two areas were at very least received well with the learners. Given that these materials were developed specifically for this reaction in the learning process, it was an important step in finalising the next stage of CuDAS. However, some important lessons were learned within the structure of this lecture that required careful attention. It was felt subsequent to the delivery that too much information had been presented over too short a space of time. This was due to the fast pace of delivery over the time constraint of one hour, but alongside this was realised the concern of depth of subject material not being adequately investigated as there was simply too much to say to cover it all. It was through this that the system of separate tutorials presented over several stages of learning was reached as the best workable option.

6.2 Centre K

Learning from the experience in the classroom and of the lecture described above, CuDAS was then developed into a full curriculum with a defined structure. The programming brought together the different tutorials under one banner and linked them through the creation of a single application. It was at this point that the detailed attention to software development described previously in this thesis was undertaken. This led to a finished product, which was ready for use in a formal learning experience and was followed in the 2009-10 academic year. The software used in this delivery can be looked upon as version one of the software. The small changes and developments made in response to the practical delivery of the learning areas has led to version 2, which is available on the multimedia DVD that accompanies this thesis.

During this period CuDAS was delivered in two quite contrasting centres. The first, centre K, was a school environment which being in the independent sector had retained its sixth form. Being part of a larger school meant that the facilities for the delivery of Music Technology were shared across all age ranges. This in turn meant a preference for PCs over Macs in line with school policy and the need to cater for other curriculum areas with the working environment. The computer lab consisted of 12 workstations arranged in a 3 sided rectangle, as can be partly seen in

Fig. 6.3 Centre K - part of the main teaching area.

fig. 6.3.

The course was run with 6 periods of 50 minutes across four days of the week, totalling 5 contact hours per week. These lessons consisted of two double periods, where no break between lessons was given, and two single periods. CuDAS was delivered across the second academic term, invariably using one of the double periods per week over 10 weeks. The age range at centre K was from year 7 to year 13 (11-12 year olds to 17-18 year olds). CuDAS was presented to the final year Music Technology students as part of their preparation for the end of year examination in this subject. There were 4 students of varying ability enrolled on this course.

Student A was a technically advanced musician. Also studying A-level Music, his knowledge and awareness of contemporary music was advanced for his age, though naïve. He began the course as a Radiohead fanatic, but had not heard of the various synthesis techniques. Although a keen user of software for music production, he had never encountered Max/MSP. Being highly proficient in the subject he had achieved maximum UMS marks in his AS examination. He had an already burgeoning interest in this area and by the time CuDAS was presented, had been offered places on scholarships to study composition at two of the London music colleges.

Student X was also an advanced music technology student. His approach to the subject was centred entirely on his passion for electronica. Very knowledgeable about the music of Kraftwerk and Jean-Michel Jarre, there were however significant gaps in his understanding of this genre and the principles behind the creation of the music. He had heard of Pierre Schaeffer and Stockhausen but did not know their music. Neither was he aware of Varese, Xanakis, Subotnik and others. Having achieved a high A grade in his AS year, Student X had applied to various universities to study music technology further and had been offered interviews later in the term at all of them.

Student R was interested in rock music. His favourite artists upon starting the course were The Beatles and The Ramones. As a drummer, this student had very little music theory, struggling to read treble clef at the start of the course and unable to read bass clef. His knowledge of keys and harmonic relationships was nonexistent. His practical coursework and examination at AS-level suffered as a result, despite considerable advances in these areas. He achieved a B in his AS year, which was considered a positive outcome for all concerned. His future plans were as yet undecided. Initially he had planned to study English at university, but he had not made any applications, instead deciding to take a year out and think further as to what he wanted to do in the next stage of his education.

Student W was also a keen musician, playing the trumpet to a reasonably high standard. His musicality and knowledge of theory were well developed, but his technical ability with a computer was weak, never having used a computer for making music before. He found working in a sequencer environment initially confusing and his work progressed very slowly as a result. None-the-less, he did achieve an A grade at AS level. His plans for HE involved physiotherapy, although he was unsure where exactly to attend and was planning to take a year out and make a PQA (post qualification application).

The course was presented to these four students in the version for PC. Essentially this is the same as the Mac version only with slightly altered window placements. Being a dual platform programme, the programming made in Max/MSP using a Macintosh computer could be transferred onto this platform with relative ease. A new application was then generated and as a result worked without any major difficulty. It soon became apparent during the dissemination of Tutorial 1 that student X had an advantage over the rest of the group as he studied physics at A-level and as a result had a working knowledge of some of the concepts covered. However, what was of particular use to him was the ability to see the graphic representations of the processes described. The only images he had seen of audio waves until this point had been from an oscilloscope and his understanding of harmonics was no better than the other members of the class. Whilst it was easier for him to retain the technical language of frequency, Hertz, decibel and so on, it was surprising just how much of the information was new to him.

Over the course of the following ten weeks CuDAS was followed by the group with an excellent level of response. It was clear that the class looked forward to the sessions using the software. It was also possible to see their collective knowledge improving rapidly. Some were more naturally inclined to retain said knowledge, but a collaborative approach to the learning was developed between the students and it became clear that they were encouraged by CuDAS to talk further about the topics covered with each other. This meant that, for example, when students A and X became very enthusiastic about the areas of subtractive and additive synthesis, their enthusiasm became contagious and the other students were motivated beyond their initial struggles with some of the concepts. They subsequently discovered that CuDAS helped them in their practical understanding of said areas until they too felt comfortable with these areas of synthesis.

The students were continually encouraged to develop their own creativity through using CuDAS. The resulting creative work, which can be found listed in 'Appendix 4 - Multimedia File Index' and heard on the included DVD, was extremely interesting. It is clear when listening to the pieces generated through the use of CuDAS that the students are working in away that is fresh and exciting to them. They have removed themselves from the constraints of a traditional composition-based approach to create purely electronic works of interesting textures and timbres. Whilst it is clear that these works remain only initial forays into the possibilities of these techniques, they none the less maintain a clear sense of purpose and structure and show a clear understanding of the principles involved. There are two works that stand out in the creative process and are therefore worth discussing further.

The first is by student R. His work on this short study is all the more impressive when one realises the context of the creativity. As mentioned above, this student was from a rock background and had little interest in electronic composition until he undertook the CuDAS programme of study. In his compositional work to date he had been resistant of even the most basic of destructive and non-destructive editing techniques in a production software package. Filtering, time stretching and pitch shifting were all met with a perplexed querying of their place and validity in his chosen genre of music. CuDAS was responsible for opening his ears to the possibilities within this framework and he quickly realised that synthesis has a major part to play in the canon of rock music as much as it does in the electronic composers of the 1950s and 60s. What CuDAS has enabled is a movement away from the stereotypical and lifeless rock music that the student was creating. He himself was perturbed by the constant recourse he was making to what he felt were clichés of the genre. He found in CuDAS an alternative way of thinking about music that enlightened his own creativity.

Through CuDAS, student R's musical interests expanded to include the idiosyncratic style of Thelonius Monk and harmonic voicings of Bill Evans. Alongside this, following a lengthy class discussion as to whether jazz was a redundant genre that was ceasing to progress, he discovered an intense passion for the 'post-jazz' of the Bad Plus and particularly of Polar Bear. When student R was alerted to the work of Leafcutter John and the integration of Max/MSP into the work of Polar Bear, it was as if a switch was somehow triggered. The creative work he had already begun in CuDAS was developed further and fed directly into his final submission for his A2 Music Technology portfolio. The 3-minute composition he was required to include in this portfolio included the use of CuDAS patches and of Leafcutter John's own Forester software. Entitled '*Alone*', when one hears this work it is clear that the influence of student R's rock roots have been retained in the rhythmic and structural elements of the piece. However, it is equally clear that the work on CuDAS has had a major impact on the sound world of the composition as a whole.

The second piece that is particularly striking is 'Absorbance', by student A. This student responded extremely positively to CuDAS. Within three weeks he had accessed the additional learning regarding the Max/MSP software and the 'create your own' section of the software. Over the Easter holiday following the end of the CuDAS course and the completion of the coursework requirements for the A-level, he acquired the Max/MSP demo and worked his way through the vast majority of the included tutorials. Within 6 weeks he was using Max/MSP to build new patches and create music of his own, either for textures within other works or actual pieces in their own right. Some of these pieces were for live performance and some were recorded to disc. 'Absorbance' was one such piece that was recorded. It uses a mixture of techniques but fundamentally remains an investigation into the possibilities of subtractive and additive synthesis. It is a work of striking maturity and considerable sonic and musical interest and serves to highlight the exceedingly influential impact of the CuDAS learning on this particular young composer's development.

6.3 The Impact of CuDAS on Academic Attainment

It is stated as one of the aims of CuDAS to improve learning within the various areas of study within the GCE in Music Technology as examined by Edexcel. It is therefore important to consider whether or not this has been a successfully achieved outcome in the foregoing examples. Naturally it is very hard to attain whether a student has achieved to a higher level with this educational training, as it is not possible for the student to sit the examination first without and then with the learning involved. However, there are substantial suggestions that CuDAS has indeed played a major role in the success of the students' academic attainment at centre K. In the examination presented as Unit 4 of the course, the results analysis as seen in *fig. 6.4* clearly shows a very high level of attainment in this area. Indeed, as a final grade awarded in August 2010, student A and X achieved an A*, with student A receiving a commendation for being in the top ten students in the country.[203] Of equal merit to this high-flying achievement was that of student R, who raised his AS grade of B to an A2 grade of A. This was largely due to the outstanding result he achieved in the examination. This can be seen to be in part due to the preparation for this area provided by CuDAS. This becomes strikingly so when one learns of the essay question in the examination, worth 20% of the marks for the entire examination.

	Marks /80	%	Grade
Student A	80	100	A
Student R	78	97.5	A
Student X	75	93.8	A
Student W	62	77.5	B

Fig. 6.4 The academic attainment for Unit 4 of the GCE in Music Technology at centre K.

> The digital sampler has transformed the sonic palette available to musicians and producers by allowing any sound to be incorporated into a recording with accurate control. Describe what a sampler is and how sampling technology has developed from the 1980s to the present day. You should refer to technical specifications of sampling equipment in your answer.

Using the knowledge learned in CuDAS it was possible to score very well in this question. A brief look at some areas of the examiner's mark scheme makes it clear that the supporting material in the software would have covered much of the technical terminology.

> A sampler is a musical instrument that stores recordings of sounds (1). These are usually played back on a keyboard (1) using MIDI (1). Sounds are played at different pitches (1) by speeding up or slowing down (1) the digital recordings. This changes their length (1) and timbre (1) and is more noticeable when transposed more than a couple of tones (1). Samples are often looped (1) to create a longer / more

sustained sound (1) or to create a groove (1). In the latter half of the 1990's sampling moved onto the PC/computer (1) because computers had enough processing power (1) and enough RAM (1). Digital audio is now stored on hard drives (1) so sample time is virtually limitless (1). Samplers usually have the same controls as a synth (1), for example, filters (DCF) (1), envelope/ADSR (1), LFO/modulation (1).

There is one further piece of evidence that links CuDAS to increased attainment in the A-level. This is related to the result attained in this examination by Student W. When analysed, it can be seen that this particular learner underachieved in his A2 year. His grade dropped from an A in his AS result to a B in his A2 year. Admittedly he was only 2 marks out of a possible 400 away from an A, but the grade still represents a fall in attainment. His mark of 77.5% in the examination topic also suggests an underachievement in comparison to the other members of the group. The reason for this dip in form was almost certainly due to the fact that in the second academic term this student became quite ill and missed a substantial amount of lessons. He suffered from exhaustion and as a result missed on average 2 lessons of every 6 each week. This led a falling behind in coursework tasks and a lack of attention to detail in examination ones as a direct result.

In relation to CuDAS this had dramatic consequences in that the student missed the sessions covering Tutorial 3 and 4. With the pressures of coursework in this subject and of also falling behind in his other A-levels, this student was unable to make up this work in his own time. This explains why there are no sound files from this student relating to these areas of study. It also helps to explain why the examination mark was not as effective. It is a contention that many of the marks dropped by this student were done so in areas directly related to material covered in the later stages of CuDAS. This can be seen to be true when analysis of the marked script is performed. In the essay question, only 8 marks were achieved from a possible 16. This is in stark contrast to the other three candidates, who achieved full marks in this question. If student W were to have had the same educational experience as the other students in this group he could well have been expected to achieve similar marks. If he had improved his examination result in line with the other candidates from this centre he would have improved his overall A-level grade from a B to an A. This provides further empirical evidence of the importance of the CuDAS learning process.

6.4 Centre T

During the academic year of 2009-10 CuDAS was also presented at centre T. This was quite a contrasting learning environment to centre K, being a Saturday morning music school at one of the top London conservatoires. The computer-sequencing lab used as the main teaching area on the Saturday was ordinarily utilised by undergraduates and masters students in the week and as a result, the facilities available to the students were excellent and of standard one would expect to encounter in industry. The computer suite consisted of 12 i-macs with a

13th linked to a projector for teacher use [see *fig. 6.5*]. All of these machines were linked using Remote Desktop, enabling the teacher to see all workstations in real-time display on one screen and take control of any one or all of the workstations. The DAWs had a wealth of music software installed, including Logic and Max/MSP.


Fig. 6.5 Centre T - main teaching area.

The students enrolled on the music technology course partook in instrumental and ensemble lessons throughout the day and as such had very full timetables. This meant that only 3 hours were given over to tuition. Open lab sessions were run in the afternoon but the amount of time a student had free to attend these sessions ranged from 2 hours to none at all. During these open sessions teaching was largely centred on one-to-one learning as the free time the students had to attend varied according to each of their individual timetables. There was no point where the whole class, or even the majority of the class, were in attendance at these sessions at the same time. 8 students enrolled on the course and all of these students were in full time education during the week so the learning covered during the course represented a sixth day of study auxiliary to their normal schooling. Being musically gifted, the students were not all of the same age range. Some were still completing GCSEs at school while others were in the lower sixth year of study.

The nature of the complicated timetabling at centre T had major implications on the format of the delivery of CuDAS. Effectively the model that was followed was for the students to complete an A-level on 3 hours tuition a week. Term-lengths were much shorter than in standard schools, there being 10 academic weeks to a term. This led to a total of 21 weeks before the coursework deadline and examination week. With such limited time it was decided that there was not enough freedom to extend learning through CuDAS with the currently enrolled A2 students. The pressures on coursework completion were too great. As a result, their examination marks were indeed considerably below the standard of those at Centre K.[204]

Due to these pressures, it was therefore decided to offer CuDAS to the AS class once they had finished their examination in May. Unlike traditional schooling, the music school offered no study leave and all classes ran as normal until the end of the summer term. This left 6 weeks where the pressures of targets and timescales were alleviated. Therefore, 18 hours were available for the effective delivery of the curriculum, unencumbered by other areas of concern within the subject.

This alternative model worked very well. The students responded with positivity and enthusiasm to the learning tackled in CuDAS. Having a focused study in this way certainly did not detract from the learning process. However, it is impossible to judge whether the learning will have had positive effects on the outcome in the A2 examination as these students will not sit this until June of 2011. None the less, it was clear that a great deal of learning was taking place and the compositional work that was undertaken as part of the CuDAS process was again interesting and of increased confidence in the genre of electronic music. The creative work resulting from the CuDAS process can be found in the sound file index in Appendix 4. These are also included on the DVD submitted alongside this thesis, where it is also possible to find videos of two of the classes from this period in action.

Fig. 6.6 Students at centre T undertaking the CuDAS curriculum.

6.5 Assessment of CuDAS and Student Feedback

Assessment of any curriculum provides an area of much debate. It can be argued that our students are currently tested to a degree beyond which is educationally productive. In 2002 Ken Boston, chief executive of the Qualifications and Curriculum Authority (QCA) until 2008 and as such the principle examination regulator of English schools during this time, described the country's schooling as an "assessment frenzy,"[205] commenting further that, "we are not giving sufficient time to learning and to preparation at the expense of the examination process."[206] This area becomes increasingly problematic when the assessment carried out is done so electronically. As Clarke elaborates, "In music … much of what is most important cannot be assessed in an automated fashion."[207] In this statement he is referring to the problems of assessing the resulting creativity from interactive software.

CuDAS has the dual goal of inspiring the imagination of the creative minds of the students but also of providing them with a great deal of knowledge and understanding in preparation for examination at GCE and extending knowledge further to prepare adequately for HE. Therefore it was deemed essential to retain some formal assessment of this secondary area. Although not included within CuDAS, alternative materials were devised in order to attain whether the learning aspired to had indeed been accomplished and had therefore justified the delivery of the curriculum. These materials were kept separate from CuDAS specifically to avoid the distraction from the learning that they may have provided. It was accepted that the acquisition of knowledge through the learning process was necessary, but great care was made to ensure that this element did not distract from the interactive nature of the software and accompanying compositions.

Upon completion of Tutorial 1 in both centre K and centre T, a short revision test was given which included the following questions;

1) Define the difference between *time-domain* and *frequency-domain* representation of an analogue waveform.
2) Draw examples of both where the signal is a sine wave at 440 Hz
3) What would you expect to see in a spectrum if a flute plays a note at 440 Hz?
4) What note does 440 Hz produce?
5) What is a *fundamental frequency*?
6) Outline the harmonic series in Hz and notation where the fundamental frequency is 220Hz.

It was pleasing to note the results given by the classes, seen in graphic form below [*fig. 6.7*]. From these it is clear that the level of knowledge in these areas had risen dramatically.

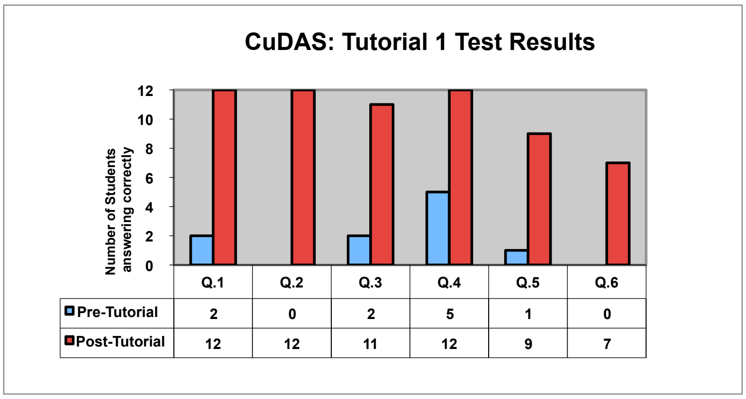


Fig. 6.7 Results of the questionnaire provided upon completion of Tutorial 1.

Further written assessment was made through an academic test given upon completion of the complete CuDAS software. This assessment was more rigorous in its design and was therefore a greater challenge to the students. An example of the test is included in Appendix 3, along with a completed example by student A from centre K. It is highly apparent that great understanding has been achieved of all the areas assessed in this set of questions and as a result CuDAS can be seen to be a major contributor in this student's overall development in the area of audio and synthesis.

When it came to student participation in the feedback process relating to CuDAS, every effort was given to facilitate this as a possibility. Alongside the creative output of the students who undertook the curriculum, '*Appendix 3 – Results Based Analysis of the CUDAS Process*' also includes the students' responses to formal and informal online structured questionnaires. Among the interesting results that these methods provided was a discussion by the students of centre K on the validity of student-devised materials within CuDAS. It was generally felt that as a process the ability to create further Max/MSP patches would be a creative one that would offer an interesting exploration of further skills, leading to alternative learning and a highly profitable educational experience. However, despite the positive response regarding the notion of creating such resources, each of the students went on to express an opinion that this would ultimately not be something they would deem as being appropriate to the curriculum as a whole, as it would in fact detract from the process. It became clear that the complicated nature of the programming had created an atmosphere of overwhelmed surprise. The students had become fixated on the notion of programming, an area which none of them had experience over.

For this reason it was decided after the presentation of the first full CuDAS course to include further information about Max/MSP and the procedures involved so as to demystify the process of programming. Whilst this area remains a very simple introduction, it none-the-less provides a useful opportunity to stretch learning further whilst ensuring that the student is not alienated from what admittedly is a highly complex area. As such, open programming in the patch concerning randomisation, as well as some simple object control in the 'about Max' patch and the availability of unlocked source patches, were included into CuDAS to further develop its educational potential.

The discussion with the pupils regarding creativity became even more interesting when the observation was made that none of the students had realised the ownership they already had over the work. Whilst they readily admitted they had created material whilst undertaking the curriculum, they did not see this as being *part* of the curriculum. It can be argued that this mindset resulted for a number of reasons related to a history of educational expectations, of self-value of creative work in progress, of work undertaken in an internal classroom environment and of self-esteem in an unfamiliar field of learning. When it was put to the students that their work could be presented in an end of term concert and lecture series, they seemed very keen and interested in the idea. When the question was then put to them again as to whether they felt they had contributed student-devised materials to the CuDAS project as a whole, their understanding of what they had achieved began to shift. They could now clearly see the resulting produce of their work and that it definably belonged to them and that, furthermore, without it, the CuDAS process remained largely simply a theoretical one with no tangible results. In essence, the students were able to see that only with their creative work completed could the CuDAS project realise its full educational potential.

The final area of assessment made was an assessment of CuDAS itself, made by the students. An online questionnaire entitled 'CuDAS Curriculum Feedback Survey' was devised and presented to the partakers at centre T. The survey asked the following questions;

1. How do you think your understanding of synthesis has been improved by following the Tutorials?
2. What elements of CuDAS helped in your understanding the most?
3. Do you think the CuDAS Tutorials were clear and informative? Please say why you think this.
4. CuDAS is designed to give written information alongside practical application of topics and composed examples. Did the combination of these three elements help in the understanding of the topics? If so, why do you think this was?

The respondents answers were extremely enlightening. They can be seen in full in Appendix 3, however, it is worth investigating some of the comments further at this juncture. In relation to the understanding of synthesis, one of the most salient comments was that of Student 2, who commented; *"It has made everything a lot clearer and easier to understand especially through the visual aspects of the tutorials and being able to experiment."* Although not equipped with the vocabulary, in essence this student is highlighting the interactive qualities of CuDAS. The word 'experiment' is central to the learning process of CuDAS. As this is a strong part of the pedagogic message of the software and interactive compositions, to receive this comment was particularly pleasing. The positive effect the syllabus has had on creative work of the students and knowledge of the principles covered by the syllabus can also be seen in the comment by student 3 when they say, *"It has helped me to be able to work with a more varied amount of techniques and effects as i can now relate the effects i am using to my knowledge of how those effects are created and how they work."* They clearly view the process of following CuDAS as beneficial to their understanding of key areas of synthesis and the words hint strongly at the preparedness to use these in a creative context in the future.

The second question was designed to offer the students a chance to feedback which of the areas of CuDAS were most effective in helping develop knowledge of the areas covered by the syllabus. The respondents were varied in their answers to this area, suggesting further evidence for the importance of combining learning styles in the material presented in CuDAS as discussed in Chapter 2.4. Student 2 clearly felt that the interface design was of importance, stating that it was this area that helped him learn most effectively. His comment that the element within CuDAS that most effectively helped him learn was *"The fact that it is colourful and user-friendly,"* justified the careful attention that had been placed in this area as previously discussed at length. Student 1 most appreciated the interactive nature of the software and the ability to both see and hear the results when parameters were altered. As he/she describes in his/her own words; *"I think that being able to change the different parts of the sound helped a lot, so that I could see what would happen to the waveshape when various different factors were changed."* Once again this was of specific interest as this design was central to the learning in CuDAS and as such it was very pleasing that this had been specifically targeted as an area of positivity by one of the users.

Student 4 also found that the ability to hear the synthesis in action helped the most in aiding comprehension. However, they also commented on the extension provided by the composed works. Naturally this was of critical importance to the CuDAS project and as such their comments underline the pedagogic importance of the works included in CuDAS as well as the way they are integrated into the software. To quote the student; *"I liked being able to hear how it works. I thought the pieces were good too. They helped me make my own versions."* This comment highlights the ability of CuDAS to serve as a springboard for student creativity through the direct use of composed examples. In this case, the works have acted as generators of imagination in the user's own explorations and as such the interactive exercises have been of great benefit to the development of their own musicality and vocabulary of timbres in electronic composition. It is this that is of essential value to CuDAS and as such this comment remains one of the most pleasing aspects of the whole delivery of the course to date.

The third question offered the students the chance to elaborate on their reasons for perceiving the tutorials as informative and yet easy to use instructional tools. With comments from student 2 and student 3 it is clear to see that it was the interactive nature of the software that most appealed to them, giving them a perception of clarity and ease of use; *"They also told you the necessary information clearly and simply and allowing us to experiment ourselves too." "… they helped me to put the knowledge, that i had found out, into practise."* This is something that is also reflected in the final evaluative question, where the integration of text, interactive software and composition is discussed. All the students found this method of presenting materials helpful but perhaps the most significant point regarding the nature of CuDAS came from student 2, who commented; *"… if you did not understand something the first time, it was a lot easier to understand perhaps when looking at the examples or by experimenting yourself. Also, many people learn best in different ways so the combination of these three elements, I think, appeals to almost everyone."* Once again, in these words are echoed some of the principle elements of the planning and structure behind CuDAS in its entirety and so to receive such feedback from the very users that the programme was designed for is extremely encouraging and highlights the success of the curriculum development undertaken.

Summary

This thesis began by looking at the role of the composer in the classroom and the development of methodologies to aid in the educational training of students. We have seen that the composers discussed have been able to achieve significant educational developments by taking their creativity directly into the classroom and using their skill for the benefit of the broader musical education of others. Their principles of pedagogy have been outlined in detail and it has been seen how the efficacy of these has fed into the devising of the CuDAS curriculum, being created as it was from the viewpoint of pedagogic composition and delivered to the students accordingly.

It has been shown how the presentation of compositional material has been made within CuDAS, with each of the compositions presented as a score, an audio file containing an acoustic recording of the work and an interactive exercise that enabled the learning to be taken to the next level. It is through this method of creative interactivity between the composer, his works and the student, that the success of the model has been attained. Alongside the major works, we have also explored how each of the tutorials also contains a study created solely from the tutorial patch, which then encourages the student to be creative within the same context. Using the record feature in CuDAS, we have learned how they then have the ability to record to an *aiff* file and edit as appropriate in order to create their own works within the field of electronic composition and manipulation.

The knowledge imparted by CuDAS has been seen to progress from the simple, with time and frequency domain representations in Tutorial 1a, to the complex, additive synthesis in Tutorial 4, through the use of slowly progressing patching techniques that introduce topics and fundamental principles a little at a time. The choice of graphics and programming has been seen to reflect this gradual progression and the use of developmental learning. This has led to an ability to educate the given subject matter in a way that was previously not attainable, moving beyond the formal texts on this subject matter and presenting an alternative, real-time learning model.

This model, through the programming of software and inclusion of interactive compositions, moves beyond the deterministic workings of sequencer programmes and into a more educationally merited domain, while simultaneously appealing to the current zeitgeist evident in today's digital age. The evidence of this has been disseminated through the chapters on programming techniques as well as learning preference models, leading to an alternative from the 'training' of the subject for examination purposes, replacing it instead with a deep and considered understanding of the topic areas. The results-based analysis of the final chapter has shown how the aims and pedagogic principles of CuDAS have been successful. It was extremely interesting to see students responding positively to the compositions and using these, alongside the interactive exercises, as a springboard for their own creativity. This can be seen to have been an underlining of the value of pedagogical composition in the contemporary context.

We have seen how CuDAS has great many strands that combine to form a strong and complete whole, allowing it to be viewed as a compositional tool, an enabler of creative teaching and learning, a piece of interactive software as well as pedagogic composition. We have also explored how it is in the amalgamation of these areas that CuDAS has been seen to be most successful and provides a model that is effective for the education of the key subject areas of the basics of audio concepts and synthesis in electronic music as appropriate for a student undertaking the GCE in Music Technology offered by Edexcel. It has been shown that this model is one that others could integrate into their own teaching and approach to education, inspiring creativity in the classroom from both tutor and learner. Indeed it is noteworthy that CuDAS will indeed be integrated into wider learning in the future, as in November 2010 it will be presented to all Music Technology departments across FE colleges in Hampshire in a series of workshops organised through the Hampshire post-16 network.

Throughout this thesis, the key issue of addressing the lack of creative education of the learning area outlined has been highlighted and tackled and it is in answering this problem that CuDAS can be seen to attain its objectives.

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1 In the educational context, the UK does not include Scotland, which has its own system and examinations.

2 In 7 years of teaching the centre I have worked at has delivered 3 different syllabuses from 3 different examination boards in both A-level Music and GCSE Music.

3 Edexcel, 2007; p.1

4 Downloadable from; http://www.edexcel.com/migrationdocuments/GCE%20New%20GCE/Spec-GCE-MusicTechnology.pdf

5 Edexcel, 2007; p.1

6 http://www.edexcel.org.uk/gce2008

7 See UCAS entry guides, 2000 – 2010

8 Edexcel, 2007; p.1

9 The source for these statistics is taken from 18 separate PDF files which are available to the public via Edexcel's website. The exact URL is; http://www.edexcel.com/iwantto/Pages/gce-stats.aspx

10 See footnote above

11 See footnote above

12 Edexcel, 2007; p.19

13 Edexcel, 2007; p.20

14 Edexcel, 2007; p.20

15 Tomlinson, 2000, p.4

16 Ginnis, 2002, p.58

17 Steen, 1992, p.12

18 Clarke in O'Donoghue, 2006; p.293

19 Steen, 1992, p.11

20 Steen, 1992, p.11

21 Steen, 1992, p.12

22 Steen, 1992, p.23

23 In answer to the online question, 'Do you think the CuDAS Tutorials were clear and informative? Please say why you think this.' The student responded; "Yes. I think it was easy to see how things got more complicated but it didn't all happen at once which helped. The pdfs were good for explaining the complicated stuff and I could ask Ollie when i didn't understand."

24 Steen, 1992, p.20

25 Steen, 1992, p.16

26 Steen, 1992, p.22

27 The first class moves faster than the second as the students were progressing at a pleasing rate. It was not deemed to be necessary to hinder their progress simply to stick to a pre-perceived timetable of events.

28 Steen, 1992, p.23

29 Blakemore, Frith, 2005; p.1

30 Blakemore, Frith, 2005; p.3

31 Blakemore, Frith, 2005; p.15

32 Blakemore, Frith, 2005; p.10

33 Blakemore, Frith, 2005; p.22

34 Blakemore, Frith, 2005; p.4-5

35 Blakemore, Frith, 2005; p.35

36 Blakemore, Frith, 2005; p.141

37 As discussed with Tim Caine, head of the PGCE course at Southampton University. Kolb and Coffield are discussed, but only in minor detail. Half of the PGCE course is subject specific and the other half is concerned with the study of general educational issues. It is also worth noting that two thirds of the course takes place in schools on placements therefore PGCE students are more likely to have access to this area when on placement than in actual lecture or seminar based environments.

38 Ginnis, 2002, p.40

39 Ginnis, 2002, p.39

40 Smith, 2001, p.3

41 Kolb, 1984, p. 38

42 Smith, 2001, p.2

43 Tennant in Smith, 2001, p.6-7
44 O'Brien, 1996, p.21
45 Available for download at http://www.creativelearningcentre.com/resources.asp
46 Prashing, 2006, p.2
47 Prashing, 2006, p.45
48 Prashing, 2006, p.45
49 Blakemore, Frith, 2005; p.111
50 Blakemore, Frith, 2005; p.111
51 Blakemore, Frith, 2005; p.1
52 Blakemore, Frith, 2005; p.112
53 Blakemore, Frith, 2005; p.113
54 Blakemore, Frith, 2005; p.118
55 Blakemore, Frith, 2005; p.118
56 Blakemore, Frith, 2005; p.117
57 Blakemore, Frith, 2005; p.118
58 Blakemore, Frith, 2005; p.121
59 Blakemore, Frith, 2005; p.121
60 Prashing, 2006, p.45
61 http://www.creativelearningcentre.com/Products/Learning-Style-Analysis/Pyramid-Model.html
62 Prashing, 2006, p.38
63 O'Brien, 1996, p.21
64 Blakemore, Frith, 2005; p.17
65 Hayden and Windsor, 2007; p.28
66 Armstrong, 2009
67 Dobson, 2009
68 Blakemore, Frith, 2005; p.149
69 Choksy, 1974; p.3
70 Kodály in Kocsár, 2002; p.15
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81 Kugler, 2008
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84 G. Orff, 1989; p.17
85 G. Orff, 1989; p.17
86 G. Orff, 1989; p.51
87 G. Orff, 1989; p.77
88 G. Orff, 1989; p.84
89 Steen, 1992, p.6
90 Wiegold, 2001; p.3
91 Wiegold, 'Peter Changes His Mind' chapter resumes, 2010, due for publication 2011
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93 Wiegold, 2001; p.1
94 Wiegold, 2010; 09:54
95 Wiegold, 2010; 10:25
96 Wiegold, chapter resumes, 2010
97 Wiegold, 2010; 11:05

98 Wiegold, 2001; p.3
99 Wiegold, 2010b; 26:50
100 Wiegold, 2005; p.2
101 Wiegold, 2009
102 Wiegold, chapter resumes, 2010
103 Wiegold, 2010; 13:21
104 Wiegold, 2010; 14:01
105 Wiegold, 2010; 18:47
106 Wiegold, 2010; 15:10
107 Wiegold, 2010; 16:10
108 Wiegold, 2010; 16:34
109 Wiegold, 2010; 15:29
110 Wiegold, 2010; 15:35
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112 Wiegold, 2010; 29:45
113 Wiegold, 2001; p.4
114 Wiegold, 2010; 32:10
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121 Wiegold, 2010; 40:57
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128 Wiegold, 2010; 1:05:05
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Appendices

Appendix 1 CuDAS Examined

1.1 The Structure of the CUDAS Syllabus

Having discussed the various areas of influence on the development of CuDAS in the last few chapters, it is at this point that we begin a thorough investigation of the software and its content. Structurally, CuDAS has been devised to follow a specifically guided educational experience. The Max/MSP patches that form the basis of the software have been programmed and refined in order to develop the key areas of learning and understanding covered in CuDAS. They offer a practical and kinaesthetic approach to the learning material covered in the curriculum as a whole through interactivity. CuDAS is divided into a hierarchical structure of four main learning areas; the basics of audio, spatialisation, subtractive synthesis and additive synthesis. These are labelled as being Tutorials 1-4. Within each of these tutorials is a further subdivision into five main learning areas, labelled as, for example, Tutorial 1a-e. Finally, contained at the end of each tutorial is a complete patch that combines all of the topics covered within that learning area in one interactive compositional tool. These can then be used to generate experiments or full compositions in electronic music using the techniques that have been covered.

CuDAS has been designed and programmed in this way so that each of the Max/MSP tutorials that make up the programme contains a microcosm of the completed patch presented at the end of the learning cycle. In this way, key fundamental concepts of electronic music can be explained in bite size chunks, ensuring a holistic understanding alongside a more developed knowledge of the chosen areas that make up the curriculum. That each of the four tutorials are subdivided into smaller areas further ensures that the amount of material presented to the learner is not overwhelming and that the particular area of learning can be absorbed in an educationally effective manner, guaranteeing comfort with the pace and development of material.

A further structural element contained within CuDAS is the pedagogic compositions that underline the integral basis of the learning and shape the ethos of the CuDAS curriculum as experienced by the student. Without them, the aesthetic value and educational purposes are diminished and as a result they form the central core of the work. As discussed in greater detail in Chapter 2.3, the compositions offer the ability to place the material covered in the areas of learning into a musical context. Due to the nature of the area of study concerned in the CuDAS curriculum, the compositions are in nature generally electronic, although there are also included acoustic works. The acoustic works tend to require computer-based software in their realisation and as such there are also works that use both acoustic and electronically generated material. These elements allow a differing perspective of electronic music and its application in the acoustic world.

The compositions are presented as part of the main tutorial structure and as such there are four examples that use the completed tutorial patches to generate short study pieces. These are labelled simply CuDAS1-4. There are also larger works that relate to areas within each tutorial and these can be found inside each of the tutorial patches as well as in the main 'compositions' window. Wherever one of these compositions is presented, it is accompanied by an interactive exercise that enables the student to learn through the manipulation of the composed material. Each of these compositions and interactive exercises is analysed in greater detail further in this chapter, showing the placement of learning and validity of inclusion in the syllabus as a whole.

The choices for the material for inclusion in CuDAS were created after considered research and with the constant questioning of the educational efficacy of every microcosm of area of study. Subsequent patching and composition in relation to the material to be included was therefore centrally targeted at CuDAS, making the pedagogic message and educational value of the software as a whole stronger and more uniform. Consistency and thoroughness of purpose in whichever area was focused on were paramount. These processes of exploration and choosing of material are outlined for each tutorial below.

1.2 General Graphic Design Principles Within CuDAS

As mentioned in Chapter 5.4, a great deal of care and attention has been paid to the area of user interface and design when programming CuDAS. This can be seen in simple alteration of certain standard Max/MSP parameters. For example, instead of the standard volume fader that is associated with the programme, an alternative was sought and used. Although this made the programming more complicated and time-consuming, it allowed for a more attractive design and as such a more effective educational model for the 16-18 year-old. Further examples of this can be seen below [*fig. 1.1*], with original Max/MSP objects placed alongside their CuDAS alternatives to highlight the attention to the visual. This involved either changes in colour, size or orientation, but also parameters. This is also possible to see in *fig. 1.1* where the sine wave represented in the spectrogram and sonogram is the same for each (1000 Hz) but appears in quite different places on each of the graphs. This was to avoid the problems noted in the Muir example discussed in Chapter 5.3, where parameters have not been set accurately enough to enable the full educational potential of the graphic displays available in Max/MSP.

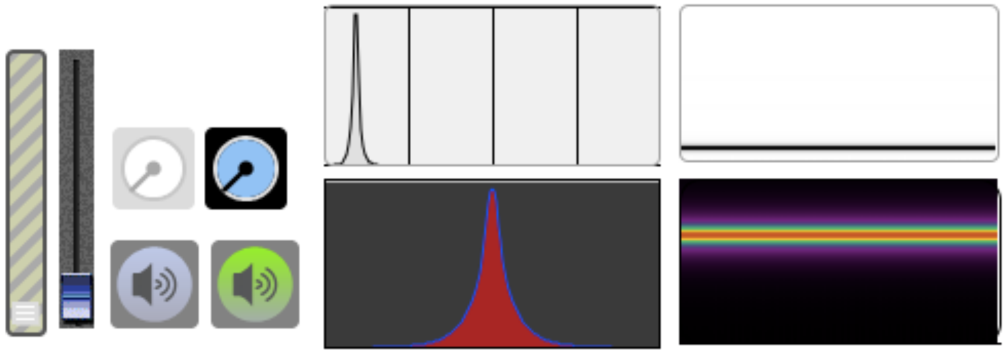

Fig. 1.1 *Examples of default Max/MSP objects (left/above) against their CuDAS programmed alternatives (right/below).*

Further attention has been applied to the visual nature of CuDAS through careful attention to the use of fonts. The standard preset for fonts in Max/MSP is 'Arial', which has the following appearance. Whilst familiar to computer users, the nature of this particular font places the lettering close together and makes blocks of text harder to read. It is less attractive than readily available alternatives. The original desire was to use the font 'TW Cent MT', which is the font that can be seen here, and is also used in the supporting material PDFs. However, upon road-testing the software it became apparent that this is a font that is only supported if it has been previously loaded into the computer's available bank of fonts. This automatically happens if Microsoft Word is installed. However, for Macintosh users this is not necessarily a common occurrence. As such, the font was not recognised on these machines and the display defaulted to the Arial font which effected all of the formatting, making the text illegible at times and unaligned in most places. As a compromise, the font 'Times New Roman', which takes the following appearance, was selected. The lettering has more of a visual impact and as such is clearer to read and enhances the visual aspect of the software.

Each of the tutorial pages in CuDAS has the same visual layout, albeit with colour differentiation between each one. The 6 tutorial block images with further learning placed above in small blue boxes are retained throughout the software [see *fig. 1.2*]. They are programmed to look the same in order to reinforce the link between the learning and further generate a sense of developmental learning. The familiarity of this layout also encourages experimentation as the curriculum is followed. The increase in comfort with the functioning of the software leads the student to explore through a position of comfort rather than feel a sense of alienation through constantly changing displays and imagery.

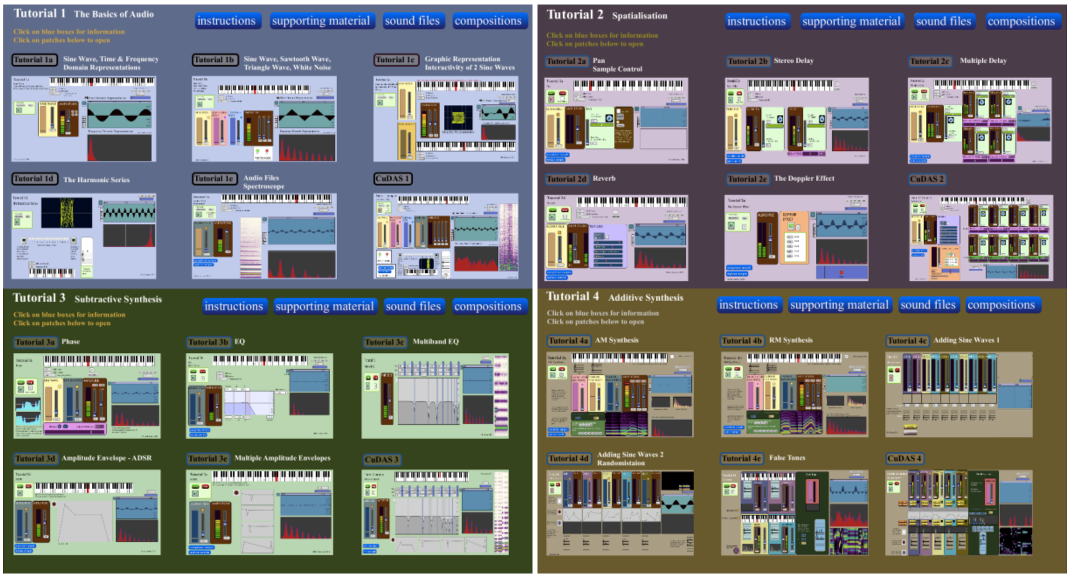

Fig. 1.2 *The visual appearance of the tutorial files showing the same layout for each with colour differentiation.*

1.3 The CuDAS front-page

As the CuDAS application is relatively large and complex, the programme takes a while to open. Rather than leaving the user in limbo while nothing happens during this process, as can be seen in similar models such as Clarke's Finnissy software, a loading message was programmed [see *fig. 1.3*, right]. This ensures that the user does not wrongly assume that there is a technical problem or lose patience and try loading the software for a second time, causing running conflicts. It can be seen that there is also an image design to CuDAS itself. This logo is made up of lettering placed over the waveform of the spoken word 'CuDAS' itself. Although ancillary to the learning itself, it does provide an interesting aside.

Fig. 1.3 *The loading message and CuDAS logo*

When CuDAS is first opened, the user interface is displayed clearly and succinctly. Three windows automatically open on start up [see *fig. 1.4*] and these windows remain open throughout the navigation of the software. This ensures the hierarchical design of CuDAS is evident throughout the learning experience. The tutorial patches themselves are layered to ensure that at no point are they completely covering the left hand panel, offering an ease of navigation and return. This left hand panel clearly shows the four learning areas and gives accessibility to each through a single click. At the foot of the pane are included further areas of learning through the coloured rectangles. These are discussed in greater detail later in this chapter.

Fig. 1.4 The CuDAS front-page

The welcome page that offered a loading note on initial opening of the software is then transformed in order to give a brief introductory message to the programme and offer advice on the initial navigation route, thus avoiding any confusion with the alternative layout and use of the software in comparison to other music technology programmes that the student may already be familiar with. The importance of the supporting material, sound files and compositions is also outlined in this earliest of stages to ensure that the pedagogical message of the interlinking of these three elements with the tutorial patches themselves is understood and pursued.

The last of the three windows to open on start-up is the 'play~record' area [see *fig. 1.5*, below]. It is here that the user can control the volume of the output. This is set to be at a reasonable level open opening but can be adjusted at any time as instructed on the panel with the words 'control volume here', highlighted in blue in *fig. 1.5.* It is also possible to turn the sound on or off through the use of the red or green speaker symbol, an alternative colouring of the max object 'ezdac'. All of the patches output their sound through this feature through the use of the *send* and *receive* objects in Max/MSP. This centrally located control greatly adds to the ease of use and also adds as a quick reference to whether or not the sound is on and the volume level is turned up, this negating any concerns for the user in this area. On the right hand side of this

Fig. 1.5 The play~record window

panel are included controls for recorded the output of the computer. Clear instructions on the use of this feature are provided, highlighted in red in *fig. 1.5*. Once activated, a 16-bit aiff (audio interchange file format) at 44.1KHz will record to the area of the computer chosen. This area is of central importance to the learning in CuDAS as it is through the ability to record his or her own output that the student is able to actively partake in the creative process that the tutorial patches have to offer.

1.4 Tutorial 1 – The Basics of Audio

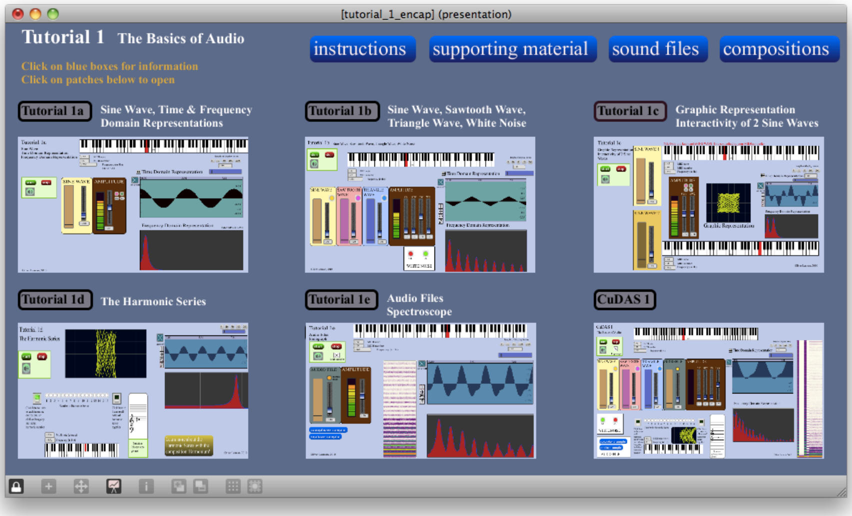

Fig. 1.6 Tutorial 1.

It can be seen that Tutorial 1 introduces the fundamental concepts of acoustics through five tutorials. These are labelled;

Sine Wave, Time & Frequency Domain Representations
Sine Wave, Sawtooth Wave, Triangle Wave, White Noise
Graphic Representation, Interactivity of 2 Sine Waves
The Harmonic Series
Audio Files, Spectroscope

The Tutorial concludes with CuDAS 1, a combination of all of these areas. The terminology and use of amplitude and frequency form a large portion of this tutorial, as the understanding of the technical language was something that was deemed to be essential to promote. Physics as a subject area does not need to be feared in the music classroom. As such, integrating an understanding of Hertz and their relationship to pitch and the relationship of decibels to dynamics are key to understanding the properties of acoustics and a wider appreciation of the way music works in practice. These are areas that were further developed and explained in the supporting material to accompany the tutorial. The use of Max/MSP was of significant value at this point due to its ability to display real-time evolution of time, frequency and graphic domain spectra through the use of the *waveform~*, *spectroscope~* and *scope~* objects respectively. This is an area that was of key educational value to CuDAS, for as Clarke points out, "aural and visual feedback greatly enhances the student's understanding and memory of the theoretical issues. This is particularly useful in complex examples where the relationship between a particular parameter and its effect on the spectrum of the sound is more difficult to grasp intuitively."[1]

The secondary area of study within the tutorial deals with the differing nature of various electronically generated tones as well as the more complex nature of audio samples. The patches begin with a single sine wave (Tutorial 1a) developing to a saw tooth wave and triangle wave (Tutorial 1b), progressing to the interaction of two sine waves (Tutorial 1c), before introducing the ability to view audio files in the same analytical processes (Tutorial 1e). This gradual progression of knowledge of electronically generated timbres and their relationship to acoustic sounds ensures the ability to cement the complex nature of any initial exploration in to this area of study, whilst also offering access to the historical sound world explored in the initial experimental music created at both the *Elektronische Musik* of the Köln School and *Musique Concrète* of the Parisian School of electronic composition. This area is of significant importance when applied to AoS3 of the Edexcel GCE in Music Technology as discussed in Chapter 1.2. Approaching the nature of sound production in this sequential way also offered an interesting opening to the discussion of the properties and complexities of white noise generation that can be seen to be integrated into the Max/MSP patch as part of Tutorial 1b through the use of the *noise~* object.

The tertiary aspect of Tutorial 1 is concerned with the implications and application of the harmonic series in defining timbre (Tutorial 1d). This was included due to the designation of essential criteria for the understanding and development of knowledge concerning the properties of sound within a musical context. Covered at length in the background supporting material, this area of study is essential to the wider comprehension of synthesis that would follow in later tutorial topics.

1 Clarke in O'Donoghue, 2006; p.302

1.4.1 Tutorial 1a – Sine Wave, Time Domain Representation, Frequency Domain Representation

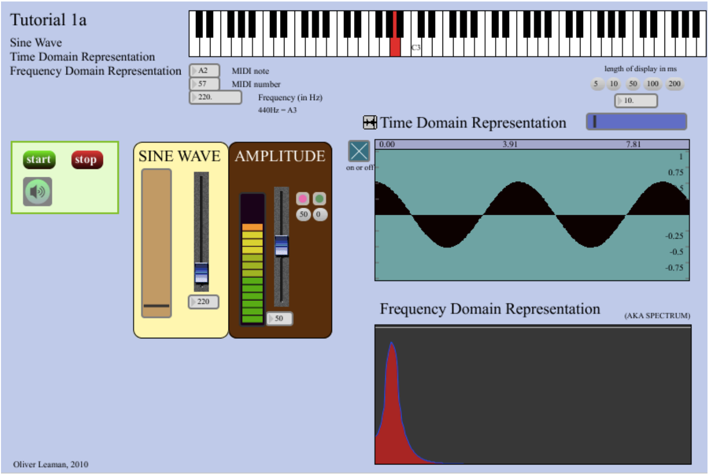

Fig. 1.7 The Max/MSP patch used for Tutorial 1a. The waveform represented is a sine wave at 220Hz.

Upon opening the tutorial, one first encounters a green instructional box. As discussed in Chapter 2.4, these boxes act as 'pop-ups' that obscure the main portion of the tutorial. Programming this to happen ensures that they cannot be ignored, a result increased by the choosing of a lurid green colour to increase their visibility. This programming technique is used for each of the following tutorials and offers a quick and simple way of putting across essential information for each before any interactivity takes place.

Once the student has moved on to the actual patch of Tutorial 1a, the essential information of this topic quickly is quickly conveyed, explaining to the students how fundamental both time and frequency domain representations are to the completed CuDAS patch in terms of their use to the composer to enable a quick reference to the output of the musical material. The Max/MSP objects used are the *spectroscope~*, set to a logarithmic scale, and *waveform~* objects, both of which are commonly used when working with audio in Max/MSP and therefore critical for the ability to enable the possibility of future extended use of the programme.

Students are invited to open tutorial 1a and experiment with altering the frequency of a sine wave input, thus showing an alteration of the output in the graphic displays. This was done with the use of a MIDI controller keyboard using the *notein* object linked to the *kslider* graphic [see *fig. 1.8*]. This graphic was clearly labelled to show C3 (middle C) to enable orientation for the students. Further patching using number boxes set to MIDI

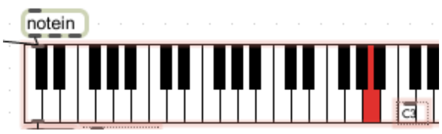

Fig. 1.8 The notein *and* kslider *objects to enable the use of a MIDI controller keyboard*

note, MIDI number and the *ntof* (note to frequency) object enabled the students to clearly see the changes they were making to the sine wave in all possible terminology [*fig. 1.9*]. As with a great deal of technical programming, this remains hidden in *Presentation Mode*. The importance attributed to avoiding cluttering the screen with information not needed by the learner was paramount to the patch's design.

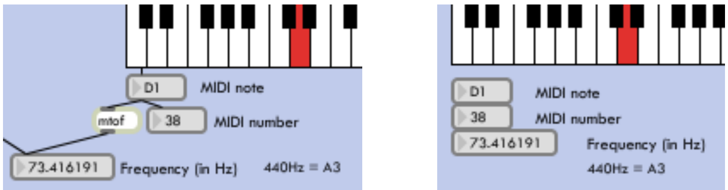

Fig. 1.9 The use of MIDI note, MIDI number *and* ntof *for numerical displays. Shown in* Patching Mode *(left) and* Presentation Mode *(right)*

The ability to further control the frequency of the *cycle~* object that provides the tone generation for the sine wave was achieved by linking it to a *slider* object that could be manipulated by the user of the patch using a computer mouse [see *fig. 1.10*]. These changes are made using the blue fader on the right, chosen due to the similarity the design of this fader has to sequencing software graphics that the students would already be familiar with. Set to a range of 4001, the *slider* offers the ability to change the frequency in 1 Hertz jumps from a range of 0 to 4000 Hz. This limit was made for two reasons. Firstly, any greater division would make the *slider* impractical for use, as the mouse would have to be dragged a very long way in order to affect a small change in frequency. The second reason was to protect the ears of the listener. If the range of Hz available reached the limits of human hearing, there would be a large area in the higher range that could potentially damage the ears if used for a sustained period of time. It was therefore deemed prudent to avoid this possibility by setting a limiter on the output of Hz at 4000.

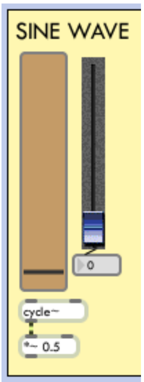

Fig. 1.10 The manual control of frequency, shown in locked Patching Mode

A similar method using the *slider* object is used to control amplitude [*fig. 1.11*]. In this instance, however, an inclusion is made of two quick *button* object controls. These are set to 0 amplitude and 0.5, on a traditional scale of 0 off and 1 maximum output. However, these are labelled as being 0 and 50 due to the nature of a sequencer labelling amplitude on a scale of 0 -100. This is educationally simpler for the student to relate to. The buttons in question are clearly identifiable by the alteration of colour; pink for 50 and green for 0.

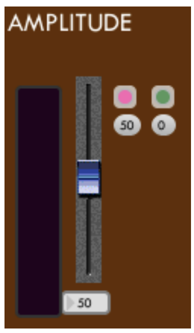

Fig. 1.11 controlling amplitude.

The interactivity in Tutorial 1a is kept to a relatively simple level. The procedures of changing frequency and amplitude are limited by the use of a MIDI keyboard and sliders. This avoids the overstimulation by excess information and dials that would inhibit learning at this early stage. This simplicity is aided further by programming the patch to work as soon as it is switched on through the use of the 'on' toggle. Pressing this function implements a series of bangs and toggles hidden in the patching that set all of the levels required for instant audio output. However, subliminally a great deal of additional information regarding the nature of Max/MSP is included at this early stage. It was decided to retain, for example, the float and integer number boxes in the patch. This builds from the outset a familiarity with these objects and will therefore be of use to the student who wishes to take the learning of CuDAS to the next level and investigate the Max/MSP programme further. This is achieved without overcomplicating the user interface or including redundant and irrelevant information.

1.4.2 Tutorial 1b – Sine Wave, Sawtooth Wave, Triangle Wave, White Noise

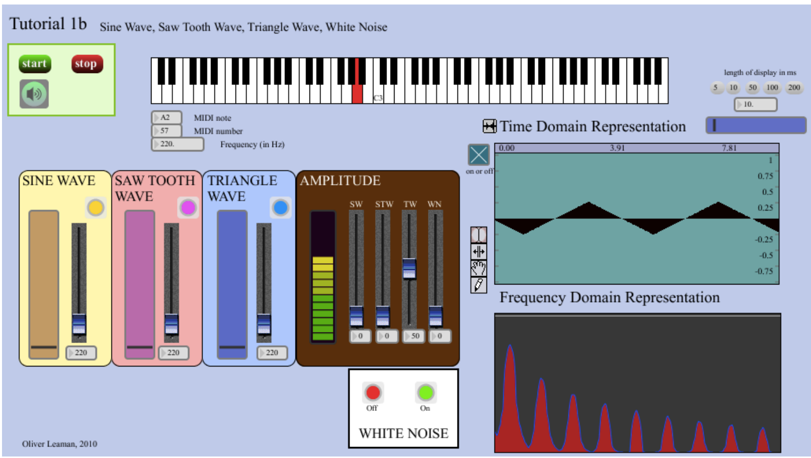

Fig. 1.12 Tutorial 1b.

The process of patching of each of the subsequent tutorials is approached from the standpoint of developmental learning. It is for this reason that the layout maintains a familiarity throughout, whilst slowly introducing new concepts and ideas and more complicated aspect from the Max/MSP programming language. This can clearly be seen in Tutorial 1b, which maintains many aspects of the previous tutorial in terms of layout, design and function. The time and frequency domain representations are retained, as indeed they will be throughout the CuDAS patches, and their manner of operation remains the same. Indeed it quickly becomes apparent that the only addition to this patch compared with its predecessor is the inclusion of further electronic waveforms offering the user understanding of alternative wave shapes and partial construction

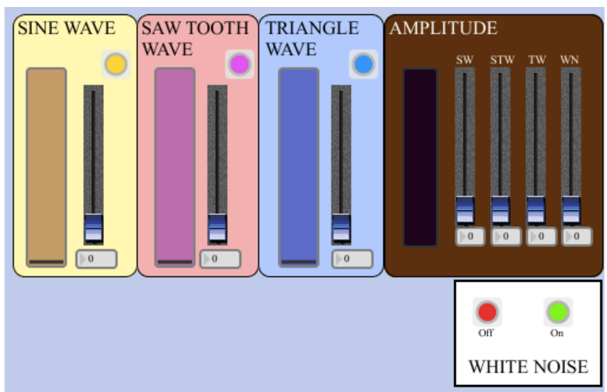

Fig. 1.13 The alternative waveforms in Tutorial 2b, marking the only change in interface design from Tutorial 1a.

associated with sawtooth waves, triangle waves and white noise [see *fig. 1.13*]. In order to achieve these sounds the *phasor~*, *tri~* and *noise~* alternatives from *cycle~* in Max/MSP were used. Through the use of multiple bangs the patching ensures that only one waveform can be sounded at any one time and therefore turning on one of the alternatives will turn the previously selected sound source off. This is to avoid overloading the sound leading to a causing of clipping of the output signal, but also to further ensure clarity between each of the electronically generated sound sources. The ability to alter amplitude of each of these shapes is also contained, reinforcing a clear understanding of the relationship between lower amplitude and the reduction in peaks in the time and frequency domain graphs.

It is through the introduction of these alternative oscillators that the work from the Koln *Electronische Musik* school in the 1950s is introduced into CuDAS. As previously mentioned, this is central to the study in the GCE Music Technology course and as such helps to provide a contextual understanding of the basic techniques explored by Stockhausen, Eimert, Kagel and others.

1.4.3 Tutorial 1c – Graphic Representation, Interactivity of Two Sine Waves

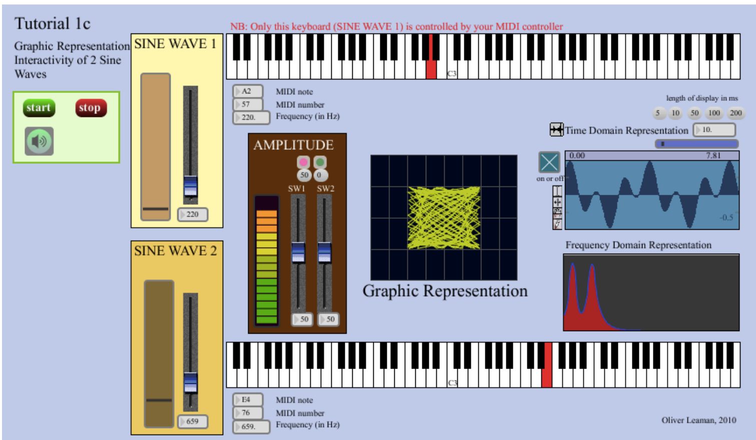

Fig. 1.14 Tutorial 1c.

Tutorial 1c offers the first dramatic change in presentation with the introduction of the *scope~* object alongside a secondary keyboard display for controlling the notes of the additional sine wave. The aim of this tutorial is to offer an early introduction into the realm of consonance and dissonance of notes. In order to achieve this, the graphic representation responds to the two sine waves to show the shapes that harmonic and inharmonic relationships produce. These relationships can be controlled by the user in the same ways as the previous control interface, enabling a clear visualisation as well as an aural appreciation of the importance of the interaction of the two frequencies.

1.4.4 Tutorial 1d – The Harmonic Series

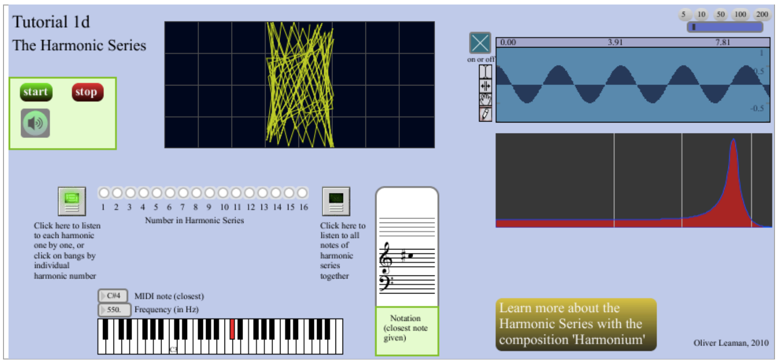

Fig. 1.15 Tutorial 1d.

The harmonic series is crucial to the understanding of all acoustic phenomena. This tutorial therefore develops the principles of its predecessor to demonstrate the importance of this area and of the fundamental frequency. The relationship that can be outlined simply as harmonic frequencies being integer multiples of the fundamental frequency is a concept that is unlikely to have been covered in the learning at this level previously and so fundamental is it to the understanding of timbre and synthesis that it was considered essential to devote a compete tutorial to the subject at this point in the learning. The harmonics are programmed according to the laws of physics and, as a result, do not adhere to the tempered scale, as can be seen in *fig. 1.16*. This may sound slightly unusual to the user at first, but it allows an exploration of the history of tonal development alongside an understanding of the importance of said interaction of tones.

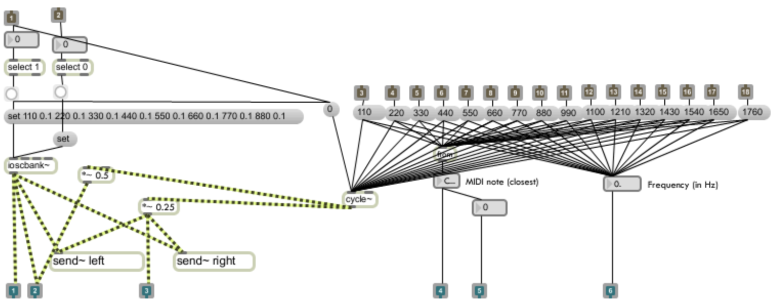

Fig. 1.16 The patching of the harmonic series according to the laws of physics as opposed to western tuning. There are simpler ways to patch this in Max/MSP, but this method was chosen for clarity of programming in the early stages of development.

The implementation of the harmonic series is made as simple as possible through the use of on/off bangs that scroll through the first 16 harmonics one by one. The patching in the tutorials is at this point becoming increasingly complex in order to fulfil the required function and so greater depths of care are implemented to ensure the user interface remains clear and simple. This can be seen as an example in *fig. 1.17*, where it is possible to see this function in patching and presentation mode. From this image one can also note the first use in CuDAS of the *nslider* object, which outputs a notational graphic. This was included to enable the student to reference the audio output with musical notation and as such further comprehend the relationship of the harmonic series. The closest MIDI note name is also given to ensure

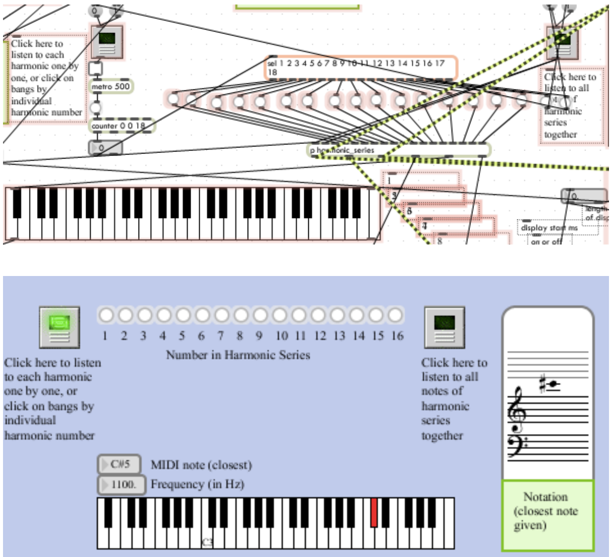

Fig. 1.17 *The scrolling harmonic function, in complex patching mode and simple presentation mode.*

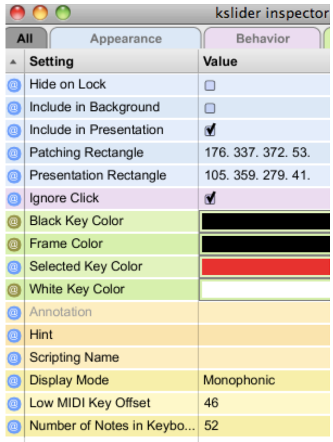

Fig. 1.18 The altered parameters of the kslider in tutorial 1d.

comprehension by both those able to read traditional scores and those unable to do so. The musical output is also reflected on the *kslider* graphic. The parameters of this object have been altered as shown in *fig. 1.18*. This ensures that clicking directly on the keyboard will have no effect, as it is not part of this particular learning exercise. The low MIDI key offset has also been altered in order to ensure that harmonic series appears in an appropriate place on the keyboard instead of disappearing off either end.

1.4.5 Tutorial 1e – Audio Files

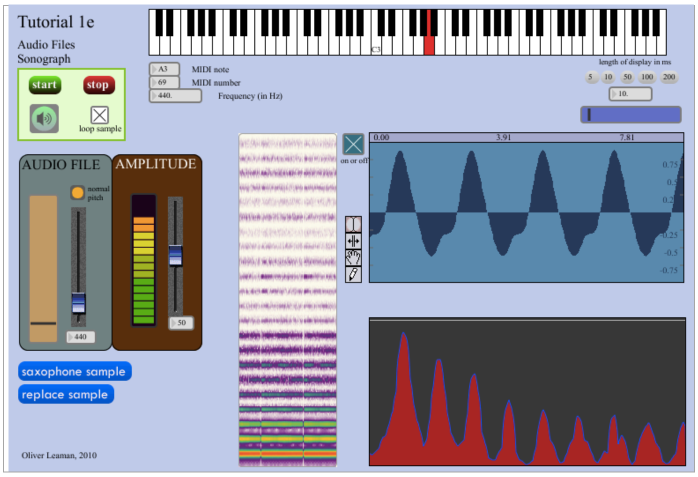

Fig. 1.19 Tutorial 1e.

The last of the tutorials in this learning area introduces the audio sample. This area was deemed crucial in the study of the *Musique Concrete* school in Paris and the composers

Schaeffer, Varese, Xenakis and others that, along with the aforementioned *Elektronische Musik* school, corresponds directly to the learning area for Unit 4 of the A-level in Music Technology. Educationally, it could also be argued that the learning is made more creative and intrinsically more musical by replacing the sine wave with a sample that can be looped. The sample chosen as the default was an alto saxophone playing a long-held note pitched at 440Hz. This was chosen as it clearly shows the partials or harmonics in a steady state and as such follows on from the learning in the previous tutorial very succinctly. The spacing of the harmonics of this particular instrument are, in terms of amplitude, very even, with a smooth curve in reduction as one moves through the partials. This was of key significance in imparting the educational message at this point.

Fig. 1.20 The 'replace sample' function in Tutorial 1e

There is also programmed into this tutorial the ability for the student to load his or her own sample directly from the hard drive of the computer, using the 'replace sample' function [see *fig. 1.20*]. This function was included in order to enable the showing of the slightly more complex nature of instrument tones and the appearance of harmonics beyond the fundamental frequency. It also offers the student the chance to take ownership of the patch and enable interaction between sonic materials of their own choice. A return to the saxophone sample can always be made through the implementing of the appropriate button.

Any sample chosen can also be controlled further through the ability to loop the sound. Until this point students will be used to sounds in CuDAS that are continuous. That is to say, once an electronic sound source has been loaded in to the software, it will sound until the user physically stops it. This is not the case with audio samples, which have a finite length. This could potentially cause a problem in that any interactive manipulation that student undertakes would cease to function after a few seconds. In order to avoid this problem, the message 'loop $1' is sent to the *sfplay~* object in Max/MSP, shown in unlocked patching mode in *fig. 1.21*. Controlled within the patch to be either on or off through the on/off toggle, the inclusion of this function enables the sample to be cycled over and over, allowing the student to continue his or her sonic investigation unencumbered by the need to continually restart the sample.

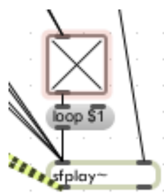

Fig. 1.21 The looping function in Tutorial 1e

This tutorial also introduces the user to the sonogram, which is made by altering the defaults of the *spectrogram* object. The display colours have also been altered quite substantially to allow for a sleeker appearance than the greyscale presets permit in Max/MSP. The inclusion of this area covers the last of the graphic representations presented in CuDAS. The three that are present in this tutorial for the most part are retained throughout the rest of the CuDAS tutorial patches, although the parameters are altered to suit the need of the topic in question.

1.4.6 CuDAS 1

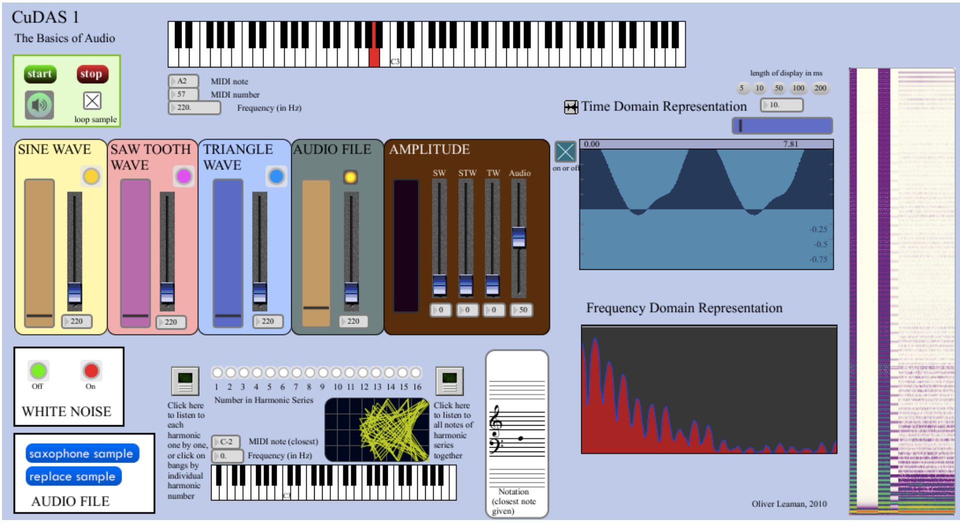

Fig. 1.22 The CuDAS 1 patch.

The final patch in Tutorial 1 is labelled as being CuDAS 1. In essence, this is a combination of all of the material covered in Tutorial 1a-e placed in one window. It offers the chance to recap all of the learning to date in one centrally positioned location. However, the patch has a far greater educational significance than this as it is here that the student is best placed to invest some of his or her own creativity. Upon opening the patch, the message box shown in *fig. 1.23* is displayed in order to clearly state to the students that this is an opportunity for them to be creative, with an example of this process provided.

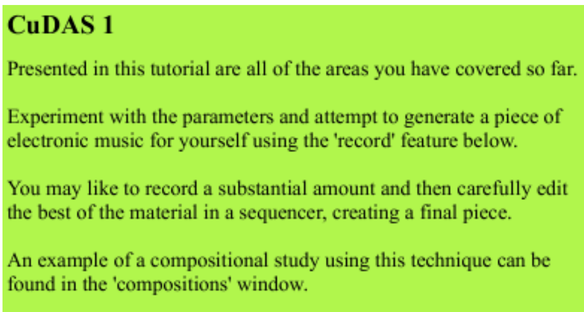

Fig. 1.23 The message box displayed upon opening the CuDAS1 patch

This opportunity for creative work with the task of generating material and then subsequently editing in a sequencer mirrors common contemporary practice in the field of algorithmic composition. The inclusion of this area underlies the need from the outset of CuDAS to develop the artistic skills of editing, creativity and aesthetics, as the students attempt to modify their experiments into creative electronic compositions in their own right. An example of the process by which this patch can be utilised in this way is included in CuDAS in the 'composition' window. Also called CuDAS 1, this short study highlights the possibilities open to the student through the interactive manipulation of the patch and provides a level of inspiration and awareness of possibility not available without the inclusion of the audio.

1.4.7 Harmonium

At this point, the first example of music composed specifically for the learning process of CuDAS is introduced. To support the tuition in Tutorial 1, the pedagogic composition 'Harmonium' is presented as a central part of the CuDAS curriculum. This adoption of composer as pedagogue into the heart of the interactive software serves to improve understanding of topics alongside development of curriculum and as such forms the basis of the pedagogical methodology within CuDAS. The ability to bring the performer into the classroom within this context was extremely useful and as such enabled further the students' comprehension and enlightenment with regard to the pedagogic nature of the composition. This was certainly made stronger still by having the composer present when delivering the material.

This piece for solo flute and live electronics [Max/MSP] underlines two important areas in the wider CuDAS curriculum. To begin with, there is the writing for the flute, which utilises only the notes from the harmonic series, played in a variety of ways, from traditional playing to extended techniques of over blowing, cross-fingering and whistle tones. These alternative techniques were chosen in order to add depth and contrast to the musicality of the piece, but also to introduce another key element of contemporary music to the students – that of extended techniques. Long associated with experimentation, these techniques and electronic music have often found themselves accompanying each other on an experimental journey together. As a result, it was necessary to offer these alternative sound worlds to the students to make them appreciate that an instrument can extend far beyond their expectations and preconceptions, just as the timbres of electronic manipulation will stretch their aural palate in a similar way.

The other area that was also opened out for the students was the use of the live electronics. In using elements from the CuDAS patches at the very outset of the tutorial topics, a sense of progressive completeness was enabled. From the very start of the learning the students are made aware of the nature of the work that is to be accomplished in this course of study. The openness and familiarity that is then generated on hearing work creating with elements of CuDAS in turn avoid alienation and confusion as the areas of learning unfold. The elements of the CuDAS patch that were chosen to be included in this piece were the ability to sample and loop, alter amplitude, vary frequency and duration and add and control reverb and pan. These resulted in a variety of textures that complemented the flute writing and helped to underline the core elements of the learning material involved whilst retaining a sense of artistic expression. This can be most noticed in the final stanza on page 4 of the score, which contains the only exception to the rule of using notes only from the harmonic series [see *fig. 1.24*].

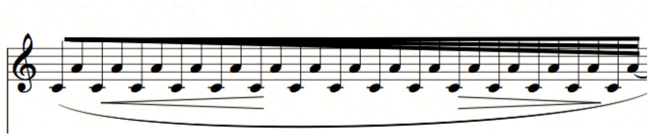

Fig. 1.24 Example of non-harmonic series material in 'Harmonium'

The flute trill can be seen to include a rogue A[3], which is external to the pattern as a whole. Aesthetically, this note is included purely as a compositional device to enable the resolution of tension that is created by the continuous cyclical nature of the notes used until this point. It gives a sense of a bridge to a finality and as such helps to turn what would otherwise be merely an exercise into a piece of artistic expression. This note also has validity educationally as it is this moment in the piece that can provide the opportunity to question the students' knowledge and aural perception to see if they can identify this one instance in the composition that forms the exception within the rule of the harmonic series.

It is this integration of aesthetic composition on the one hand and an educational tool on the other that is the key to the success of 'Harmonium' as a piece. It would be remiss to suggest that the work was composed as an example of a specialist piece for inclusion in the solo flute repertoire. Although it has been performed in the concert hall as a piece in its own right[2], it is pragmatically reasonable to assume that it needs the pedagogic context to completely justify its existence. However, despite this point, neither can the piece be seen to be a mere exercise in explaining various levels of technical data. Arguably this can and has been done more effectively in various textbooks, classes and lectures and certainly in other areas of the CuDAS software itself. However, 'Harmonium' remains a clear example of the role of composer in the context of CuDAS as a practitioner, something that could and should be encouraged in other composers and education professionals.

This relationship between the scientific and the artistic in composition is one that has been exploited to the full in the CuDAS project and one that is believed to be a fundamental and yet very often overlooked compositional tool and aesthetic principle. Indeed, it could be argued that the scientific and aesthetic approach, rather than being in opposition, guide and complement each other until a higher plain that transcends the one dimensionality of either one or the other is reached. 'Harmonium' is one such example of this, where the aesthetic ideals that are striven for entwine with the scientific and demonstrative principles applied, leading to a work that is stronger on both levels, in part due to the influence of one on the other in the compositional process.

1.4.8 Harmonium – Interactive Exercises 1& 2

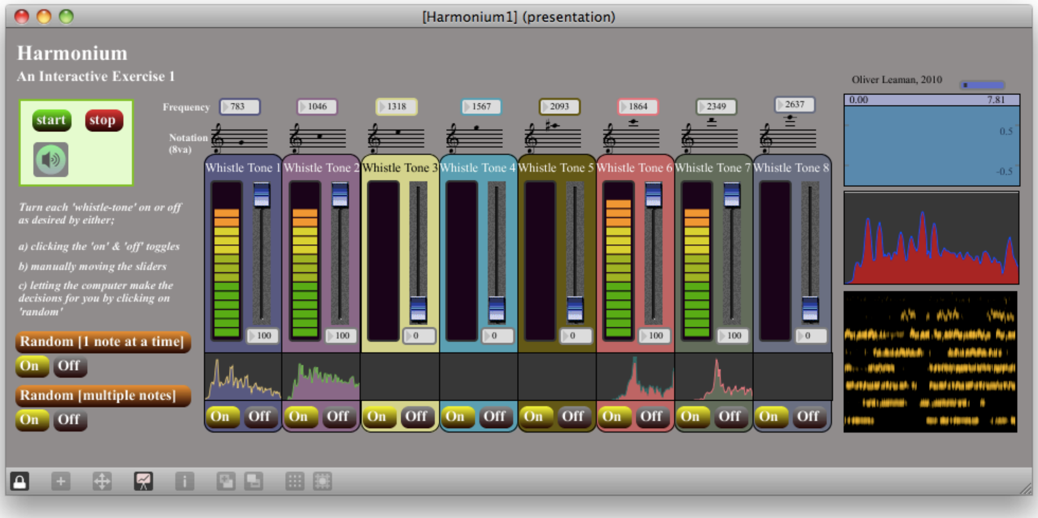

Fig. 1.25 *The 'Harmonium – interactive exercise 1' patch.*

Alongside the audio and score of 'Harmonium', CuDAS also presents two interactive exercises. These are included in order to further engage the students with the compositional material and, in so doing, enable the compositions to become interactive in their pedagogic message, thus strengthening the educational value contained within. They also serve to further underline the relevance the piece has to the learning involved in CuDAS and highlight the cohesive nature of the curriculum. The first of these [see *fig. 1.25*] allows the student to manually introduce each of the 8 whistle tones heard in the opening material of 'Harmonium'. By clicking on the 'on' or 'off' window at the bottom of each channel strip, a sample of each corresponding frequency and notated tone will fade quickly in or out. This in turn is represented through the amplitude fader, meter level and graphic domain representations. The resulting sonogram and spectrogram outputs of the combination of tones are then shown on the right hand side of the patch as will now be familiar to the student through the use of the CuDAS tutorials.

This learning exercise is creatively extended through the use of the 'random' feature, found at the bottom left of the patch. This allows the computer to select the notes, either one at a time or a random combination of any of the tones. The programming ensures that only one of the random options will work at any one time, so turning the second example on will also turn the

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2 Performed by the flautist Lucille Burns for Weymouth Music society, November 2009 with the composer performing the

first off, and vice versa. Through these methods the student will appreciate the ability of the computer to generate compositional material and also further understand the consonant relationship that is created by notes of the harmonic series.

The second interactive exercise is introduced at the end of the next tutorial in CuDAS, Tutorial 2a – Pan. Although this investigation is chronological in nature, it is more appropriate to look at this exercise in greater detail at this point due to the enhancement it makes on the previous interactive patch. The placement of this exercise at the end of the first tutorial in the secondary level of the CuDAS learning highlights the cross-referencing nature of the software and highlights to the student that the learning in Tutorial 1 is directly related to the following tutorials. It also offers the opportunity to take the creativity of the Harmonium exercises a stage further. *Fig. 1.26* shows that many of the elements of the patch are repeated from the first exercise.

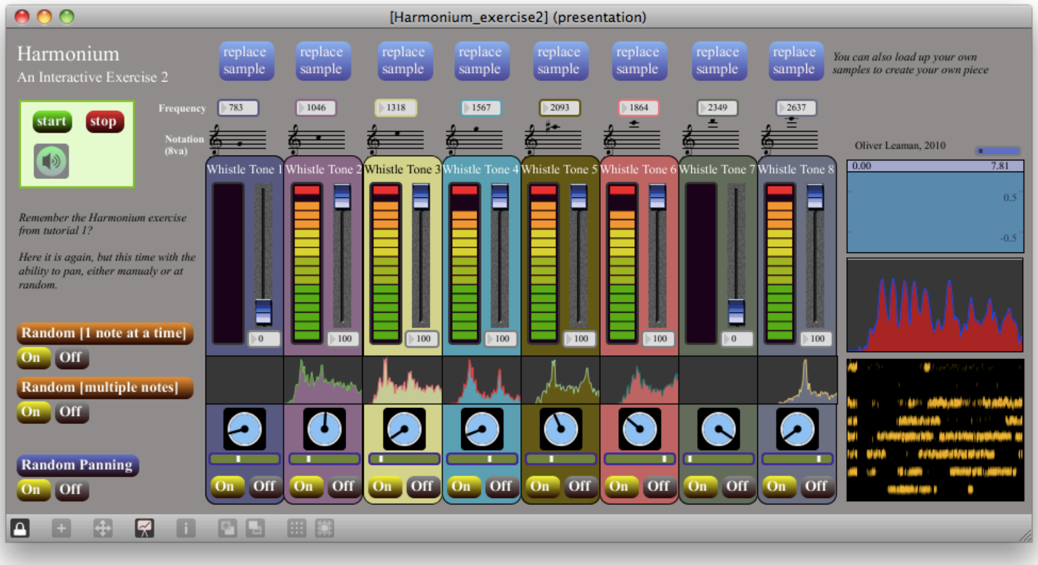

Fig. 1.26 *The 'Harmonium – interactive exercise 2' patch.*

The ability to fade in each of the tones at will or at random, in combination or alone, makes the operation of the exercise familiar. However, introduced on top of this learning is the ability to control the azimuth of the audio signal through both pan position and speed taken to move to that position. These elements are manually set through the use of the light blue pan pot dial and the green horizontal slider found above the 'on' and 'off' switches in the channel strip. These controls in turn can also be randomised by the computer, allowing for a more cohesive musical experience through the implementation of stereo into the audio output.

The final element of the patch that enables the student to engage further with the learning process is generated through the ability to replace the whistle tone samples. The 'replace

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Max/MSP part.

sample' function found at the top of each channel strip allows the learner to experiment further with this creative tool using his or her own sounds and samples. In this way, they can take full ownership of the outputted material and as such use the interactive patch as an instrument for the generation of musical material in its own right. This helps to develop the students' ability in compositional areas concerning electronic music and also maintains the interest level through the CuDAS process.

1.5 Tutorial 2 – Spatialisation

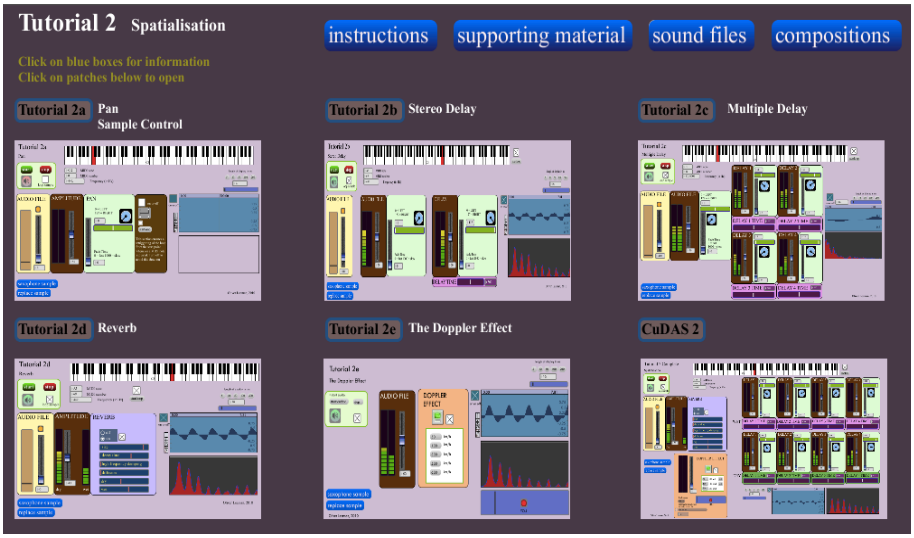


Fig. 1.27 Tutorial 2.

Tutorial 2 presents five new areas of learning, also combined in a final sixth patch called CuDAS2. The tutorials are labelled from a-e and cover the following principal areas;

Pan, Sample Control
Stereo Delay
Multiple Delay
Reverb
The Doppler Effect

Central to the learning in Tutorial 2 is the notion that it builds from the essential terminology and basics of analogue and digital audio learned in Tutorial 1. This is an ongoing concern throughout the curriculum of the CuDAS project; the notion that the learning is developmental and that the students undertaking the programme of study can clearly identify that the knowledge and skills that they are enhancing are related from tutorial to tutorial and that, moreover, they clearly link in a sequential way, providing a sense of completeness that can only be achieved by the continuing of the study through all four of the tutorial topics. The second tutorial achieves this by developing the language of amplitude, frequency and harmonics into the three-dimensional world in which we live, thereby including the key areas of spatialisation; namely azimuth, zenith and distance. Given the ability that electronic music has to replicate the characteristics of our everyday hearing experience, these categories are clearly essential to the understanding of the development of stereo electronic music production.

Through the discussion of distance and azimuth, it was also possible to introduce the key areas of reverb, delay and pan. Whilst these are intrinsic to any recorded music and therefore areas that are likely to be familiar to students in their second year of Music Technology studies at the GCE level, it is none-the-less worth re-iterating the knowledge that they have already acquired whilst underlying the new notion to them that the reasons that are made with regard to these processes are done so due to the world and nature of psychoacoustics. It is for this reason that it was also valid and of specific relevance to introduce the Doppler shift phenomenon, which was also included in the programming of the Max/MSP patches associated with this tutorial.

1.5.1 Tutorial 2a – Pan

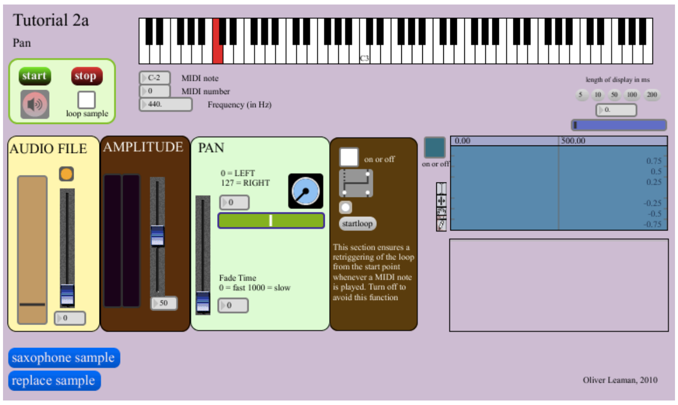


Fig. 1.28 Tutorial 2a.

Tutorial 2a introduces the two-dimensional stereo world through the use of pan. It can be seen upon loading the patch that there are areas that are retained from the previous tutorial. These include the general layout, use of graphic domain representations, the *kslider* object and the general principles of controlling the audio material through the use of level meters and sliders. Alongside this, the audio sample used as the default in this patch remains the same sample as previously heard in Tutorial 1e. This was retained to add cohesion to the developmental learning of CuDAS and as such this sample is retained throughout the learning process and is used as the default for all of the remaining patches that require an audio sample to function. Also retained is the ability to replace this material should one so desire.

Fig. 1.29 The pan pot design.

As previously mentioned, pan is an area that is almost certain to have been covered in the study at AS level. For this reason little explanation is needed in order to make the patch function. A simple pan pot controls the ability to move the sound around from left to right [see *fig. 1.29*]. Set to a value of 0-127 to reflect the MIDI protocol, the graphic has been redesigned from the standard Max/MSP *dial* object in order to appeal more directly to the user familiar with sequencing software. Having enabled the function of pan, this tutorial aims to stretch the use of this tool further

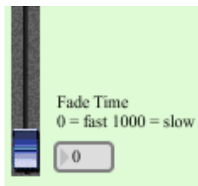


Fig. 1.30 The fade-time tools.

by introducing the area of *fade-time* [*fig. 1.30*]. Set between 0 and 1000, the lower the number, the faster the audio appears to jump from one position to another. A higher number will enable the signal to slowly move across to the new pan position. The ability to alter the speed of pan movement is, unlike the function of pan itself, an area likely to be unexplored by the student and as such offers plenty of opportunity for creative learning.

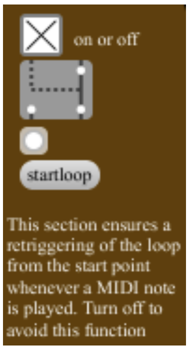


Fig. 1.31 The ggate startloop function.

The final new control surface introduced in this tutorial is the option to restart the sample from the beginning when a new note is pressed on the linked MIDI keyboard. This 'startloop' function can be toggled on or off as desired. The introduction of the object in this way also allows for the presentation of a new object, the *ggate* [*fig. 1.31*]. The graphic of this object is fairly easy to understand. Either a connection is made and the object works, or it is not and it fails to be implemented. This mode of operation will be returned to in later tutorials and as such providing an example of it at this point is a useful exercise in familiarisation.

1.5.2 Tutorial 2b – Stereo Delay

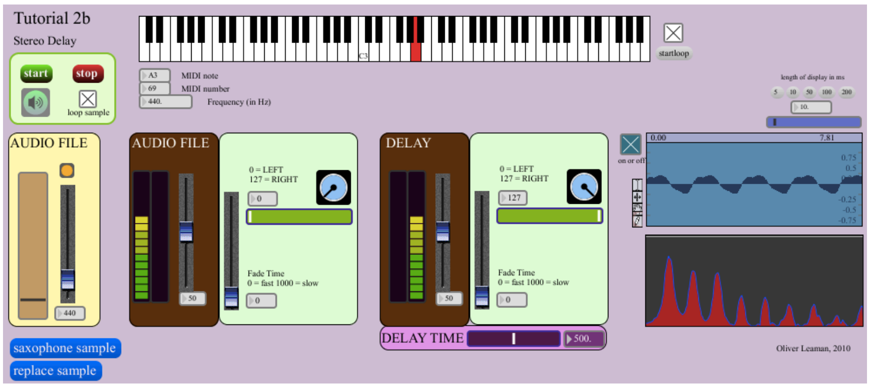


Fig. 1.32 Tutorial 2b.

Building from the initial workings of azimuth, Tutorial 2b extends this principle further by applying a stereo delay to the sample in order to demonstrate the physical workings of the outer ear as described to the students in the supporting material document. Through this patch the learner is able to implement the technique of placing a sound in space simply through the altering of delay and amplitude parameters. Audio delay can be programmed in Max/MSP in a number of ways. Indeed, there is an object, *delay~*, specifically for the purpose. However, the method used in CuDAS is that of the *tapin~* and *tapout~* objects. These need to be

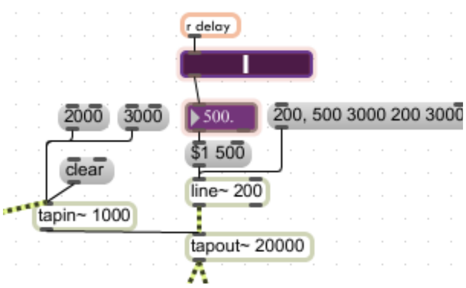


Fig. 1.33 The patching method used for the delay function, shown in unlocked patching mode.

interconnected in order to function as demonstrated in the patching method in *fig. 1.33*. This method was chosen primarily due to the greater control it offered over the delay time. This is controlled by the purple horizontal fader seen in the image. This can be set to range between 0 and 1000 milliseconds through the interactive controls. The secondary delayed signal is then displayed as a separate channel block in the patch. Both the original signal and the delayed variant can then be panned in the same manner as the previous tutorial. When initally activated, the patch defaults to a hard left-right pan of these two signals with a 500ms delay.

1.5.3 Tutorial 2c – Multiple Delay

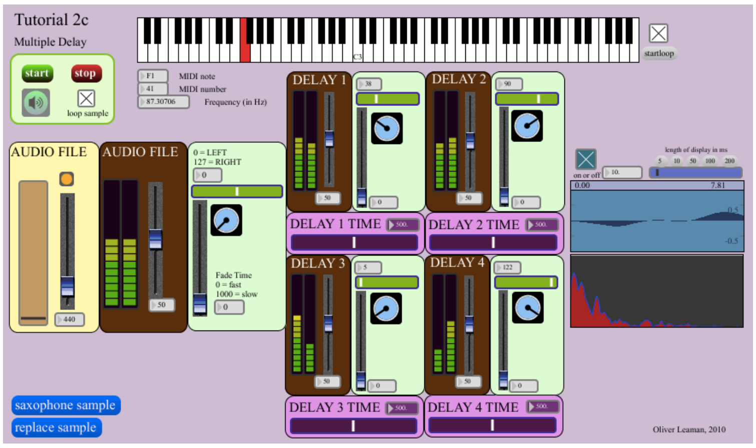


Fig. 1.34 Tutorial 2c.

Tutorial 2c extends the learning of stereo delay into the realm of multiple delay. The patch is relatively straightforward when approached through the structure of CuDAS as it mirrors the previous example almost exactly, simply containing a greater number of delay lines offering a greater ability to creatively spatialise using this method, thus increasing the understanding and creative application of the knowledge and skills learned.

1.5.4 Tutorial 2d – Reverb

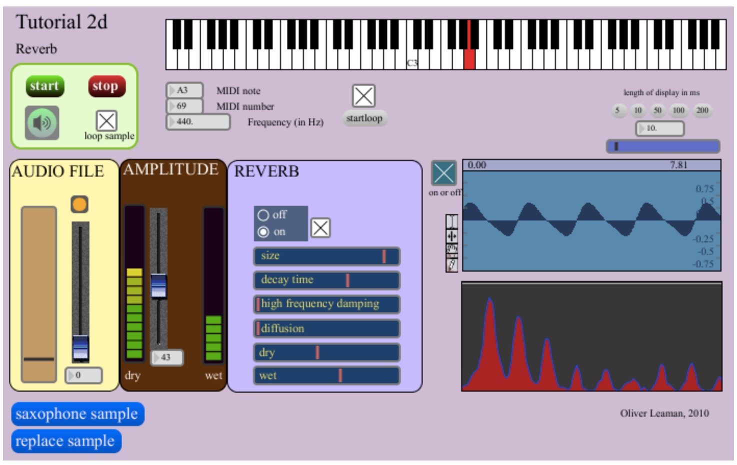


Fig. 1.35 Tutorial 2d.

Having dealt with azimuth in the previous tutorials in this learning area, the next topic to be introduced is that of distance, through the application of reverb. In this patch the amplitude box offers two level meters, one for the dry signal and one for the wet signal. From this display it is possible for the learner to visually realise the contrast between the two signals as well as hear the difference. Changes to the levels are made through the movement of the blue horizontal sliders that control size, decay time, high frequency damping and diffusion, as well as the amount of dry and wet signals.

These areas were chosen for inclusion as they are common to sequencer plug-ins that the student will already be familiar with and as a result will offer the opportunity to further development the understanding of each of these parameters in turn. The supporting material is essential in achieving this and a direct link is made in the 'sound files' area of learning that includes an example of the implementation of reverb in an affective and non-effective manner using the techniques contained within this patch. These alternatives can then be explored through the saxophone sample supplied or through the choice of other samples as desired. In this way, this simple reverb generator can be used in other parts of the GCE Music Technology course as a way of implementing alternative reverb settings to sound files or mixes without the need to enact CPU-draining externals in production software.

1.5.5 Tutorial 2e – The Doppler Effect

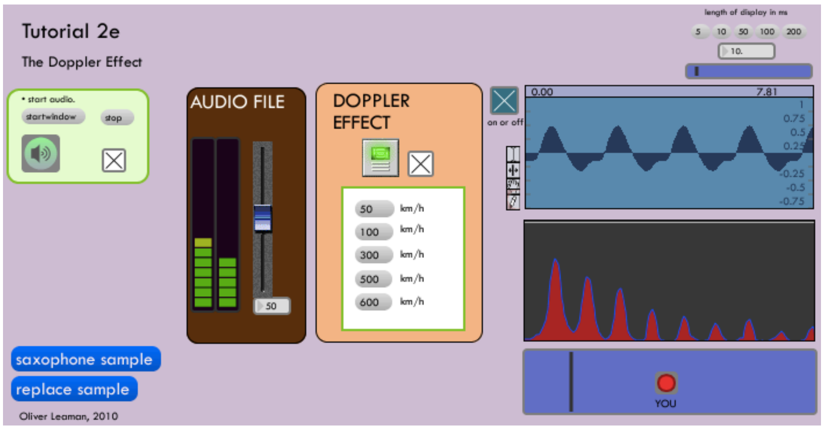


Fig. 1.36 Tutorial 2e.

Although simple to use, this patch contains one of the most complicated areas of Tutorial 2. Upon clicking on one of the speeds in the main 'Doppler Effect' window, the audio file will move from left to right and decrease in pitch as appropriate to the velocity chosen. An automated slider to show the physicality of the movement of sound is included beneath the spectrum analysis to further engage the listener with the action of the patch.

1.5.6 CuDAS 2

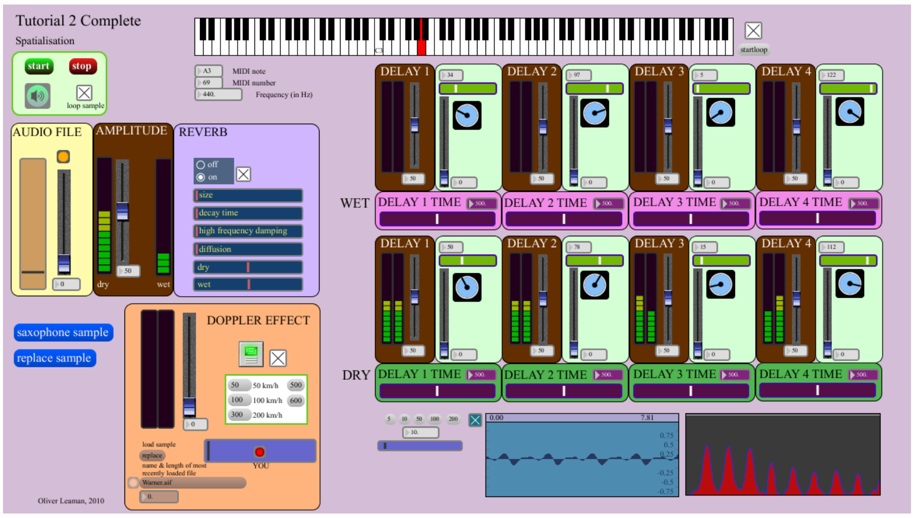


Fig. 1.37 The CuDAS 2 patch.

CuDAS 2 follows the same principles as CuDAS 1. The patch contains all of the preceeding devises used to generate differing aspects of spatialisation gathered together in one working environment. Multiple delay lines are offered in both wet and dry signals and these can be panned as desired. The Doppler controls are also included which have the ability to run concurrently with any audio loaded into the rest of the patch. From using this patch it is possible to generate compositional material in a similar way to CuDAS 1 and an example is again presented in the 'compositions' window. This is again a short study that typifies the options available through the use of CuDAS as a creative, as well as educational, tool.

1.5.7 'Non Vox Sed Votum'

To aid the learning in the spatialisation topic, 'Non Vox Sed Votum' was composed, specifically with the intention of displaying an alternative use of spatialisation in practice. A conscious decision was made to maintain the work as acoustic, devoid of any electronic manipulation or devices. This was in order to aid in the teaching and learning of the importance of generating spatialisation primarily in response to the acoustics of the world in which we live, and to highlight that this can be experimented with without needing to resort to the use of modern technology to achieve what is essentially simply an alternative approach to the performance spaces which we as composers write for. This therefore approaches the philosophy of *listening* as being as key an element in the generative emotive response as the actual composing itself. It highlights the need to apply thought and reason behind all compositional practices and gives an important educational lesson in applying reason and debate into the area of spatialisation, rather than the haphazard way in which this area tends to be approached in modern production techniques, where decisions made in GCE coursework tend to be based loosely on 'rules' as defined by the tradition of popular music recordings, rather than approaching the topic as the creative building block that it can provide.

The first performance of this piece was given in a service in Winchester Cathedral and as such the compositional process was fully enveloped in the knowledge of the extensive possibilities and characteristics available in the field of spatialisation in the use of this unique performance space. It can therefore be seen that the holistic approach to the building is evident throughout the completed score and can be noted in all aspects of writing, from rhythmic, melodic and harmonic material, development of said material, placement of performers and even instrumentation. Specific evidence of this can be seen in page one of the score, where detailed instructions are given to the performers as to their whereabouts in the space. These make use of the actual floor plans of Winchester Cathedral, but could none-the-less be transferred to any large-scale church, priory or cathedral.

A more detailed analysis of the spatialisation implemented in the piece shows the process of composing to express a principle, in this case the principle being the development of learning and understanding of spatialisation in a live performance space. The opening alto saxophone exchanges in bars 1-13 are heard from opposite ends of the cathedral, the first saxophone being positioned at what we would aesthetically think of as the rear of the building, that being the most Easterly point whereas the second alto saxophone is at the very 'front', the West door, of the building. This gives an ethereal quality to the musical material as the passage is reflected from opposite ends of the building, utilising to the maximum the two-dimensional aspect of the building from the points of the compass. The large amount of reverberated signal on the first saxophone completely masks the direct signal for the listener whereas the second instrument has a much more direct sound, especially for those sitting towards the back of the congregation. This alternate use of direct and reflected sound can be fully appreciated due to the inclusion of fermatas of varying lengths throughout this opening section, enabling the acoustic of the building to contribute to the performance of the work. In this unaccompanied opening the musical material appears to resemble that of a delayed signal, or an elongated echo, as first one saxophone and then the other utter cascading arpeggiodic passages. In actual fact, the melodic line retains its shape by being passed between the two instruments, thus highlighting the alternative spatialisation.

The ability to automate spatialisation in electronic music is reflected in the direction to both players to move during the secondary interplay of bars 18-23, shifting the expectations of the listener as the direct sound begins to approach, highlighted by the addition of the contrasting violoncello entry in bar 24, the spatial placement of which is as centrally located within the listeners as possible. The musical material itself is also designed to play with the spatial projection of the sound. This can be most acutely observed at bars 29-33 where the five soprano soloists exchange the first five notes of the Dorian mode. The soloists are placed at alternate positions around the nave, encircling the congregation as if carved angels in the vaults were made temporarily flesh. Their material is always presented as slow-moving counterpoint akin to 14th century plainsong, first noticeable in this opening scalic introduction. All five of the notes first stated are heard in each re-sounding during this passage, but the relationship of the notes will change for the listener as the spatial context of each note is altered. The effect of this, naturally, will be affected by the seating position of the listener. Someone on the right hand side of the front row will interpret the movement of the notes in a different way from someone sitting on the left at the back of the nave. There are further uses of various reverberation and spatialisation throughout the piece. Examples include the melodic material at bar 37, shared between the choir location of the altar and the lead soloist at the very front, or western door. The offstage saxophone solo at bars 73-92 is a further example of this, as are the use of the violoncello and tenor saxophones to double the inner parts of the SATB choir from alternate locations.

In bars 101-104, the two soprano soloists placed opposite each other halfway down the nave are used to display a direct canonic figure, where the material is delayed by one bar. This gives the impression of one side 'catching-up' the other, as if following instructions. A direct copy of material reinforces this impression, where alternative material would be less effective in highlighting this. The material presented in the SAT parts of the SATB choir through the whole of section E is designed to further play with the reverberant qualities of the acoustic in Winchester Cathedral. The resulting effect is that of a slowly accumulating babel of voices emerging from the calm and sedate organ material that precedes it, a relative cacophony that dissolves into the chorale-esque chords of the ending at F, bar 112. Inspired by the Latin text which at this point reads "Let your tongue reflect your thoughts," the notion of vocalising the inner-thoughts of the listener, with more than a passing reference to the act of 'speaking in tongues', was made possible through the extended spatialisation of the building, the soloists retaining the angelic status afforded to them throughout the piece.

Fig. 1.38 Example of pedagogic nature of choir entries in 'Non Vox Sed Votum'

The challenges presented in performance of this work are numerous. Perhaps the most pronounced of these is in the need to ensure all of the musicians are able to remain in time with one another despite the complexity of hearing each other at different rates depending on the relative positions of the individual performers. Initially, the idea of synchronised metronomes from a computer programme such as Max/MSP was debated, but this proved to be unworkable due to the large scale of the cathedral. In the end the most practical solution was to use three conductors, one in the nave and one in each aisle, thus maintaining lines of sight at all times. The movement of the saxophones and four and five of the soprano soloists also required some planning. On a simply practical level, the instrumentalists had to be provided with multiple copies of the music in order to ensure they could continue to read the score and perform an accurate representation of the notated piece. However, the movement of musicians and use of the space provided far greater challenges to the performers' musicality. Retaining tuning and entries were specific challenges and as the main body of choir was made out of non-professional school children, the material on entries attempted to be as generous as possible n terms of supporting the abilities of the composer. A clear example of this can be seen at bar 99, where the organ not only repeats first the tonality of the entry that is to follow for the sopranos, but also builds up the rhythm to make sure that the choir is fully in command of an area that has potential to be problematic [see *fig.1.38*, above].

The Music Technology students that were taking the CuDAS curriculum as part of their classes in their second year of GCE were present at the first performance of this work and in the weeks leading up to the event it was therefore advantageous to be able to explain and analyse the material with them, focusing on the implications of spatialisation in acoustic live performance. Once the material had been presented to them in performance, it enabled the fulfilment of this piece's intentions; that of altering the context of spatialisation for the listener and learner. Adding a dimension that could seen to be more secularly spiritual than the previous example presented to the learners helped to underline the topic, make it more memorable in the long term learning and also underline, justify and prove some of the academic claims regarding spatialisation that were presented in the tutorial topic.

1.5.8 Non Vox Sed Votum – Interactive Exercise

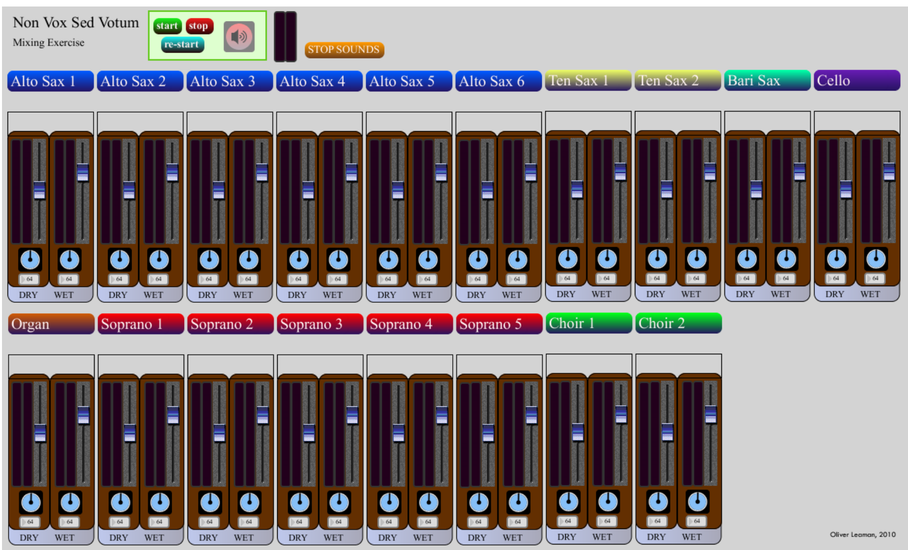


Fig. 1.39 The 'Non Vox Sed Votum' interactive exercise.

Alongside the listening and score reading exercises that 'Non Vox Sed Votum' offers, learning through the inclusion of this composition is further increased through the accompanying interactive exercise. As can be seen from *fig. 1.40*, the patch offers the student the opportunity to generate his or her own mix of the opening section of the piece. Each instrument has a channel track with parameters included for altering amplitude, reverb and pan, both of the dry and wet signals. The layout of the patch is intended to closely resemble a typical software mixing desk, whist retaining clear labels for track names and parameters available. This ensures that the material of 'Non Vox Sed Votum' can then be re-examined by the student from his or her own personal and creative perspective. Offering the student ownership of the material in this way is once again a key example of the pedagogic nature of CuDAS and the way in which the act of composition has been approached as a teaching and learning tool and instructional aid in the classroom.

1.6 Tutorial 3 – Subtractive Synthesis

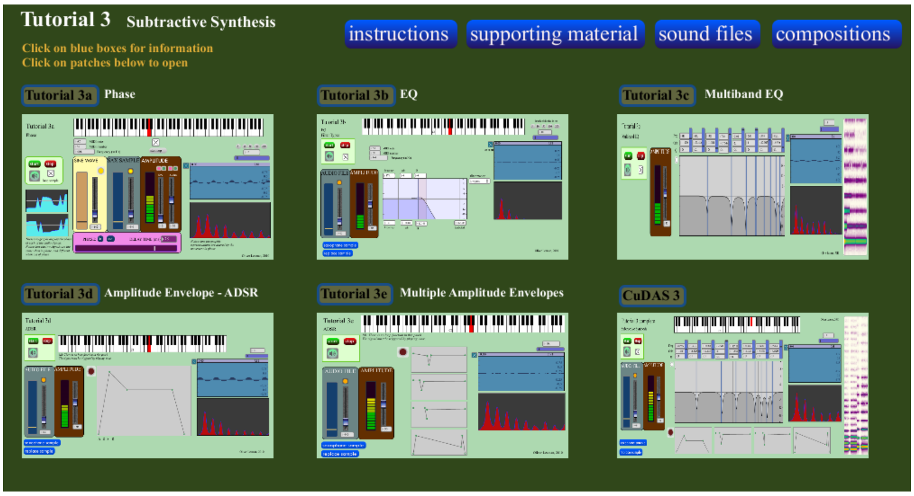


Fig. 1.40 *Tutorial 3.*

The development of the synthesiser has been named on the GCE syllabus as a specific area that may be examined in Unit 4 at A2 level. There is no doubt that study of this area must include the notion of subtractive synthesis. The five tutorials contained in Tutorial 3 work through the following areas;

Phase
EQ
Multiband EQ
Amplitude Envelope - ADSR
Multiple Amplitude Envelopes

This area is arguably more complicated than anything the student enrolled on the GCE course is likely to have encountered thus far and as a result CuDAS aims to clarify and highlight key areas relating to this subject in Tutorial 3. Once again a step-by-step approach is taken whereby the material develops slowly through the development of smaller principles leading to a larger holistic understanding by the end of the tutorial.

Choosing the type of material to be included was a more complicated procedure than for the previous two tutorials as the area of subtractive synthesis is large and complex in nature. Attempting to generate interactive learning tools without alienating the student through over complication was one of the main challenges faced at this point. The learning areas can be identified as relating to two subgenres. The first is that of frequency-related subtraction and the second of amplitude related techniques. The first three tutorials concern themselves with phase, and through the understanding of this topic is introduced EQ over the next two tutorials. The secondary area is covered in the following two tutorials with the controlling of amplitude envelopes. These areas then combine at the end to form the CuDAS 3 patch.

1.6.1 Tutorial 3a – Phase

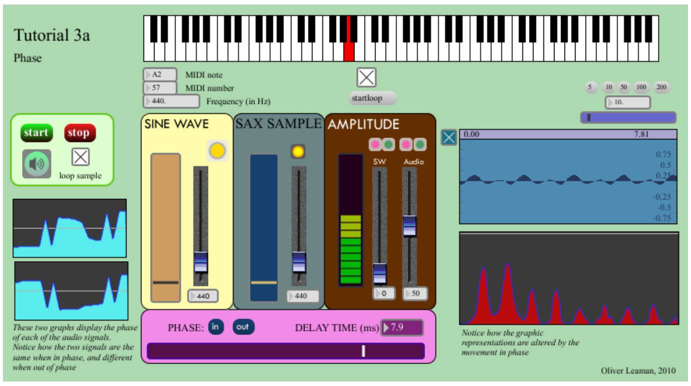


Fig. 1.41 Tutorial 3a.

Phase is one of the most important aspects of sound recording. It shapes a great deal of the applications of sound manipulation and so for that reason it was deemed necessary for it to be dealt with in its own tutorial. Phase cancellation is an essential piece of terminology that needs to be coherently understood by all students on the Music Technology GCE course. However, the understanding of these terms in relation to the principles by which they work is not something that is strictly catered for in the course structure. Tutorial 3a introduces the concept of phase cancellation in an interactive aural and graphic exercise.

As is to be expected in the schematic programming of CuDAS, this tutorial has much that is in common with those of the previous two tutorial subject areas. The ability to choose between sine wave and saxophone sample is by now self-evident in the learning, as are the functions of amplitude and the workings of the time and frequency domain representations. As both the signals are preset to load at 440Hz, the same initial settings regarding phase can be provided to both. Using the delay function from Tutorial 2b, the signal was passed into the same output thus providing the ability to generate phase cancellation techniques. The time of

Fig. 1.42 The phase function, showing 'in' and 'out' of phase toggles, delay time and horizontal fader.

delay was calculated to match the wavelength in question in order to programme in preset phase functions that can be switched from in phase or out of phase as desired [see *fig. 1.42*]. This in turn directly corresponds to the delay time, displayed in milliseconds. In order to implement a gradual movement from in phase to out of phase, a horizontal slider was also included, affording the ability to slide between the two states.

Included in this patch is also an alternative way of viewing the *spectroscope~* object. Shown in *fig. 1.43*, it is possible to display the phase response of a signal rather than the partials. The example included here clearly shows opposing signals, creating an out of phase output which can be further analysed through the graphic displays included to the right of the patch. These should clearly show a reduction in certain harmonics in the frequency domain graph and as such a change in wave shape in the time domain graph.

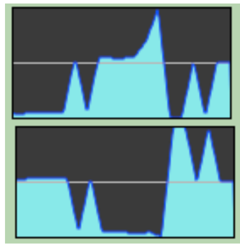


Fig. 1.43 The spectroscope objects of the two signals showing phase response.

1.6.2 Tutorial 3b – EQ

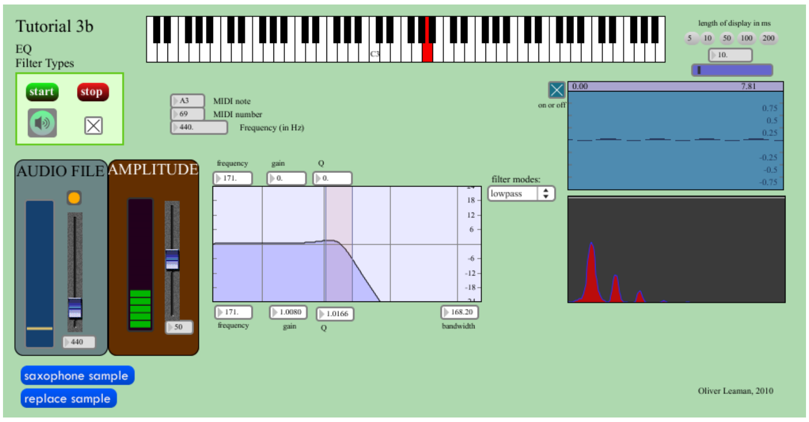


Fig. 1.44 Tutorial 3b.

Tutorial 3b extends the notion of phase to introduce the area of equalisation. The supporting material document for Tutorial 2 explains at length the importance of phase and therefore the subtracting of signal to implement EQ changes and this patch enables the student to both see and hear this process in action. Those in the second year of GCE Music Technology will already be familiar with EQ as a function as it is one of the assessed areas in the coursework that is submitted for examination. However, CuDAS enables the growth of knowledge in this area further through the use of the *filtergraph~* object [see *fig. 1.45*], which unlike sequencer packages has the ability to be programmed to display alternative EQ shapes at the single click of a button.

An example of this is the jump made from high to lowpass filter. If one were to attempt this process in Cubase or Logic then it would be necessary to first turn off the highpass filter before implementing the lowpass filter. The presets are also not useful for educational purposes as they pertain to the world of music production and as such need to be adjusted to make a pedagogic point. This whole process can be seen in *fig. 1.46*, where the steps needed to implement these changes in Logic are included. In CuDAS, all that is required is one click. The programming in CuDAS also ensures that a significant number of frequencies are affected by the shelves and pass filters and as such it becomes a far more useful educational tool. Added to this is the ability to resize the object to an appropriately large graphic, which is not permissible through sequencer plug-ins without losing definition through on-screen zooming.

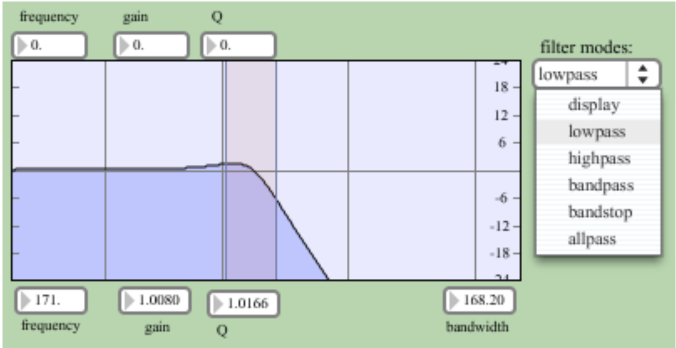


Fig. 1.45 *The phase function, showing 'in' and 'out' of phase toggles, delay time and horizontal fader.*

				
1) highpass filter enabled	2) turn off hpf	3) turn on lowpass filter	4) adjust frequency of lpf	5) adjust Q of lpf, lpf enabled

Fig. 1.46 *The steps in Logic taken to implement a change from a highpass to a lowpass filter, enabled in CuDAS through a single click.*

The filter modes included in the drop down menu visible in *fig. 1.50* include lowpass, highpass, bandpass, bandstop and allpass filters. These alternative filter types are discussed at length in the supporting material and through the use of the pre-loaded saxophone sample or replacement of a sample of his or her choice, the student is able to hear the change these filters make to the sound and also see the resulting influence they have on the time and frequency domain representations. Further interaction is also made through the inclusion of frequency, gain and Q controls, which enable the learner to physically manipulate the EQ graph to his or her own customisation. These can be seen above the graph in *fig. 1.50*, with the same options below offering output data rather than input information.

1.6.3 Tutorial 3c – Multiband EQ

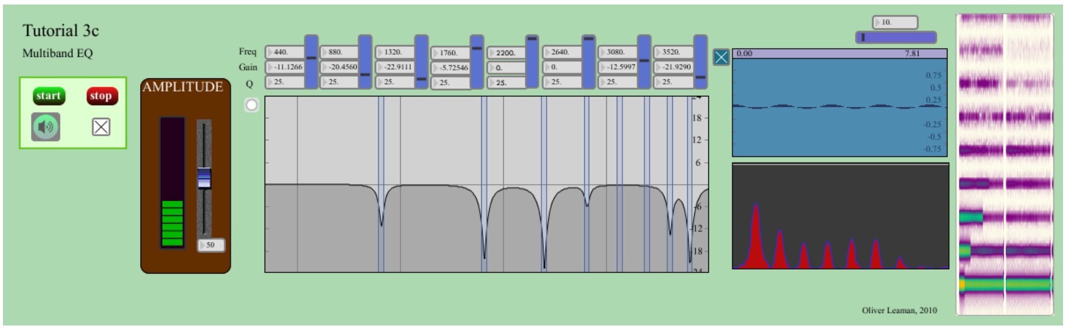


Fig. 1.47 Tutorial 3c.

The tutorial that follows an investigation into EQ takes the process a stage further. A series of 8 EQ bands are implemented, preset to each of the harmonics of the saxophone sample. In this way a full subtraction of frequencies can now be implemented. For this reason only the saxophone sample is included with no sample replacement option. This is to enable the sonogram included to provide an accurate representation of the synthesis ensuing. The patching for this process was complicated, as the Max/MSP *filtergraph~* object is not supplied with a simple method for implementing multiple bands in this way. This can be seen from *fig. 1.48*. It was important to the functioning of CuDAS that most of this information was kept hidden as it is not relevant to the learning process. Instead, only the frequency, gain and Q data is retained so that the student is able to see which areas are being affected by each of the filters.

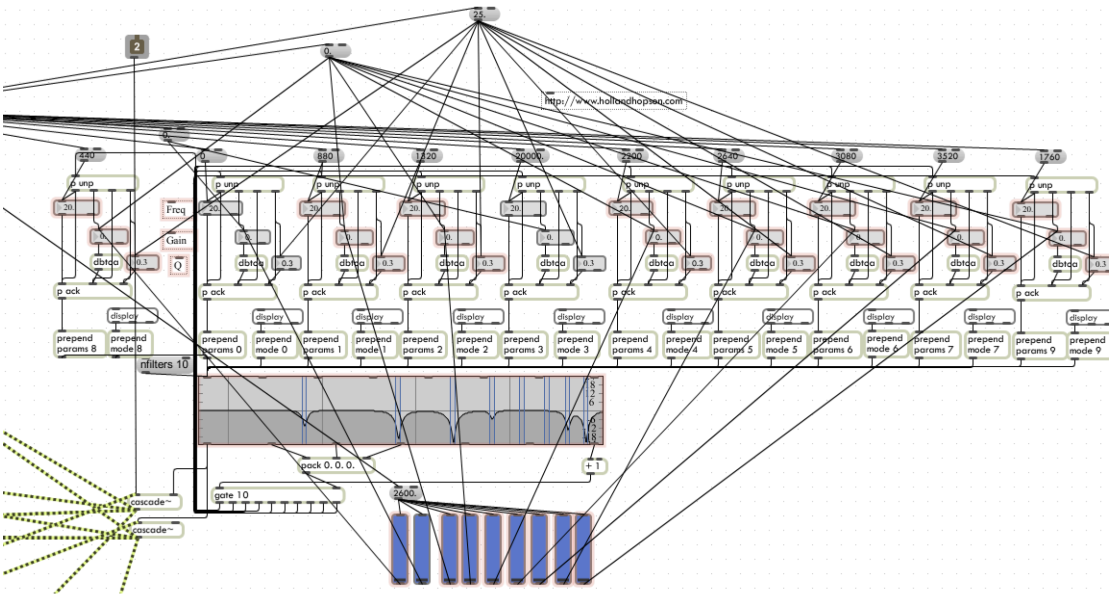


Fig. 1.48 The complicated nature of programming filtergraph~ for Tutorial 3c, shown in unlocked patching mode.

By removing the harmonics as required, it is possible for the student to clearly hear how the saxophone tone is comprised of the elements of the harmonic series in this way. Through this method it is therefore possible to construct new tones out of the sample and it is in this interactive exercise that the main understanding of Tutorial 3c and of the relationship between EQ and subtractive synthesis is contained. It is also possible to realise the educational value of the earlier inclusion of Tutorial 1d, which introduced an understanding of the harmonic series before the topic in Tutorial 3c was targeted. Without this curriculum design the learning in this area would be far less effective.

1.6.4 Tutorial 3d – ADSR

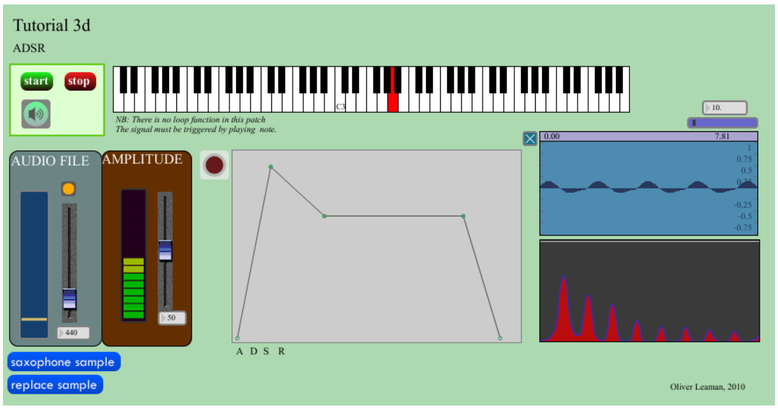


Fig. 1.49 Tutorial 3d

Tutorial 3d introduces the second principle area covered in the subtractive synthesis study patches; that of synthesis through the manipulation of amplitude. The Tutorial has an almost identical look and function as that of Tutorial 3b, with the only difference being the replacing of the EQ graph with an ADSR envelope graphic. The image displayed in *fig. 1.54* clearly shows the four areas of attack, decay, sustain and release that this device requires to function. This area of learning was included to ensure an understanding of the principles of such controls as applied in early voltage controlled synthesisers. These instruments are discussed in detail over the course of the supporting material for both Tutorial 3 and 4 and as such the importance of envelope filters is one that is made clear to the student. Reinforcing this important factor through the learning of CuDAS ensures greater knowledge and understanding in this area.

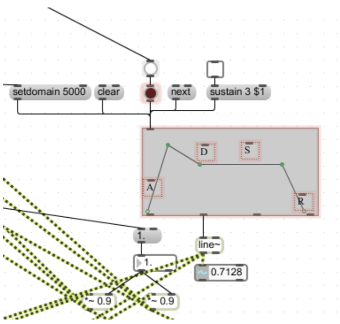


Fig. 1.50 The patching of the ADSR envelope, shown in unlocked patching mode.

Once again the patching of the ADSR is much more complicated than is practical for inclusion in the main software display [see *fig. 1.50*]. However, patching in this way has a practical purpose directly related to the user interface, in that a button is included below instructional text to ensure the student is able to operate the ADSR function [see *fig. 1.51*]. This is critical in the learning at this point as for the first time in CuDAS the operation of

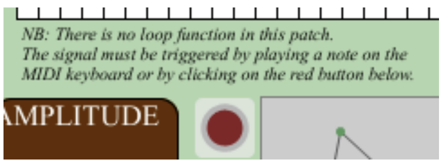


Fig. 1.51 The instructions for ADSR operation, shown in locked presentation mode.

the sound is made through an alternative function. Until this point in the learning process, the sound has always 'appeared' when desired as it is programmed to switch on when the patch is operated for the first time and to remain on until the patch is stopped or closed. In this patch, however, the ADSR must be triggered to work. Therefore the instructional text was included to aid this process. This alternative way of generating the audio to sound is introduced at this point to aid future learning, as it will feature much more heavily in Tutorial 4.

1.6.5 Tutorial 3e – Multiple ADSR

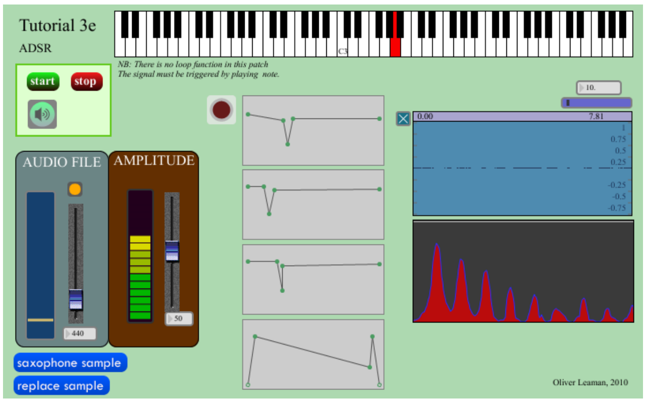


Fig. 1.52 Tutorial 3e

In a similar vein to the way in which a singular EQ function was developed into the ability to effect multiple EQ changes, so the same is true in the incremental learning between Tutorial 3d and Tutorial 3e, where multiple ADSRs are introduced to complete the learning of subtractive synthesis. Through the now recognised method of image and aural analysis, the learner is able to implement a series of changes on the tone heard, allowing for a musically rich and creatively developed appreciation of the ability to alter the tonal makeup of a sample through the process of amplitude filtering. The user can alter the ADSRs included and the results can be heard in instantaneous real-time, thus aiding comprehension of the techniques involved in this process.

1.6.6 CuDAS 3

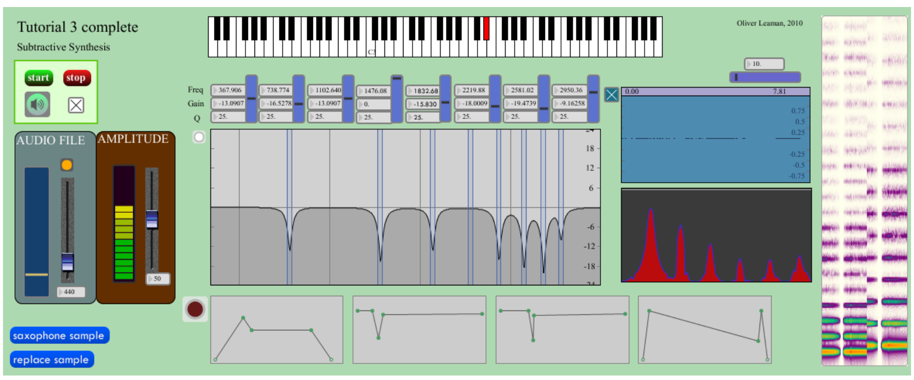


Fig. 1.53 The CuDAS 3 patch.

Following on from CuDAS 1 and CuDAS 2, CuDAS 3 provides a complete patch combining all of the elements learned in the previous 5 tutorials for use in a creative context. To accompany the patch there is a further example of a study piece that uses the techniques learned in the progression of the Tutorial as a whole.

1.6.7 'SubSyn'

The composition 'SubSyn' offers the student a chance to hear the practical working of subtractive synthesis through the use of filtering. The piece is made by using the saxophone sample present throughout CuDAS and as such varies from the other compositions presented as it relies on electronic looping in order to function. In essence, this leads to a thorough investigation of the possibilities of filtering the first 8 harmonics of a saxophone at 440Hz. This is extremely useful in the principled pedagogy of CuDAS as it helps to reinforce the learning of this complicated area. It is likely that the students will have covered some basic aspects of spatialisation in their first year of A-level studies. However, only the most advanced and investigative student will be aware of subtractive synthesis. For this reason, this area needs to be reinforced in a very deliberate manner and it is for this reason that the composition presented at this point in the learning makes such a strong reference to the learning of the tutorial topics.

1.6.8 SubSyn - Interactive Exercise

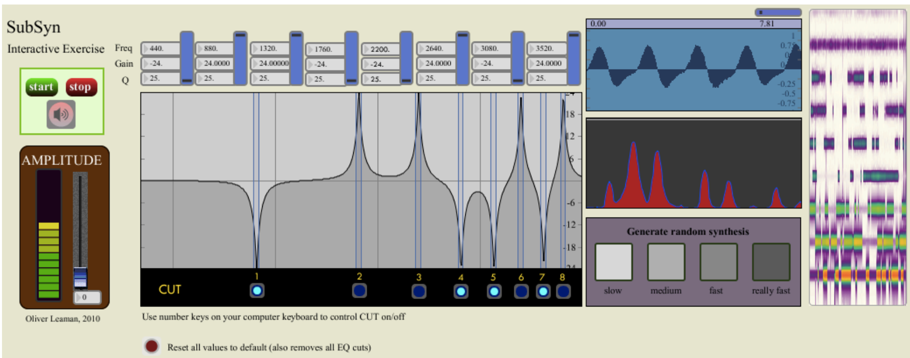


Fig. 1.54 SubSyn -Interactive Exercise.

The interactive exercise that accompanies the 'SubSyn' composition builds on the filtering heard within the piece. The student is able to enact a frequency cut of each of the first 8 harmonics of the saxophone note heard by manually altering the faders and thus highlight certain characteristics of the sample. The opportunity to allow the computer to take control of this process is also included, and four alternative states are included: slow, medium, fast and very fast. The inclusion of this area within the learning of CuDAS is to further increase the students understanding of the ability through subtractive synthesis to generate alternative timbrel qualities without the need to destructively edit or change the original sample loaded.

1.7 Tutorial 4 – Additive Synthesis

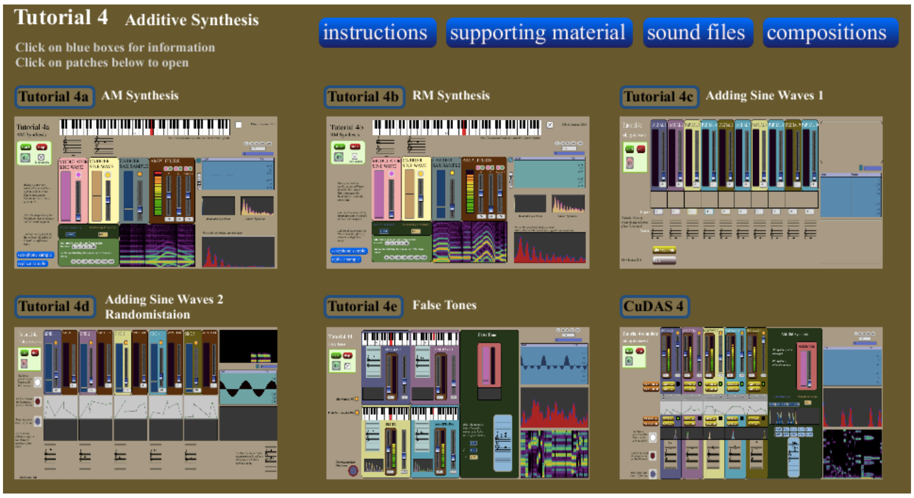


Fig. 1.55 Tutorial 4.

The final learning area covered by CuDAS builds on the material covered in Tutorial 3 and introduces the learner to the area of Additive Synthesis. As with the previous tutorial, this is an area that is key to the understanding required for the GCE A2 Music Technology examination and as such the background and theory to this material is covered in great depth in the supporting material. Through this document it is possible for the student to gain an understanding of the key sections of this topic, which Tutorial 4 then proceeds to develop in an interactive learning environment to further ensure the comprehension of this complicated area and stretch auxiliary learning through the use of creativity. The patches themselves that make up the whole of the tutorial consist of an introduction to AM synthesis, RM synthesis, the building of tones through the addition of multiple sine waves and the creation of false tones through the use of audio samples of acoustic instruments.

1.7.1 Tutorial 4a – AM Synthesis

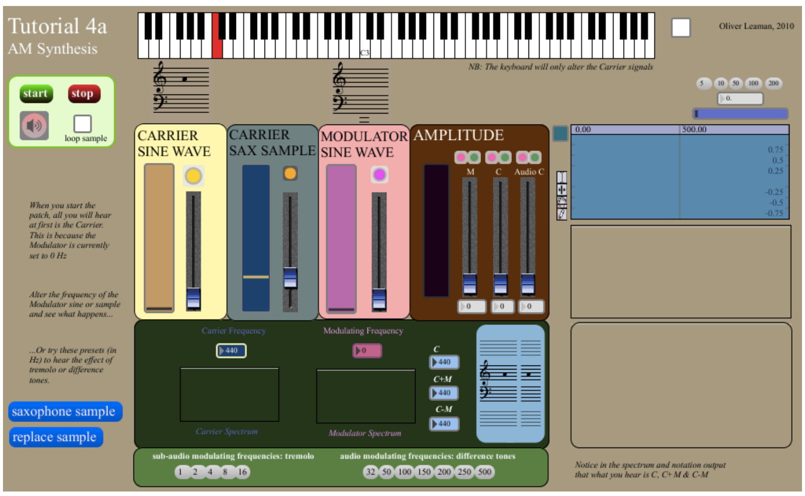


Fig. 1.56 Tutorial 4a.

Tutorial 4a introduces one of the most important areas in this learning topic; that of amplitude modulation. As this is a more complicated area than most of the previous tutorials there is quite a substantial amount of subtext included in the patch to ensure smooth operation. This was considered necessary as although it was possible to include some of this information in the green pop-up window, much of it needed to be retained in sight when operating the patch itself. The nature of this text is included in the collation of *fig. 1.57*. From this it is possible to see that a portion of this text is explanatory and the rest is present to aid functionality. These two areas combine to ensure that the student is able to make use of the patch to its full potential.

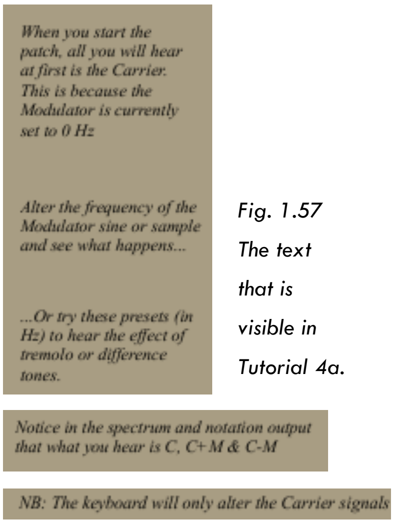


Fig. 1.57 The text that is visible in Tutorial 4a.

The carrier signal is able to be switched between a sine wave and an audio sample, once more of a saxophone or replaceable for something of the learner's choice. The modulating signal is that of a sine wave, preset to 0 Hz upon loading so that the effect of AM synthesis only becomes noticeable once the student implements a change. The dark green section [see *fig. 1.58*] offers a clear understanding of the input and output sections of the synthesis, showing frequencies and frequency domain spectra transformed into the notation of the outputted material.

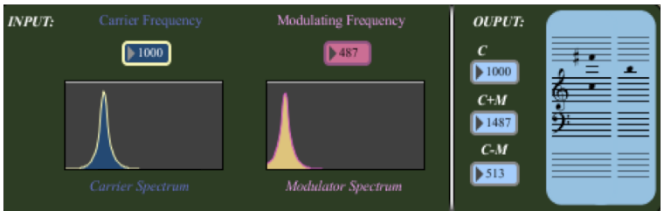


Fig. 1.58 The input and output section of the AM synthesis patch.

Further understanding of the process of amplitude modulation and its subsequent uses in electronic synthesis can be obtained through the exploration of the preset sub-audio modulating frequencies that produce tremolo effects and the non sub-audio frequencies that provide harmonic difference tones, as seen in *fig. 1.59*. The learning in this section of the patch is two-fold as it offers a practical explanation of the function of AM synthesis in early voltage controlled synthesiser design as well as introducing the notion of difference tones. The creative potential of these tones will be explored in greater detail in Tutorial 4e.

Fig. 1.59 The presets showing tremolo and difference tones through sub and non sub-audio modulating frequencies.

1.7.2 Tutorial 4b – RM Synthesis

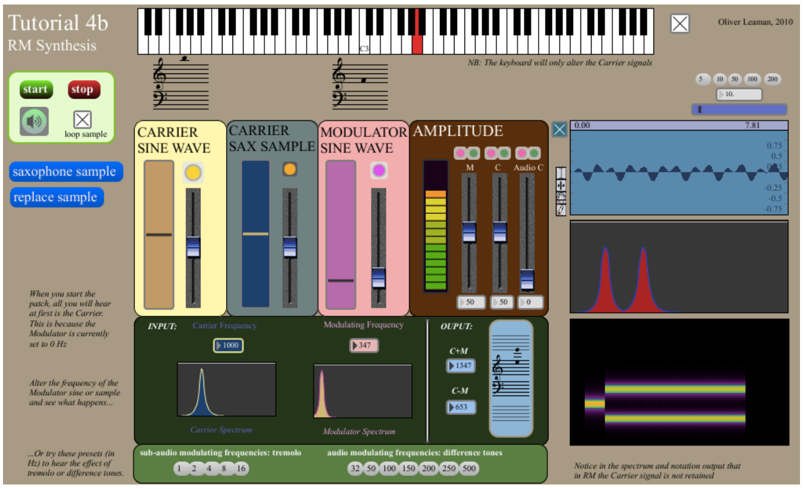


Fig. 1.60 Tutorial 4b.

The layout of Tutorial 4b mirrors exactly that of the previous learning area. Sine wave and audio sample are presented as the carrier signal, the modulator is still a sine wave preset to 0 Hz and the various graphic representations of notation and audio signal have the same parameters. Indeed, the only visual difference is in the *output* section of the dark green synthesis section of the patch. Here it is possible to see that the carrier signal has been removed from the output to give just the sum and difference of the carrier and modulator in the outputted signal [see *fig. 1.61*]. This is achieved through the use of a unipolar modulator signal rather than the bipolar signal used in the previous tutorial and it is this that gives us Ring Modulation. The patching used to create this for CuDAS can be seen in *fig. 1.62*, below, alongside that used for amplitude modulation, included here to allow understanding of the alternative methods used to produce the required outcomes.

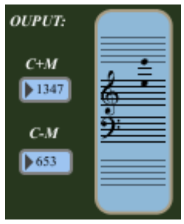


Fig. 1.61 The output section of Tutorial 4b

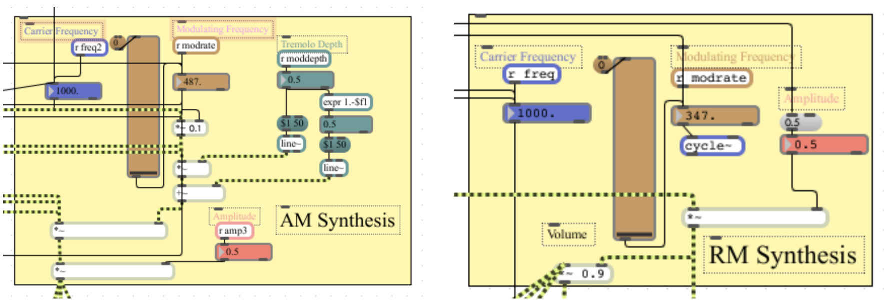


Fig. 1.62 The patching of AM and RM synthesis in CuDAS.

This area of learning is of particular interest to students undertaking the GCE in Music Technology not only because of the impact the method has had on electronic synthesis, but also due to the historical significance RM synthesis has made in popular music more generally.

Used as an 'effect' in the same way that distortion or flange might be, the 1970s saw a number of artists use the synthesis technique to add character to their studio and live performances. Some notable examples are included in the 'sound files' section of this tutorial to highlight this area, including the voice in Pink Floyd's 'One Of These Days' and the guitar solo in Black Sabbath's 'Paranoid'.

1.7.3 Tutorial 4c – Adding Sine Waves 1

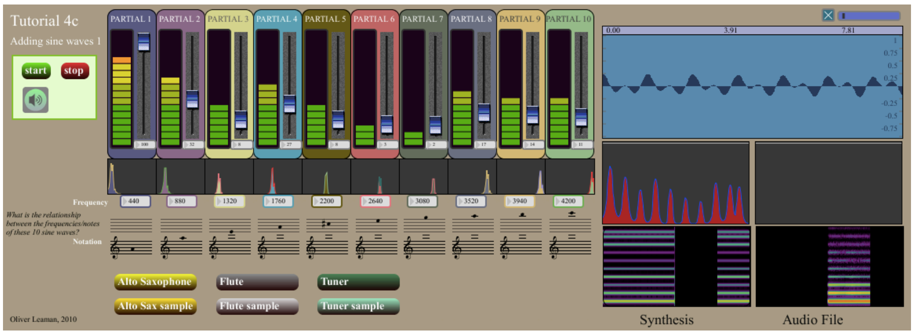


Fig. 1.63 Tutorial 4c.

Tutorial 4c offers the opportunity to use aural and visual analysis of audio files in order to recreate the timbre of each sample included using only the first 10 notes of the harmonic series. There are a number of topics of learning within this one tutorial. The first of these acts as a recapitulation of the learning from Tutorial 1d, where the harmonic series was first introduced. It has been seen that this area was also returned to in Tutorial 3c and so in this case the question is posed to the student as to whether they have understood this concept. The notes of the harmonic series are displayed at the bottom of in the channel-strip format in both Hertz number and traditional notation. Next to these areas is written the question, as seen in *fig. 1.64*. The implication in the pedagogy of CuDAS at this point is that the student should by now have a firm grasp of the concept of the relationship between the notes of the harmonic series and their corresponding frequencies. The inclusion of this direct questioning is made to provide both the teacher and the learner with the opportunity to review the learning process and ensure that the appropriate knowledge is being retained.

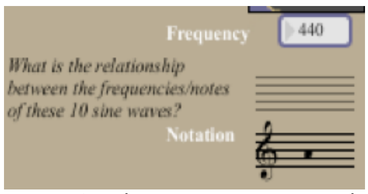


Fig. 1.64 The questioning in Tutorial 4c.

The inclusion of two frequency domain representations and sonograms in this patch allows for the comparison between the synthetic sound and the audio sample of each timbre. This feeds into the secondary layer of learning in this tutorial whereby the student is required to implement changes in the levels of the sine waves to perfect an approximation that is given as a preset. The sine wave versions of the samples are by no means accurate, offering only a nod in the correct direction. It is possible through the interactive manipulation of this patch for the student to make this approximation far closer to the actual desired sound. In this way their ability to discriminate and make aural and visual judgements are tested with considerable effectiveness. In order to aid in this process, the audio files in the tutorial have been treated using the software AudioSculpt to remove unwanted noise and retain only the harmonics in the timbre. This enables the said harmonics to be seen more clearly in the sonogram and as such a closer representation can be made by the student when attempting to replicate the timbre of the audio sample through using only the sine waves given.

Various samples are presented in this tutorial in order to further develop the student's ear. The saxophone sample is retained and placed alongside it are those from a flute, a trumpet and an electronic tuner. These were chosen to show the subtle difference between such timbres. They also served the purpose of not being over complicated. Other timbres were experimented with, such as a piano and a violin, but these were far harder to replicate, in part because of the rich harmonics above the 10th partial, but also due to the quite striking transients, which were not able to be replicated in this tutorial. Of the timbres finally settled upon, the tuner was especially interesting due to the almost complete lack of the fundamental frequency. Although the pitch of all these samples is 440Hz, the actual amplitude make up of the partials is varied enough to make learning in this topic area particularly striking.

1.7.4 Tutorial 4d – Adding Sine Waves 2

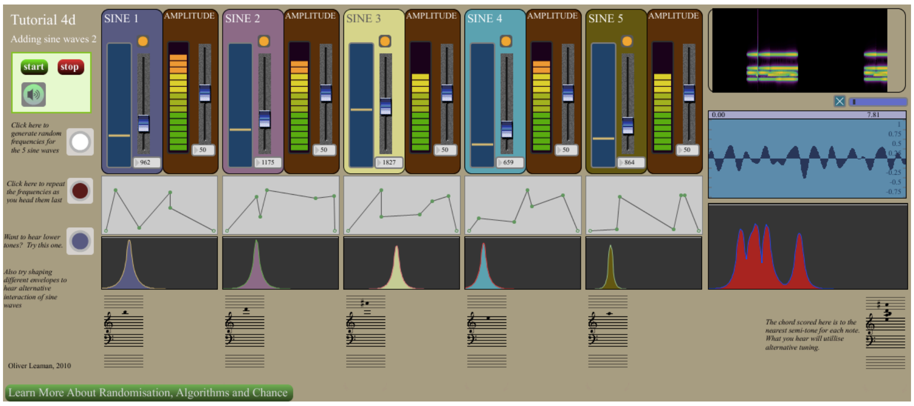


Fig. 1.65 Tutorial 4d.

The second of the additive sine wave patches retains elements of its predecessor in that the channel strip feel of the interface is largely intact, as are notational and graphic elements. However, there are also contained within Tutorial 4d some fairly major changes that impact directly on the learning. It can be seen that the ability to alter pitch has returned to the programming, as has the amplitude envelope. This in itself has an alternative application, as more edit points are contained, offering greater scope for creativity within this area. Once again there are included some key instructional texts to aid with the learning and operation of the patch, as can be seen in *fig. 1.66*. These offer the user advice on how to generate the musical material in the patch and also how the notational output varies from what is actually heard.

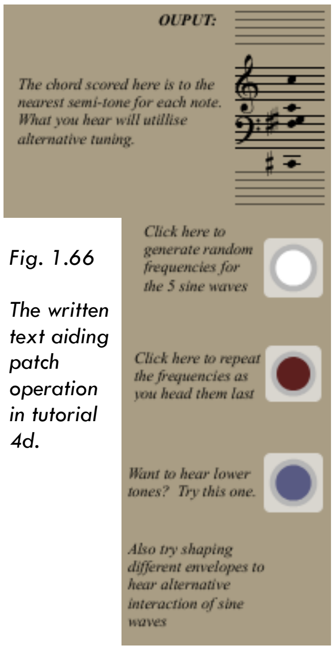


Fig. 1.66

The written text aiding patch operation in tutorial 4d.

This patch also introduces the student to the first example of the computer taking control of the musical output, rather than the patch user within the context of the tutorial patches. This was achieved through the use of the *random* object and patched in order to implement random frequencies of either 0-4000 Hz or 0-1000 Hz (implemented through the purple button seen in *fig. 1.66/7*). The patching used can be seen in *fig. 1.67*. Implementing this feature allows the student to realise that random generation of electronic synthesis can play a major part in the creation of interesting works. Should the computer generate a 5-note chord that is of especial interest to the student, they have the option to repeat the tone. This could then be saved using the 'record' function and then used in an alternative compositional context. This offers at this point the opportunity within CuDAS to present extra learning about randomisation and chance and the importance this area has on the world of algorithmic composition. This area will be discussed in detail in Appendix 1.8.

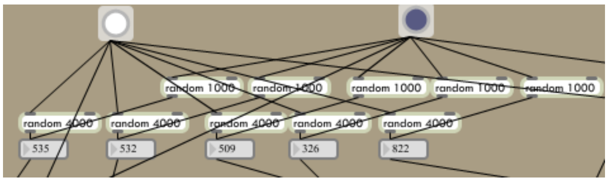


Fig. 1.67 *The use of the random object in Tutorial 4d, shown in locked patching mode.*

1.7.5 Tutorial 4e – False tones

Fig. 1.68 *Tutorial 4e.*

The final area of learning presented within the CuDAS tutorials is that of false tones. Otherwise known as difference tones, the student is introduced through the use of sine waves and audio samples of a saxophone and a flute to the notion of the psychoacoustics of this phenomenon. It is of some fascination to students that even with acoustic instruments it is relatively easy to perceive a false tone when the notes played are of a certain frequency. This patch enables the generation of these frequencies with graphic and notational explanations as to the nature of the tones heard in comparison to those that are actually physically made by the players.

When turned on, the patch will automatically load the sine wave section of the tutorial. This was considered useful as with these pure tones it is far easier to hear the third note created. Indeed, it is actually of amplitude equal to the other two notes. Through the simple implementation of the yellow toggle on the left hand side of the patch the student can switch to the audio samples and back again as desired. Both have a *kslider* graphic which although not controlled by a MIDI device, do offer a user initiated alteration of pitch. It is then possible to see the notation chosen as well as a frequency domain spectrum of each of the singular tones. An explanation into the physical properties of the generation of the false tone is offered in the dark green section along with a chord showing the actual notes heard [see *fig. 1.69*].

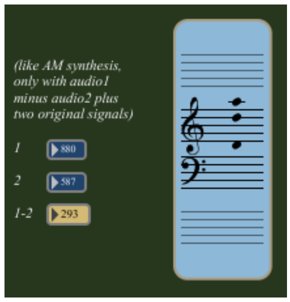


Fig. 1.69 The output explanation within Tutorial 4e.

The ability to let the computer make the decisions regarding choice of material is also retained from the previous tutorial. In providing this function a problematic area was uncovered, in that generally the process of false tones with the acoustic instruments is more effective if the frequencies are relatively close together. In order to achieve this and subsequently produce a more cohesive output relevant to the task offered, the use of the + object with appropriate scaling of inlet numbers as seen in *fig. 1.70*. This object was also used in ensuring that the difference tone produced by the sine waves matched those of the audio files, as a simple AM

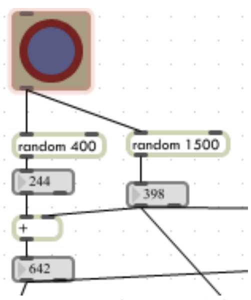


Fig. 1.70 The use of the + object to generate clear sounding false tones.

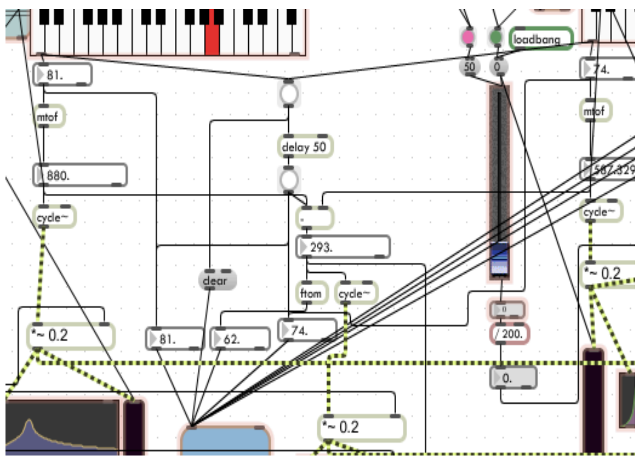


Fig. 1.71 The unlocked patching of the sine wave difference tone.

or RM patch could not be used in this instance due to an alternative output requirement. The patching used to create the difference tone for the sine waves can be seen in *fig. 1.71, above.*

One further technical consideration in this patch was the need to ensure that the polyphonic display of the *nslider* reset each time a new chord was chosen. This required a patching in of a 'clear' function. However, this needed to be delayed in order to avoid clearing the input before the user had the chance to see the display. This was achieved through the use of the *delay* object. This can be seen in the centre of the image displayed in *fig. 1.71*.

1.7.6 CuDAS 4

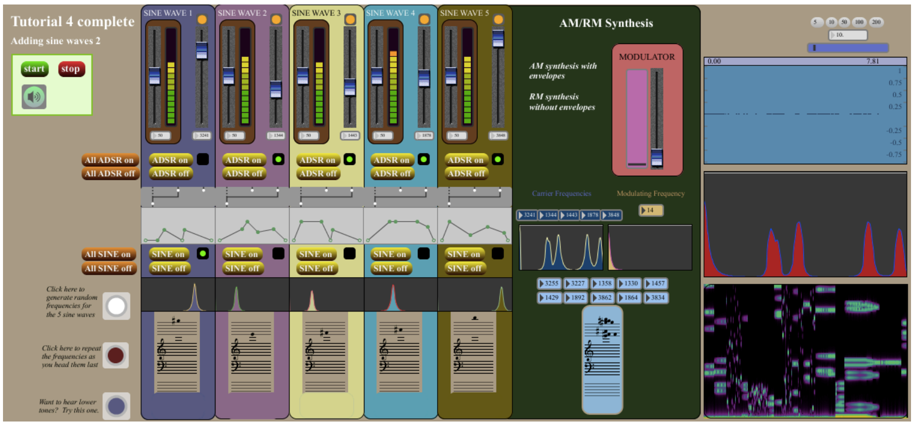


Fig. 1.72 The CuDAS 4 patch.

As with the previous tutorials, Tutorial 4 ends with a complete patch encompassing the ideas of all the previous learning areas accompanied by a short study to highlight the techniques involved. It is possible for the student to switch between AM and RM synthesis and command randomisation of sine waves. Amplitude envelopes can be bypassed using the *ggate* object first seen in Tutorial 2a. As five sine waves are present, with AM synthesis employed it is possible to create chords of up to 15 notes, all of which are displayed in the light blue score graphic. However, if using the amplitude envelopes these will fade in and out and as such not all notes will be heard at once. Inversely, at times there may also be more due to the appearance of false tones between each of the separate sine wave outputs. What is offered is a rich and complex electronic synthesiser using only the techniques discussed through the tutorial that the student can creatively implement through an understanding of the key areas rather than a mere button pressing exercise that arguably would have resulted without following the structured CuDAS software from beginning to end.

1.7.7 'Dissimiletude'

The composition *Dissimiletude* provides the learner with an extended investigation into the sonic world of difference tones. This highly fascinating area of psychoacoustics is covered in detail in order to open up interest in this area, which the student may wish to pursue further in his or her own creative work. It also enables the discussion of modular synthesis to be placed in concrete examples in the acoustic world, thus making it both more pertinent to music making. The piece utilises a flute and a soprano saxophone. It was found that these two instruments made an excellent combination in terms of their ability to produce difference tones. The smooth timbre of both the instruments ensured that the harmonics produced resulted in very clear sounding third notes and as a result these can clearly be heard throughout this piece.

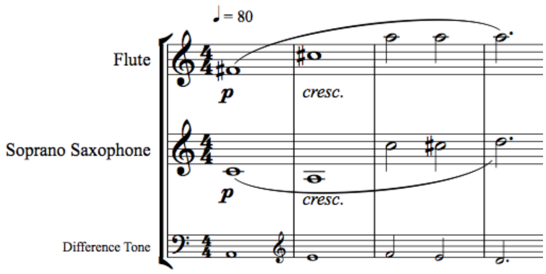


Fig. 1.73 The opening bars of Dissimiletude, showing the difference tones created.

The available difference tones were mapped out and then the construction of the composition was made using these relationships. An example is given of the first few bars of the piece in *fig. 1.73* where it is clear to see the harmonic relationship between the three notes as the phrase develops. The notation of the difference tone in the score is kept to basic tuning. Naturally the physics of the effect produces tones that are in actual fact often either sharp of flat. It is common to see these notated as quartertones or with other contemporary notation, but this method was avoided in this example so as not to obscure the pedagogic message of the composition. It was felt that the introduction of this notation system at this point in the learning would obscure the true educational significance of this composition, namely the ethereal and unusual sound world created by working entirely with difference tones in a harmonic manner.

1.7.7 Dissimiletude – Interactive Exercise

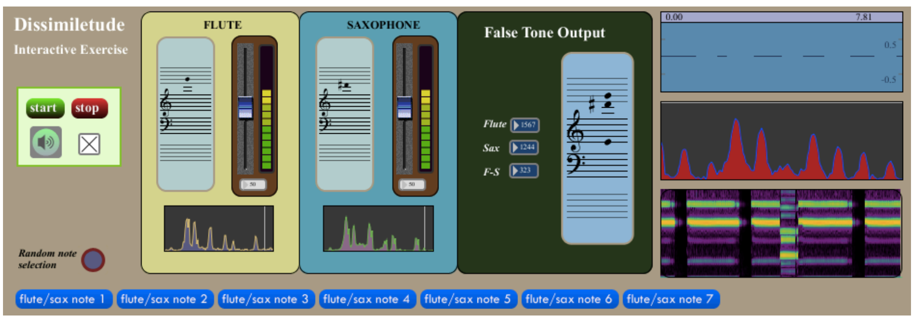


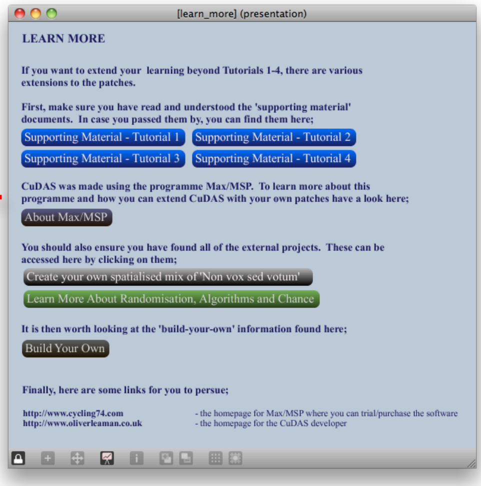
Fig. 1.74 Dissimiletude - Interactive Exercise.

The interactive exercise that accompanies the learning in Tutorial 4 presents seven intervals from the 'Dissimiletude' piece in the context of the tutorial design of CuDAS. Through the manipulation of the seven blue toggles and amplitude controls, it is possible for the students to generate their own version of a section of this piece, choosing a rhythm and order of intervallic movement as according to their own sense of creativity. The intervals are shown in the exercise as both traditional score and frequency output, along with the difference tone that is heard. The intervals chosen provide particularly resonant difference tones and as such this exercise is a strong addition to the aural development and the students' comprehension of this area of learning.

There is also included the ability to allow the computer to take control of the process, with eight choices at random rhythmic generation. The eighth choice the computer is able to make is that of a rest, where no sound is heard, thus breaking the continuous cycle of output and offering a more musical result. It is intended that the student using this exercise will experiment with the relationship of the triads produced by the difference tones and as such further comprehend the way in which this psychoacoustic phenomenon can be harnessed creatively.

1.8 Additional Learning in CuDAS

Fig. 1.75 The 'Learn More' subpatch. Clicking on the highlighted area will open the secondary window, right.



Beyond the main learning in the four tutorials of CuDAS there is also presented extra learning at various levels. This additional material can either be accessed on route or found collectively in the 'learn more' section from the front-page [see *fig. 1.75*]. The educational reasons for inclusion of this material are covered in detail in Chapter 2 where differentiation and accessibility are discussed. From the window that opens upon clicking the 'learn more' toggle, it is possible to see a recapitulation of all the learning to date. The learner is encouraged to ensure the supporting material documents have been read and assimilated in full as it is in these areas that learning can develop at the highest academic level, transcending a one-dimensional knowledge and linking a theoretical understanding to a practical one.

Included in each of the tutorials are subpatches entitled 'supporting material' and 'sound files'. These can be accessed by clicking on the named toggle in each tutorial as displayed in *fig. 1.76*. The pedagogic nature of these areas of learning and reasons for inclusion in CuDAS are discussed in detail in Chapter 2.4. The supporting material documents can be found in *Appendix 2 – The Supporting Material for the CuDAS Tutorials*. The included material of the sound files that are referred to in these documents can be found in *Appendix 4 – Multimedia File Index*. Together these areas form a key area of the CuDAS software, offering references, examples, historical placement and explanations of technical theory that would overcomplicate the patches if included directly within them. The text and sound files are therefore programmed to be contained in a separate area so as not to crowd the learner with an over abundance of information in the user interface area of the software. This principle was adhered to in reference to the brain-based learning preference models discussed in Chapter 5 in order to ensure CuDAS remained as educationally useful as possible.

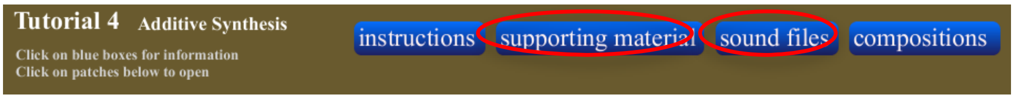


Fig. 1.76 The supporting material and sound file location, highlighted in red.

The 'learn more' patch also provides a link to the compositions and interactive exercises to make certain these areas have been discovered by the user before introducing the extra learning area of algorithms and chance in electronic music.

Inclusion of this area was made for several reasons. Firstly, in the world of electronic composition, algorithms play an essential role. Students may have previously come across chance music that can be seen to lead to a dissemination of aesthetic principles through the early algorithmic serialist works of Stockhausen and Berg. However, it is a central theme of CuDAS that electronic composition can retain a sense of these principles and the two are not mutually exclusive. The simple algorithmic aspect present in CuDAS facilitates the achievement of emotive music making. It creates a conflict of uncertainty and resolution that keeps the tension present throughout the piece, thus aiding the work as an artistic statement. It reflects the ability of chance to aid the compositional process, as noted by Essl who remarks that "algorithmic composition … is a method of constructing a model in order to create aesthetic works."[3]

Indeed, the inclusion of chance methodology in the software is used as a way for both the composer and the learner to break away from stereotypical thinking and techniques in

3 Essl in Collins & d'Escriván, 2007, p.107

composition. This overcoming of barriers caused by our musical upbringing, our pre-conceptions or simply the temptation to conform to a compositional or listening habit does more than simply extend our own expectations of the creative or learning process. Essl goes as far as to say that it has the ability to break down obstacles that are "erected by our social environment."[4] By this he would display a tendency to believe that our preconceptions of our own compositional techniques are defined the exposure we have to methods in our social interaction. This idea can be extended to include the educational establishments where we learn. It soon becomes apparent that the need to expose the learners in the CuDAS curriculum to the notion of algorithmic composition was justified.

The reasons for this are numerous, but perhaps most importantly is the example it sets with regard to control and the ability we have as composers to delegate responsibility and to work in a dialogue of partnership with our material and performers. This is a notion that is strongly echoed in the pedagogic works of Wiegold (see Chapter 2) and his notion of a 3rd way. If we are to pertain to the idea of working in true collaboration of this nature than it is important to realise the potential that chance offers. In CuDAS the passing of responsibility to the computer in terms of the shaping of the material and the ability to find a path through the generation of a new piece is a delegation of positivity. By this it is meant that the choice to allow this has been a proactive one, made in the belief that it will aid not only the compositional process of the work, but also the final outcome of performance. It is a sharing in the artistic decision making contained within the work, conforming to the notion that "By composing a piece with … material drawn from an automatism, many artistic decisions are replaced by an algorithm."[5] It frees the composer of the arguably unhealthy and counterproductive need to feel the necessity to retain tight control over every aspect of the compositional process as witnessed through the musical material of, as an example, Reich which makes no allowance for 'mistakes' by, and therefore the humanity of, the performer. As Essl says, "With the help of algorithms, the composer is no longer a demiurge who controls every

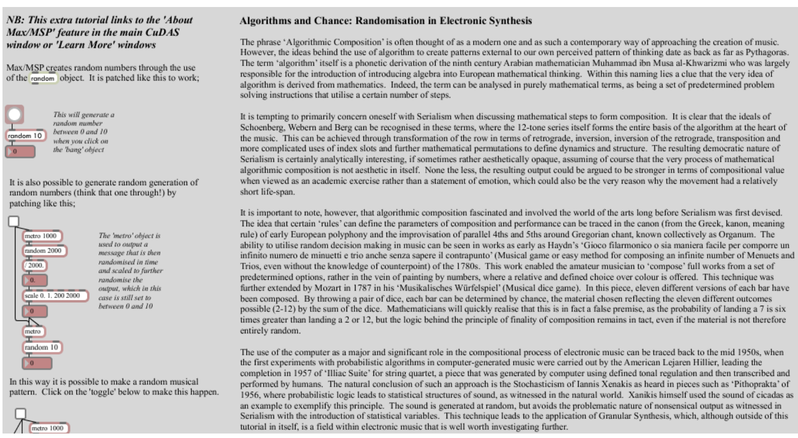


Fig. 1.77 Part of the randomisation, algorithms and chance patch

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4 Essl in Collins & d'Escriván, 2007, p.107

5 Essl in Collins & d'Escriván, 2007, p.115

tiny detail of a composition."[6] This is an important factor in the ability of a creator to free himself of the autonomy of the tradition of composition and to realise a route into the more democratic and collaborative methodology of the arts as seen in contemporary approaches to artistic creativity.

The Randomisation Max/MSP patch takes this notion a stage further, allowing the decision making of material to be undertaken outside of the composer's influence. Essl comments on how computer algorithms have enabled the ability to allow "some artistic decisions [to be] delegated to an external instance."[7] It is this notion of the automata of random choice making and paths to be followed that makes the educational potential of this tutorial so marked. It is not an immediately accessible area of electronic composition, perhaps due to the complex nature of the computer programming for such algorithmic control. However, if algorithmic music generation in real time can be seen to be "the most challenging aspect"[8] of current electronic music experimentation, then it is clearly an area that must be exposed to the learners in this curriculum.

The learning environment of the randomisation patch was initially introduced in Tutorial 4d but the reiteration of its existence at this point helps to offer more accessibility to the patch that accompanies it. Upon opening the file, it is clear that the patch is divided into two differing areas, clearly visible in *fig. 1.77*. The first of these, on the right hand side, takes the form of the supporting material from previous tutorials. In essence this is a small essay or description of the historical importance of algorithm in compositions leading to a modern day interpretation using computers. This document is included in the supporting material appendix [*Appendix 2.5*]. To the left hand side of the patch is seen examples created in the Max/MSP environment of randomisation in action [*fig. 1.77*]. This patch, unlike all of the other tutorials, is presented in patching rather than presentation mode. This is to enable the student to see the physical connection being made between the various objects. As there are allusions to the Max/MSP environment in this patch, a message is included above these patched objects advising the student of the link between this area and the patch entitled 'About Max/MSP'.

This is the final area of learning within CuDAS and paves the way for a possible extension for the student in his or her own private study. In this thesis it has been commented at large that the environment of Max/MSP has enabled learning to be progressed and developed in a way that other software packages could not allow. The many reasons for this that have been discussed, leading to the conclusion that the creativity the software encourages should be passed on to the student and as such Max/MSP in itself is presented as a final learning area.

6 Essl in Collins & d'Escriván, 2007, p.108

7 Essl in Collins & d'Escriván, 2007, p.108

8 Essl in Collins & d'Escriván, 2007, p.124

The learning of this programme is complicated and lengthy and as such cannot realistically be presented in the CuDAS software itself. However, it is possible to open the door to that world and as such create the possibility that the student engaged in the CuDAS learning programme will be encouraged to investigate the sound worlds further. The notion that a composer can be a programmer and that this is an activity that is to be encouraged is therefore the final learning strategy of CuDAS. The learning will have opened up new sound worlds and compositional ideas to the student. By following the course to the logical conclusion and learning a little more about Max/MSP, there is every chance that those who work with CuDAS in this way will develop into creative and knowledgeable music technologists.

1.9 Further Considerations on the Learning Areas of CuDAS

The aim of choosing the above topics to implement as tutorials was to create a sense of completeness within CuDAS. The curriculum is intended in designed to be a fully rounded system addressing certain parameters. The purpose of these areas was to provide an introduction to the key areas of synthesis and involve the student at a level that would cover the requirements of, whilst simultaneously progressing beyond, the Edexcel GCE Music Technology syllabus. CuDAS does not claim to be an exhaustive covering of all elements of electronic music which is why there is no place in the software, for example, for granular synthesis, Fourier analysis and wavetable synthesis, all of which have been consciously omitted.

The decisions made in the editing of material to be included were not arbitrary. Rather, it was decided to take a historical approach to the project. Sampling with pitch changes is a direct reference to the work of Pierre Schaffer and the Parisian *Musique Concrète* school. Work with sine waves, particularly involving AM and RM synthesis, can be seen as a reflection of the work of Stockhausen and the *Electronische Musik* School in Koln. Indeed, spatialisation can be seen to reflect, among others, Varese and the 1958 Brussells fair and development of his 'Poème Électronique'. This leads through to Modular Synthesis and the development of the Voltage Controlled Synthesiser in the 1960s, an area that was to have such a major impact in the sound world of popular music.

The fact that these pre-determined choices about material and topic inclusion were made has aided in the creation of a closed system. The four key areas covered in the tutorials could be likened to traditional music lessons, where one might study first melody, then harmony, then rhythm, then polyphony and so on. Each tutorial introduces a new level to the idea of electronic music and its creation. The final CuDAS patch can be seen to have all of these elements contained within. The CuDAS tutorials contain the smaller sum of its parts, thus completing the circle of a wider whole. This circle is completed with in-depth supporting material, practical work for the student to undertake, sound files containing examples as well as composed material to demonstrate the topic in question. Each tutorial has the same structure, thus leading to a sense of completeness, enhanced by the full working of material once access to that particular area has been opened. The addition of composition to this learning process is where the power of CuDAS lies. The constant mediation between the idiosyncrasy of personal composition and the systemic working of a closed system of learning makes the process of teaching and learning that much more powerful.

To add to the sense of completeness, each of the tutorial topics were designed to replicate each other, thus causing each to be a mirror of the other, assisting the perception of familiarity and leading to continuity throughout the sections of material presented in the CuDAS curriculum. This was achieved through the implementation of various predetermined factors. These included ensuring that the accompanying text that made up the Supporting Material was of a similar layout and length. Each topic is broken down into smaller key areas under clearly identifiable subheadings, thus avoiding saturating each of the areas, which if presented as a whole could be argued to be too dense in their subject material and as a result to counteract against the positive learning otherwise developed. The actual body of text for each of the supporting material documents is approximately 2,000 words. This is an important factor in maintaining the sense of wholeness in the project. It enables the reader, be it teacher or learner, to engage with each topic knowing from the outset how much material is likely to be covered and in what time scale. The short essays also enable an in depth discussion without turning the subject material into too much of a myriad of topics and over-extended detail.

The main body of the CuDAS tutorials themselves also have underlying similarities. Initially it is clear that they are similar in layout, with an initial topic heading and then a series of subheadings that deal with each of the subgenres contained in each of the main areas of study. Each of the four tutorials makes some reference to the works or sonic examples that pertain to it in order to show examples of the subject matter at hand. Further reference to an acoustic pedagogic work that has been specifically composed with aiding the understanding of the topic area is also included.

This approach to familiarity between tutorials can also be witnessed throughout the CuDAS patches. Initially it becomes clear that the layout of graphics is similar and that each tutorial retains pieces of the last, making them progressive in their intention. The amount of material contained in each of the separate patches is also designed to appear familiar as the course is undertaken. A number of differing factors are included, for example amplitude, frequency, harmonics and white noise in the first patch. These are all covered in the supporting material for each tutorial and also allow exploration of the patch on a number of levels, thus increasing the interest above and beyond the tutorial patches that make up CuDAS. Alongside this, it can be seen that each one of the CuDAS tutorial patches contains elements of the completed and much larger final CuDAS patch, thus making the entire experience a holistic one, key in the designing of any curriculum based learning.

It can be seen in the tutorial topics that where images are used to further explain technical examples of the acoustics of sound, no one individual programme is given preference over another. In order to appeal to the familiarity of all students taking the GCE Music Technology course, examples are included from the graphics of Cubase, Logic, Pro-tools and Max/MSP. This non-specific approach to the use of visuals enhances the likelihood of appealing to the widest-ranging learning groups

There is also an intrinsic understanding within CuDAS that as each tutorial is tackled, the gradual building of expectations in terms of understanding and development of previous knowledge is increased. The time taken to complete each topic is designed to be similar. However, this is only the case because of the work already covered in earlier tutorials. If a student were to start at Tutorial 4, it would take them much longer to complete and gain full understanding than one who starts at Tutorial 1 and works his or her way progressively through the topics. This is important for stretching and developing the students in their work and to give a sense of concatenation through the curriculum.

Until recently, the interface designs of computer technology have relied on software only, with the only kinaesthetic element added being the inclusion of a mouse, QWERTY keyboard or possibly a joystick. That interfaces with physical interaction are becoming more and more popular can be witnessed by the tactile approach in the games industry with the introduction of the Nintendo Wii and the success of Activision's Guitar Hero and other similar gaming systems. These rely on the variability of gesture and effect and of interaction between manipulator and software, leading to what Richard Hoadley, creator of electronic user interfaces for collaborative performance, labels as "emergent behaviour,"[9] that being the desire for interaction coupled with the dynamic levels of expectation and surprise. Max/MSP offers the possibility of such interaction through the use of Jitter and advanced programming techniques. It was deemed necessary to the success of the CuDAS project to include this tactile resource in the devising of the tutorial patches. For this reason, for pitch control a user interface that enables the student to manipulate the sound through the use of a SmartBoard™ was included. In centre K where the CuDAS curriculum was first offered, such pieces of hardware were available in every room, thus making the tutorial patches available for manipulation in any location with the use of a laptop.

Although the system is, as described above, a closed one, this is not to say that the topics that lie outside the boundaries of inclusion are not to be touched upon. The system contains the material it does for a reason, but this of course does not necessarily mean that the ideas contained within cannot be lengthened and stretched by teacher or pupil. Having defined and gained the interest required for the learning of the basics of electronic music, the possibilities for extension into other areas using the same methods are there. It is not suggested that CuDAS contains all that is required to have a complete understanding of electronic music, rather that it contains all that is required to have an initial understanding, to develop a burgeoning interest and to cover the essential material required in a productive, more positive and more enjoyable alternative environment with an enlightened methodology.

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9 Hoadley, 2009

Tutorial 1

Representation of Waveforms: Amplitude, Frequency and the Harmonic Series

Wavelengths

We hear sound due to the changes in air pressure caused by the vibrations of an instrument, be it bow on string, reed against ebonite mouthpiece, stick on drum or lips against brass. In the case of electronic music, this is replicated with movements of a loudspeaker controlled by voltage changes in the electronic signal it receives. Where one can easily see the displacement of water and the way a ripple is formed both above and below the surface (see fig. 1.1, below), the same happens with particles of air as the vibrations interfere with them. The principle difference is that we cannot see the change and must think of the air molecules as tiny dots. Vibrations that cause a repeated pattern of air pressure create what is known as a *periodic waveform*. If there is no pattern, then what we discern is noise. One repetition of a periodic waveform is known as a cycle, the number of cycles per second showing the fundamental frequency, or first harmonic, of the vibration. This is measured and displayed in Hertz. Therefore an increase in cycle length, often referred to as the wavelength, will result in a decrease of cycles per second.

Fig 1.1 Water droplet showing displacement of water in ripple above and below surface

Amplitude and Time-Domain Representation

This information is reproduced graphically in two different ways. Time-domain representation will show the waveform in a graph of amplitude over time, the amplitude being measured as the distance between the highest or lowest pressure point, or in other words, the air pressure change where an increase of air pressure is seen from 0 to 1 and a decrease from 0 to -1. Due to the fact that air pressure changes very quickly, the time axis on the graph tends to be expressed in 1millisecond (one thousandth of a second).

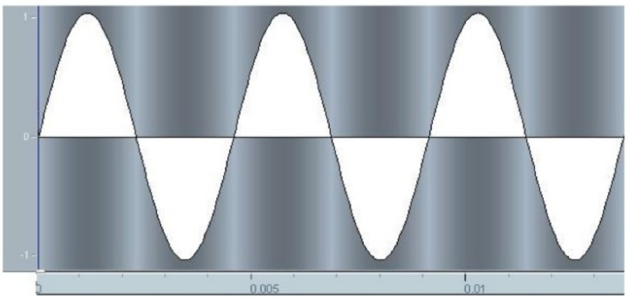


Fig 1.2 Time-domain representation graph showing air pressure vs time of a sine wave at 220 Hz. Each notch on the x axis is 1ms

Amplitude, or what we might call *dynamics* in music, is measured on a logarithmic scale, just as frequency is. This means that if you want to double the amplitude of an instrument, it is not as simple as just doubling the number of instruments. You will actually need to add 9 more instruments to that sound so that you have 10 in all. To double the amplitude again, you will need 100, then 1000 and so on. Sound file 1.3 shows an example of this phenomenon. The amplitude changes can be monitored from the original player, to two players (a small increase in amplitude), to ten (a doubling of the original amplitude), to one hundred. This phenomenon goes a long way to explaining why there are usually around 20 violins in an orchestra, ten playing the first violin part and ten playing the second violin part. In the 19th century, the Romantic orchestras quickly learned that adding more players made very little difference to the volume of the sound beyond a certain point. Hiring a further 90 players to get twice as loud a sound would, after all, be impractical, as well as very expensive.

Pitch and Frequency-Domain Representation

The alternative way of displaying this information is through a frequency-domain graph, usually displayed in amplitude over *frequency*, substituted for the word *pitch* in musical language. In this instance, amplitude is measured in decibels (commonly written dB), named after Alexander Graham Bell and the work he achieved with his telephone systems at Bell Telephone Laboratories in the early 1900s. Zero dB tends to represent the threshold of human hearing, talking registering at 50dB, an aeroplane at 120dB, although you wouldn't want to be quite that close to a sound source so loud – the pain would be quite intense. Graphically, rather like amplitude on a time-domain graph, it is the change in decibels that is measured. This is expressed as a Sound Pressure Level, often abbreviated to SPL. That is why zero on a mixing desk's fader tends to be three-quarters of the way up. This represents no change. Decreasing from zero into negative numbers will indicate a reduction in SPL and although this is measured in decibels, it is not a representation of the decibel level.

The x axis is measured in either harmonics, sometimes referred to as partials, or in frequency. This is normally displayed from 20 Hz to 20,000 Hz as this is the accepted range of human hearing. The Tutorial Patch contains a section for creating White Noise, the generation of multi-frequency bands across the spectrum. These are clearly visible as taking up the entire frequency band in the spectrum. In reality it is doubtful that hearing really does fall into these bandwidths as experiments have shown it to be closer to 17 to 19,000. Even this is debatable as particularly low lend frequencies tend to be *felt* rather than heard, due to the weight of air pressure change. Also, hearing degenerates with age as the follicles on the cochlea are non-regenerative. So a younger person may hear above 20 kHz where as an older person will struggle to perceive noise above 17 kHz. Either way, the pitch of such a frequency will certainly disintegrate at this level, becoming a quite painful and piercing noise. Perhaps one reason 20 – 20 kHz has been deployed so often is that it does tie in quite conveniently with the concept of perfect vision being expressed as 20/20.

When frequency is the displayed measure, the representation is always shown using a non-linear scale. There are two reasons for this. Firstly, the difference between, say 20 and 21 Hertz is clearly definable, whereas the difference between 10,999 Hertz and 10 KHz (10,000 Hertz) is undetectable to the human ear. If the scale was linear, it would be given the same emphasis as any other relationship, which would not be appropriate. But perhaps the stronger reason for the alternative use of a logarithmic scale is due to the nature of our need for it. Our hearing is far more sensitive from the 800 Hz to 14 KHz range. This is the bandwidth that speech occupies and so it makes sense for our evolutionary needs for it to be the most definable to us. It is therefore the most important to display in a scale.

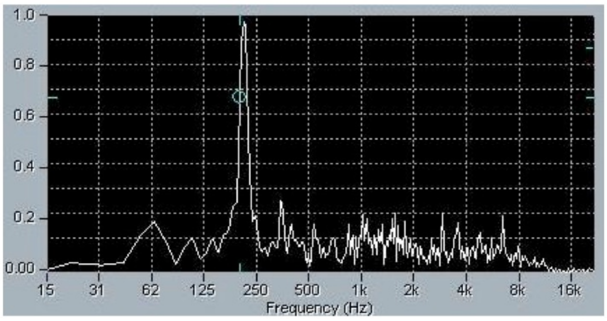


Fig 1.3 Frequency-domain representation (also known as a spectrum). This example is of a processed snare drum.

Interestingly, it is the top end of this scale that we lose in old age. A common misperception is that hearing difficulties in old age are caused by a reduction of amplitude. In fact, they are far more likely to be caused by a reduction in frequency. The reduction of the sibilant, high pitched sounds makes understanding speech very difficult. The consonants – the Ss, Ds, Ts and so on – which are so important in speech, occupy the higher end of our hearing bandwidth. Listen to sound file 1.1 as an example. The file contains Barack Obama making his speech at his presidential swearing-in ceremony. Widely considered to be a talented orator for his clear annunciation as much as the political content of his words, this ability is negated by the addition of a low pass filter that has been gradually applied as a ramp during the process, cutting off frequencies above 800 Hz. The results are startling and go some way to experiencing life as an elderly person. Pronounced diction will enable a sufferer to hear far more clearly than a raise in amplitude ever will, as will the realisation that a great deal of speech recognition is visual. It is also important to realise that although this deterioration is a natural event and that there is little you can do about it as such, it has been shown that constant exposure to loud noise will accelerate the process. Listening to music on an mp3 player at constantly loud volumes can damage the basilar membrane in the ear and is therefore likely to advance the hearing loss in the ear by as much as 40 years.

The phenomenon of frequency loss in old age has been exploited in recorded music in many ways. The removal of lower and higher frequencies is what allows mp3 encoding to take up so little space relative to full bandwidth Aiff or Wav files. Indeed, this phenomenon was used creatively by John Lennon who included a 15 KHz buzz at the very end of 'A Day in the Life' from the 1966 album, *Sergeant Pepper's Lonely*

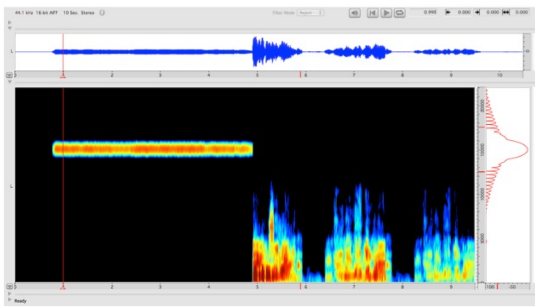


Fig 1.4 AudioSculpt analysis of the end of' A Day In The Life'.

Hearts Club Band [sound file 1.2 and fig. 1.4]. His wish was to have something that would be audible to the youth, but not the older generations. Originally only on the first vinyl pressings, this can now be experienced by all on the re-mastered CD. One wonders whether he would approve of the use of this device to send piercing high frequency shocks to remove youths from outside shops or places that they are not desired, whilst the older generation walk on by not even registering the contrivance.

Harmonics

Earlier it was mentioned that frequency could be likened to pitch. In actual fact it is a little more complicated than that. Every sound you hear, except the electronically generated sine wave and its sisters the sawtooth wave and square wave, is made up of many frequencies. The more frequencies contained in a sound, the 'noisier' it is, by which is not meant louder, just more complex. So the sound of a piece of paper being torn up has more a lot more frequencies in it than the sound of an air-raid siren, even though the latter is louder. It is the complexity and individuality of the make up of the frequency components that give each sound and therefore each instrument its unique sound. Despite the differing sounds produced, the instruments have one thing in common; when playing the same note, the frequencies contained within that note are all the same and these frequencies are known as the *harmonic series*. The frequencies are related to each other by being a constant addition of the fundamental frequency. So if the first harmonic (the actual note heard) is, for example, 440 Hz, the other notes in the series will be 440 Hz + 440 Hz (880 Hz), + 440 Hz (1320 Hz) + 440 Hz (1760 Hz) and so on.

These notes can be displayed in one of two ways; either in standard notation (*fig 1.4*) or in a frequency domain representational graph as amplitude over harmonics, where harmonics replace frequency (*fig 1.5*).

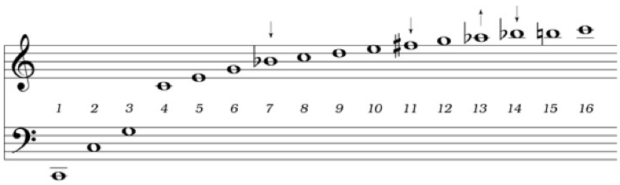


Fig 1.4 Notation of the Harmonic Series (arrows indicate sharp or flat intervals)

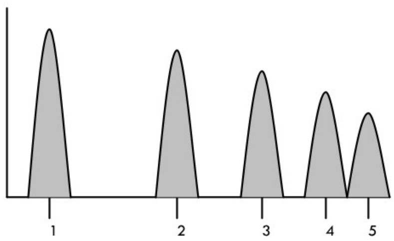


Fig 1.5 Amplitude over harmonics representation (logarithmic)

The relationship between the notes or frequencies of the harmonic series has fascinated musicians, physicists and mathematicians for centuries and one can see an immediate relationship in both graphical representations. Musically, the first seven intervals of the series can be seen to be an 8^{ve}, a perfect 5th, a perfect 4th, a major 3rd, a minor 3rd, a flat minor 3rd and a sharp second. In terms of the logarithmic scale with which frequency is displayed, the notes are less obviously connected, but the

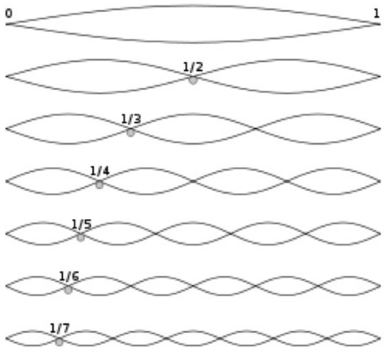


Fig 1.6 Wavelength ratios of the Harmonic Series

ratios are still in tact, these being 1/2 for an octave, 1/3 for a perfect fifth, 1/4 for a perfect fourth, 1/5 for a major third and 1/6 for a minor third and so on (see fig 1.6).

It is also clear from the example of the flute (*fig 1.7*) that the amplitude peak of each subsequent harmonic is reduced. It is this relationship of harmonic amplitude peaks that define the timbre of the sound. It is possible to see from other examples (*fig 1.8-1.9*) the extent to which these vary. It is key, however, that it is the amplitude of the harmonics that change, not the harmonics themselves.

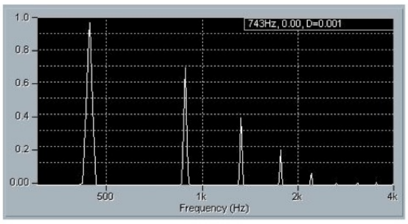


Fig 1.7 Spectrum at 440Hz – flute

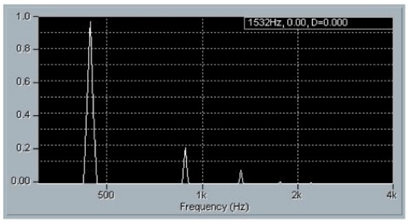


Fig 1.8 Spectrum at 440Hz – alto saxophone

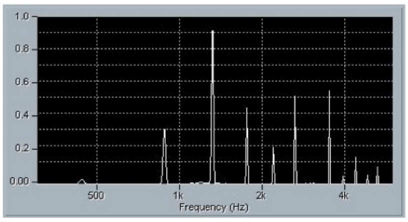


Fig 1.9 Spectrum at 440Hz – electronic tuner

AUDIO EXAMPLES

1.1 Low pass filter on speech

1.2 'A Day in the Life' – 15 kHz buzz at end of track

1.3 1, 2, 10 & 100 Saxes

Supporting Material for Tutorial 2

Spatialisation: Pan and Reverb

Angle and Pan

The concept of spatialisation in music is not a new one. Composers have long played with the physical properties of sound, particularly within the context of acoustical properties of performance spaces. As early as the 16th Century, Gabrieli was writing antiphony for two or more choirs in a call and response pattern, intended to pass from one side of the worship space to the other. J. S. Bach utilised the fantastical opportunities of the organ loft space and position in one of his early posts, where he found himself raised to the roof, as if delivering his music form the heavens. Mozart used two orchestras placed opposite each other in his Serenades K239 and K286. There are many more examples of pieces that employ these techniques throughout the history of music, from these early classical works right up to modern popular music recordings. The examples of creative use of stereo in this genre are too numerous to mention, but a good starting point would be the production on the Queen track 'The Prophet's Song', from the 1975 album, 'A Night at the Opera', from 3:23 onwards. The common link between all of these differing examples from differing genres and centuries is that of a sense of horizontal movement. Known technically as azimuth, this can be explained as the angle between two fixed sound sources on a horizontal plain. In music signal processing this is referred to as panning, a process which gives us a sense of stereo field.

There are three main ways in which the brain determines azimuth. The most obvious is the difference in time taken to reach the two ears, referred to as the Interaural Time Difference (ITD). If the sound source is heard a fraction earlier in the left ear, even by a millisecond, the brain is able to deduce that the sound source is therefore closer to the left side of the body. The time differences needed to detect this difference in location are staggeringly short, recognised as being as little as 20 millionths of a second. The same is true of the differing amplitudes on the two ears, known as the Interaural Intensity Difference (IID), particularly those of high frequencies. Where the head obscures the sound, the reduction in amplitude alongside what amounts to a low pass filter indicates to the brain that the signal is located at a certain position. Our bodies are also designed to aid us in the process of sound location as reflections from the pinna (the outer ear), shoulders and torso all help to give us a series of spectral cues. These methods become obscure below about 270 Hz, which helps to explain why the position of a subwoofer in a surround sound system is not integral to the representation of localisation.

In electronic music, there are three ways in which one can simulate azimuth, providing one is using at least a dual speaker output placed either side of the listener. The first is to implement a small delay, thus deceiving the ear into believing the sound source is closer to one ear than the other. The second is to administer an amplitude change across the two speakers. The louder signal will give the impression of a change in position in that direction. The third is to effect a high frequency change across the two split channels, once again tricking the ear, this time into believing something is occurring spatially rather than the actual change of frequency control. Listen to the four sound files [sound files 2.1, 2.2, 2.3 and 2.4] to hear examples of these three techniques. Each is of the identical sound source – an alto saxophone playing a long note at 440Hz. The first is in mono, and therefore contains no stereo field. The following three are of the same source affected in different ways. The first alteration has a slight delay, the second an amplitude change and the third a low pass filter. The position of the three altered files is not constant, and you should be able to detect a change in position, even though no actual *movement* of the sound source has been employed. In recorded music the method of using a small delay to give the impression of alternative placement or a larger number of instruments has been one of the most frequently used methods. Two examples of this technique can be heard in the contrasting recordings of Les Paul's "I'm Forever Blowing Bubbles' from 1956 and U2's 'Where The Streets Have No Name' from 1987.

When dealing with stereo delay it is worth being aware of the law of Constant Power Panning. In essence, this works by preserving the constant intensity required to balance the perceived loudness of the generated signal across the stereo field. It is helpful that this is achieved, to lesser or greater degrees of success, in computer programmes, however, is still worth bearing in mind when undertaking any compositional experiments with panning at their core. If not, the balance of the music can be severely compromised as the sounds travel around in the stereo field. It is also worth noting that these equations will have dramatic implications for mixing multi-track recordings in stereo, where files placed at extremes of the stereo field appear to jump out further in the mix than those placed closer to the middle.

Distance and Reverb

It is also possible for the ear to determine the distance of a sound object, particularly when it is static. This is achieved by an instantaneous analysis of the amount of direct signal compared to that of the reverberated signal, which will inevitably include a reduction of dBs. There is also a loss of high frequencies that is associated with increasing distance, as well as a loss of detail due to the absence of the softer sounds. All of the above help to form sound localisation, often associated with the term 'depth of field'. This has also been used creatively in classical music, an example being Gustav Mahler's Symphony no.2, where in the Finale, offstage brass mingle with onstage flute and piccolo to give an eerie sense of spatial interplay, heard at around the 19 minute mark in most recordings.

There are various ways to simulate distance in an electronic piece. The most obvious is to reduce the amplitude to give the impression of the sound source being further away. A low pass filter can give the impression of being outside where high frequencies are lost in travel very quickly. A series of short echoes can also give the impression of being in a larger space, a phenomenon we will all be aware of from personal experience of caves, housing estates, valleys and so on. However, the most commonly used method, and therefore the one that is most associated with giving a sense of depth of field, is that of reverberation.

Meaning a series of naturally occurring closely spaced echoes, reverberation can be seen as being the reflected sound from a sound source. There are usually up to about 1000 of these reflections per second, as the sound travels and bounces off any surface it encounters. This reflected sound is distinguishable from the direct sound by the lower amplitude, the slight delay and the low pass filter caused by the absorption of high frequencies in the air and by reflective surfaces. In a concert hall, the original impulse of sound reaches the listener after about 25 milliseconds, this small gap being known as a pre-delay. The earliest reflections arrive after about 50 milliseconds, although this can vary greatly depending on the acoustic design of the performance space. They are normally spaced into definable individual echoes with slightly altered time delays. These gradually reduce in amplitude before a sudden increase in fused reverberation where thousands of echoes per second build to an amplitude close to the original direct sound. The great numbers of peaks contained within the fused reverberation are all of slightly differing amplitudes in order to avoid an artificial ringing of constant frequencies. These then curve away over time, the length of which shaping what is known as *reverberation time*. This is determined as being the time taken for the reverb to decay by an amount of 60dB from the peak amplitude, this amount being a thousandth of the peak energy. Due to the decibel reduction used to work out the reverberation time, this is also commonly known as RT60 (reverberation time -60dB) and is commonly between 1½ and 3 seconds in concert halls.

That naturally occurring reverberation can be created artificially leads to some interesting possibilities in terms of creativity within spatialistaion of depth of field. The work completed by M. Schroeder on what essentially amounts to a system of time delays, filters and amplitude variation has been developed into a complex set of parameters to define reverb where early reflections are created with tapped time delay of several versions of the signal each delayed by a different amount. Fused reverberation cannot be created in this way due to the sheer volume of delays and so recursive comb and allpass filters are used in multiplicity to avoid phase cancellation. There are many controls which include Type, which offer the user the possibility of changing from hall or chamber to plate or gated reverb, the latter of which gives the distinctive explosive drum sound heard in pop recordings from the 1980s, explored initially on the introduction to 'Intruder' from Peter Gabriel's 1979 title-less 3rd solo album and made famous by Phil Collins on 'In The Air Tonight' [3:40], recorded a year later. Interestingly, Phil Collins was the session drummer on 'Intruder', and is credited as a co-creator of the then new drum sound. *Size* offers the chance to effect the simulation of larger room sizes, whilst *Predelay* determines the space before the onset of the effect is heard. Control over *Input delay*, being the reverb heard before the original impulse, can be common, as can *Diffusion*, which alters the density of the echo through the impression of a lesser or greater number of reflections. *Reverb time* to set the length of RT60, *mix* to effect the ratio between dry and wet sound and *highpass* and *lowpass filters* complete the common controls, all of which combined give great scope for recreating the natural effect of reverberation.

All of these alternate ways of effecting the reverb in common sequencer plug-ins and hardware reverberators make it possible to create some 'unnatural' reverb effects, such as a very small size with a very long reverb time and a large mix setting, or perhaps a large wet to dry mix with a large density, a low pass filter and a very short reverb time. Both of these alternative uses of reverb have been recreated as audio examples [sound files 2.5 and 2.6].

So far we have dealt entirely with reverberant sound of a static object. It is also possible to detect movement of objects through the variation of reverb. It may be obvious to suggest that when reverb is increased, it will appear as if the object of sound will get further away. However, if the source is to appear as if it is moving away, it is the direct sound that needs to be reduced, rather than the reflections that need to be increased. The difference in the two techniques is quite pronounced, as files 2.7 (increasing reverb) and 2.8 (decreasing direct sound) will show. However, there is another technique for determining the velocity of a moving sound source and this is due to a pitch change known as the Doppler shift effect. So named after the 19th Century astronomer C. Doppler, this is described simply as being a pitch shift downwards as the sound source passes the listener and a pitch shift upwards as it moves towards the listener. In more complex terms, it can be understood as a change in relative pitch due to the radial velocity of the source relative to the listener due to shrinking of wave fronts as the source moves closer. All frequencies are shifted together on a logarithmic scale, thus giving the impression that the entire sound source lowers in pitch. The most obvious everyday example of this, and one we have all experienced and wondered at, is the passing of a rescue services automobile with the siren on, included for reference as sound file 2.9.

It is possible to work out the actual pitch change using the formula; *new_p = original_p x [vsound/(vsound-vsource)]* where p = pitch and v = velocity. Taking the speed of sound at sea level to be 340.29 metres a second (although this is in itself an assumption as the speed can vary by as much as 5 m/s depending on atmospheric pressure), otherwise expressed as 1115 feet per second or 760 miles per hour, if a sound is travelling at 20 meters a second (45 mph), one would expect to hear a pitch shift of a minor second, expressed as an overall percentage of 6.15% over all frequencies. Therefore, at 10,000Hz there would be a reduction of 615Hz, whereas at 1000Hz there would be a reduction of 61.5Hz. If the pitch shift were linear, the 1000Hz would reduce not to 938.5Hz but to 385Hz, which is obviously not compatible as it would destroy the inter-harmonic relationships of the sound components. A good resource for the basic understanding of the Doppler Effect in action can be found at; http://www.walter-fendt.de/ph11e/dopplereff.htm. The effect can also be heard in music, for example in sections of Kraftwerk's '*Autobahn*'.

Height and Multiple Channel Projection

There is one further way in which we determine the localisation of sound. This is how we perceive the height or altitudinal range of the sound source, often referred to as *zenith*. This is interpreted largely by a change in the sound spectrum caused by reflections of our outer ear and shoulders, and as such is practically impossible to replicate using a simple two speaker sound system. However, by the mid 1950s, composers of electronic music had begun to experiment with multiple channel works that could enable an all round sense of spatialisation. Karlheinz Stockhausen's '*Gesang der Jünglinge*' of 1956 used five groups of loudspeakers, spaced around the room, although the projection was in mono. He went a step further with the 1960 composition '*Kontakte*' which is now recognised as being the first work for four channel tape that could allow sound to pass around the listener, although he was no doubt influenced in this by Iannis Xenakis and his multimedia work '*Concret PH*' for the Brussels world fair of 1958, which employed 11 channels and 425 loudspeakers. The scaling down to four channels by Stockhausen, however, can in effect be seen to be a precursor to quadraphonic sound of the 1970s which was used perhaps most creatively by

Pink Floyd in the 4 channel mix of their 1973 album '*Dark Side of the Moon*'. We have, of course, now become accustomed to surround sound, in its 5.1 version, as an element of our cinematic experiences in either multiplexes or as an integral part of our own home entertainment systems.

AUDIO EXAMPLES

2.1 Detecting azimuth - mono
2.2 Detecting azimuth - delay
2.3 Detecting azimuth - amplitude
2.4 Detecting azimuth - frequency
2.5 Creative reverb application a)
2.6 Creative reverb application b)
2.7 Movement of sound source a) – increase in reverb amplitude
2.8 Movement of sound source b) – decrease of direct sound amplitude
2.9 The Doppler Shift effect on a siren

FURTHER LISTENING

ARTIST	**WORK**	**ALBUM**	**YEAR**
Collins, Phil	In The Air Tonight	Face Value	1981
Gabriel, Peter	Intruder	Peter Gabriel III (Melt)	1980
Les Paul	I'm Forever Blowing Bubbles	The Very Best of Les Paul and Mary Ford	1956
U2	Where the Streets Have No Name	The Joshua Tree	1987
Mahler, Gustav	Symphony no.2, Finale	Symphony no. 2 in C minor, 'Resurrection'	1894
Mozart, W. A.	Serenades K239 and K286		1776
Pink Floyd	Money	Dark Side of The Moon [Quad mix]	1973
Queen	The Prophet's Song	A Night at the Opera	1975
Kraftwerk	Autobahn	Autobahn	1974
Stockhausen, Karlheinz	Kontakte	Elektronische Musik 1952-1960	1960
	Gesang der Jünglinge		1956
Varèse, Edgard	Poème Electronique	OHM+: The Early Gurus Of Electronic Music [Disc 1]	1958
Warner, Daniel	Delay in Glass MVT I.	Electro Acoustic Music 1	1987
Xenakis, Iannis	Concret PH		1958
	Hibiki Hana Ma		1970

Tutorial 3

Subtractive Synthesis: Phase, Envelopes, Filters and EQ

Phase

One complete cycle of a wave, as discussed in Tutorial 1, from the starting point and back again is defined as being a 360° phase. The physicality of such a phase can actually be measured as the number of cycles per second giving the frequency. An interesting practical exercise that shows this is to play a sine wave at 440Hz over a loudspeaker and move from side to side to hear the shift in the standing wave, so called due to its stativity. It soon becomes apparent that the wave lowers and rises in intensity over a distance of about 80 cm[i]. Upon doubling the frequency to 880Hz and thus raising the pitch an octave, the standing wave will decrease in size in a directly proportional manner, becoming exactly half the size (39.2 cm). If this sine wave is then shifted out of phase by 90° so that the starting position is a quarter of the cycle behind the original time-domain representation, what is achieved is a cosine wave, so called due to the related mathematical properties. When the phase is shifted by 180°, so that one signal has the appearance of being the exact opposite of another, we reach a point where the polarity is reversed. This is more commonly known in recording terminology as *phase inversion*, critical to avoid at all costs for a recording of high sonic quality. The reason this must be avoided at all costs is that the effect of this is no signal at all, as 1amp + -1amp = 0 amp, as shown [see *fig. 3.1*]. A practical experience of this can be detected when speakers on a hi-fi unit are wired incorrectly. If one is 180° out of phase with the other it can cause quite noticeable degeneration of the quality of the audio signal.

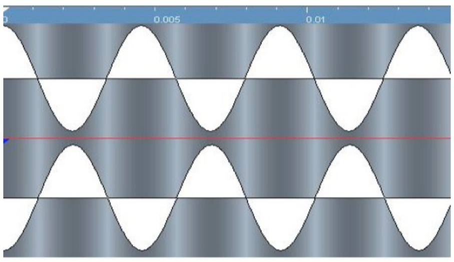


Fig 3.1 Two phase inverted time-domain representations of a sine wave at 200 Hz

Interestingly, when phase inversion is applied to more complex waveforms, some interesting phenomena can be observed. The net result is still similar as there will be a substantial reduction in amplitude as the waves cancel each other out. The less complex the audio sample, the more phase cancellation will occur. However, due to the peaks of air pressure not quite aligning, some rogue peaks become evident. This is clear in the example to the right [*fig 3.2*], where two phase inverted saxophones playing at 196 Hz result in a much quieter waveform that has a 360 cycle° half the length of the original sample. This means it will be exactly an octave higher (392 Hz). What has resulted is a phase cancellation of the fundamental frequency, whilst the secondary and subsequent harmonics

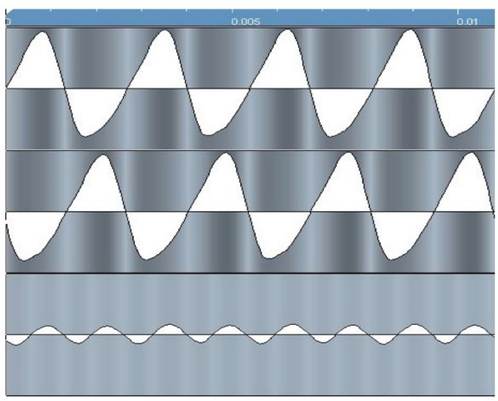


Fig 3.2 Two phase inverted time-domain representations (a&b) of the same saxophone sample displayed in Tutorial 1 [fig. 1.10]. The third waveform(c) is the output amalgamation of the two phase inverted notes (a+b=c). Note the dramatic reduction in amplitude as well as the interesting resulting peaks at half the wavelength, therefore one octave above, the original waveform.

are still contained within the waveform. This example is included as sound file 3.1.

An excellent interactive online resource for demonstrating the shapes of changing sinusoidal waveforms, as well as a more detailed description of the mathematics involved, can be found on the University of Nottingham website with an example given below [*fig.* 3.3][ii];

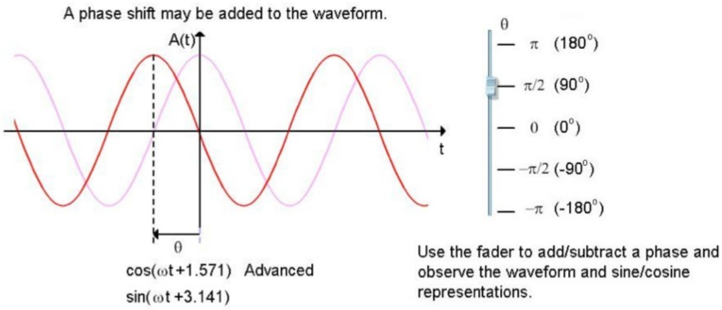


Fig. 3.3 *The fader can be used to show the change from sine wave, to sine wave and phase inverted wave patterns. This example is of a cosine wave in red, 90° out of phase with the original sine wave placed underneath in purple.*

Filters and Equalisation (EQ)

What is interesting about the theory of phase-shifted sine waves is that if frequency-dependent phase cancellation effects are applied to more complex audio files, the resulting aural experience is that of applied filters, as can be seen from the example above [*fig. 3.2*]. These can be heard as simple EQ changes where the filter boosts or cuts selected frequencies, or more complex time-variable phase or flange effects, or both types in any number of combinations together. However many filters and however they are applied, it soon becomes apparent that understanding the physical properties of these filters is essential for the analysis and therefore re-synthesis of sound as in essence a filter can perform any operation on a signal at all, which has major implications for the synthesis of sound. Applying filters to manipulate sound in this way is known as Subtractive Synthesis.

Usually expressed in simple frequency response curves [see Tutorial 1], filters are abundant in their application in everyday life, as can be seen from the spatialisation techniques of filtering in Tutorial 2. Concerning the electronic reproduction of music in practical terms, the most obvious and common example of filtering would be the frequency response of a loudspeaker, which naturally boosts the signal in the 100 Hz to 16 KHz range by as much as 3dB, while simultaneously applying a reduction below 100 Hz and above 16 KHz. Having discussed the frequency response of the human ear in Tutorial 1, it is easy to see why these processes are applied, leading to the conclusion that perhaps the clearest example of filtering frequency comes from the human ear itself.

Filters are usually expressed in four main types. These are *lowpass*, *highpass*, *bandpass* and *bandreject* filters. Examples of all four are shown below [*fig.* 3.5-3.8] with the same signal, the resulting audio peaks displayed as a frequency response spectrum. In this instance, the signal is that of a small excerpt from Radiohead's '*Fitter, Happier*'. The resulting effect on the sound can be heard as sound files 3.2, 3.3, 3.4 and 3.5. The untreated audio is also included as a norm value [*fig. 3.4* & sound file 3.2] with which to compare the differences of the filtered versions.

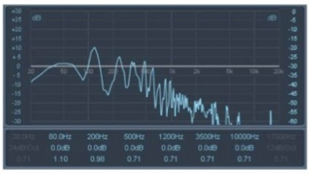


Fig. 3.4 Original file (no filter)

Fig. 3.5 Lowpass filter

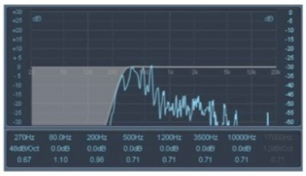


Fig. 3.6 Highpass filter

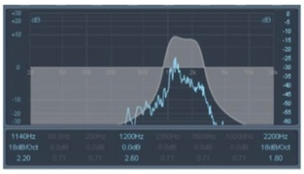


Fig. 3.7 Bandpass filter

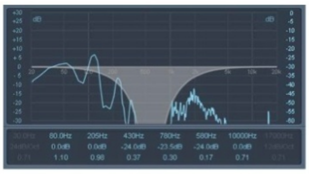


Fig. 3.8 Bandreject filter

The height of the curve in the graphic display of a filter shows its gain level, or rate of dB change. The depth of the slope is referred to as 'Q' and can be altered to be low (gentle) or high (steep), the latter focusing the filter more tightly on a specific area of frequencies and being useful for isolating resonant frequencies such as the ringing tone found in a snare drum.

The term 'equalisation' is derived from the notion that in order to process a sound through any electronic system, the frequency response of the signal must be corrected, or made equal. Although filters can be used to perform changes in EQ, this in itself is not equalisation. Rather, it is the process of applying one of the above filters that equate to equalisation.

The history of equalisation is a long and complex one. It quickly becomes apparent that all audio recordings have been altered by equalisation due to the slowly waning limitations of the technology used to record the sound. However, the uses stretch beyond the need for reproduction of phonographic records. The technique was used in telephones to avoid the phenomenon of a loss of high frequencies when transferred through long cables. The range of human hearing was discussed in Tutorial 1. With this knowledge it may not surprise you to learn that early telephone systems applied bandpass filters between 400 and 3,400 Hz. In this instance, any frequencies contained in the voice below 400 Hz or above 3,400 Hz would be filtered out. Listen to sound files 3.7 and 3.8 to hear examples of this, first with no filtering, and then with the bandpass filter applied.

Equalisation of a sound and the processing of filters on the signal can be seen to be very important in music due to the aesthetic nature of the way we perceive, and therefore wish to improve our electronic generation of, sound. The way we apply EQ may be simply to simulate the standing waves associated with differing acoustics and ambience, often referred to as *Remedial EQ*, or it may be to enhance the potential of the creativity of the music, this often called *Creative EQ*. In this latter category, it is possible to implement very simple creativity through the EQ of, say, white noise (see Tutorial 1). Through various filtering techniques it is possible to filter the frequencies to recreate to a high level of comparative fidelity the sounds of the wind, the sea or traffic rumble. The table below shows the basic areas of frequency EQ and the effect on the sound that any implementation in that area is likely to have.

Frequency Range in Hz	Commonly referred to as…	Description	Effect
10 - 60 Hz	Sub-bass	Often felt rather than heard	Rumble Too much leads to 'muddy' sound
60 - 250 Hz	Bass	Fundamental frequencies of rhythm section	Boom, warmth Too much leads to 'boomy' sound
250Hz - 2 kHz	Low Middle	Low harmonics of most instruments	500 – 1 kHz sound like a horn 1 – 2 kHz sounds tinny
2 - 4 kHz	High Middle	Speech recognition (e.g. m, b, v)	Crunch Too much causes the listener to shut-off
4 - 6 kHz	Presence	Clarity and definition of instruments	Edge Boosting can make music seem closer
6 - 16 kHz	Brilliance	Brilliance and clarity	Too much leads to sibilance
16 KHz +	Air	Hiss or noise	Can be used as audio effect Too much leads to 'noisy' recording

Envelopes

There is one further piece of terminology that it is useful to have an understanding of in this topic and that is the notion and practical application of envelopes. There are two main types of envelopes in electronic music, amplitude envelopes and frequency envelopes. Both of these involve the altering of the sound through a filter of the given type, so that an amplitude envelope will affect the loudness of a sound, and a frequency envelope will affect its timbre, or even pitch. In the former, the envelope is divided into four areas, labelled as being Attack, Sustain, Decay and Release. The abbreviation of these distinct parts gives the common place terminology of *ADSR envelope* (see *fig 3.9*, right).

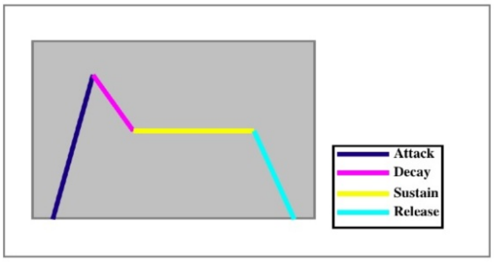


Fig 3.9 A typical ADSR envelope, showing amplitude over time

The *Attack* part of the envelope describes how long in time it takes for a sound to alter from no volume at all to maximum intensity. The characteristics of musical instruments vary greatly in this area. Bowed instruments tend to have a long attack time, whereas percussion instruments have a very short attack time, although this of course depends greatly on the performance technique employed. To this end it is possible to change a violin sample from *legato* to *marcato* simply by shortening the amplitude envelope. The *Decay* section simply describes how long it takes for the sound to decrease from maximum intensity to the level where the sound level will be constant. Most instruments have a short decay time, particularly those of a percussive nature. Once the sound has decreased to a constant level, the next section has been reached, known as *Sustain*. This constant level is the hardest to measure, and in applying synthesis the hardest to control. At times it seems frustratingly to make little difference to the sound, particularly when playing shorter notes, but on a very basic level one can imagine that the sustain time of a cymbal is far greater than that of a woodblock. The final section, known as *Release*, acts in the opposite way to that of attack, in that it shows the amount of time the note takes to decay to its initial starting point, that being silence. Once again, it is clear to see that a piano note has a very long decay time, whereas a wind instrument has a very short one, as the note decays almost immediately at the point where the air ceases to be passed through the instrument.

In electronic music, ADSR envelopes can of course be applied in contrary to expectations in order to deliver some very interesting effects. Listen to sound files 3.9 – 3.10, where one can here a sample of a violoncello as normal, and then with two very contrasting ADSRs as shown below (*fig. 3.10* and *3.11*) in a different graphic representation, this time taken from Max/MSP. The ADSR times are shown in milliseconds.

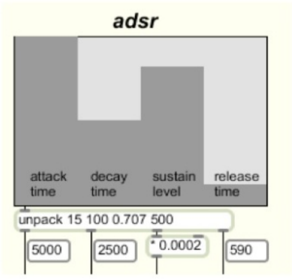


Fig. 3.10 ADSR envelope applied to sound file 3.9

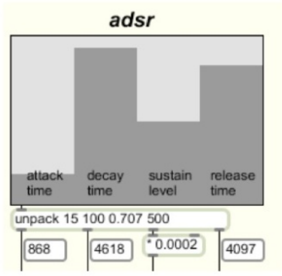


Fig. 3.11 ADSR envelope applied to sound file 3.10

It is also possible to alter the way in which envelopes are applied. The examples shown so far have all been *linear* envelopes, that is to say the lines that connect the differing parts of the envelope are all straight. If one were to change these lines to be curved then the envelope would be *exponential*.

Subtractive Synthesis

It soon becomes apparent that a great deal of creativity can be applied to a sample using simple amplitude envelopes. When one adds to this the possibilities created through frequency controlled envelopes through EQ, it is clear that this area is a great tool of potential creativity to the electronic musician. By removing harmonics of electronically generated signals such as a sawtooth wave, it is possible to emulate acoustic instruments as well as creating new synthetic sounds. By controlling the frequency and resonance of these harmonics, experimenters quickly found a limitless number of possible ways to treat and therefore alter the sound in a creative manner. It is with these principles that the first analogue synthesisers were designed, such as the influential Moog synth of the 1960s. Initially the sounds they used were a combination of sine, square, sawtooth, pulse and triangle waves, but as the technology increased more complicated waveforms could be manipulated. Early drum machines of the late 70s and early 80s used subtractive synthesis for manipulating white noise into sounding like, for example, a snare drum. Today, digital sampling allows the upload of any sound source to be manipulated in this way. It is also possible to achieve these results with yourself, making filtered white noise by altering the shape of your mouth whilst producing a '*shh*' sound.

Some recorded examples of defining and seminal works that use subtractive synthesis are included below in the table of Further Listening.

AUDIO EXAMPLES

3.1	Phase cancellation on an alto saxophone at 440Hz
3.2	Untreated excerpt from '*Fitter, Happier*' by Radiohead (*fig. 3.4*)
3.3	Lowpass filter on sound file 3.2 (*fig. 3.5*)
3.4	Highpass filter on sound file 3.2 (*fig. 3.6*)
3.5	Bandpass filter on sound file 3.2 (*fig. 3.7*)
3.6	Bandreject filter on sound file 3.2 (*fig. 3.8*)
3.7	Voice with no filtering
3.8	Voice with bandpass filter between 400 and 3,400 Hz (as used in early telephone systems)
3.9	'Cello sample with ADSR envelope example 1 applied (*fig 3.10*)
3.10	'Cello sample with ADSR envelope example 2 applied (*fig 3.11*)

FURTHER LISTENING

ARTIST	**WORK**	**ALBUM**	**YEAR**
Kraftwerk	Autobahn	Autobahn	1974
Oliveros, Pauline	Alien Bog/Beautiful Soop	Alien Bog/Beautiful Soop	1966/67
Scott, Raymond		Manhattan Research inc	1953-69
Spiegel, Laurie	Appalachian Grove	OHM: The Early Gurus of Electronic Music	1974
Stockhausen, Karlheinz	Study I and Study II		1953
Subotnik, Morton	Silver Apples of the Moon		1967
Tangerine Dream	Phaedra	Phaedra	1974

[i] The exact science is actually as follows; wl = ss/fr where wl = wavelength, ss = speed of sound and fr = frequency. The speed of sound is 345 metres a second which = 770 miles per hour. Therefore a note at 440Hz will give a standing wave of 78.4cm

[ii] http://hermes.eee.nott.ac.uk/teaching/cal/h61sig/sig0001.html#

Tutorial 4

Additive Synthesis: RM, AM, FM Synthesis and False Tones

Noise Modulation and Modular Synthesis have made a lasting impression on the development of electronic music. It remains one of the most common methods of synthesis and to this end is essential in any study concerning the synthesis of sound and the historical context contained within. The term *Noise Modulation* refers simply to the idea that by modulating waveforms with external filtered noise, interesting results that might not at first be expected are presented. The initial waveforms can be simple, such as combining two or more sine waves to create more complex waveforms. Alternatively, the waveforms as a starting point can be more complex, such as the timbres of acoustic instruments, or indeed filtered white noise, which of course contains all frequencies. Depending upon whichever is chosen, more complex results will be achieved, but the analysis of these results remains the same due to various psychoacoustic phenomena. This area of synthesis is generally and generically referred to as *Additive Synthesis*.

Jean-Claude Rissett employed the psychoacoustics of additive synthesis when conducting his 1964 experiments into producing the first synthetic bell sound. He realised that the reversing of the original audio tone made the familiarity of the sound disappear due to the lack of transient attacks. It was his working on these characteristics according to how we actually *hear* sound rather than the physics of it that gave the breakthrough in terms of the synthesis of sound and the recreation of audio instruments through purely electronic means. The derivation of these sounds through sine waves with alterable oscillated frequency, amplitude and phase, can be seen to be derived by the Fourier theorem, named after the French mathematician Joseph Fourier (1768-1830), who realised that sound was made up of a series of sinusoidal components contained within a certain waveform and gave legacy to the ability to create complex waveforms from the summing of these components.

In all of the differing modular synthesis patterns, the principle remains the same. A waveform, known as the carrier signal, is varied by a secondary waveform, known as the modulator. When the frequency of the modulator rises above 20Hz into the audible range of the human ear, sidebands of the carrier signal appear. These sidebands can be seen to be partials or harmonics that contribute to the original carrier signal, thus enriching the timbre.

RM Synthesis

	Input		Output	
Ratio	**C**	**M**	**C+M**	**C-M**
4:1 (harmonic)	800	200	1000	600
8:2.1 (inharmonic)	800	210	1010	590

Ring Modulation has widely been used creatively since the introduction of the analogue modulator by Robert Moog in the 1960s. It is a piece of equipment hardware still available commercially to this day and is also usually found as a plug-in in most Sequencer packages. In RM synthesis, the carrier and modulator signals are both bipolar. If the modulator signal is below 20Hz, the amplitude of the carrier signal is varied at the frequency of the modulator signal. This has the effect of applying tremolo to the carrier signal [see sound file 4.1] if the modulating signal is greater than 20Hz, then the audible sidebands appear for each of the sinusoidal components of the original carrier signal. This can be simple, such as a sine wave [sound file 4.2], or complex, such as the human voice [sound file 4.3]. The sidebands that are produced are ratios of each other, being the sum and the difference of the two carrier signals in the case of a pure tone. In more complex tones the sidebands are the sum and the difference of all the harmonics contained within the waveform. Therefore, the more complex the original signals used are, the more complex the resulting spectrum of sidebands will be. This is also true when one uses inharmonic ratios rather than harmonic ones, as shown in the table, right.

If the modulating signal is greater in frequency than the carrier signal, negative frequencies are created, which when viewed on a time domain graphic representation (see Tutorial 1) will show as a line down from the *x* axis rather than a line above it. This has no audible effect other than changing the phase of the sidebands, which could in turn be important due to phase cancellation, as discussed in Tutorial 3. It is also important to note that in each of the sound files 4.2 and 4.3, the original carrier signal is replaced by the side chains rather than combined with it. This is a peculiarity of RM synthesis caused by the circuitry of the two bipolar signals and as such does not appear in other forms of modular synthesis.

AM Synthesis

Amplitude Modulation, through the control signal being altered by the loudness of the modulating signal, is what gives us the common effect of a pulsing tremolo in synthesis. This effect of a softer and louder signal without a change in pitch is caused by a modulating signal below the audible range, so therefore less than 20 Hz. However, this effect is most noticeable with the use of a pure sine wave [sound file 4.4]. The slightly altered patterns of a sawtooth wave (which contains the first 8 harmonics of the harmonic series) [sound file 4.5] or a square wave (which contains the 1st, 3rd, 5th and 7th harmonics) [sound file 4.6] change the rate of pulsation quite dramatically. In the case of an audio file, the complex nature of harmonics causes the tremolo effect to all but disappear, being replaced instead by the side bands familiar from RM synthesis. The only difference between the two types is the use of one bipolar, the carrier, and one unipolar, the modulator, signal and it is this that causes the retention of the original carrier signal at the final output in AM synthesis. This means that the perceived sound is actually that of the carrier frequency, the carrier frequency plus the modulator frequency and the carrier frequency minus the modulator frequency.

FM Synthesis and the Voltage Controlled Synthesiser

If the initial experiments into electronic composition can be classed into two definable categories, namely the *Musique Concrète* school of Paris and the *Electronische Musik* of Koln, then arguably the third school should be labelled as being the defining American experiments of the 1950s and 60s that brought about the development of the voltage controlled synthesiser and with it the experiments that would become to be known as Frequency Modulation Synthesis (more commonly referred to as simply FM Synthesis).

The work that went into the development of the transistor radio in the late 1950s saw an end to the reliance on valve-based technology. Long recognised as being fragile, oversized and offering a lack of versatility, the freedom from these constraints led to a surge of creativity in the area of electronic music. The invention of the Melochord by Harold Bode made clear the advantages of a modular design with compact and transportable self-contained units. This removed the need for oscillators, filters and modulators to be controlled by uniquely assigned sliders and knobs. The transistor-based electronics allowed any number of these to be controlled by a common set of voltage characteristics, eradicating the need to interconnect each audio output in a chain from one device to another. These internal controllers continued to take the form of knobs and dials, but the potential was also quickly realised for a suitable external voltage source with a secondary chain of interconnections.

The frequency and amplitude controllable oscillators contained within a voltage controlled synthesiser were one of the chief characteristics of this kind of device. The voltage was defined by *potentiometers* which regulate the voltage levels that are supplied to the internal circuitry from a common power supply, which was typically about 5 volts. This was all integrally constructed so that the amplifier regulated the levels of the signals at the output. The easiest way to think of this is to imagine a separate control line for each of frequency and of amplitude, both powered by the same original 5 volt source. Each control line has a potentiometer to alter the variables on that line, and when the two are combined an oscillator adjusts between the two lines before leading to the output.

Each of these control lines could be further altered by break points which could include additional voltage from on external source, either of a unipolar nature, and therefore positive voltage increment, or of a bipolar nature, which would give a negative decremented supply. This external source was almost always a keyboard, by which is meant a musical keyboard, not a *qwerty* keyboard. The middle of the keyboard would be designated zero volts into a break point, each octave then increasing or decreasing logarithmically by up to 0.5 volts. The most common application of the keyboard would be to control the frequency of an oscillator. The two devices would combine to create a monophonic melody generator. This explains how keyboards can be altered from standard western tuning, as all that is needed to be done is alter the calibration of the external voltage supply, thus altering the relationship of incremental voltage addition or subtraction for each of the keys. Later in development, circuits were included in the keyboards to include the ability to play differing velocities through touch sensitivity, 0.5 volts typically offering an increase in amplitude of 10 dB. Another later development saw first the introduction of polyphonic devices and later the tracking of oscillators to filters, enabling a constant and consistent modification of timbre regardless of pitch.

All of this led the New York based Robert Moog to construct a transistor voltage-controlled oscillator and amplifier in 1964, work which was simultaneously developed by Sender and Subotnick in San Fransisco. All of the different designs became commercially available by 1966 and this, of course, had a huge impact on the popular music industry where for the first time for a decade the keyboard was elevated to a status level to, or in some cases above and beyond, that of the electric guitar.

Following Rissett's earlier psychoacoustic development of synthetic timbre, John Chowning discovered the most successful commercial sound synthesis technique to date, that of Frequency Modulated Synthesis. Chowning developed a number of sidebands producing a complex spectrum by modulating the Carrier oscillator in frequency by the Modulating oscillator. The relationship of complex ratios produced entirely depended on the amount of modulation applied to the Carrier, giving the ratio of Carrier to Modulator frequencies, usually referred to as the *C:M ratio*. Still producing sum and difference tones, a greater number could be produced, thus drastically altering the timbre of the sound, whilst retaining the same amplitude, as can be seen in the table, right;

	Ratio 4:1		Ratio 8:2.1
C	800Hz		800
M	200Hz		210
C+M	1000Hz		1010
C+(2xM)	1200Hz	sum	1120
C+(3xM)	1400Hz		1230
C-M	600Hz		590
C-(2xM)	400Hz	difference	380
C-(3xM)	200Hz		170

FM synthesis has become very popular in electronic music since it was made famous by the introduction of the Yamaha DX7 in 1983. Modern sequencers often have an FM synthesiser as an audio instrument, such as the ES1 in Logic. It is clear from loading up such an instrument (see below) that the parameters on offer, and they way in which they interact with each other, reflect those initial experiments into this sound world. These experiments and sound worlds can be heard in various examples of pieces that use FM Synthesis, including Chowning's *Turenas*, from 1972, as well as Paul Lansky's *Mil und Leise*, from 1973 which was later sampled to great effect by Radiohead on their track *Idiotique* from the 2000 album, *Kid A*. All of these pieces are interesting when contrasted with the initial experiments into sine waves of the Köln-based Elektonische Musik school. Karlheinz Stockhausen's piece *Studie I* and the interplay of harmonic and inharmonic relationships formed by his choice of material and the subsequent serialisation of dynamics by dB and note lengths in proportion to the frequency scale is certainly worth more than a cursory glance.

Fig 4.1 Logics ES1 synthesiser. Notice the ADSR envelope on the right hand side (see Tutorial 3)

AUDIO EXAMPLES

4.1 RM tremolo
4.2 RM synthesis on a sine wave
4.3 RM synthesis on a voice
4.4 Sub-audio AM of a sine wave
4.5 Sub-audio AM of a sawtooth wave
4.6 Sub-audio AM of a square wave

FURTHER LISTENING

ARTIST	WORK	ALBUM	YEAR
Kraftwerk	Autobahn		1974
Chowning	*Turenas*		1972
Paul Lansky	*Mil und Leise*		1973
Radiohead	*Idiotique*	*Kid A*	2000

Appendix 2.5 Subsidiary Learning

Algorithms and Chance: Randomisation in Electronic Synthesis

The phrase '*Algorithmic Composition*' is often thought of as a modern one and as such a contemporary way of approaching the creation of music. However, the ideas behind the use of algorithm to create patterns external to our own perceived pattern of thinking date as back as far as Pythagoras. The term 'algorithm' itself is a phonetic derivation of the ninth century Arabian mathematician Muhammad ibn Musa al-Khwarizmi who was largely responsible for the introduction of introducing algebra into European mathematical thinking. Within this naming lies a clue that the very idea of algorithm is derived from mathematics. Indeed, the term can be analysed in purely mathematical terms, as being a set of predetermined problem solving instructions that utilise a certain number of steps.

It is tempting to primarily concern oneself with *Serialism* when discussing mathematical steps to form composition. It is clear that the ideals of Schoenberg, Webern and Berg can be recognised in these terms, where the 12-tone series itself forms the entire basis of the algorithm at the heart of the music. This can be achieved through transformation of the row in terms of retrograde, inversion, inversion of the retrograde, transposition and more complicated uses of index slots and further mathematical permutations to define dynamics and structure. The resulting democratic nature of Serialism is certainly analytically interesting, if sometimes rather aesthetically opaque, assuming of course that the very process of mathematical algorithmic composition is not aesthetic in itself. None the less, the resulting output could be argued to be stronger in terms of compositional value when viewed as an academic exercise rather than a statement of emotion, which could also be the very reason why the movement had a relatively short life-span.

It is important to note, however, that algorithmic composition fascinated and involved the world of the arts long before Serialism was first devised. The idea that certain 'rules' can define the parameters of composition and performance can be traced in the canon (from the Greek, *kanon*, meaning *rule*) of early European polyphony and the improvisation of parallel 4ths and 5ths around Gregorian chant, known collectively as *Organum*. The ability to utilise random decision making in music can be seen in works as early as Haydn's '*Gioco filarmonico o sia maniera facile per comporre un infinito numero de minuetti e trio anche senza sapere il contrapunto*' (Musical game or easy method for composing an infinite number of Menuets and Trios, even without the knowledge of counterpoint) of the 1780s. This work enabled the amateur musician to 'compose' full works from a set of predetermined options, rather in the vein of painting by numbers, where a relative and defined choice over colour is offered. This technique was further extended by Mozart in 1787 in his '*Musikalisches Würfelspiel*' (Musical dice game). In this piece, eleven different versions of each bar have been composed. By throwing a pair of dice, each bar can be determined by chance, the material chosen reflecting the eleven different outcomes possible (2-12) by the sum of the dice. Mathematicians will quickly realise that this is in fact a false premise, as the probability of landing a 7 is six times greater than landing a 2 or 12, but the logic behind the principle of finality of composition remains intact, even if the material is not therefore entirely random.

The use of the computer as a major and significant role in the compositional process of electronic music can be traced back to the mid 1950s, when the first experiments with probabilistic algorithms in computer-generated music were carried out by the American Lejaren Hillier, leading the completion in 1957 of '*Illiac Suite*' for string quartet, a piece that was generated by computer using defined tonal regulation and then transcribed and performed by humans. The natural conclusion of such an approach is the Stochasticism of Iannis Xenakis as heard in pieces such as 'Pithoprakta' of 1956, where probabilistic logic leads to statistical structures of sound, as witnessed in the natural world. Xanikis himself used the sound of cicadas as an example to exemplify this principle. The sound is generated at random, but avoids the problematic nature of nonsensical output as witnessed in Serialism with the introduction of statistical variables. This technique leads to the application of Granular Synthesis, which, although outside of this tutorial in itself, is a field within electronic music that is well worth investigating further.

Perhaps the most important innovator of chance music, however, was John Cage. He devised many algorithmic systems that used chance operations for the choice of musical material. His ideal was to allow the removal of human interpretation and influence in the music. This in itself, however, is a paradox, for in order to achieve this aim he found he had to apply very rigorous human intervention to the process of algorithmic development and subsequent choice of material. His work with Hillier on the piece 'HPSCHD' of 1969 involved three computer programs that derived material for harpsichord from the Mozart dice game mentioned earlier, bringing the use of electronic and traditional acoustic chance composition together.

Chance music can also be seen in the field of popular music. Brian Eno famously generated unrepeated combinations of tones by playing loops of differing lengths on his 1978 work 'Music For Airports'. This notion that music could last forever without repeating itself, as long as the algorithm was calculated effectively, can be witnessed in various online projects, the most accessibly of which can be found at; http://www.r4and.org

Another key element to this music is that the randomisation happens in real time. In computer programming pieces of the 1960s and 70s, the algorithm had to be pre-imagined and the results pre-organised. The material generated required 'translation' into traditional notation to actually be performed. However, since the recent increase in performance power and speed of personal computers, this is no longer the case. Through the use of voltage-controlled synthesisers, Gottfried Koenig developed what is known as a 'variable function generator', which was essentially a programmable sequencer that could store time-variant voltage data that could be implemented at random. This enabled Koenig to compose chance music without the need for tape or live musicians. Transferred into computer terminology, this model can be seen to be the forerunner of random operations in computer programming language, such as the operating system Max/MSP which initially worked in the realm of MIDI, but which are now capable of real-time random manipulation of audio, thus removing the need for a composer in this field to have an understanding of computer programming, or at least of having a collaborator to aid in the development of computer algorithms. This has enabled the creation of electronic chance music to happen in real-time, by the composer, in a live performance situation. It is this, which has captured the imagination of so many composers and concertgoers in recent years, and therefore an integral part of the story of the development of electronic music.

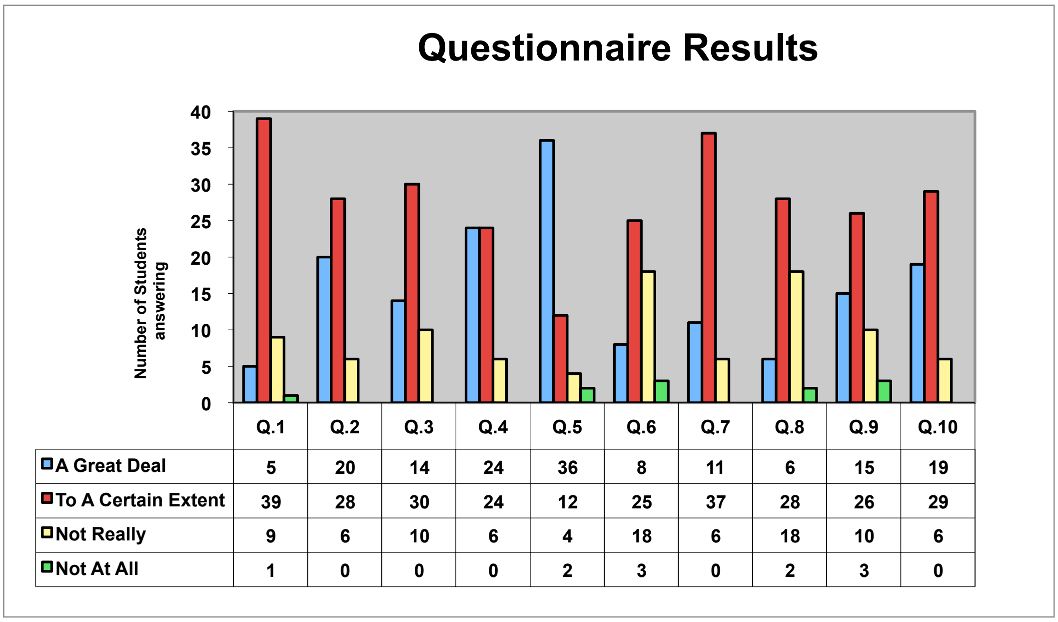
Appendix 3 Results based analysis of CuDAS

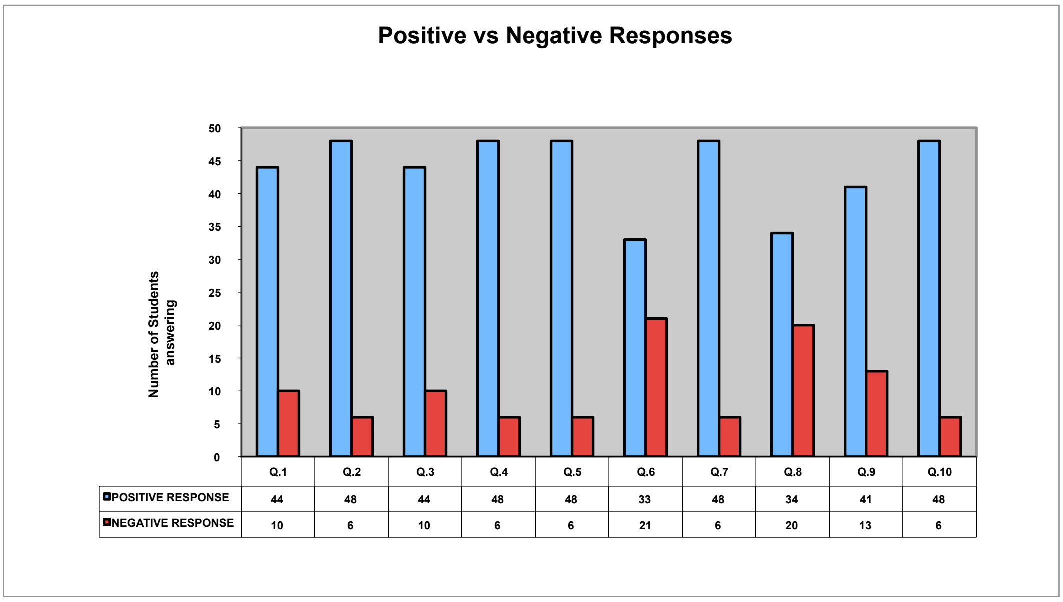
3.1 The Interplay of Music & Physics – a lecture

QUESTIONNAIRE

In order to help the evaluation of this lecture please complete the following questions.

		A Great Deal	To A Certain Extent	Not Really	Not At All
1.	Did the lecture improve your understanding of the key concepts covered?	5	39	9	1
2.	Did the lecture come across as clear and informative?	20	28	6	
3.	Do you feel that the lecture was relevant to your A-level studies?	14	30	10	
4.	Do you think other A-level Physicists [or Music Technology students] should attend a lecture like this one?	24	24	6	
5.	Was the presentation and delivery more enjoyable than a traditional lecture/lesson?	36	12	4	2
6.	Did you learn things today that you didn't already know?	8	25	18	3
7.	How much of this knowledge do you think will be retained in your memory for future reference?	11	37	6	
8.	Is your perceived retention of information higher than that of a normal physics/music lesson	6	28	18	2
9.	Was it helpful was it to have composed musical examples to explain the concepts?	15	26	10	3
10.	Was it helpful to see the computer programme that showed the changes in real-time?	19	29	6	

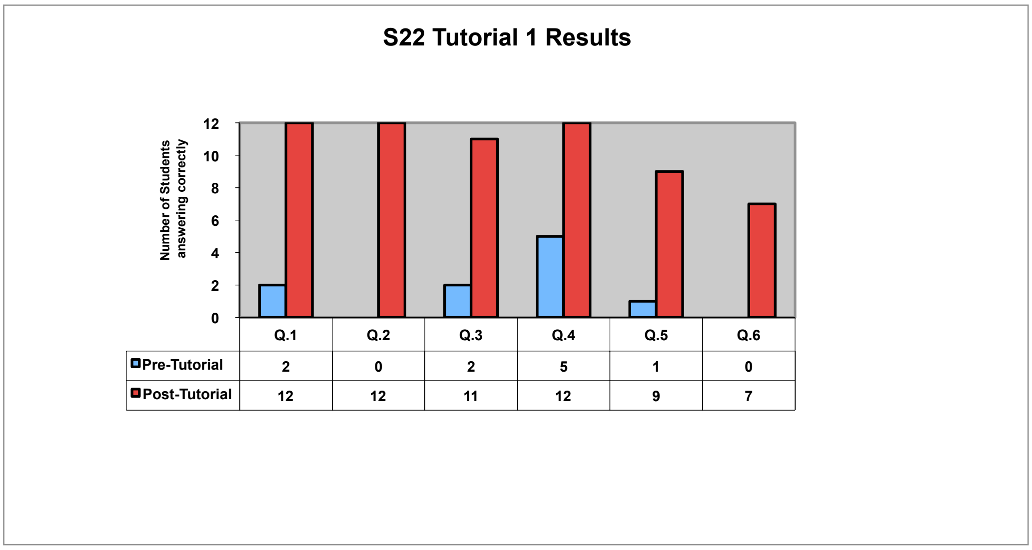




	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6	Q.7	Q.8	Q.9	Q.10
POSITIVE RESPONSE	44	48	44	48	48	33	48	34	41	48
NEGATIVE RESPONSE	10	6	10	6	6	21	6	20	13	6

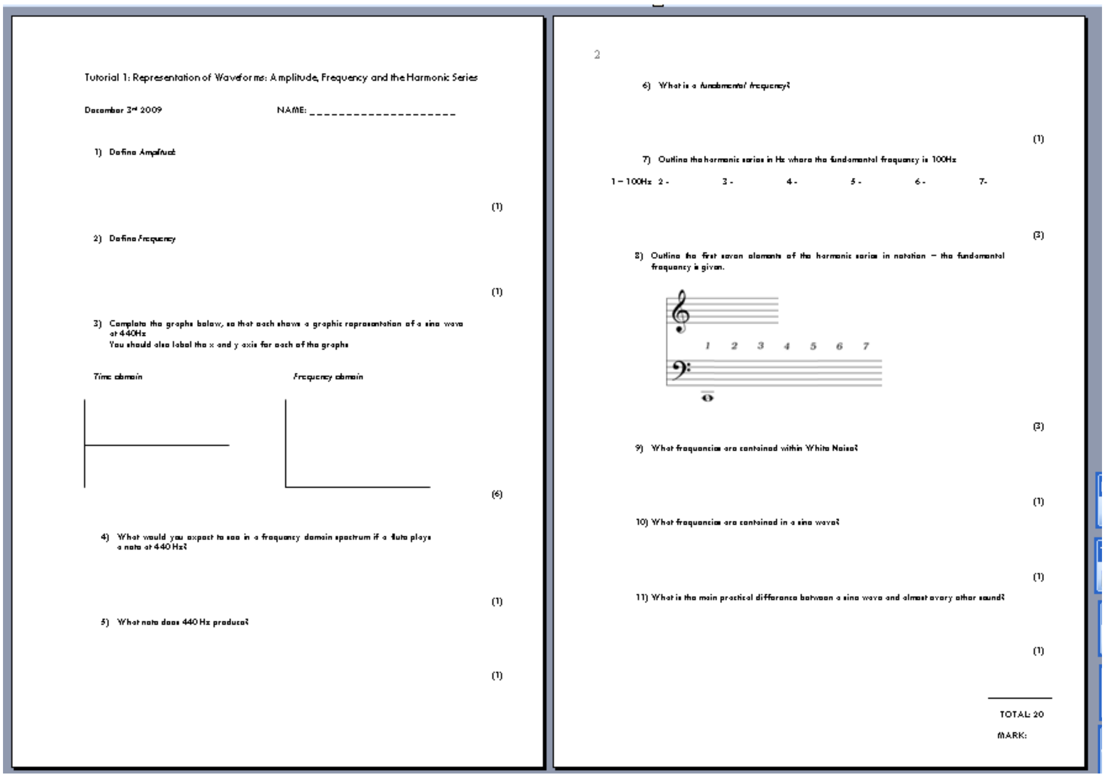
3.2 Tutorial 1 - Short Test

1) Define the difference between *time-domain* and *frequency-domain* representation of an analogue waveform.
2) Draw examples of both where the signal is a sine wave at 440 Hz
3) What would you expect to see in a spectrum if a flute plays a note at 440 Hz?
4) What note does 440 Hz produce?
5) What is a *fundamental frequency*?
6) Outline the harmonic series in Hz and notation where the fundamental frequency is 220Hz



	Q.1	Q.2	Q.3	Q.4	Q.5	Q.6
Pre-Tutorial	2	0	2	5	1	0
Post-Tutorial	12	12	11	12	9	7

3.3 Tutorial 1 – Academic Test



Tutorial 1: Representation of Waveforms: Amplitude, Frequency and the Harmonic Series

December 3rd 2009 NAME: ____________________

1) Define Amplitude (1)

2) Define Frequency (1)

3) Complete the graphs below, so that each shows a graphic representation of a sine wave at 440Hz
You should also label the x and y axis for each of the graphs

Time domain Frequency domain

(6)

4) What would you expect to see in a frequency domain spectrum if a flute plays a note at 440 Hz? (1)

5) What note does 440 Hz produce? (1)

2

6) What is a *fundamental frequency*? (1)

7) Outline the harmonic series in Hz where the fundamental frequency is 100Hz

1 – 100Hz 2 - 3 - 4 - 5 - 6 - 7-

(3)

8) Outline the first seven elements of the harmonic series in notation – the fundamental frequency is given.

1 2 3 4 5 6 7

(3)

9) What frequencies are contained within White Noise? (1)

10) What frequencies are contained in a sine wave? (1)

11) What is the main practical difference between a sine wave and almost every other sound? (1)

TOTAL: 20

MARK:

3.4 CuDAS Curriculum Feedback Survey

Response Summary

1. How do you think your understanding of synthesis has been improved by following the Tutorials?

1. Well I knew nothing about synthesis before, and I know some stuff now so my understanding has definately improved.
2. It has made everything a lot clearer and easier to understand especially through the visual aspects of the tutorials and being able to experiment.
3. It has helped me to be able to work with a more varied amount of techniques and effects as i can now relate the effects i am using to my knowledge of how those effects are created and how they work.
4. I now get how harmonics work. Phase is easy to understand and additive and subtractive synthesis too. I thought it was complicated at first but it got easier.

2. What elements of CuDAS helped in your understanding the most?

1. I think that being able to change the different parts of the sound helped a lot, so that I could see what would happen to the waveshape when various different factors were changed.
2. The fact that it is colourful and user-friendly helped to understand why sound changes with and the different frequencies relating to the different waves.
3. the tutorials, especially when i was given information on how the sound waves, for example, work. Apply the information i had read and was taught in class, i found the tutorials helped me see how it is put it into practise.
4. The programmes were good. I liked being able to hear how it works. I thought the pieces were good too. They helped me make my own versions.

3. Do you think the CuDAS Tutorials were clear and informative? Please say why you think this.

1. I found it quite good as a exercise to work things out, so that it want just a huge 'lump' of information, but when I didn't understand it then I did have to refer to the huge load of ino which was a little confusing.
2. Yes because they were simple, not over complicated. They also told you the necessary information clearly and simply and allowing us to experiment ourselves too.
3. Yes, because they helped me to put the knowledge, that i had found out, into practise.
4. Yes. I think it was easy to see how things got more complicated but it didn't all happen at once which helped. The pdfs were good for explaing the complicated stuff and I could ask Ollie when i didn't understand

4. CuDAS is designed to give written information alongside practical application of topics and composed examples. Did the combination of these three elements help in the understanding of the topics? If so, why do you think this was?

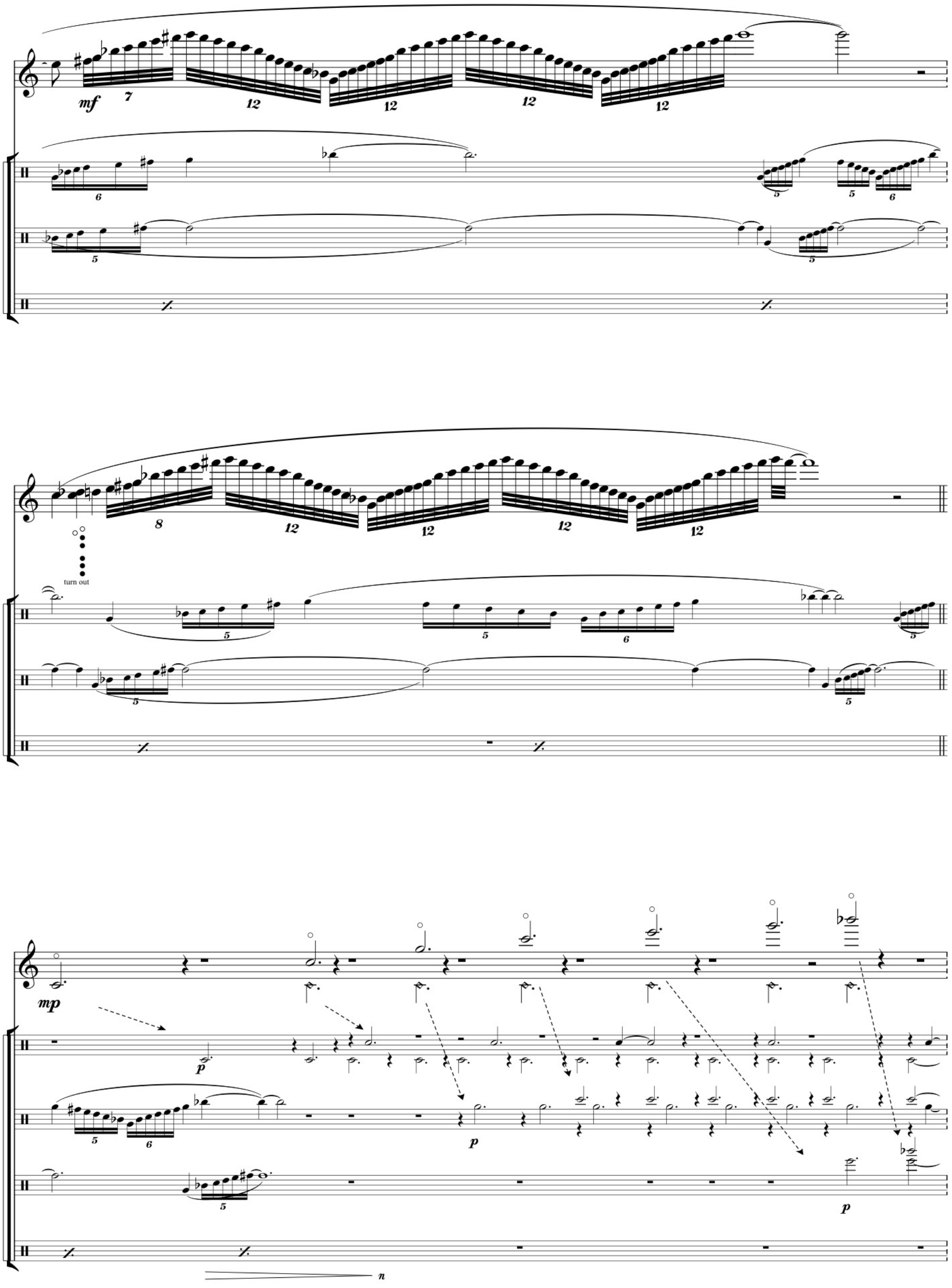
1. Yes it was helpful, but I think it was better when you explained it when I didn't understand, instead of having to refer to the written information and sifting through various complicated terms.
2. Yes as if you did not understand something the first time, it was a lot easier to understand perhaps when looking at the examples or by experimenting yourself. Also, many people learn best in different ways so the combination of these three elements, I think, appeals to almost everyone.
3. Yes, because the knowledge helped me understand the tutorials and was a basis for me in the practical examples.
4. yes. being able to play with the computer helped me undertsnad. i liked the way the graphics showed you how the sound changed as you did the synthesis. The way I could hear examples of the stuff also was good. I could easily see and hear how it all worked.

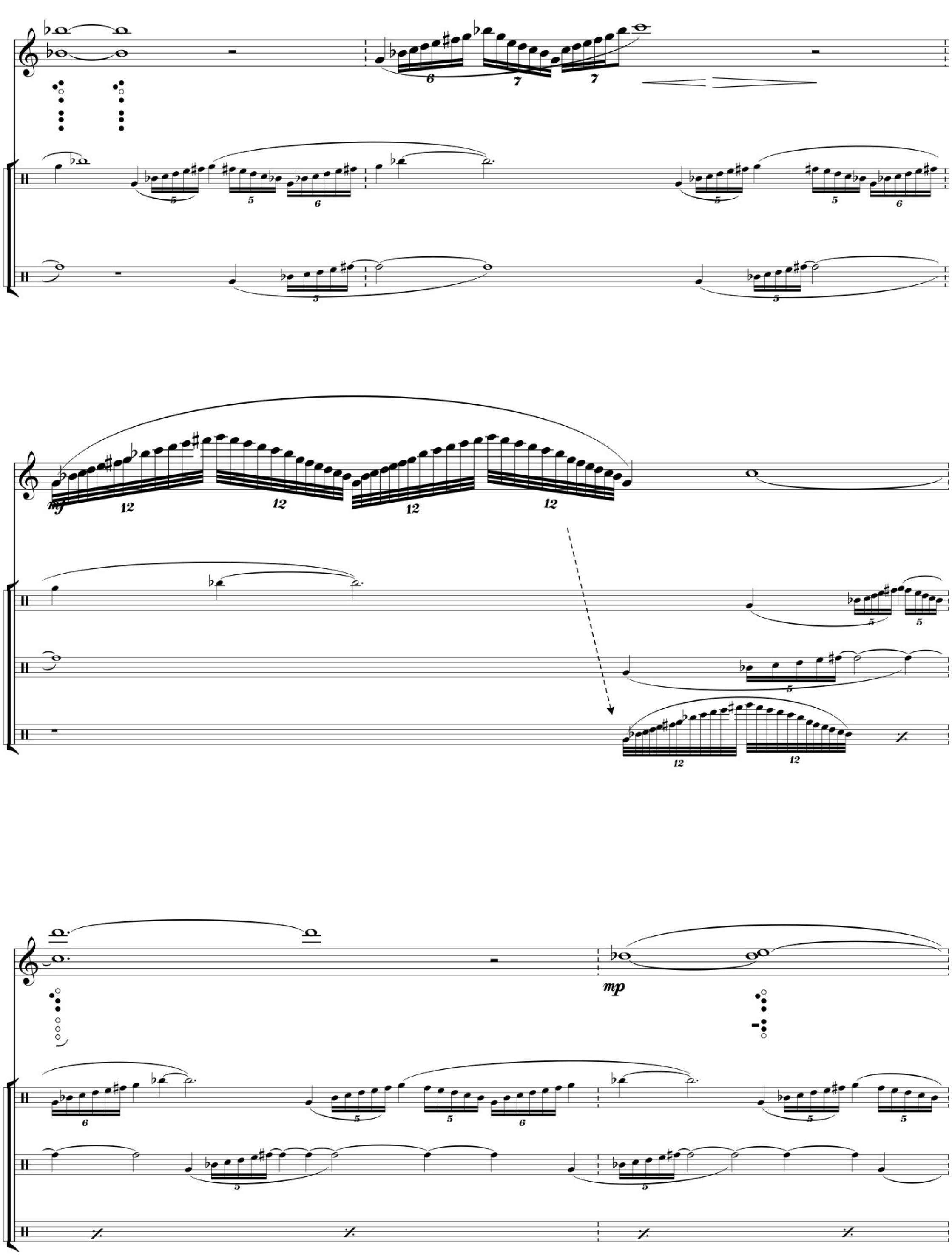
Appendix 4 Notated Scores

Harmonium

for Flute and Max/MSP

Oliver Leaman
2010


mf
turn out
mp
p
p
p
n


mf
mp

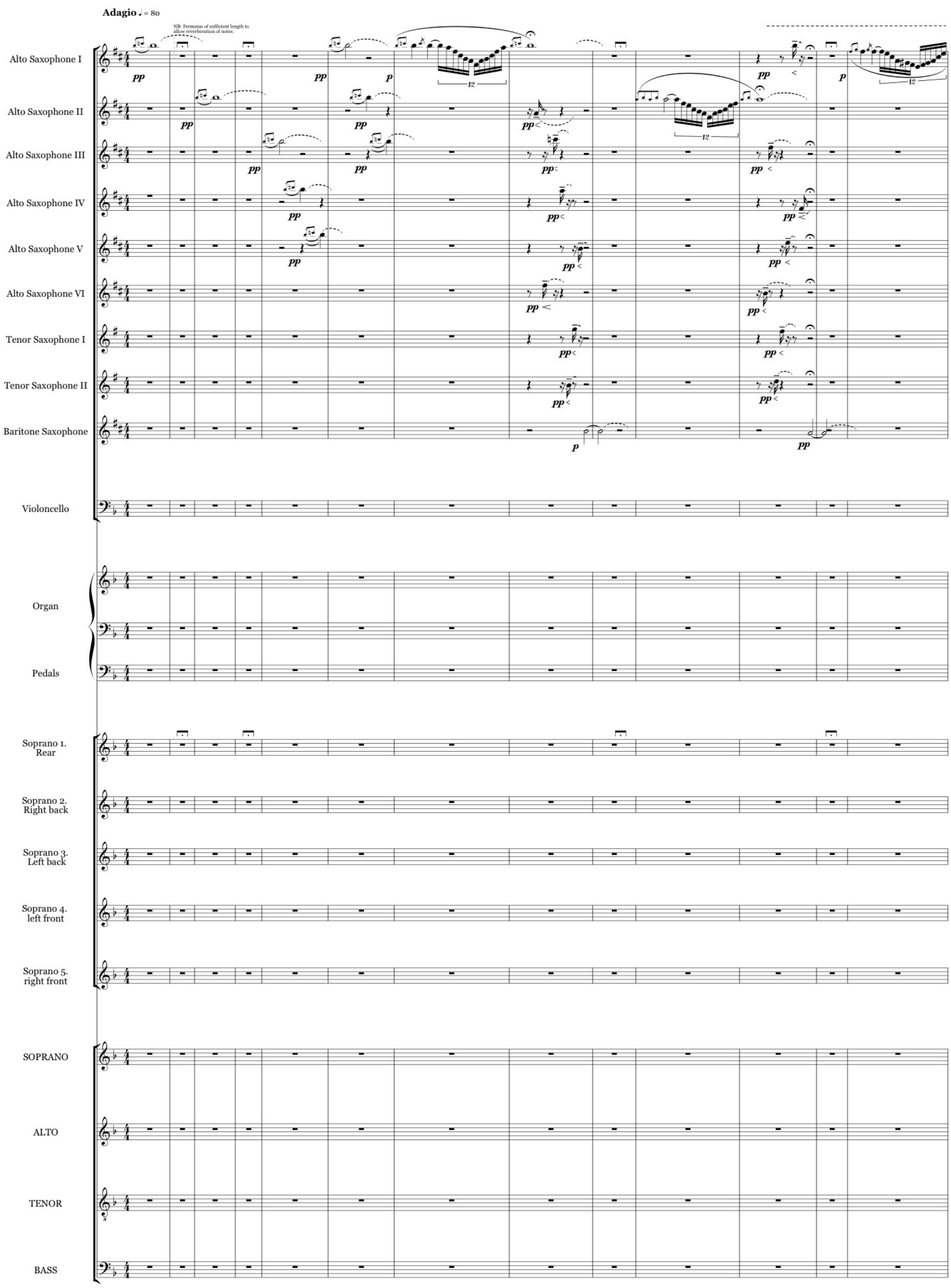

21
dim. until only key noise remains
22
8va
p
n
p
mf
①
Random amplitude, pan and pan rate
n
p
(8)
24
8va
(8)
p
n


bien articule
mf
20
mp

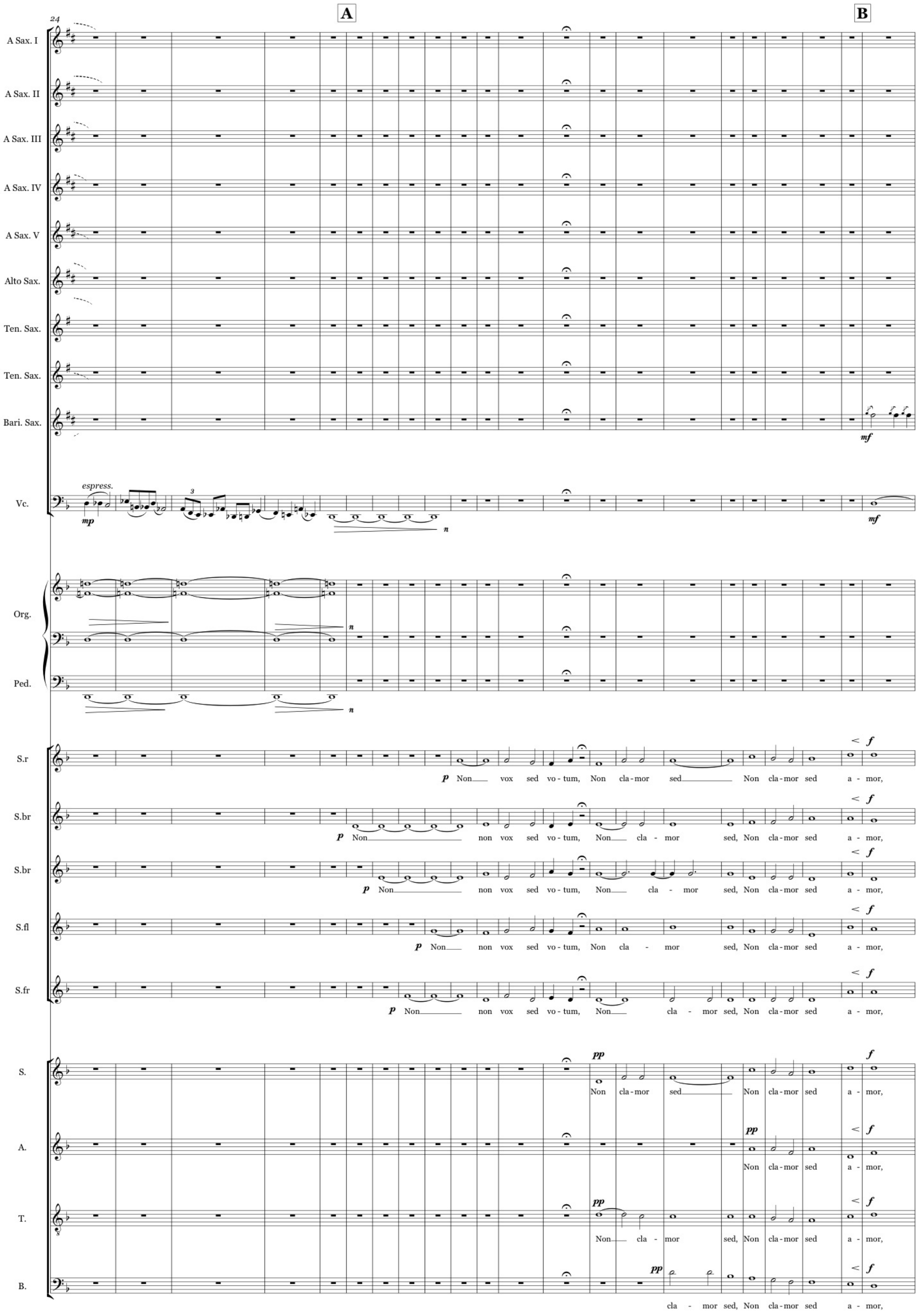
Non vox sed votum

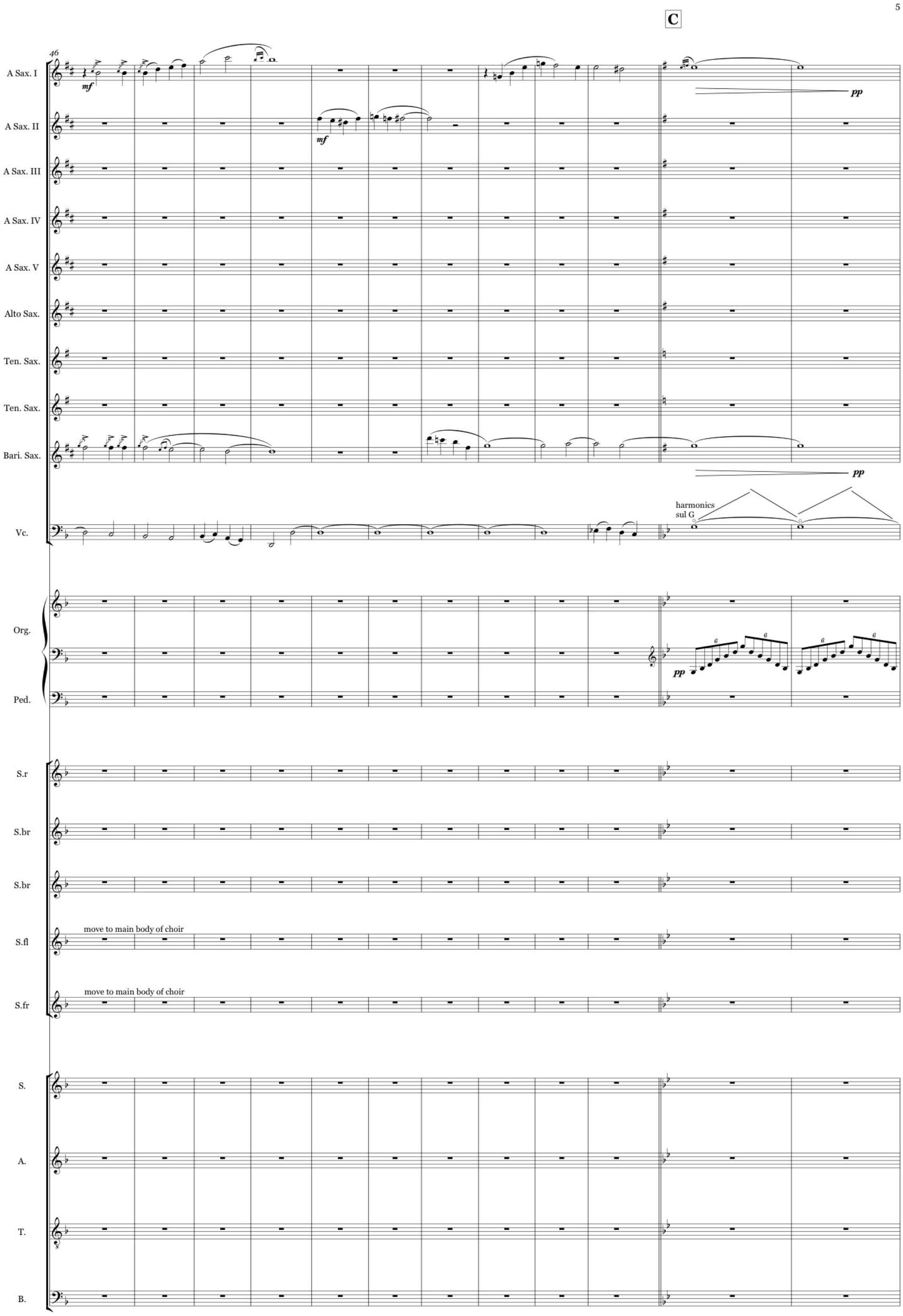
Music: Oliver Leaman

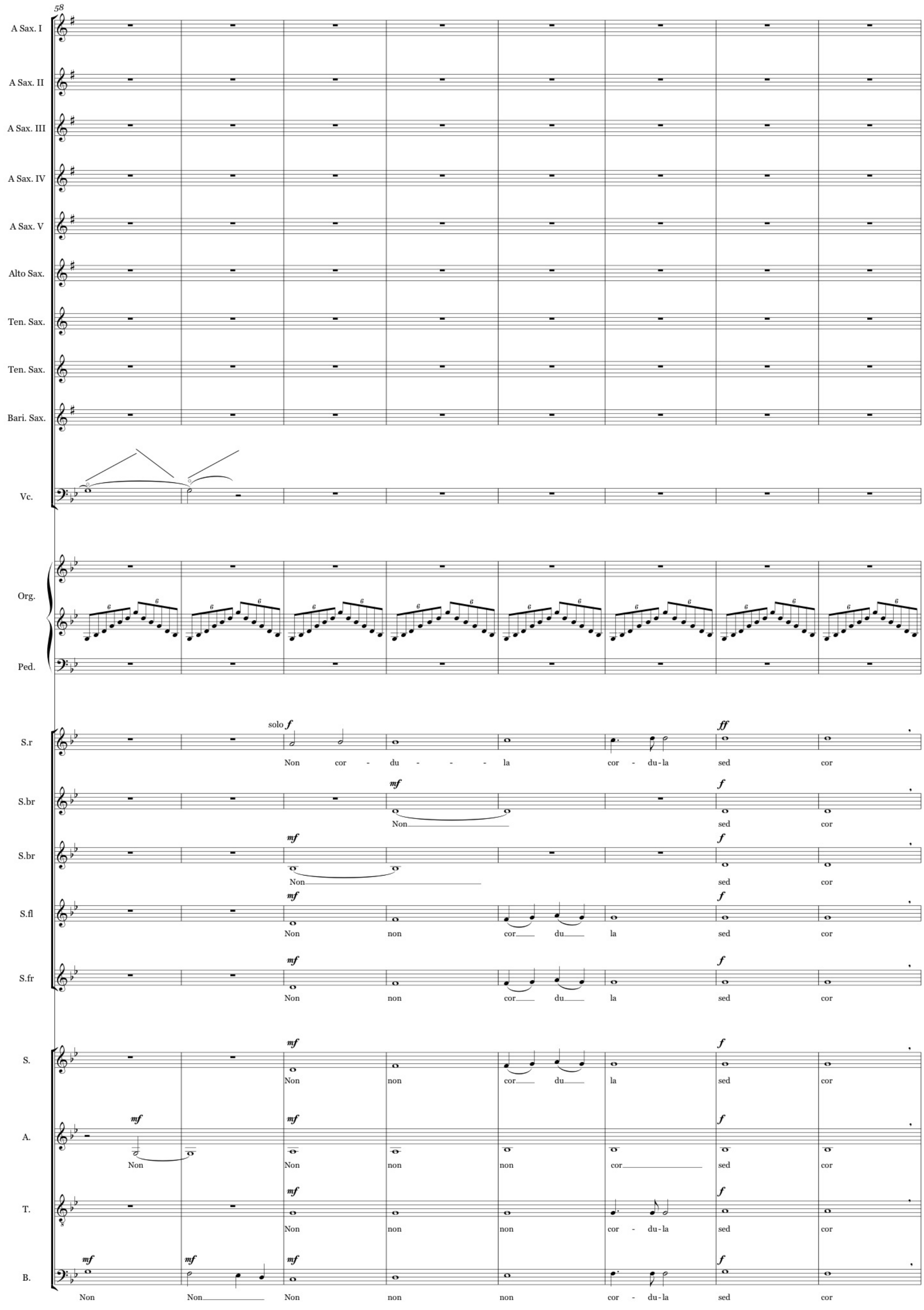
Text: 16th century inscription in
the church of San Damiano, Assisi




14
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
Org.
Ped.
S.r
S.br
S.br
S.fl
S.fr
S.
A.
T.
B.
Gradually walk to performace point 2
pp
mp
p
ppp
n


24
A
B
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
espress.
Org.
Ped.
S.r
Non vox sed vo-tum, Non cla-mor sed Non cla-mor sed a-mor,
S.br
Non non vox sed vo-tum, Non cla-mor sed, Non cla-mor sed a-mor,
S.br
Non non vox sed vo-tum, Non cla-mor sed, Non cla-mor sed a-mor,
S.fl
Non non vox sed vo-tum, Non cla-mor sed, Non cla-mor sed a-mor,
S.fr
Non non vox sed vo-tum, Non cla-mor sed, Non cla-mor sed a-mor,
S.
Non cla-mor sed Non cla-mor sed a-mor,
A.
Non cla-mor sed a-mor,
T.
Non cla-mor sed, Non cla-mor sed a-mor,
B.
cla-mor sed, Non cla-mor sed a-mor,


C
46
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
Org.
Ped.
S.r
S.br
S.br
S.fl
S.fr
S.
A.
T.
B.
mf
pp
harmonics
sul G
move to main body of choir
move to main body of choir


58
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
Org.
Ped.
S.r
solo f
Non cor - du - - - la cor - du - la
ff
sed cor
S.br
mf
Non
f
sed cor
S.br
mf
Non
f
sed cor
S.fl
mf
Non non cor du la
f
sed cor
S.fr
mf
Non non cor du la
f
sed cor
S.
mf
Non non cor du la
f
sed cor
A.
mf
Non
mf
Non non non cor
f
sed cor
T.
mf
Non non non cor - du - la
f
sed cor
B.
mf
Non
mf
Non
mf
Non non non cor - du - la
f
sed cor


66
D
solo
Am
Em/G
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
Org.
Ped.
S.r
sed cor Psal - lit in au - re, in au - re Dei.
S.br
sed cor Psal - - lit in au - re Dei.
S.br
sed cor Psal - - lit in au - re Dei.
S.fl
sed cor Psal - lit in au - - ra Dei.
move back to solo position
S.fr
sed cor Psal - lit in au - - ra Dei.
move back to solo position
S.
sed cor Psal - lit in au - - ra Dei.
A.
sed cor Psal - - lit in au - re Dei.
T.
sed cor Psal - - lit in au - re Dei.
B.
sed cor Psal - lit, Psa - lit in au - re Dei.
cresc.


76
Gm/A
Dm/E
Am
Em/G
Gm/A
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
change stop
Org.
Ped.
S.r
S.br
S.br
S.fl
S.fr
S.
A.
T.
B.


86
Dm/E
multiphonics
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
Org.
Ped.
mp
change stop (reedier)
S.r
S.br
S.br
S.fl
S.fr
S.
A.
T.
B.

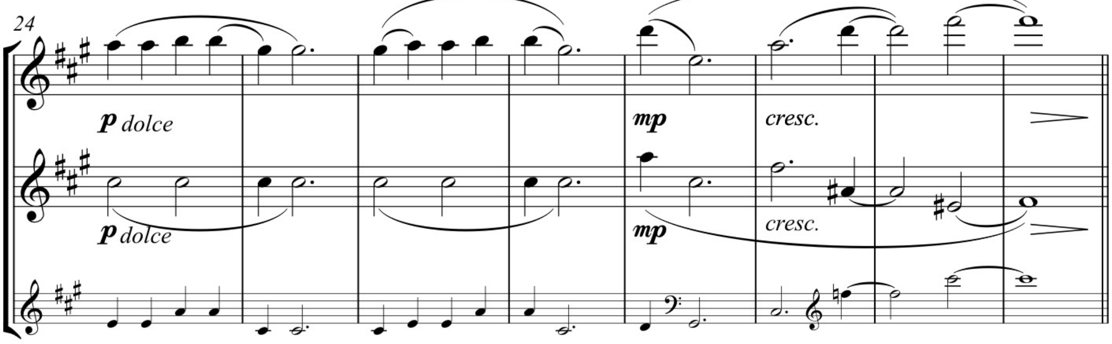

E
100
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
Org.
Ped.
S.r
S.br
S.br
S.fl
S.fr
S.
A.
T.
B.
p
cresc.
mp
mf
Lin - - - gua con - - - son - - - et men - - - ti,
Lin - - - gua con - - - son - - - et
Lin - - - gua con - - - son - - - et men - -
Lin - - - gua con - - - son - - -
Lin - - - gua con - -
Lin-gu - a con-son-et men - ti,

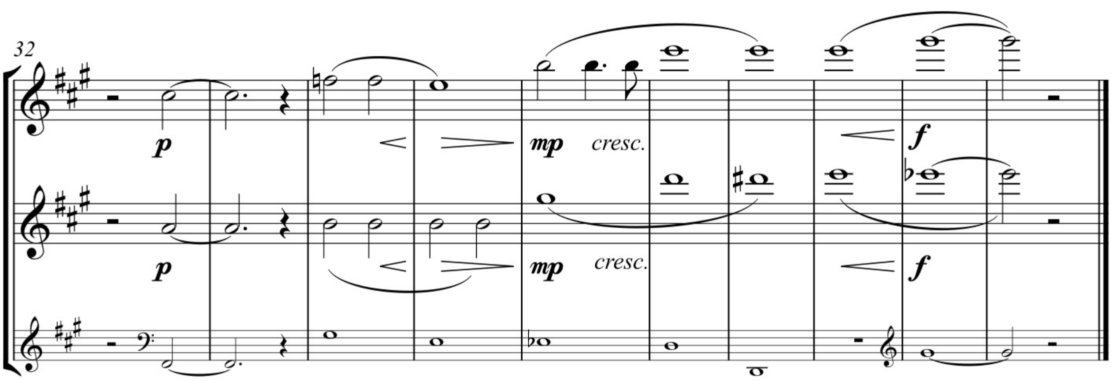

107
F
A Sax. I
A Sax. II
A Sax. III
A Sax. IV
A Sax. V
Alto Sax.
Ten. Sax.
Ten. Sax.
Bari. Sax.
Vc.
Org.
Ped.
S.r
S.br
S.br
S.fl
S.fr
S.
A.
T.
B.
change stop (softer)
dim.
Et mens con - - cor - - det.
men - - ti, Et mens con - cor - det.
ti, Et mens con - - cor - det.
et men - - ti, Et mens con - - cor - det.
- - - son - - et men - - ti.
E - t mens con - cor - det De - o, De - o, De - o.
Et mens con - - cor - - det De - o, De - o, De - - - o.

Dissimiletude

A Study of Difference Tones

Oliver Leaman
2'50


24
p dolce
mp
cresc.
p dolce
mp
cresc.

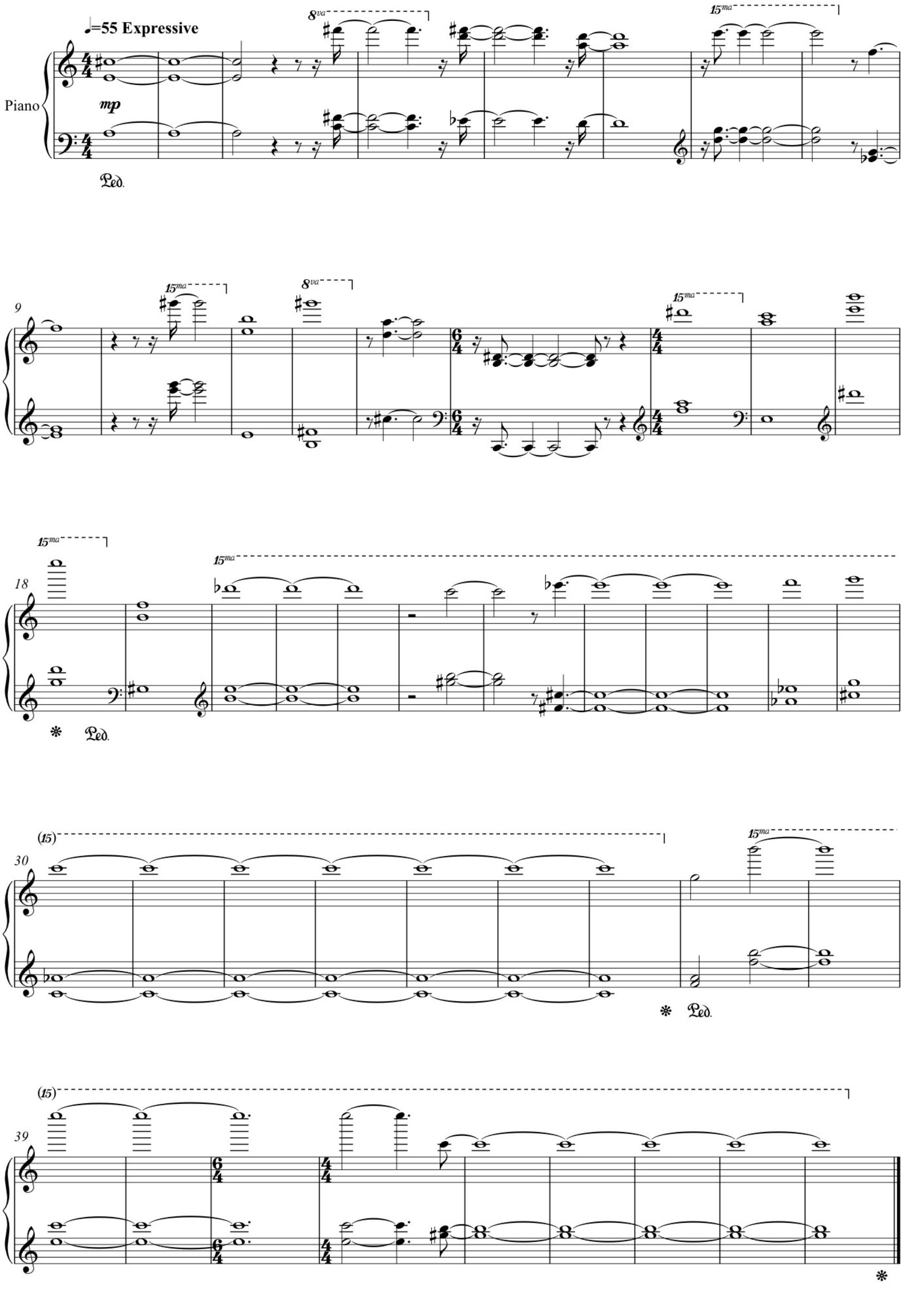

32
p
mp
cresc.
f
p
mp
cresc.
f

Dissimiletude

[Piano Version]

Oliver Leaman

2"45



Appendix 5 Multimedia File Index

The CuDAS Sound Files

Tutorial 1

1.1 Low pass filter on speech. [Taken from Barack Obama's presidential inauguration]
1.2 The Beatles - A Day in the Life [ending - showing 15 kHz buzz]
1.3 100 saxes

Tutorial 2

Examples
2.1 Detecting azimuth - mono
2.2 Detecting azimuth - delay
2.3 Detecting azimuth - amplitude
2.4 Detecting azimuth - frequency
2.5 Creative reverb application 1 - small reverb size, long reverb time, large mix
2.6 Creative reverb application 2 - large reverb size, low pass filter, short reverb time
2.7 Movement of sound source 1 - increase in reverb amplitude
2.8 Movement of sound source 2 - decrease of direct sound amplitude
[2.7 & 2.8 taken from Barack Obama's Nobel Prize acceptance speech]
2.9 The Doppler Shift effect on an ambulance siren

Further Listening
1 Collins, Phil - In The Air Tonight
2 Gabriel, Peter - Intruder
3 Paul, Les - I'm Forever Blowing Bubbles
4 U2 - Where The Streets Have No Name
5 Mahler, Gustav - Symphony no. 2 in C# Minor, Finale
6 Mozart, Wolfgang Amadeus - Serenade K239
7 Pink Floyd - Money
8 Queen - The Prophet's Song
9 Stockhausen, Karlheinz - Kontakte
10 Stockhausen, Karlheinz - Gesang der Jünglinge
11 Varèse, Edgard - Poème Electronique
12 Warner, Daniel - Delay in Glass, mvt I
13 Xenakis, Iannis - Concret PH
14 Xenakis, Iannis - Hibiki Hana Ma

Tutorial 3

Examples
3.1 Phase cancellation on an alto saxophone at 220Hz
3.2 Untreated excerpt from '*Fitter, Happier*' by Radiohead
3.3 Lowpass filter on sound file 3.2
3.4 Highpass filter on sound file 3.2
3.5 Bandpass filter on sound file 3.2
3.6 Bandreject filter on sound file 3.2
3.7 Voice with no filtering
3.8 Voice with bandpass filter between 400 and 3,400 Hz (as used in early telephone systems)
3.9 'Cello sample with ADSR envelope example 1 applied
3.10 'Cello sample with ADSR envelope example 2 applied

Further Listening
1 Kraftwerk - Autobahn
2 Oliveros, Pauline - Alien Bog/Beautiful Soop
3 Spiegel, Laurie - Appalachian Grove
4 Stockhausen, Karlheinz - Study I
5 Stockhausen, Karlheinz - Study II
6 Subotnik, Morton - Silver Apples of the Moon
7 Tangerine Dream - Phaedra

Tutorial 4

Examples

4.1 Ring Modulation: tremolo of a carrier signal by a modulating signal below 20 Hz

4.2 Ring Modulation: simple side bands in a sine wave where the modulating signal is greater than 20 Hz

4.3 Ring Modulation: as 4.2, producing more complex side bands of a human voice

4.4 Amplitude Modulation: tremolo as heard with a sine wave modulator

4.5 Amplitude Modulation: tremolo as heard with a triangle wave modulator

4.6 Amplitude Modulation: tremolo as heard with a square wave modulator

Further Listening

1 Daleks from Doctor Who

2 Pink Floyd - One of These Days

3 Black Sabbath - Paranoid

4 Kraftwerk - Autobahn

5 Chowning, Robert - Turenas

6 Lansky, Paul - Mil und Leise

7 Radiohead - Idiotique

The Compositions

1 CuDAS 1

2 CuDAS 2

3 CuDAS 3

4 CuDAS 4

5 Harmonium

6 Non Vox Sed Votum

7 SubSyn

8 Dissimiletude

9 CuDAS, as performed in concert at 'Naked'

Student Creative Work Resulting From CuDAS

1 Tutorial 1, student X

2 Tutorial 1, student R

3 Tutorial 1, student W

4 Tutorial 2, student X

5 Tutorial 2, student R

6 Tutorial 2, student W

7 Tutorial 3, student A

8 'Alone' - final portfolio submission, Student R

9 'Absorbance' - extra curricular work, student A

Video Files

1 Introduction to CuDAS

2 The teaching of Tutorial 1, centre T

3 The teaching of Tutorial 2, centre T