Making Scientists: Developing a model of science identity

A thesis submitted for the degree of Doctor of Philosophy

by

Saima Q Salehjee

Department of Education

Brunel University

31st January 2017

Abstract

This study is an analysis of a three-phase study with twelve professional scientists and non-scientists (Phase One), one-hundred and twenty-three science and non-science university students (Phase Two) and thirty secondary school girls (Phase Three), to illustrate their 'science lives'. I have used identity theories and transformational learning theory (TLT) to illustrate transformation or movement of learners towards, or away from, science. The understanding of these models and theories have led me to design a theoretical model of science identity (Sci-ID) that represents the global forces (GF) experienced by learners, the social agencies and agents (SA) that embody those forces, the transformational learning (TL) experiences (events, triggers and interventions) that shape personal meaning, and the inclinations and individual internal agency (IIA) that impact upon individuals' subject and career choices.

I have adopted semi-structured 'narrative' styled interviews, a descriptive questionnaire and science 'intervention evaluation' approaches from the three cohorts. The data generated has been analysed in several ways, including the use of synoptic analysis to construct individual stories about the participants, in third-person voice, from their responses. These stories and the broader, aggregated, thematic, outcomes have been used to examine the Sci-ID model. These outcomes stress three main themes related to the study (or not) of science, that include (i) progressive transformational learning and smooth transformation, (ii) progressive transformational learning and wavering transformation and (iii) reconstructive transformational learning and wavering transformation. These themes indicates that people in life accept and reject certain TL experiences that either 'go with their IIA' or 'go against it'. The majority find their way, choose and select TL experiences exhibiting small or medium movement towards or away from science. However, very few people exhibit large movement accompanied by regressive TL experiences. This study also reveals the existence of two very broad kinds of people (i) people who demonstrate stable pro-science or anti science and (ii) 'fluid' people who populate the centre-ground between pro-science and anti-science people. The fluid group caught my attention because their IIA shows greater ambivalence and the impact of GF, SA, incorporating events, triggers and interventions appear to have more impact than on those with a more stable science identity. Therefore, through six science education-based interventions I was able to work with – and influence - more 'fluid' kinds of secondary school girls. I used a number of mini-transformative experiences that led them to gain appreciation of science-based education and possible future science careers.

Table of Contents

List of Figures

List of Photographs

List of Tables

List of Appendices

List of Abbreviations

BIS	Business Innovation and Skills
BOS	Bristol Online Survey
CBASS	College of Business, Arts and Social Sciences
CBI	Confederation of Business Industry
E&E	Enhancement and Enrichment
EBL	Enquiry Based Learning
GF	Global Forces
HEFC	Higher Education Funding Council
IIA	Internal Individual Agency
JCQ	Joint Council for Qualifications
LiD	Learning in Depth
NoS	Nature of Science
Ofsted	The Office for Standards in Education, Children's Services and Skills
PSHE	Personal, Social and Health Education
SA	Social Agent(s)
Sci-ID	Science Identity
SEN	Special Educational Needs
STEM	Science Technology Engineering and Maths
TL	Transformative Learning
TLT	Transformative Learning Theory
UKCES	UK Commission for Employment and Skills

Acknowledgements

I would like to express my special appreciation and thanks to Professor Mike Watts for allowing me to grow as a researcher, writer and teacher. I appreciate all his contributions of time and priceless ideas to make my PhD experience productive and stimulating. I am also thankful for the excellent example he has provided as a successful physics teacher, excellent writer and an outstanding professor of education.

I am thankful to all my PhD colleagues and Brunel staff from the education department, especially, Dr Emma Wainwright, Dr Jane Essex, Dr Rob Toplis, Dr Lorraine McCormack, Dr Cathy Gower, Dr Geeta Ludhra, Dr Telima Adolphus and Helen Lee for their continued help throughout the research and writing process of this thesis.

I am thankful to all my participants' for sharing their personal experiences and life journey. Special thanks to my students and school management for trusting me in carrying out the intervention study.

A special thanks to my family. Words cannot express how grateful I am to my mother and sister for all of the sacrifices that they have made on my behalf. Your prayer for me was what sustained me this far.

Publications and Conference presentations

Publications

- Salehjee, S. and Watts, D.M. (2015). Science lives: school choices and 'natural tendencies'. *International Journal of Science Education*. 37(4), pp. 727-743.

- Watts, M., Salehjee, S. and Essex, J. (2017) But is it science? *Early Child Development and Care*. 187(2), pp. 274-283.

- Salehjee, S. and Watts, D.M. Being sciencey: Science identity, inherent inclination and social influence (in press)

Conference Presentations

- London International Conference on Education (LICE-2014), London, UK

  Title: Science lives: school choices and natural tendencies.

- Brunel University London Equality and Diversity Conference (April- 2016), London, UK.

  Title: The impact of science interventions for girls.

- Australasian Science Education Research Association (ASERA- 2016), Canberra, Australia.

  Title: Being science: Science identity, inherent inclination and social influence

- International Academic Conference on Teaching, Learning and E-learning (IACTLEl -2016), Budapest Hungary

  The impact of science interventions: to enhance science teaching and learning in secondary school.

Chapter One – Introducing the study

1.0 Introduction

This study explores some of the experiences that move people towards or away from science. I construct an overall picture through a 'timeline' of people in three different phases of life in order to delve into the events, triggers, interventions, the prompts that transform their initial science attitudes towards and/or away from the study of science. These three 'slices' of data the address twelve university scientists and non-scientists, one-hundred- and-twenty- three university students and thirty secondary school girls. Within each slice, I have used diverse methods and asked slightly different but linked questions to generate varied but congruent and accumulated data. The study highlights the main reasons why these participants, from three different generations of life, decided to undertake and persevere with the study (or not) of subjects and careers within STEM (science, technology, engineering and mathematics) or – in too many cases - non-STEM. The STEM subjects and careers include maths, biology, chemistry, physics and other biological sciences, medical science, physical sciences and engineering and technology. All of these subjects are considered under a broad 'STEM umbrella' and will be included in the category of 'science' with - for the sake of this analysis - arts, languages, history, geography, humanities and social science subjects included in my 'non-science' category.

Overall, the thesis makes use of Jack Meziow's (1991) Transformative Learning Theory (TLT), not least through its iteration by Kund Illeris (2014) and Abes, Jones and McEwens's (2007) Reconceptualised Model of Multi-dimensions of Identity. The work is influenced by my own formative life experiences as a science student and science teacher in Pakistan, and subsequently as a Muslim science teacher in the UK. It acknowledges the construction of what has been called the 'science identity' of my participants, and uses a wide age range of narrative stories about school choices, school interventions and 'transformative triggers' in life to chart their 'natural tendencies' towards and/or away from science. The most 'longitudinal' part of my research describes six classroom interventions enacted within science lessons over a period of one year in an all-Muslim girls' school. My aim has been to examine the impact of these interventions on the likely uptake of science and non-science subjects by these girls in the future.

This chapter will first outline the context to the study area, including my own personal experiences, and the key issues for students choosing science education and careers. The contextual framework then enables me to present the research aims leading to the four research questions - and possible ways to answer them. Later, I discuss the theoretical framework in terms of possible gaps in knowledge within science education, along with my research design and some limitations.

1.1 Context

> *I am often asked whether my African childhood led me to become a biologist. I'd like to answer yes, but I'm not confident. How can we know if the course of life would have changed by some alteration in its early history? I had a trained botanist for a father and a mother who knew the name of every wildflower you could normally expect to see – and both of them were always eager to satisfy a child's curiosity about the real world. Was that important in my life? Yes, it surely was.' (Richard Dawkins, 2013).*

This quote from Richard Dawkins's autobiography provides a valuable introduction to the study. It captures the science identity of a biologist who believed that his formative experiences of nature through his African childhood, combined with his parental influences, conspired to 'make' him a scientist. During the process of my PhD research, I have reflected on my own decisions concerning science education and my career choices. I believe there was more than one formative experience that prepared me to study biochemistry after A-levels: the most prominent of these personal 'triggers' was actually Chapter Ten of my college chemistry textbook - 'The Chemistry of Life'. My chemistry teacher left this chapter out of the syllabus because of time limitations, not being very important (in her view) for the final exams. So I read it by myself and realised there is something deeply fascinating in chemistry. I loved the chapter partly because I could relate it to my own body and, partly, because I read it independently as a personal non-exam-driven assignment. My young craving for fizzy drinks was over and I even stopped taking sugar in tea after understanding the chemistry of glucose, the effects of insulin, allied to the fact that my mother is diabetic. For me, it was one of the clearest transformative experiences towards science. I was very much on my own, however, because none of my close friends opted for biochemistry at undergraduate level. A second trigger was my older sister, who completed her studies at university in her major of neuropharmacology, a branch of biochemistry. So, there was certainly biochemistry ‘in the air’. Then, as a science teacher, I noticed that a majority of my female students veered strongly away from science because science education at school is just a ‘usual’ school activity, one that - unfortunately - leaves their perceptions of the world unchanged at best, and disliked at worst. I had no initial intention of conducting research in a Muslim all girls’ school, this hinged on taking a post as a science teacher at The Salehjee Girls School (a pseudonym) in London in late 2014. I was struck by the negative attitude of these girls towards the uptake of science at A-levels, and this motivated me to design (hopefully) a series of ‘transformative interventions’ to suit the needs of the girls and school science curriculum. Put together, these personal triggers resulted in me researching recent literature on the relative lack of students studying (at least one) post-secondary STEM subject or choosing some form of STEM career in the future. The section below will highlight the key issues in ‘making a scientist’ in the UK context.

1.2 ‘Making’ scientists in the UK

Data shows that there is relative lack of skilled scientists in the UK and this is a cause for concern for advanced economies that need to deal with the increasing demand of science and technology in everyday life (Winterbothan, 2014). Beginning at the output end, MacDonald’s (2014) comprehensive survey clearly documents that the UK’s STEM industries experience significant difficulty recruiting people with the STEM skills and competencies they need. The UK Commission for Employment and Skills (UKCES, 2013) reports that 26% of core STEM employment vacancies in England are hard to fill; the Confederation of British Industry’s (CBI) survey in 2014 found that 39% of businesses seeking STEM skills face pressing recruitment problems. In their report, *‘The State of engineering’*, Engineering UK (2013) estimate that engineering will require 1.86 million new skilled entrants between 2010 and 2020, which looks impossible to achieve from the current pool of young people coming forward from schools.

At this point, turning my attention towards universities, further and higher education, the picture can be seen to be positive rather than rosy. In 2013-14, 98,000 students were accepted on STEM undergraduate courses, the highest level ever recorded (Higher Education Funding Council (HEFCE), 2014), an 8% rise on the last academic year, and an 18% rise since 2002-03. At this tertiary level, however, some of the internal social inequities became manifest so that, for example, more female undergraduates study languages than those studying engineering, computing, physical sciences and mathematics combined. The number of male undergraduate students in these scientific subjects is more than three times that of female students (UKCES, 2013). Needless to say, not all those with STEM qualifications emerge to take up STEM occupations and in 2011 only one third of new STEM graduates actually worked in either STEM employment or the STEM sector or both, down from 45% in 2001 (UKCES, 2013). This drop is seen as part of a general trend of dispersion of STEM workers from traditional STEM occupations and sectors, spreading out throughout the overall workforce. In which case, if I turn focus further back, there is an obvious need for a greater number of school students to feed into the system.

Here at school level, too, the pre-university picture is relatively positive. The UK's exam board figures (Joint Council for Qualifications (JCQ, 2014) show a rise in the numbers of students of both sexes taking Advanced Supplementary-level (AS) maths, biology, chemistry and physics. Where out of these STEM subjects the highest to lowest number of subject take-up includes from maths to biology, then chemistry and least number of students opted for physics. The gender division here amongst 16-18 year-olds, though, is even more marked: physics loses more students than most subjects after AS-level and girls are more likely than boys to stop studying the subject. By the second year of A-level study (A2) only 20% of students continuing with physics are female. Across all subjects, the dropout rate between AS and A2 was 37% in 2013. In physics, the figure was 39.9% overall: 37.8% for boys, but 46.7% for girls (JCQ, 2014).

Moving the focus ever younger, a key claim is made that science education, particularly in physics and chemistry, remains unpopular among students (Hofstein, Eilks, & Bybee, 2011; Holbrook, 2008; Osborne & Dillon, 2008) - students are simply not interested in science learning and/or not motivated by science subjects (Osborne, Simon & Collins, 2003). One frequently cited reason is that learners perceive school science and science more broadly as both difficult, and as 'irrelevant' both for themselves and for the society in which they live and operate (Dillon, 2009; Gilbert, 2006; Holbrook, 2008; Stuckey, Hofstein, Mamlok-Naaman & Eilks, 2013). While science teachers have worked to make education 'more relevant' in order to better interest and motivate their students (Holbrook, 2003, 2005; Newton, 1988a, 1988b), it remains, however, very unclear that this has had much effect. According to Duit and Treagust (2003, p. 671), findings from many studies over the past three decades show that students have little prior knowledge of scientific concepts and skills, and hold 'deeply rooted' misconceptions on science practicalities. There has been an enormous literature to examine the 11-16 year-old curriculum in schools, not least that summarised by Archer and her colleagues (Archer, DeWitt, Osborne, Dillon, Willis &

Wong, 2012; Archer, DeWitt, Osborne, Dillon, Willis & Wong, 2013/2014[b]; Archer, DeWitt, and Willis, 2014[a]). Their ASPIRES (2013) study surveyed the development of young people over the age period 10-14, exploring the influences on their aspiration towards a science-related career. These studies combined online surveys of over 9,000 students, and repeat interviews with a selected sub-sample of students and their parents. Survey and interview data were collected at three time points: age 10/11 (Year 6), the second year of secondary school (age 12/13, Year 8) and the third year of secondary school (age 13/14, Year 9). Their (2014) analysis indicates that aspirations are,

> *not simply individual cognitions residing within children's heads, unaffected by their social contexts. Rather, children's aspirations and views of science careers are formed within families, and these families play an important, albeit complex, role in shaping the boundaries and nature of what children can conceive of as possible and desirable and the likelihood of their being able to achieve these aspirations* (Archer et al.[b], 2014, p. 902).

A further major point is that young people's attitudes towards science, and particularly physics, are already fairly hardened at this stage (age 10-14) of schooling. Further, Murphy and Beggs's (2005) influential study argued that, while student interest in science at age 10 was high and with little gender difference, the point of decline was already clearly evident from the final year of elementary school in the UK (children aged 10/11).

So, the key question is - what are the issues that affect young children's early dispositions towards science? MacDonald (2014) is unequivocal, the social science research on identity formation indicates that a student's 'science identity' affects his/her interests and motivations, 'self-identity is a significant element in their subject/career choice' (p. 26). The classical division here is whether a young person's early 'dispositions' or 'identity' are driven primarily by internal (intentional) or external (extensional) factors (Giddens, 1991), by individual personal dynamics, or the greater forces of cultural and social structures. A third way, of course, is that such a polarity is iniquitous, both sets of factors are vitally important; there is a 'duality of forces' at play. It is certainly the case that Archer et al. (2012) allow for the possibility of children 'going against the [social] grain' (Reay, 2010, p. 889) of formative social and familial expectations. This was seen to work both ways, with some young people resisting a strong science 'steer' from the family environment - while others proactively chose science *despite* little awareness or science resources at home. Moreover, 'it remains unclear whether the effects of family background can be explained by academic disparities' (Codiroli, 2015, p. 2). However, Archer and her colleagues strongly suggest that, using the language of Bourdieu (1977), the interplay of family capital and habitus does provide a powerful structuring context that strongly influences how children formulate their aspirations.

My concern in this study is that the pendulum has swung rather too far towards the power of social factors to explain these aspirations to the detriment of explorations of individual personal agency (see Wong, 2015). My empirical research aim is to analyse and discuss the individual's self-perceptions on the power of external global forces mediated by the social agents, along with transformational learning experiences towards or away from science. I am also interested to discuss the internal individual agency that shapes one's science and non-science identity.

By global forces (GF) I mean broad, sweeping, social dynamics that include culture, ethnicity, race, gender and religion. I see these to be prevalent through 'social agencies' such as family structures, schools, employment, churches and religious centres, numerous forms of media and so on. The GF I am discussing, then, are enacted by 'social agents' (SA) such as parents, peers, teachers, youth leaders, religious leaders, supervisors, managers and celebrities. These external, extensional, global forces interact with each person's individual internal agency (IIA) in many ways and, here, by IIA I mean the personal push, drive, dynamism and ambition exhibited by people. Needless to say, each individual can 'go along with', be ambivalent to or can oppose such global forces, social agencies and agents in their lives. While some young women will fall into the pattern of 'girls can't do science', 'science is really not for me', others will actively challenge these notions and make a 'bee-line' towards science. My broad question here is how and why do both of these happen?

1.3 Initial theoretical framework

I have adapted Mezirow's Transformational Learning Theory (TLT) to support this research and to interpret life events from participants' points of view. I use Mezirow's (2000) theoretical framework to understand the stories, the ways in which individual lives have developed and been transformed in the journey from early science through compulsory science education, then onwards to becoming a scientist or non-scientist. There are clearly many different kinds of transformative experiences and events in people's lives, from numerous small 'nudges' to deeply salient events that shape people's 'direction' and, given my particular focus, impel people towards or away from a study of science. I have supported Mezirow's theory by an 'identity theory' based largely on Illeris's (2014) descriptions and identity model, which is further linked to Abes, Jones & McEwen (2007) 'reconceptualised model of multiple dimensions of identity' (Figure 1). This has resulted in my formation of a combined 'science identity' model that I abbreviate to 'Sci-ID'. This Sci-ID model uses the transformational concepts (progressive, regressive and restoring/ reconstructive) as described by Illeris (2014) to visualise the participant's (professional scientists and non-scientists, university students and secondary school girls') responses and narratives about their science education.

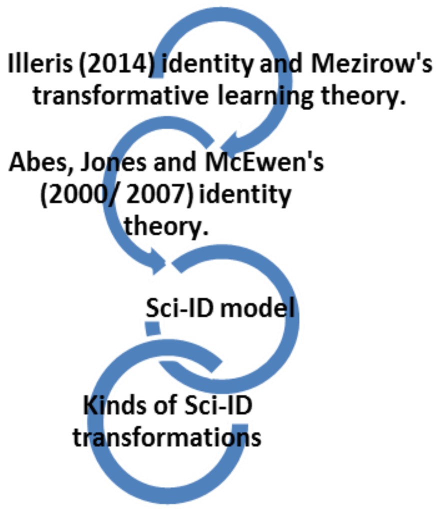


Figure 1.1: Theoretical framework

The very idea of a 'core identity' is a contested one – not all writers in this area agree that there is such a thing. I discuss this at length in the next chapter as part of my review of literature. I have also used the expression 'natural inclination' as an aspect of an IIA, in particular where I want to discuss the power - the individual agency - of people in relation to gravitating towards science and/or non-science. Through 'natural inclination' I identify a 'person's natural tendency or urge to act or feel in a particular way' (English Oxford living dictionaries, 2016). The empirical sections of the thesis examine individual participants, their science and/or non-science inclinations, sometimes by asking direct questions on their natural inclination and, where direct questions were not always possible, by interpreting their responses as an indication of their natural inclinations. The IIA is the drive and energy that accepts or rejects transformative learning (TL) events, triggers, interventions and/or circumstances in life.

1.4 Gaps in knowledge

In this introduction I have already noted some of the extensive literature in science education that deals, with great emphasis, on the lack of STEM skilled workers in UK society, and which has provided various reasons and possible solutions to overcome the problem. But, these solutions remain as just possibilities because the problem still persists (for example MacDonald, 2014) and shows few signs of abating. From my reading, the majority of the literature in science education relates to the many 'global forces' that shape the decline in science education and science careers – particularly in Western economies. However, my own research experiences in relation to scientists and non-scientists, university students and school students suggest that there is something still missing in terms of the social agents involved - and individuals' self-perceptions of themselves and science. My three-phase research, then, is important because my respondents are from different age groups are in different stages of life, exhibiting different levels personal 'identity stability' and fluidity to different degrees in their lives. I am hopeful that this multi-dimensional approach can give a broader picture of the 'transformational learning' that has - or will - stabilise or transform their science (or non-science) identities. Illeris (2014) has indicated how identity is linked to transformational learning (TL) and, while there is some empirical study within this context in science education (for example, Gerstner, Neubauer & Lehmann, 2014), this is not explicitly in relation to the uptake of science or non-science subjects and careers. Needless to say, while some people (like Richard Dawkins) might 'fall in love' with science at an early age, others reject it equally easily and quickly. Conversely, others remain steadfastly 'anti-science' over a lifetime, while some come gradually to appreciate it, through hobbies and pastimes like gardening, star-gazing, music, health and fitness (Watts, 2015).

Moreover, while a considerable body of research focuses on gender inequality and the shortage of girls in science education – again – there are but a few research papers (for example, Wong 2015) based on Muslim girls' science aspirations in a mainstream co-educational environment - so more detailed research in all-Muslim girls school is missing. The choice of Muslim girls was important because, being a Muslim female science teacher myself, I wanted to find out the reasons why Muslim girls' lack interest in the science, which I loved from school age, and how I might encourage them into the field of science education and careers.

This leads me to frame my key research questions:

1.5 Research Question One

The aim of this broad question is to describe the influences on personal inclinations that result in people's decision towards subject choices and future career decisions in science or non-science fields:

What are the main events and circumstances that generate transformation in peoples' identity towards and away from science?

As discussed above, I am interested in the 'what?' and the 'why?' of the changes in peoples' lives that take them in one direction or another. To do this, I see the need for a model of 'science identity' that acknowledges the global forces that act while, at the same time, featuring the personal inclinations and agency of individuals. So:

1.6 Research Question Two

What kind of model of identity can represent the social forces, the social agents, the triggers, the transformations, the personal meanings, inclinations and agency that impact upon an individual's choices in relation to science?

The aim of this question is to research and design a model of Sci-ID that illustrates how the external world (social forces, social agents, triggers, interventions) links with an individual's meaning-making capacity, natural inclinations, IIA. Moreover, I look to describe the impact of these internal and external forces upon individuals' education and career choices into or away from science.

1.7 Research Question Three

To what extent can a model of Science Identity be used to illustrate progressive, regressive and reconstructive transformation(s) in individuals?

To help answer this question, my literature review describes models of identity, and uses Illeris's (2014) idea of 'progressive', 'regressive' and 'restoring' transformation to visualise the ways in which transformational learning links with the stability or fluidity of the science identity.

1.8 Research Question Four

In what ways can a series of mini-transformative experiences (multiple classroom intervention activities) be sufficiently persuasive to alter secondary school Muslim girls' perceptions of science?

The aim of the fourth question relates to the design and 'impact' of classroom interventions on the secondary school girls I teach. To help answer this question, I have used Bell's (2014) 'successful intervention model' to design an intervention programme. I first designed six broad in-school and out-of-school intervention activities based on Enquiry Based Learning (EBL). These interventions link more broadly to literacy, numeracy, history within the school curriculum – for reasons I explain later (Chapter Four). Moreover, this part of the empirical study also provides some answers to questions One to Three above, by comparing the impact of series of interventions on changes in students' 'direction of travel', their preferences, understanding or meaning-making of scientific concepts - and then linking this to their science or non-science education and career choices.

A word or two here, about The Salehjee Girls School, which is a local-to-me (London borough) independent Muslim girls' school. The Head-teacher approached me to teach Key Stage 3/ Key Stage 4 science because the previous teacher left the school. One of the current teachers was also about to leave – not least because the school held her personally responsible for poor grades in KS4! I was initially given Year 10 (14 year-old) and Year 11 (15 year-old) groups to teach but, eventually (in January 2015), I took over all her classes including Year 7 and 8. The expectations of the school, the Head-teacher, parents and students were all very high, so I tried my best to do as much as possible to enthuse the girls (before entering KS4) in science with an agenda of 'science for all'. My firm belief was that, in time, some of the girls may become scientists or, even as homemakers (mothers), they might positively influence their own children - and other people - to become future scientists. The students of The Salehjee Girls School achieved poor results, their patent lack of interest in science certainly shaped my work as a teacher-researcher, and I was keen to bridge the rather austere, traditional, gap between students and teachers. This resulted in the application of my six interventions, which included a combination of individual activities and group work. Moreover, I wanted to design and implement more interventions in the school(s), especially to cater for 'science for all'.

1.9 Overall research design

My research design consists of three phases. The first is an opportunistic sample of established university-based scientists and non-scientists. The second phase surveys science and non-science university students who are engaged in their subject choices, and have a fair idea of future career choices. The final phase includes the secondary school girls who, in this study, are still at the compulsory age of science education. A chart of the phases, the instruments used to collect data; the participants and purposive sample size are shown in Table 1.1 below. A detailed description of methodology is reported in Chapter Three.

Stages	Method	Participants	Average age	Sample size
Phase One	Semi-structured ‘narrative’ interviews	Scientists and non-scientists	40	12
Phase Two	Survey questionnaires	University students	25	123
Phase Three	Intervention evaluations, questionnaires and semi-structured interviews	Secondary school girls	13	30

Table 1.1: Phases of the research process

Semi-structured ‘narrative’ interviews, descriptive questionnaire approaches and ‘intervention evaluations’ allow me to explore how and why adult participants decide to continue with science education and science related professions, what ‘triggers’ act to transform attitudes and aspirations, how this might vary from person to person and from time to time. I have written summarised stories by aggregating the data and also used thematic analysis to compare and contrast the notion of ‘natural inclination’ (into or away from science), personal preferences and meaning-making of science, and relations with social agents (including parents, school science and teachers) in order to understand participants’ transformative learning experiences that has led them to uptake a particular educational and professional decisions.

1.10 Some limitations of the empirical study

This study is not a sociological study on a 'grand scale' such as the studies conducted by Louise Archer and colleagues (2010- 2015) on science identities and social factors. Rather, my study is limited to Brunel University London and The Salehjee Girls School. Both institutions are in close vicinity and the majority of the secondary school girls might actually expect to enrol for a degree at Brunel University when they reach that stage. The university provides a comprehensive range of science and non-science undergraduate and post-graduate courses. That said, I do believe this research is more widely applicable to different schools and universities because the research questions can be applied to a variety of populations, not least as in developed and developing countries, where science and mathematics are taught from as early as age 5-6. It would be unusual if similar samples of respondents in other parts of the country, or in other countries, related their experiences and a preference in *exactly* the same way as my participants here, but my sense is that there would be important commonalities. The thematic analysis of responses relates directly to these participants and are, intentionally, my interpretations of what they say, what they write. While I am, to some extent, an 'insider researcher' in this research, I am able to operate at several levels of 'insiderness'. So, I am clearly an insider within the field of science education, but am not (yet!) an established university academic and so can operate as a detached researcher in that respect in Phase One of the study. Nor am I an undergraduate student, I left behind my 'insiderness' in that respect some years ago and, so, again, can claim some detachment and neutrality from those responses in Phase Two. I am, however, very distinctly an insider in relation to teaching the girls. There is a question, therefore, as to how 'honest', 'truthful' and 'accurate' they can be in discussing their perceptions and experiences with me, their science teacher. I happen to believe that these girls are 'feisty' young women, never slow to speak or comment, and have responded to the very best of their abilities. To overcome possible limitations, I have employed pilot studies, response validation processes and other approaches to validation, and discuss these in a section on research validity in Chapter Three.

1.11 Thesis chapters

This chapter has presented a brief introduction to ideas of global forces, the agents that generate these forces at a local level, transformations in learning, the possible shape of science identity and given some of the context of the research. I have also outlined the focus, objectives and research questions at the heart of the study. The chapters to follow are:

Chapter Two - The *Literature review* will present the relevant literature on the theoretical framework I have used for this study (and as illustrated in Figure 1.1 above). It shapes a series of models of identity in relation to transformative learning (TL) in science, and I emerge from this review by setting out a series of terms and expressions, and suggesting a distinct model of science identity (Sci-ID) that I carry forward into the following chapters of the thesis.

Chapter Three - The *Methodology* chapter will discuss how and why each particular research strategy was selected. It also includes a brief description on the selected qualitative method, ethical considerations and the strategies used to explore the Sci-ID model and to analyse the ensuing data. I also discuss the issues of validating the interview and questionnaire data that I generate.

Chapter Four – This chapter focuses on the science education based intervention design and its implementation in The Salehjee Girls School.

Chapter Five – This chapter focuses first on the responses of the twelve established/ professional scientists and non-scientists. Their interview responses are detailed in themselves but can also be crystallised into a series of narrative accounts that illuminate aspects of their approaches to science. This chapter also presents and synthesises the outcomes from the survey of university students.

Chapter Six –This chapter presents the findings from evaluative questionnaires and semi-structured interviews over a year-long process.

Chapter Seven – This *discussion chapter* will present answers to the four broad research questions (mentioned above) using the analysis study obtained from the empirical data supported by recent literature. Some conclusions *are* presented in order to highlight the main points raised by the research. This chapter will also discuss the strengths and weaknesses of this research, recommendations as well as suggest avenues for further study.

Chapter Two - Literature review

2.0 Introduction

The previous chapter introduced the study, where I outlined the context, and the research questions that helped me to identify gaps in the field. I then presented a brief discussion on the theoretical framework and an overview of the research design to include the three phases of data collection. I also discussed some of the expectations and limitations and the overall structure of the thesis.

This chapter will first present a debate on external and internal forces in the making of science identities and the ways in which a few key researchers have addressed these issues. Next I will further review research to elaborate the impact of specific social agents in the development of student identities. Where I will be focusing on how and why people accept or reject transformational learning (TL) experiences, then my focus will mainly involve transformations and changes in identity, the development of identity from its fluid to stable state. This will lead me to present Mezirow's Transformative learning theory (TLT) (2000). TLT will then establish further grounds that will lead to present Illeris's (2014) and Abes et al.'s (2007) model of identities. Next, I will present a combined science identity model that I abbreviate to 'Sci-ID'. Sci-ID model will include a few ingredients of Illeris (2014) and Abes et al.'s (2007) models, with my illustration of the each ingredient. Finally, I will elaborate Illeri's kinds of transformation in a science context.

2.1 Science identity

Identity-based research has a long tradition in education, and is mirrored in science education (Lee, 2012). At heart, the debate is neatly captured in the reflective paper by Albright, Towndrow, Kwek & Tan (2008): the extent to which the construction of identity is an expression of 'internal' individual agency or of 'external' cultural and social forces. They make the obvious, but relevant point that identity is conceptualized and bounded by the theoretical frameworks used, with identity being 'a slippery eel to grasp when it comes to informing educational practice' (p. 146). The classical division here is whether a young person's early 'dispositions' or 'identity' are driven primarily by agency or structure, that is by 'individual internal agency' (IIA), or the greater 'global forces' (GF) of social structures. As Block (2013, p.126) stated, the theoretical rigidity between structure and agency is a 'tension often mentioned but seldom explored in depth'. The third way, of course, is that such polarities are iniquitous, both sets of factors are vitally important. This third way is nicely captured by Giddens (1979) when he stated that 'structure enters simultaneously into the constitution of the agent and social practices, and 'exists' in the generating moments of this constitution' (Giddens, 1979, p. 5). Giddens (1991) does believe that, while there exists 'ontological security' that gives a 'sense of continuity and order in events', 'self' is not a passive entity, determined solely by external forces. In this manner, Giddens moves away from 'dualism' ('agent/agency' and 'structure/rules of resources' are viewed as the two distinctions) to 'duality' where both agency and structure are viewed as a part of the same phenomenon (Ransome, 2010). Moreover, Giddens, in his book 'Modernity and Self-identity' (1991) highlighted that modernity features 'an interconnection between two extremes of extensionality and intentionality: globalising influences on one hand and personal dispositions on the other' (Giddens, 1991, p.1). He therefore avoids an extreme positioning of extensionality and intentionality, and considers these positions to be two sides of the same coin.

My intention here is not to discuss further the various theoretical tension in relation to structure and agency identified by Block (2013), instead I am interested in exploring 'science identity' that is shaped by 'internal individual agency' (IIA). Moreover, I am interested in exploring the influences derived from 'social agents' (SA) that link the IIA with the 'global forces' (GF) of society such as social class, race, religion, ethnicity, gender, institutional status etc. As I noted in Chapter One, by social agents I mean, for example, families, parents, peers, schools, teachers, churches, clerics, youth centres, youth workers, employment, and employers. These are social agents (SA) that are situated – and that intercede - between the larger social forces and individual agency. In this thesis I focus on the GF, SA, TL experiences, natural inclinations and IIA in relation to science education and career preferences, and highlight science identity-linked research models that explore IIA, TL experiences, SA and GF in shaping one's science identity.

(i) Identity model one

I begin with Brickhouse, Lowery & Schultz (2000) who have stated that educators and researchers have worked to incorporate identity-based research into the broad landscape of science education but,

> *have not sufficiently attended to the more fundamental question of whether students see themselves as the 'kind of people' who would want to understand*

the world scientifically and thus participate in the kinds of activities that are likely to lead to the appropriation of scientific meanings (p. 443).

Brickhouse et al.'s (2000) 'kind of people' are those who positively adopt scientific interpretations and exhibit engagement in science in relation to science identity. Illustrating this from my personal experience, a twelve year-old female student in my chemistry lesson might identify herself as quite enthusiastic about separating chlorophyll (pigment) colours on a chromatogram but, outside the science laboratory, she identifies herself as a person who 'hates chemistry' because her IIA does not overlap with science learning. In such instances, according to Brickhouse et al. (2000), students 'forge identities in communities of practice' (p. 443), but may not sustain this identity outside the community. In contrast, another student with similar enthusiasm might identify herself as a person who loves chemistry even in a non-science context, because the student's IIA overlaps with science and exhibits a form of 'ontological security' (Giddens, 1991), indicating a 'kind of person who understands the world scientifically' (Brickhouse et al., 2000, p.443). In addition Brickhouse et al. (2000) believe that identity is certainly not 'stable or single' (p. 443) because a person can be actively involved in different communities of practice at the same time and identify oneself as a different person in each one.

In this vein, Brickhouse et al. (2000) adopt Lave and Wenger (1991) 'identity in practice' as a means of discussing transformation in the process of learning. They illustrate this by addressing the global forces experienced by one of their students, Ruby. Their results revealed that African American GF had an impact on the movement of participants from suburban middle school to urban high school. Ruby broke the norms of feminism and African American identity through her interaction with people from a variety of ethnic and gendered backgrounds – not least through support from her father (Brickhouse & Potter, 2001). The central feature of Ruby's story is that, in order to transform African American girl identity, she needed to challenge and overcome negative self-perceptions (for example: African American girls' restricted identity) that were enacted through social interactions with SA such as mainstream schooling, peers and teachers. Moreover, Brickhouse and Potter (2001) recommended that teachers and schools have a responsibility to address the issues of diversity and identity in science classrooms and to provide better opportunities and space for students' identity constructions in relation to their multicultural backgrounds (Brickhouse & Potter, 2001). From this example, I believe Brickhouse and Potter (2001) view both ‘others’ and one’s personal control on identity to exhibit duality - and work in harmony, combining both IIA and GF (ethnicity, gender), the mediating SA between IIA and GF recognised by Brickhouse and Potter (2001) include schools, peers, teachers and parents. In my view, I see no reason that duality necessarily implies ‘harmony’. While this can be the case where people ‘go along with prevailing forces’; there are numerous examples of people ‘going against the grain’ as Archer et al. (2014[b]) have already noted.

(ii) Identity model two

In a similar vein to Brickhouse et al., Gee (2000) defines self-identification as ‘the kind of person one is seeking to be and enact in the here and now’ (p.13) - and thereby be recognised as a certain ‘kind of person’ in a given context (p. 99). Gee uses the term ‘socially situated identity’ to illustrate the multiple identities people adopt in different practices and contexts, and argues that identity can be viewed in four different ways:

> (i)Nature-identity, which refers to a state developed from ‘forces in nature’ rather than, say, global forces. Gee (2000) believes that identity provided by the nature lies outside the control of individuals and gives an example of an ‘African American’ ethnic label, which he believes can be understood as being a biological construct. In my opinion, however, this sense of identity simply confuses matters because it is possible that some African Americans might see an ethnic label like ‘African American’ in a biological context.
>
> (ii)Institution-identity, a position authorised by authorities within institutions. Gee (2000) here indicated a form of identity where the control of institution overshadows the IIA. For example, people can be identified by their passport number, their national health number, their employment payroll number, or a prisoner might be identified in prison as ‘prisoner number 3’. It is interesting to consider how a person perceives the attribution ‘prisoner number 3’ given by the authority (SA). He or she might perceive ‘number 3’ as unlucky for him and in future exhibiting IIA might avoid this number to deal with daily life activities.
>
> (iii)Discourse-identity is an individual trait recognised through discourse/dialogue of/with ‘rational’ individuals. Gee’s (2000) discourse-identity considers individual traits, features and qualities that are passively recognised by social agents (SA) such as schools, teachers, youth workers and governments, or actively recognised by the individual. For example, black

Caribbean boys are seen to be underachievers and are at risk to school failure. Passive discourse identity is act of acquiescence by the individual; whereas active discourse identity exhibits a kind of control over it to please others (that is SA) in order to achieve something better in life. An example might be an individual making false claims on an inability to work due to poor health conditions in order to receive public funding from the government. The active discourse identity trait gives a certain degree of emphasis to IIA.

(iv)Affinity-identity, which refers to the experiences shared in the practice of 'affinity groups'. For example, according to Gee (2000, p. 100) African American people could identify themselves in relation to their 'participation in certain practices' (p.109). Similarly, Kelman (2006) defines identity by saying that 'an individual accepts influence from another person or a group in order to establish or maintain a satisfying self-defining relationship to the other' (p. 3). In addition people accept and/or decline certain decisions to please a particular SA or a group, in order to achieve certain reward (or approval) and avoid punishment (or disapproval) from other (s) (Kelman, 2006). Where, these personal and group identities represent individual agency. (Gee, 2000, p. 100-121).

Like Brickhouse et al. (2000), Gee (2000) also believes that there is no such thing as a *definitive* core of identity because the core is never fully formed - or always has a tendency to change (transform). Unlike Brickhouse et al. (2000), I believe that in Gee's four ways above, aspects of IIA are guided principally by the social agents such as institutes, schools, families, group of people etc., to 'enact' the global forces (ethnicity, race etc.) in shaping one's identity.

Carlone and Johnson (2007, p. 1191) extended Gee's (2000) identity viewpoints directly into science education, to present three science identity trajectories, namely *competence* ('knowledge and understanding of science content'), *performance* ('social performances of relevant scientific practices'), and *recognition* (recognising oneself and getting recognised by others'). They do give emphasis to IIA, in that they incorporate individual identification of competence, performance and recognition and, at the same time incorporate the importance of SA to enact GF. Carlone and Johnson (2007) argue that identities are not built in isolation and state that 'identity arises out of the constraints and resources available in the local setting' (p. 1192), for example families, career counsellors and institutions.

These authors' classic work on 'understanding the science experiences of successful women of color' was published in 2007 and involved a longitudinal research for six years to establish the practical grounds of science identity in women. Their analysis developed three science identity trajectories that interacted IIA with SA (like university faculty members) and GF (ethnicity, race and gender). The first is that of 'research scientists', where the participants themselves as well as the science faculty members identify them as 'sciencey people'. The second identity group were females with 'altruistic science identity' somewhat similar to Gee's (2000) 'nature identity'; the participants felt science to be an integral part of their 'genetic makeup' and, in addition, were recognised by others as sciencey 'women of colour'. The last trajectory emerged as 'disrupted scientist identity', where the participants were not recognised as 'sciencey' by the others. Although these women were successful in their scientific careers, they were excluded from being 'science people' in terms of gender, ethnicity and racial factors. So, despite their 'disrupted scientist identity', women, black and other ethnic communities can, and do, survive and retain some science identity. Like Brickhouse and Potter (2001), Johnson, Brown, Carlone and Cuevas (2011) acknowledged that successful women of colour have succeeded in science careers through working harder than white male peers (with similar or even with less ability) to achieve recognition. Therefore these 'disrupted scientists' succeeded in their science careers by avoiding negative identities attached to them by SA and placing themselves in a place where gender/ racial identity intersects with science identity.

From this perspective, I see Carlone and Johnson taking their influences from Gee (2000) rather than from Brickhouse et al. (2000). For example, Carlone and Johnson state that while 'cultural production' allows the 'possibility of the women transforming meanings of "science people" and what it means to be a woman of color' (p. 1192), in actuality their female participants 'were not free to develop any kind of science identity' (p. 1192). This showed a considerable reliance on social agents in the system, and of broad global forces. In this thesis, my focus is to discover rather more the sets of self-freedoms (IIA) and cultural productions (GF) in developing 'science identities' rather than focusing on science identities as predominantly a construct of 'cultural production'. In addition, like Brickhouse and Potter (2011) and Gee (2000), Carlone and Johnson (2007) indicate that identities are not fixed at any point and, instead, develop and stabilise over time in accordance to the social context. Moreover, the SA acting as a mediator between IIA and GF, as recognized by Gee (2000) and Carlone and Johnson, mainly includes institutions (school, science industries), teachers, peers/ faculty members and government. This seems to preclude the individual agency that I believe is also important.

(iii) Identity model three

Hazari, Cass and Beattie (2015) followed Carlone and Johnson's (2007) model using the three dimensions of recognition, performance and competence, initially based on Gee's identity construct. Here, these authors are critical of Gee's (2000) emphasis on external recognition to the neglects IIA - that is the role of personal thoughts, emotions, cognition and learning. Therefore, to further incorporate IIA, they added a fourth dimension of 'interest' in their model. They consider this to be 'critically relevant in influencing the decision of who and what a student wants to be?' (Hazari, Sonnert, Sadler & Shanahan, 2010, p. 982). I understand interest here as a verb that exhibits IIA, that in turn shapes one's preferences, choices and/or decisions. Moreover, Hazari et al. believe 'performance, perceptions of competence, perception of others, and interest all influence a focal construct' (p. 998) in developing - in their case - 'physics identity'. To this extent, they believe that students with physics identity most probably desire to enter in physics careers. Their work also included testing different teaching strategies to activate physics identity in female students, where they found a strategy of 'discussion on underrepresentation of women in physics' to be significant enough to activate physics identity in female students (Hazari, Potvin, Lock, Lung, Sonnert & Sadler, 2013). They understand that the teachers and educators need to cater individual students held cultural identities in the science classrooms. Moreover, Lock along with Hazari and Potwin (2013), indicated that the main contributors towards physics career choices involve recognition and interest dimensions of the science identity trajectories. While, like the above researchers, Hazari et al. (2013) also indicate that science (physics) identity can be developed through the mediation of SA with an emphasis on teachers and teaching strategies, in this case I see, in comparison to Gee (2000) and Carlone and Johnson (2007), that Hazari and her colleagues are inclined more towards IIA than GF (for example gender). The dimension of recognition involves both self-recognition and recognition by others; moreover the aspect of 'interest' is quite individually-centred.

(iv) Identity model four

In his work, Kane (2012) also acknowledged Carlone and Johnson's (2007) competence, performance and recognition construct of science identity. In his empirical research he included students' self-narrated interviews involving 'their experiences in school and science with their performances of self in the midst of complex, spontaneous classroom engagements with their peers and teacher' (p. 457). Kane's work (2012) highlights IIA such as self-confidence, interest, self-ability, understanding of self as a good student etc.; these IIA factors were found to be of different degrees and were valued differently by the students themselves, their peers and their teachers (SA). Making recommendations to educators and teachers, Kane believes that, for African American children, identities need to be given special corrective attention because teachers and wider society often do not take students' individual competence, performance and recognition into consideration and, rather, see such learners as being at risk. Moreover, Kane (2012) and Rodrigues (2014) suggested the need to appreciate the multicultural diversity students bring to science classrooms and to change culture in order to prevent the marginalisation of stigmatised groups. Kane (2012) also suggested that educators need to consider the multiple identities of individuals not only as science students, but as an overall student, as the two constructions are tangible and resemble Brickhouse's (2000) construct of IIA - for example, where a 'brainy' student might position himself/ herself within a sciencey group. Therefore, Kane (2012) emphasised IIA and the impact of SA in developing science identities in African American children (GF). In my opinion, Kane, like Brickhouse, believes that SA 'enacts' the global forces (GF) in shaping 'science identity' which needs to be changed in relations to the IIA. The SA being investigated by Kane (2012) included school, teachers, peers and educators.

(v) Identity model five

Robnett, Chemers and Zurbriggen (2015) view 'identity as a scientist' as a core component of individuals' identity. They also acknowledge the work by Estrada, Woodcock, Hernandez & Schultz (2010) by arguing that there will be some students, though not all, who will continue with science studies because of positive exposure to academic science, not least through science outreach programme. In this vein they give more emphasis to individuals deciding who they are and then deciding those communities of practice in which they wish to participate, and less emphasis on the communities deciding those individuals' position in society. Like Hazari and her colleagues (2015), the aspect of 'interest' also argues for self-efficacy that acts as a mediator between positive science research experiences and science identity. They understand 'science self-efficacy' to originate from sources like mastery experience and vicarious (mediated) learning which they discuss as prominent, particularly within undergraduates. However, Robnett et al. (2015) reported that the association between 'research experience', 'science self-efficacy' and 'identity as a scientist' - model did not show any significant differences in relation to gender and ethnicity. They did indicate, though, that students from overrepresented ethnic backgrounds (Asian American or European American) exhibited 'more variance in identity as a scientist' as compared to students from underrepresented ethnic backgrounds (African American, Latino or Native American).

I take from this that Robnett et al. (2015), like Hazari and her colleagues (2015), are inclined more towards IIA constructs. They believe that external forces, like outreach programmes, do increase an individual's experience and willingness, so the aspect of self-efficacy is important in filling the gap between positive science research experiences and science identity. I also understand that more powerful attribution should be given to self-narrated stories rather than having community perceptions decide individual identities. However, I am not interested in using self-efficacy (Robnett et al., 2015) and or choice 'measuring scales' (Wang, Eccles & Kenny, 2013) to measure identity. For my research I understand self-efficacy as an individual's self-perception and self-beliefs of their own ability that leads to self-confidence (Bandura, 1990). And, instead of using self-efficacy empirical measures, I am much more interested in short biographies of people and their self-narrated perceptions on whether they see themselves as 'sciencey' or not and why? The SA that might act as mediators, as mentioned by Robnett et al. (2015), includes science research experiences through outreach programme.

(vi) Identity model six

In science education, Archer and her colleagues (2010; 2013; 2016) have extended the work of Bourdieu on identity and developed the term 'science identity'. Before discussing Archer's work, it is necessary to outline Bourdieu's approach.

Bourdieu's work has been widely used in identity based research and 'the two key constructs fundamental to Bourdieu's understanding of structure and agency are *habitus* and *field'* (Block, 2013, p.136). The habitus provides space where individual agents act in a specific 'field' or context, utilising *capital* or resources (economic, cultural, social or symbolic). Broadly, Bourdieu (1986) describes three main types of capitals: economic, social and cultural. Economic capital involves goods, money and could be institutionalised in property rights, which Bourdieu believes to be the basis of the other capitals. Social capital is described as 'the aggregate of actual or potential resources linked to possessions of a durable network of essentially institutionalised relationships of mutual acquaintance and recognition' (Bourdieu, 1986, p. 248). In other words, it involves social obligations or connections that can be converted into economic capital. Cultural capital exists in the following three states:

> (i)Embodied: It is the state in which the habitus (individual dispositions) are quite automatic and pre-reflexive which does not involve consciousness control and transformation at this state is quite limited (Claussen & Osborne, 2012). This relates to something that is learned in life and emerges in different occasions in one's life as an automatic response/ action. Here I understand 'embodied' as an IIA construct because Bourdieu (1990) stated that the embodied state 'is an active subject confronting society as if society were an object constituted externally' (p. 70).
>
> (ii)Objectified: This is the state where 'it takes the form of cultural goods (pictures, books, dictionaries, instruments) and can easily be transmitted in its materiality. However, this form requires embodied capital to fully appreciate and use it beneficially' (Claussen and Osborne, 2012, p. 62). Here I do agree that certain cultural goods can be of benefit and can arrive to its embodied state as discussed before not all the students will actually turned out to be scientists with all the essential cultural goods and with an understanding of the value of becoming a scientist.
>
> (iii)'Institutionalised' state or 'institutionalised capital': this is provided by the institution, which resembles to Gee's (2000) institution identity. It is 'a certificate of cultural competence which confers on its holder a conventional, constant, legally guaranteed value with respect to culture' (Bourdieu, 1986, p. 50). Here the emphasis is on SA (institution) who will decide the competence of the person's capabilities rather than the IIA being prominent. (Bourdieu, 1986, p. 47 - 50).

Jenkins (1992) and DiMaggio (1982) criticised Bourdieu's concept of habitus as being deterministic (less emphasis on consciousness and agency). This criticism was addressed by Bourdieu and Wacquant (1992) when they stated that 'both the objectivism of action, understood as mechanical reaction without an agent and the subjectivism which portrays actions as the deliberate pursuit of conscious intention…'. King (2000) believes that Bourdieu did acknowledge subjectivism with objectivism in regards to meaning-making processes. However, King (2000) later stated that 'Bourdieu has failed to take his own greatest insight seriously, and he has slipped into the very objectivism whose poverty he has done so much to highlight' (p. 431).

Moreover, Sullivan (2002) also acknowledged that 'Bourdieu's theory has no place not only for individual agency but even individual consciousness' (p. 163). Similarly, he has been critiqued on his over-reliance on GF involving external cultural identity (Reay, 2004). Sullivan (2002), too, critiqued Bourdieu's distinction and strengths of cultural capital over the other forms of capital (social, economic) as being unclear. Moreover, Erel (2010) indicated that 'Bourdieu has rarely explored how forms of capital are activated for resistant purposes' (p. 647). Through my limited reading of Bourdieu, I understand his work not to be *wholly* deterministic, and see his arguments along similar lines as Block (2013), in that 'Bourdieu constantly navigated the line between determining social structure and individual agency in his work spanning some 40 years' (p. 136).

In science education, Archer and her colleagues acknowledge IIA, where students enjoy science but think of science as 'not for me', as it becomes 'unthinkable' when it comes to taking up a career in science (Archer, DeWitt, Osborne, Dillon, Willis & Wong, 2010). However, the main reason they indicate this deeply rooted IIA within the students and SA is because of the powerful influence of GF. In their extensive work, they strongly advocate the combating GF of society (culture, class, ethnicity, family, peers), laying the root causes of non-science participation largely outside of the girls themselves (Archer et al, 2014[b]). In addition to their identity construct, Archer et al. (2013) have used the idea of Bourdieu's capitals in science education and referred to this as 'science capital' - which deals with 'science related qualifications, understanding, knowledge, interest and social contacts' (p. 3). Their three main forms of science capital are as follows:

> (i)Science linked to social/symbolic capital (for example: gender, ethnicity, social class, science communicated in social networks; interacting and/or idealising people with scientific knowledge and/or science related jobs)
> (ii)Science linked to cultural capital (for example: science qualifications, scientific literacy, and understanding about nature of science)
> (iii)Science linked to economic capital (for example: money to gain science capital and opportunities like visiting events and science centres). (Archer & Dewitt, 2016).

Archer and her colleagues also come in for the same criticism as discussed above in regards to Bourdieu's cultural capital. Similarly, Archer et al.'s science capital resembles an over-riding argument that identity as a sense of self is predominantly socially constructed within social settings (Spillane, 2000), which resembles an outcome of dialectical engagement with practical social activity, rather than being an innate property of individuals (Roth, 2007). In addition, Archer et al. have also been critiqued for the way Bourdieu's concept of cultural capital has been used to describe science capital. As Claussen and Osborne (2012) indicate, it is not clear whether Archer's science capital is intrinsically justified or it dominates because of socio-historical contexts. Jensen and Wright (2015) have criticised, too, in that science capital must be distinct from cultural capital - Bourdieu offers a much broader range of the concepts that encounters social mobility in an inherently unjust socio-cultural system. This is much more than 'science capital' can manage. Moreover, like Bourdieu, the Bourdieu 'field' identified by Archer, Dawson, DeWitt, Seakins, and Wong (2015[b]) affecting the struggle over science capital is unclear. That said, I *can* see the point of the three divisions (social, cultural and economic) identified by Archer and DeWitt (2016) and Archer's understanding of intersectionality described above. But the criticisms of Archer et al. are telling. I believe that there is a clear role for IIA, the propensity for students to identify themselves as a science person without the need to resort to discussions of science capital (social, cultural, economic). There is the clear possibility they might reject certain non-science capital in relation to IIA in shaping their own science or non-science identity.

From this reading of contemporary literature on science identity, I can identify with three general parts of 'identity', the:

> (i)GF (such as ethnicity, religion, race, gender etc.), these are relatively powerful, although individuals' have agency by which they act with, against and through these GF
>
> (ii)IIA, the individual agency, inherent dispositions, an internal force that accepts or rejects the GF, SA, events etc. and
>
> (iii)interacting between these two: through mediating social agents (like parents, school and teachers). The importance of SA influences and the tendency of SA to link GF and IIA, leads me to review this final point on the roles of the SA.

2.2 Social agents (SA)

It is important to identify the various SA that other researchers have noted. I will further highlight some of the literatures on SA influences (the impact of parents, school science/ science literacy and science teachers) on individuals' science identities that allow them to countenance a science-based education and career:

(i)Parents

Numerous studies have identified parental involvement as an important ingredient in promoting academic success (for example: Jeynes, 2010; Seginer, 2006). In this vein, it is noted that parental influence varies on the basis of GF such as ethnicity, race, class, gender etc. For example, Bourdieu and Passeron (1990) indicated the importance of the 'disposition, which middle class students or middle rank teachers, and a fortiori, students whose fathers are middle rank teachers, manifest towards education' (p. 192). Archer et al.'s (2012, 2013, 2014) ASPIRES study uses a Bourdieusian framework as discussed above to indicate that a family's 'science capital' refers to science-related qualifications, understanding, knowledge (about science and 'how it works'), interest and social contacts (e.g. knowing someone who works in a science-related job). Their (2014) analysis indicates that aspirations are 'not simply individual cognitions residing within children's heads, unaffected by their social contexts. Rather, children's aspirations and views of science careers are formed within families, and these families play an important, albeit complex, role in shaping the boundaries and nature of what children can conceive of as possible and desirable and the likelihood of their being able to achieve these aspirations' (p. 902).

However, Archer et al. (2013) also indicate that the majority of the parents 'felt that science careers are associated with masculinity and held a perception of science as being an area that more men than women study and work in…. over half did view the sciences as dominated by men, although views differed considerably among parents as to the reasons for this imbalance, being divided between biological/genetic arguments and socio-cultural/structural arguments…' (p. 181). This view of gender inequality was also viewed by the students but not as intensely as the parents. For this reason, in the final analysis, the authors recommend that 'there is a strong case to be made for the implementation of strategies designed to increase science capital within the UK families, to help make science (and hence science aspirations) more 'known' and familiar within families' everyday lives' (p. 189). In a similar vein, Gilmartin, Li and

Aschbacher (2006) research, conducted in Southern California utilising 1126 tenth grade (age range 15-16) students, reported the importance of ‘family science orientation’ (‘students’ perception of family interest in and value of science’) – although in their case, this depends more on ethnicity than gender.

Other than gender issues, Archer et al. (2014[b]) point out that those families with higher levels of science capital (similar to Bourdieu’s social, cultural and economic capital) tend to be middle-class -although this is not always the case, and not all middle-class families necessarily possess much science capital. I see something of this at the individual level: not all children within a ‘high science capital family’ will aspire to a future in science, some ‘rebel’. Equally, some within a ‘low science capital family’ do find a route into science. Similarly, Gilmartin et al.’s (2006) reports of career aspirations do not depend much on having a family member with science related occupations. In their work, Latino and Asian-American student perceptions of family science support linked more to students’ science career aspirations rather than White and Black/African American students. The authors suggested that this difference in ethnicity/race is not clear as compared to White and Black/African American - the Latino and Asian/ American parents seem to have more power because of the cultural aspects. Gilmartin et al. (2006) indicated that the way parents exert their power on children could be through clear communication about their likes and dislikes on prospective career choices.

Parental power has also been indicated in Chinese parenting styles (Tao, 2016) – such as the concept of Chinese ‘Tiger mother’, which refers to mothers with very high power over their children’s academic achievements. These mothers exert power through setting explicit targets for children, and they expect their children to attain the best despite their ability range and the child’s IIA. In contrast, Ing (2014), in the context of the USA, noted that external motivation given by the parents tends to be short-lived and does not help to push levels of attainment forward. For this reason, parents who intrinsically motivate their children (Ing, 2014) achieve better attainment, and generate greater student’s persistence in the subject (in this case mathematics). Similarly, Jungert and Koestner (2015, p. 376) reported that the ‘parental autonomy support’ in high school students (age15-16) was seen to be mainly helpful to students already with ‘an intrinsic disposition in a domain’. Like Ing (2014), Jungert and Koestner (2015), I also believe that parents should support students intrinsically to have long-lasting effect on students; moreover, an effective way of communication based on future subject and career choices between parent and the child is needed in an effective manner (Hyde, Rozek, Clarke, Hulleman & Harackiewicz, 2016).

(ii)School science and science literacy

There is a considerable body of work addressing the importance of school science (for example Hulleman & Harackiewicz, 2009; Yeager & Walton, 2011). From these perspectives, school science can act as a resource to influence science identity and students' aspirations towards future science education and career (Pike & Dunne, 2011). A positive influence of school science curriculum means a positive view of 'science literacy for all'. Because the majority of the students cannot become scientists, they can all however become science literate citizens (Hassard & Dias, 2009). This is recognised by many science educators as a worthwhile goal because they believe that pre-professional and established science is not as important as a broadly humanistic approach. Another suggestion is to include 'life problems' within science teaching and learning so as to incorporate the 'Nature of Science' (NoS) to which students can relate to daily life science (Mandler, Mamlok-Naaman, Blonder, Yayon & Hofstein, 2012). Most recently, Archer et al. (2014[a]) in the UK context, emphasise the provision of scientific literacy and NoS in the science classrooms, and state that 'widening participation in STEM is not only beneficial for the STEM "pipeline" (the supply of professionals to work within STEM fields of employment) and the UK's economy, but also for increasing the scientific literacy of the general UK population. Both are desirable because scientific literacy is viewed as an important form of symbolic capital' (Archer et al., 2014[a], p. 22). On the other hand, these authors also note that, 'despite the rhetoric of scientific literacy for all students, science in schools remains virtually unchanged; students are confronted with basic facts and theories' (p. 5). For this reason Osborne (2014) designed a model based on 'scientific activity', the model is composed of three phases: 'investigation', 'evaluation' and 'developing explanations and solutions'. In supporting his model, he criticised that in the science classrooms, investigation (laboratory work) aspect is given more importance to incorporate enquiry based teaching and learning. However, in terms of working scientifically, Osborne (2014) believes that the incorporation of the evaluation phase is quite important because in real practice all scientists need to deal with the evaluation part of the scientific enquiry. Most recently, Chapman and Feldman (2016) adopted their research from Carlone and Johnson (2007) (mentioned above), and showed that the performance aspect in school science can be extremely fruitful in both establishing and polishing individuals' science identity with a focus on enquiry-based science learning

(EBL) and teaching. Chapter four, ‘science education intervention’, will provide a brief description on scientific literacy, outside classroom learning, social and cultural aspect and communicative science in incorporating EBL.

In connection to a humanistic approach, a recommendation of incorporating NoS is to include ‘socio-scientific issues within science teaching’ which is seen as ‘highly relevant in the sense that the societal dimension broadly influences science education’ which is ‘also influenced by the teacher’s personal beliefs, behaviour and practices’ (Stuckey et al., 2013). In connection to scientific literacy for all (discussed above), Hattam and Zipin (2009) indicate that, due to poor teaching practices, the school system has failed to incorporate cultural diversity and equality. Similarly, ‘science teachers emphasize more heavily on science content objectives (traditional approach) as compared to NoS and application objectives (humanistic approach)’ (Hassard and Dias, 2009, p. 45).

In addition to ‘scientific investigation’, Osborne (2014) has indicated that the incorporation of literacy in teaching and learning science is very important because scientists spend a good part of their lives in reading, writing and communicating science with others. For this he proposed five major ‘communicative activities’ that are: ‘writing science, talking science, reading science, doing science and representing scientific ideas’ (p. 188). Moreover, he recommended that mathematics should act as a ‘core feature’ to incorporate NoS in the science classrooms and stated that ‘avoiding the opportunity to use mathematical forms and representations is a failure to build students competency to make meaning in science’ (Osborne, 2014, p. 187). The Canadian National Science Curriculum has also emphasised the inclusion of cross-curricular learning opportunities including numeracy, literacy and computing in order to avoid fixed and isolated transmission of science content knowledge (Davies, 2015a). For example Davies (2015b), like Archer et al. (2014[a,b]) and Osborne (2014) mentioned that teachers are required to develop pupils’ mathematical skills in science learning and incorporate daily life science teaching and learning strategies.

From the above discussion, it is quite obvious that the school (institution) has considerable influence as an SA in mediating between school cultures. I believe that the role of school science is important but, nevertheless, various attempts to make school science sufficiently aspiring for students have failed (MacDonald, 2014). These critiques and suggestions indicate that it is important to develop (i) scientific literacy for all (ii) students’ personal science aspirations and appreciate (iii) students’ cultural diversity in the classroom.

(iii)Science teachers

The role of science teachers in building a science (STEM) workforce is seen as an important factor. Archer and DeWitt (2016) view the role of science teacher as one of the main SA in helping students to identify themselves as 'science is for me'.

Lock, Hazari and Potvin (2013) report that students with a positive science identity (physics identity) believe that their physics teacher sees them as a 'physics person'. However, like Kane, the current situation seems unjust - as Kane (2012) and MacDonald (2014, p. 6) have pointed out - where 'teachers often have lower (stereotypical) expectations of under-represented groups in STEM reinforcing their non-STEM identity'. Teachers, MacDonald (2014) says, should play a vital role in nourishing the agency of a student rather than labelling students in terms of ethnicity, gender, academic achievement etc. Moreover, Reid and McCallum (2014) recommend that 'teachers and schools must engage in discussions with students about their aspirations to consider how their learning connects with significant people and places in their communities' (p. 205). Moreover, as Elmesky and Seiler (2007) point out, a further recommendation is to incorporate successful social interaction through a positive emotional climate that, they say, is a key to establishing science identity. In a similar vein, Lewis (2008) in relation to IIA recommends that science educators, schools and teachers should 'give emotions the same status as cognitions. Just as cognitions can lead to emotions, emotions can lead to cognitions. The theory implies no status difference' (p. 745). Taking his point further, Hampden-Thompson and Bennett (2013) found that the effect of emotions in altering science engagement is quite obvious - and teachers should cater these aspects of 'triggers' in the classroom. Because, it is believed that students' inner sense of self (schema) comes in contact in the science classroom field against positive social interactions, which leads to nurtured emotional energy and which, in turn, results in approved emerging identity (Carambo, 2015). Where negative emotions (fear, anger, lack of focus, failing tests) result in hardening of 'cultural boundary', that is, when students inner 'sense of self is disrespected' by the teachers and/or school (Carambo, 2015, p. 161).

There are numerous other reasons and suggested possible solutions that have been researched in association with school science, such as the lack of science specialist teacher (for example Taylor, 2009), support and training (for example House of Commons Children, Schools and Families Committee, 2010), appropriate use of teaching resources (Beauchamp & Parkinson, 2008; Wood and Ashfield, 2008;

Tissenbaum, Lui & Slotta, 2012) - and many other 'improper' teaching practices. The limits of space prohibit these being included in this literature review.

2.3 Identity subject to change

So far, I have acknowledged the power of global forces (GF) and seen how these can shape young people through the actions of some of the many social agents in their immediate zones of activity. I now move to consider the stability and change of individual identities and the nature of a core identity.
The nature of individualised identity in relation to agency and in relation to the others (SA) has been identified many years ago by Erikson **(**1968) through his psychosocial theory of identity. This was followed by Marcia's (1966-1980) empirical operationalisation of Erikson's work, and exhibits an individual's identity transformation within eight psychosocial stages from infancy (ages 0-1 1/2) to maturity (ages 65+). Erikson's (1982) adolescence stage (between 13-19 years or teenagers) sees identity construction reaching its maximum fluidity. At the adolescent stage, young people accept, reject and challenge different options by experiencing a great deal of freedom, accountability, progress and what Erikson (1973) calls 'in-grouper' and 'out-grouper' identifications: 'the sense of ego identity… is the accrued confidence that the inner sameness and continuity prepared in the past are matched by the sameness and continuity of one's meaning for others, as evidenced in the tangible promise of a career' (p. 75). The aspect of 'in-grouper or out-grouper' can be understood by teenagers in terms of skin colour, cultural backgrounds etc. which could lead to self-labelling (stereotyping), self-beliefs and self-identifying people. These grouping according to Erikson (1973) act as a defence system (resembling Giddens's (1991) 'ontological security') that works against a sense of identity confusion. Erikson views identity formation to be successful and stable when one identifies who he/she is, who he/ she wants to be within himself/ herself, and who he/she wants to be in a particular social context. Identity confusion is possible only when identity formation is fluid, when the adolescent is unsure of who he/she is?, how he/she want to see themselves as individuals and in social settings, to answer these questions an individual gains TL experiences from the external forces (Erikson, 1968) in order to attain certain form of stability in life.

Illeris (2014) acknowledges Erikson's work on identity and indicated that identity confusion implies transformative learning (TL), with a change in the social context, in relation to the SA enacting GF; the transformation is either added as something new or it might change or reject (Illeris, 2014) previously held self-labelling (stereotyping), self-beliefs and self-identifications mentioned above. Illeris (2014) links identity to transformational learning (TL), as he believes that ‘the concept of transformative learning comprises all learning that implies a change in the identity of the learner’ (Illeris, 2014, p. 40). Illeris views identity transformation in the similar vein to Mezirow’s Transformational Learning Theory (TLT), which was initiated in 1975 with his study on women's re-entry programmes in community colleges. His most recent work was published in 2009, entitled ‘Transformative learning in practice’. Mezirow has been the founder of TLT and this has been widely used in defining adult transformational processes. He explicitly used two main terms in his theory: first is ‘meaning schemes’, which are ‘set of related and habitual expectations governing if-then, cause and effect, and category relationships as well as event sequences’ (Mezirow, 1990, p. 2). Second is ‘meaning perspectives’ which are ‘broad sets of pre-dispositions resulting from psycho-cultural assumptions, which determine the horizons of our expectations’ (Mezirow, 1991).

2.4 Transformational learning

Mezirow (2000) has indicated ten phases of transformation. However, for my purposes here, I will focus on just four principal points he describes:

(i)Elaborating Existing Frames of Reference
(ii)Learning New Frames of Reference
(iii)Transforming Habits of the Mind (or meaning perspectives)
(iv)Transforming Points of View (Mezirow, 2000, p. 22).

A frame of reference encompasses ‘structures of culture and language through which we construe meaning by attributing coherence and significance to our experience’ (Mezirow, 2009, p. 92). This elaborates the process of the continuing conflicts in daily life leading to ‘learning new frames of reference’ and eventually leading to self-development (D’Amato & Krasny, 2011). The continuing conflict within and relation to daily life resembles to Erikson’s identity confusion. A frame of reference consists of ‘two dimensions - habits of mind and resulting points of view’ (Mezirow, 2009, p. 92). Habits of mind constitute a specific way of individual’s thinking or feeling that results in a set of codes, and specific habits of mind result in specific ‘points of view’ as an awareness through, belief, sustained as a memory and/ or attitude, the way of judging future related actions (Mezirow, 2009). For example, gender discrimination acting as a code can result in a point of view that science is 'not for me, because I am a girl'. This belief can remain in one's perception as a memory that, later in life, acts as a judgement/decision for not choosing science subjects in the future.

Mezirow's transformative learning theory indicates that identity is fluid and is subject to transformation but - at the same time - belief that fluidity depends on some form of disorienting dilemma, a possible dramatic life experience leading to transformation. As Mezirow (1978) states '…to negotiate the process of perspective transformation can be painful and treacherous… [one's] sense of identity and integrity…' can be challenged (p. 11) leading to transformed behaviours, feelings, beliefs, identity (Mezirow, 1991) values, attitudes, and perceptions (Jackson, 1986).

In my view, the primary link between Mezirow's TLT and Illeris's (2014) identity model includes the 'meaning-making' process whereby individuals negotiate their understanding of self that shapes (transforms) their identity in a certain social or cultural contexts. Mezirow's (2000) four principal points mentioned above also includes the core component of meaning-making. With similar intentions, Abes et al. (2007) introduced a 'meaning-making filter' as one of the main parts of their identity model in order to elaborate, extend or even transform the 'meaning-making capacity integrated' (p. 7) into a person's self-perceptions. This ties with Mezirow's suggestion that TL incorporates the 'making of meanings', and he describes the process as an intense, thoughtful journey of constructing meaning of oneself through life experiences. The meaning-making process in a person's learning depends upon critical self-reflection on the experiences that have taken place within a particular context.

At first, a person's life experiences (rather than typical academic learning) act as the key initiators of change, and these depend on the varying contexts and time at which the life changing experiences are practiced (Mezirow, 2009). These contextual life experiences have been visualised by Abes et al. (2007) in their 're-conceptualized model of multiple dimensions of identity' where 'a person experiences (his or) her life, such as family, sociocultural conditions, and current experiences' (p. 3). It is quite clear that not all the contextual influences/ life experiences will be life-changing, and Illeris (2014) makes the case that life experiences (and/or influences) need to be of 'higher order' and require considerable energy to create changes - especially if those changes interfere with strong pre-held affiliations towards something. These 'life changing TL experiences' which includes events, triggers and interventions initiate 'discourse leading to critical examination of normative assumptions underpinning the learners … value judgments or normative expectations' (Mezirow 2000, p. 31). Such discourse elements lead to self-examination of pre-held assumptions, and are catered through dialogue with self and with others. Dialogue allows people to critically reflect on the contextual influences, and these evaluations require a ‘critical and reflective lens to authenticate their reasons to adapt new actions’ (Mezirow, 1996, p. 162). Through dialogue, one can determine the boundary that accepts or rejects certain life experience through ‘continuous effort to negotiate contented meaning’ (Mezirow, 2000, p. 3). When this meaning system is found to be inadequate in accommodating some life experience, it can be replaced with a new meaning perspective that exhibits change in habits of the mind, one that is ‘more inclusive, discriminating, open, emotionally capable of change, and reflective’; in other words, more developed’ (Mezirow, 2000, p. 7) which results in transforming points of view.

I believe that, for some people, a complete transformation in their meaning perspectives is possible and can happen. For example, there are numerous accounts of people undergoing life-changing events – after a significant illness or disability, a significant change in relationships, a major shift of occupation, and so on. For some people smaller life changes might have higher impact in choosing science or non-science discipline. For example, a love for physics (in general) at school might later occupy meaning of one’s life after meeting a rocket scientist. Mezirow’s TL theory has been challenged for its individualistic mode of analysis, with few links to social action (Welton, 1995).

2.5 A return to intentionality

This places Mezirow’s theory principally within ‘intentionality identity’ (IIA) rather than an extensionality (external forces) view. TL accords with Erikson’s (1973) ‘epigenic’ identity theory that links the later stages to previous developmental stages based on crisis. Within a similar framework, Kegan (1994, 2009) understands meaning-making and identity transformation as forms of intentionality because he gives credence to individuals working towards their own personal pre-held dispositions. As Kegan (2009) suggests, post-modernism requires learners (especially adult learners) ‘to win some distance’ from pre-held dispositions, identify areas of incompetence in order to ‘embrace contradictory systems simultaneously’ (p. 52). Kegan (2009) has criticised Mezirow’s TL theory for a lack of distinction between informational and TL, and that the theory recognises adult education as a separate domain.

Taking up this point, Jarvis (2013) views individuals as a 'person' and their personality relates to the way they learn from the external culture. He believes that learning can be a 'lifelong process intrinsic to the living organism itself, whereby the individual internal life force experiences externality (through body and mind) and generates a permanent state of becoming in the human being' (Jarvis, 2013, p.13). His 'internal life force' is the force derived from IIA and in turn identity that then interacts with externality leading to identity formation; therefore Jarvis applies both external forces (extensionality) and IIA (intentionality) to the construct of identity. The idea of 'being itself' resembles Abes et al.'s (2007) idea of core and 'externality' meaning, when an individual is exposed to contextual influences. Jarvis also indicates the fluid nature of the person's learning processes, which eventually form an identity. Within this view of learning, Jarvis (2009) has criticised Mezirow's TL theory because it focuses mainly on adults creating a gap between adult and children's learning and fails to relate Jarvis sense of lifelong learning as a whole. In contrast, Jarvis (2009) believes that it is not always the meaning-making process that transforms learning - it can be daily life experiences that can be transformed by learning.

Illeris (2014) views identity transformation in a similar way to Mezirow's TL, and has stated that 'the concept of transformative learning comprises all learning that implies a change in the identity of the learner' (p. 40). In addition, Illeris (2014) believes that 'identity involves learners' mental whole' (p. 39) and the important changes within person's mental whole can be taken as TL that leads to alter one's identity in a way that we want ourselves and others to identify us (Illeris, 2014). Illeris (2014) has been critical of Mezirow on the issue of 'meaning perspectives and frames of reference' as being dominated by cognitive rather than affective learning. In answer to this critique, Mezirow recognised the importance of affective phenomena and believes that a frame of reference can have 'cognitive, conative and affective' functioning - consciously or unconsciously (Mezirow, 2009, p. 92). Even then, Illeris (2014) stated that while Mezirow (2000) links and understands emotions at the same time 'he understand emotions as a kind of concomitant or even distracting phenomenon in relation to what the real transformation is about, which is precisely meaning perspectives, frames of reference or as here our beliefs' (Illeris, 2014, p. 36). Unlike Erikson (1982), Mezirow (2000) and Illeris (2014) are not certain that identity is constructed within the time frame of adolescence - and actually believe that transformation cannot *really* occur at the early stage of 'teenage'. While Illeris (2014) concedes that episodes of provisional identity might emerge in the early ages (even before the age of thirteen) and can form ‘long lasting effect on identity’ (p. 124), Mezirow (2000) believes that transformation is fully prominent in adults. Illeris’s (2014) view is that identity development mainly takes place after adolescence and, therefore, after the compulsory age of school (science) education from ages 11 -16 years.

2.6 Illeris’s model of identity

As noted above, Illeris’s (2014) general structure of identity belongs within a framework of intentionality. His model exhibits a three-layered structure of identity that includes a core identity, personality layer and preference layer (Figure 2.1).

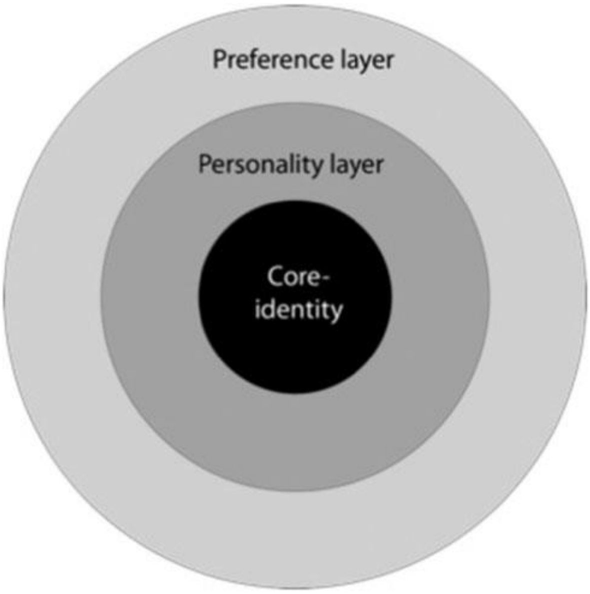


Figure 2.1: The general structure of identity (Illeris, 2014, p. 71)

Illeris termed the inner most-layer the ‘core’, the most stable and solid layer that controls the construction of the subsequent layers. He believes that the core identity is developed and extended during childhood by elements such as gender; family identity etc. and that change in the core are quite gradual unless it experiences a life changing event. Surrounding the core is the ‘personality layer’ where transformation is primarily apparent. Illeris (2014) believes that this layer includes ‘who and how the individual wants to be and appears in relation to others and the surrounding world’ (p. 72). This layer is susceptible to change ‘in connection to important experiences, events, exchange of views and similar kind of interactions’ (Illeris, 2014, p. 73). The impact of exchanges of views and social interactions resemble Gee’s (2000) ‘affinity identity’, which is experienced through shared practices with ‘elite’ groups of people. This allows for free will in choosing a particular group to which an individual is attached. Rodogno (2012) describes this as 'attachment identity' (and is a 'deep' understanding of a notion of identity) that relies on expressions such as 'caring about', 'of importance', 'attachment to' and 'what matters to me'. That is, it is an identity ultimately anchored in a person's attachments. Again Gee (2000) emphasises the free will exercised in choosing the group in accordance to the 'kind of person they are' (p. 106) – it is a freedom that might be restricted for those who 'lack access, networking and mobility' (p. 121).

Illeris's outermost layer is the preference layer, where the individual chooses and acts without entailing too much effort (thinking, feeling or acting). The changes in the conditions (daily life activities) being experienced in this layer are somewhat independent of self-perceptions and involve minimal energy to make any change: 'whether we in the situation to have the energy to make such changes … [they] do not mean much to us, and we have long ago got used to the idea that we shall be open and ready for change' (Illeris, 2014, p. 73-74).

This identity model gives a general structure that exhibits the possibility of identity transformation interlinking both one's core identity and out-facing personality. It serves both external and internal forces and, in relation to external forces, involves an individual's participation, dialogue and/or discourse with social, cultural and/or economic 'capitals' or resources that can be linked to the personality layer. Illeris's (2014) core identity empowers the personality layer, which is more susceptible to transformation (through conscious understanding of self in relation to others) than the core. Robnett et al. (2015) and Illeris emphasise the stability of core identity as being dominant over influences from others and surroundings. It is only very limited and strong life changing events that have the ability to transform the core identity. Robnett (2015) refers 'being a scientist' as part of the core component of identity construct.

(i) Illeris's Transverse model of part identities

In addition to the general structure above in Figure 2.1, Illeris (2014) extended his identity model to involve different 'part identities' such as work identity, family identity, everyday identity etc. (Figure 2.2). He believes this transverse model of part identities to be interlinked with the central identity (including core, personality layer and preference layer) and each different part identity comprises of all the three layers identified as well. The idea of part identities working simultaneously is an appealing notion, because an individual can utilise part of – say – his or her work identity with cultural identity etc. Moreover, people act and/or react differently in different situations and the activation of various identities is evident when trying to accomplish different roles (Burke & Stets, 2009). So, in this case a particular identity (surrounding the central identity) can switch on/off due to the exposure to different situations, influences and/or experiences. And this switching on and off process might later affect the central identity. Therefore, Illeris's (2014) model of part identities combined GF (extensionality) and IIA (intentionality) ideologies resulting in a composite model (Figure 2.2).

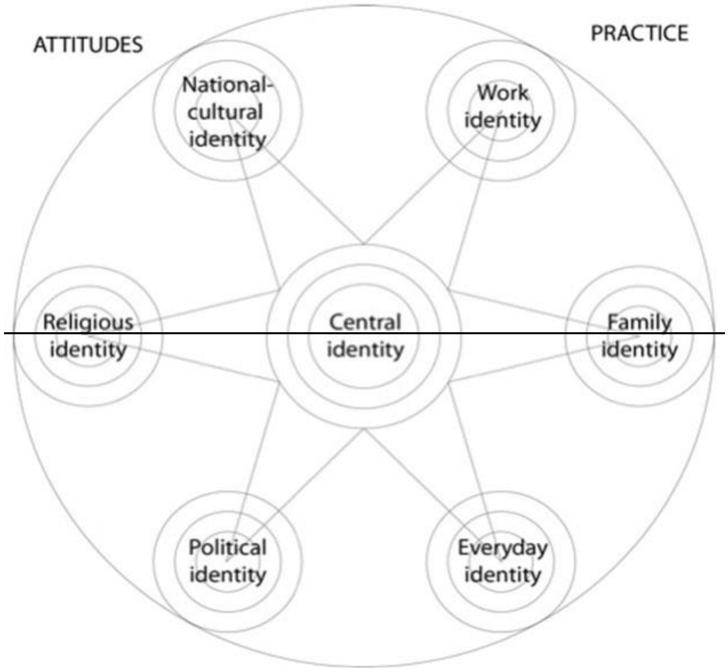


Figure 2.2: An example of part identity structure (Illeris, 2014, p. 76)

It is important here to note a few limitations to Illeris' model. First, in connection to his preference layer, Illeris is inexact about the everyday conditions that have an ability to transform parts of the personality layer and that might even transform the core. As Illeris (2014) himself believes, the boundary between the personality layer and preference layer is unclear. My sense of remedy here is to suggest a 'controlling filter' between the personality layer and preference layer. I see this controlling filter as a filter that controls the conscious conditions (like Kane's (2012) contested spaces) and/or objects (like Bourdieu's objects), a filter that permits or rejects the opposing conditions/ objects. This permission or rejection is based on the intensity of the conditions in relation to the automatic dispositions (embodied).

Second, while Illeris's (2014) transverse model does give an insight to part identities surrounding the central identity, again, the interlinking between one form of the outer structure identity to the central or to another form of identity seems unduly complex. It seems to me to be extraordinarily difficult to link the different identities to the central identity. For example, it is not straightforward to understand how Illeris's (2014) 'work identity' in its own orbit surrounds the core, personality and preference layers because, in this particular situation, work might not be of over-riding concern for the individual. But then, nor did 'work identity' fit in the preference layer, and so linking 'work identity' to the central three layered identity might prove difficult to adapt.

(ii) Accidental or planned transformations

The life changing triggers mentioned earlier could be accidental or planned. An example of accidental trigger could be 'trees', as Loehle (2010) has stated:

> Some individuals find themselves fascinated with ants or birds or fossils from a young age. Why? I have never seen an explanation for this early attraction to a scientific subject. For me it was trees. I can remember the trees in the neighbourhood where I lived at age 7 so well I can still tell you what species they were and how tall (p. 13).

Another example of an accidental trigger could be death of a younger sibling that transformed the decision of a business student to become a child specialist. A planned trigger could be when a teacher designs a particular visit to a hospital (in one of the deprived areas in their country X) to incorporate students role as citizens. At the hospital, students came to know that - due to the lack of child specialists in their country – there are high mortality rates of children under the age of seven. This planned intervention along with a series of other planned interventions might transform some of the 'non-sciencey' students towards becoming a child specialist, a nurse, a laboratory technician or even someone who wants to build a children's hospital in country X. Six planned interventions are part of the empirical study, which will be discussed in Chapter Four.

Archer et al. (2012, 2013, and 2015) indicate such triggers to be linked with 'science capitals' involving resources such as parents, schools, and teachers. Abes et al. (2007) call these contextual influences, Illeris (2014) described them as 'conditions', and Mezirow (2000) sees them as 'experiences' leading to disorienting dilemmas. But, at the same time, from the above discussion based on self-identity subject to transformation, depends on the stability and fluidity of identity. When young adults are asked what subjects they will choose at A-level, they take time to answer and give their decision. This entails some kind of stable core that gives them positive and negative signals, where some students might take longer than others, where their identity is quite fluid and the core is challenged by both enjoyable and unpleasant experiences.

The stability of core identities is always in question. It could be that the transformation takes place gradually as Heddy and Pugh (2015, p. 56) believe: that ‘transformative experiences may be a way to facilitate micro changes in students that, when accumulated, lead to TL outcomes’. Nohl (2015) argues that transformation need not necessarily start with a disorienting dilemma - it can start ‘unnoticed, incidentally, and sometimes even casually, when a new practice is added to old habits’ (p. 45) or, even sometimes, the process of transformation starts with great emotional experiences but then later the processes fail or even the new meaning-making process does not challenge the pre-held disorienting dilemma. People with ‘fluid’ science identities can - potentially - be more open to accidental and/or planned transformative interventions and widen their options, exhibiting transformation.

2.7 Models of multiple dimensions

Unlike Illeris’s (2014) transverse identity, Jones and McEwen’s (2000) model appears less complex in terms of picturing one core surrounding the multiple identities. Moreover, this model provides a distinction between multiple identities and contextual influences and, in my opinion, the presence of contextual influences provides an open space to capture social influences/ triggers – a space that is lacking in Illeris’s (2014) general model. Jones and McEwen (2000) describe identity theories as ‘representing the on-going construction of identities and the influence of changing contexts on the experience of identity development’ (p. 408). They propose a conceptual model (Figure 2.3), where they argue that there are two general parts to an ‘identity’ construct:

> (i)The outer contextual layer includes influences from family background, socio-cultural conditions, current experiences, career choices, etc. The intersecting circles termed as identity dimensions placed around the core identity and within the premises of contextual ring. Moreover, the intensity of the ‘relative salience of these identity dimensions is indicated by dots located on each of the identity

dimension circles' (Jones and McEwen, 2000, p. 410). These include self-perceived dimensions such as gender, culture, faith, class etc.

(ii)The central core, which includes the 'inner personal identity' that we have for ourselves. This resembles to Illeris (2014) core identity.

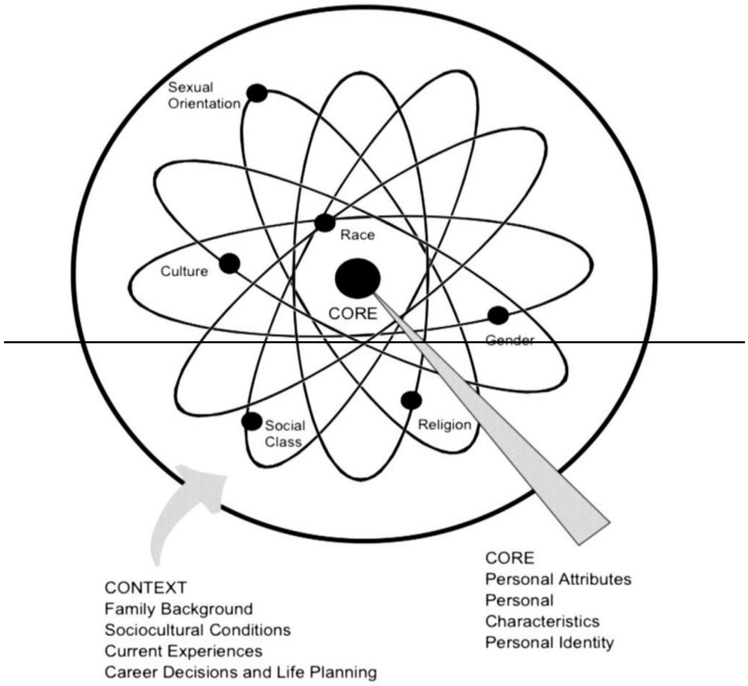


Figure 2.3: Model of multiple dimensions of identity (Jones and McEwen, 2000)

Later, in 2007, this model of multiple dimension of identity (MMDI) was reconceptualised by Abes, Jones and McEwens. They called their new 'advanced' model a 'Reconceptualised Model of Multiple Dimensions of Identity (R-MMDI)', utilising Kegan's (1994) ideas of meaning-making processes during identity development, and based on research on lesbian college students by Abes in 2004. In this work, (Abes, 2004) it was suggested that the inclusion of meaning-making process in the MMDI was important because it allows the researcher to better understand the links between core and social identities as well as a relationship between contextual influences and the salience of identity dimensions. The results from Abes (2006) entails a 'meaning-making capacity served as a filter through which contextual factors are interpreted prior to influencing self-perceptions of (particular) identity and its relationship with other identity dimensions' (p. 6).

The reconceptualised model now consists of the following four main parts:

(i) The outer contextual influences, which are placed outside the identity circles. Illeris (2014) sees these as conditions
(ii)Social identity dimensions are now viewed in relation to personal perceptions of multiple identity dimensions. This resembles Illeris (2014) part identities
(iii)Meaning-making filter, this is placed between (i) and (ii). The filter depends on the depth and size of the mesh opening. Complex, meaning-making can be represented by increase thickness (increase depth) and smaller grid openings. Where meaning-making with less complexity is indicated as a thin filter (lower depth) and bigger grid openings. This resembles to Mezirow's (2009) dialogue element of transformational learning and Gee's (2000) discourse identity, whereas such a filter is missing in Illeris (2014) identity model (Figure 2.1)
(iv)Finally core indicating self-identity resembling to Illeris (2014) and Robnett et al. (2015) core identity.

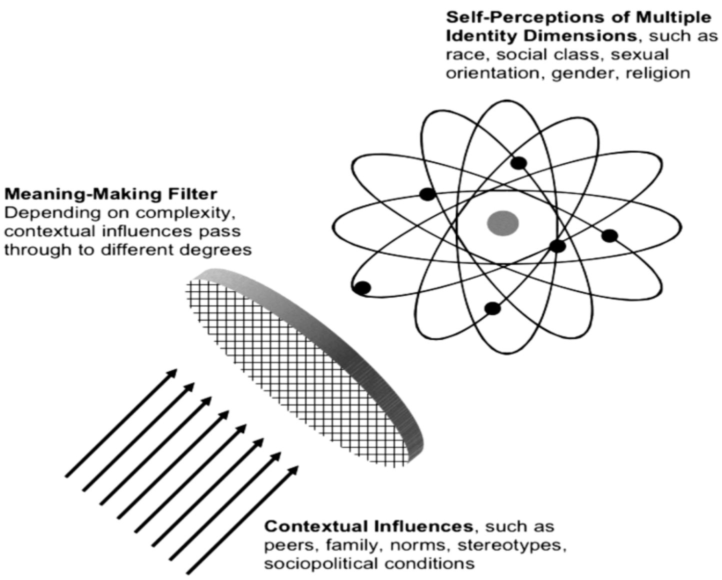


Figure 2.4: Reconceptualised model of multiple dimensions of identity (Abes, Jones and McEwen, 2007, p. 7)

In summary the above model (Figure 2.4) gives space to capture individual self-perception in the following ways:

(i)First, the meaning-making filter will allow me to capture the understanding of scientific concepts and procedures
(ii)Second, whether the meaningful positive/ negative science linked influences had an impact on their self-perception of single identity or self-perception of multiple identities at the same time

(iii)Third, whether these meaningful influences have transformed one's science or non-science core

(iv)Then, the basis of the outcome will enable to distinguish between active or passive science and / or non-science identity formation during a lifetime of the participants' (individuals').

2.8 A proposed Science Identity Model (Sci-ID model)

The literature review on science identity and identity transformation has enabled me to suggest a science identity model (Sci-ID model) adapted principally from Illeris (2014), Abes et al. (2007) and Jones and McEwen (2000).

The science identity model (Figure 2.5) I envisage here consists of seven main parts:

1.**Global forces (GF)**: This involves external influences in relation to ethnicity, gender, race, religion, class etc., resembling to Giddens's (1991) 'globalising influences'.

2.**Social agents (SA)**: Are the agents that mediates the global influences with the individual through interaction and relationships. For example: parents, school, teachers, peers, churches etc.

3.**TL experiences** (events, triggers, interventions): These are the resultant experiences, events, triggers and interventions gained from the SA and/or GF which could have high, intermediate, low or no impact on individuals.

4. **Meaning-making filter**: I have introduced Abes et al. (2007) meaning-making filter (Figure 2.4), this part of the model involves understanding of the scientific concepts. More complex meaning-making filter (a thick layer with small grid opening) allow little understanding and a less complex filter (thin layer with large grid opening) allows greater understanding of the scientific concepts being studied.

5. **Preference filter**: I have introduced this layer from Illeris's (2014) identity model (Figure 2.1), which constitutes Mezirow's meaning schemes (Illeris, 2014). For me these meaning schemes are the TL experiences that have been sieved by the meaning-making filter (or not). Now a preference filter will actually select the preferred (liked) experiences that have the potential of some degree

to interact with the IIA. More complex filter exhibits little or no preferences and less complex filter exhibits preferences/ likes towards science. The non-preferred experiences will not proceed further inside the identity model. This filter differs from Illeris identity model (Figure 2.1) first, it is represented as a filter and second, it forms the second layer in my model and outermost layer in Illeris's model. As in my opinion Illeris is aware of meaning-making of the events as well as preferences however he has not separated both in his identity model.

6. **Individual Internal Agency (IIA)**: This part of the model involves personal 'drive', the ways in which people can go against TL experiences, SA and/or GF – or go with them. This layer is quite stable unless exposed to life changing (high impact) TL experiences leading to movement (transformation) into or away from science. This layer resembles to Mezirow's meaning perspectives where higher order of pre-held schemes can be transformed based on the experiences received from the previous layer (preference layer), where critical reflection is extended further (Illeris, 2014). Illeris named this layer as personality layer, where I do not, as the intention of this study is not to look deeply into the personality theories and huge number of personality issues but rather I am interested in self-perceptions of people towards science and non-science education and career.

7. **Core**: It resembles Abes et al. (2007) and Illeris (2014) inner most central core. Which I believe could be stable or fluid. If the transformation in IIA layer is successful or IIA layer is in ambivalence then there is a possibility that the pre-held transformed viewpoints could change the core identity. I understand it in such a way that if the core is stable then transformation at the core level is quite difficult and time consuming but if the core is fluid than the transformation is relatively easier and less time consuming.

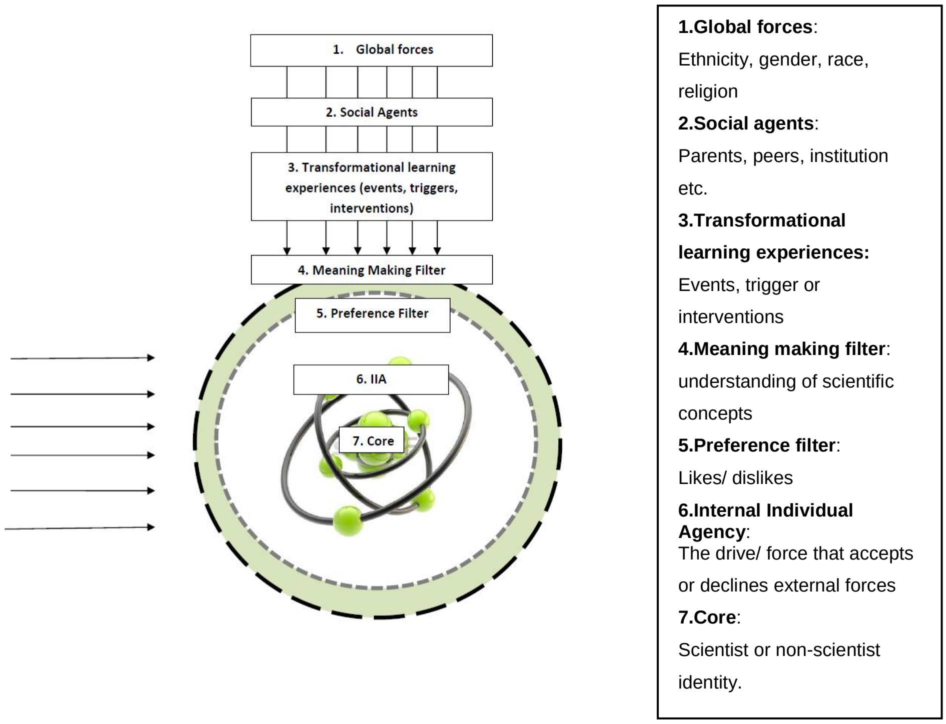


Figure 2.5: Sci-ID model

2.9 Kinds of science identity transformation

In addition to Mezirow (2000), Illeris (2014) extended transformative learning theory into progressive, regressive and restoring transformations. I will now describe my viewpoints on the three kinds of science identity transformation with examples. My intention here is not to include Illeris (2014) collective transformation in this study, which has the potential for further research. I will now use the above model to describe the three kinds of Illeris's (2014) kind of TL and later the model as a theoretical framework will be used to analyse my findings in Chapters Five and Six.

(i) **Progressive transformation**

Progressive transformative learning involves goal oriented purposeful learning with awareness of self and others. It involves progression towards the intended goal and throughout the journey making learning improved, implying actions appropriately and modifying identity accordingly to reach a desired position in life. This leads to identity change 'into something better, more proper, more promising or more rewarding' which Illeris (2014) termed it as progressive transformation (Illeris, 2014, p. 93). A theoretical example is as follows:

Sam believes himself to be a 'brainy person' reflecting on this he believes he is a 'sciencey person' and perceives to have positive SA influences (teachers, peers etc.). A further exposure and reflection made him compare and contrast the subjects in science, showing progressive transformation into physics and maths (and not biology, chemistry etc.) studies at the university; now he believes to be a 'physics and maths person'. Sam almost completely ignored the existing non-science external GF, SA and TL experiences. Finally he further progressed to become a 'physical engineer' (not a chemical engineering etc.); and believes to have an identity of a physical engineer. This shows that even within science discipline a numerous positive self-perception in relation to science external forces originated but were then further reduced to a more better and rewarding transformation in relation to the stable belief of a 'sciencey person'.

(ii) **Regressive transformation**

Regressive transformations involve individuals who enrol themselves in an activity or in a situation where transformation is necessary. Which could be intended or situational transformation and people might withdraw the progressive changes despite of having all the necessary challenges and support that are provided in the form of contextual influences. In this situation the progressive transformation could be felt as too demanding and unbearable despite of individual's attempts to keep up the progressive transformative expectations. This withdrawal leads to regression that Illeris termed it as 'regressive transformation' (Illeris, 2014). A theoretical example is as follows:

Sarah preferred to take up medical science at the university, few science based external influences has made meaning in her life for example that a degree in science provides better career opportunities, earns respect and money. But then later due to failure in her exams she realised that she is unable to live up to the desired expectations and found it too hard to carry on with medical sciences. This fairly sudden regression will be quite upsetting for Sarah so then she tried an english course but failed again. This might lead Sarah to completely move out from education exhibiting a fairly regressive transformation. It seems that even with time Sarah's core and IIA did not become stable and forceful enough that could make her fight against the negative external force. Instead, failure rooted quite deep in Sarah's identity. This regressive TL towards education could even paralyse the person to look for other avenues, even if the opportunities/ resources are available.

(iii) Reconstructive transformation

Third is restoring transformation that is a combination of progressive and regressive transformation. The regressive transformation above could have been sudden upsetting change but can be useful and progressive in the long run. The regression towards these adverse experiences might be useful later in life, which could act as the first step towards the initiation of progressive transformation. This type of transformation is termed by Illeris (2014) as 'restoring transformation' where I call it as reconstructive transformation because I believe progression after regression will allow a person to accept quite different TL experiences incorporated through a certain drive/or force (IIA). A theoretical example is as follows:

> Deborah was expected to do a degree in chemistry, as both her parents were working in the field of chemistry. She entered into a chemistry course at university, struggled to pass first year exams. While discussing her failure with her friends from the arts department she realised that chemistry is not for her. Deborah later recognised that her real interest lies in studying arts as she likes to be creative and imaginative like her friends. This resulted into a progressive transformation of becoming something better in accordance to one's agency.

2.10 Summary

In this chapter, I have reviewed and analysed the aspects of GF, SA, TL experiences, IIA and their incorporation key science identity research models. I have also discussed the transformation of identities using identity models and kinds of transformation. In this chapter I have argued that:

(i)identities are fluid and the journey towards stability depends on different factors for example age, experiences, relationships, events, triggers etc., (ii) identities are not entirely fluid, there is some kind of stability, a kind of internal force or agency that empowers people accepting or declining the influences from the external forces; and (iii) one's identity depends on the strength of certain GF, SA, TL experiences (events, triggers, interventions) and the strength of one's IIA that goes with it or against it.

The understanding of GF, SA, TL, IIA, stable and fluid identities led me to design a theoretical Sci-ID model principally adopting Illeris (2014) and Abes et al. (2007) identity models. Moreover, I have also proposed theoretical example stories to illustrate progressive, regressive and reconstructive TL practices adopting Illeris (2014) TL theory.

The above arguments on stability and fluidity of identity, proposed a Sci-ID model, which is now ready to be tested using the empirical data. For this reason I have chosen and implemented an appropriate methodology, methods, research design, sample and mode of data analysis, ethical considerations and validation practices. The description of the chosen methodology is dealt in the next chapter - Chapter Three.

Chapter Three - Methodology

3.0 Introduction

In Chapter Two, I critically reviewed the literature on science identity using the broad dimensions of GF, SA, TL experiences (events, triggers, and interventions), natural inclinations and IIA. From this I constructed a model of identity that gives a structure by which to analyse the individual biographies of the participants in this research. A combination of my professional (science teacher) interests and the literature on research methodologies directed me initially towards a longitudinal study - so that I could study people's 'life events' towards and away from science throughout their lifetimes. Needless to say, research practicalities limit such ambitions, and the restrictions of maintaining and sustaining long-term contact with participants has led me, instead, to take three 'horizontal slices' of data (Figure 3.1) over a relatively short period of time. Each slice has addressed one of three different constituencies, has asked slightly different questions, and generated slightly different data. That said my overall aim is still to look at an overall picture of movement towards or away from science along this 'timeline' of people. Due to the nature of the research question and framework, I have used an interpretivist model of research, generating qualitative data using narrative enquiry-based semi-structured interviews, descriptive questionnaires and school-based interventions (Chapter Four), and these data have been aggregated to form individual stories and I have also used thematic-based approaches to analysis. This chapter critically discusses the suitability of the research design against Denzin and Lincoln's (2011) four main elements of a research paradigm: 'epistemology, ontology, methodology and ethics'. I begin with a discussion of ontology and epistemology of the research followed by sample selection, qualitative methods, ethical considerations, data analysis process and finally a discussion of the validation processes undertaken before, during and after the research.

3.1 Ontological and Epistemological positioning

According to Ritchie, Lewis, Nicholls and Ormston (2014) the two key philosophical issues in social research are ontology and epistemology. Ontology 'concerns the very nature or the essence of the social phenomenon being studied' (Cohen, Manion

& Morrison, 2007). The phenomenon here is what we know about science identity and non-science identity, and how these identities can be transformed over a period of time in people from different age groups, cognitive levels and through social experiences. Moreover, to find out whether or not the adapted Sci-ID model (Figure 2.5) can help to envision a person's life journey through TL experiences as depicted by Illeris (2014). For this reason, I wanted to gather stories from the perceptions of participants, stories that give diverse interpretations on identity transformations. Second, epistemology is defined as 'a science of knowledge studied from the philosophical point of view' (Horrigan, 2007, vii). Epistemology is concerned with how we know and what we know (Crotty, 1998); it involves 'the nature of the relationship between the knower and what can be known' (Guba & Lincoln, 1989, p. 83). An epistemological approach questions my aim here to gather life stories, experiences, anecdotes that involve not only 'what' people select to do after the compulsory school age of science education, but also why they make those choices, and 'how' the transition happens in one's life. I have treated the participants' recollecting stories, interpretations and their opinions as factual evidence about their science/ non-science experiences, perception of natural tendencies, employment choices, school science curriculum, teachers and parental influences in making their decisions towards or away from science even, though I know they are interpretations of what might or might not be the case.

3.2 Interpretative research philosophy

Interpretivism is an 'essential methodological tool in the social sciences' (Williams, 2012, p. 88) where 'interpretivists believe there is a clear distinction to be made between the natural and the social world, and therefore we need a methodology and methods of gathering data that are more in tune with the subjects we are studying' (Grix, 2010, p. 83). As I am studying the reasons behind the likes, dislikes and life choices of our participants, I obtained qualitative data using narrative enquiry styled semi-structured interviews, descriptive questionnaires and intervention evaluations.

My research questions are designed to interpret the lived experiences of three different groups of people in three different phases of their lives, from broadly science and non-science educational and or career interests; to interpret the external (GF, SA, TL experiences) and internal (natural inclination, IIA) forces, meaning and reasons associated with their action(s) during their path of life by deriving categories to understand the social reality. As mentioned above, I do believe that the stories of the participants are not faultless and fixed because they are from the participants' own perspective and interpreted in past, present and future time. Although interpretivism is criticised for working at a higher level of (data) generality and interpretivists believe it to be a meaning-making process where observers' self-interpretation can be more dominant over participants' interpretations. For this reason, I have chosen an epistemological interpretive route as the aim is to understand the meaning of an occurrence rather than to generalise the outcomes from data (Cranton, 2001; Walker, 1996). Moreover, the interpretive approach can provide valuable novel information that requires application in the area being studied and for further research. For example, stories from scientists and non-scientists revealing their lived experiences based on daily life science experiences involving 'the doing of science' (for example working in the laboratory to working in the garden) and/or 'doing research on science as a social institution' (for example talking to people about misconceptions of a scientist in society etc.) could reveal the way scientists and non-scientists think of science.

For this research, these stories act as personal retrospective descriptions of life experiences and can serve to generate knowledge about significant areas of the human realm (Schank, 1990). This tackles a key theme that has come to characterise the development of narrative research in educational theory—the ongoing tension between stories and science. A story, rather than just being a passive rendering of events, assumes 'the double role of mimesis-mythos' (Kearney, 2002). That is, a story, unlike a chronology—a list of events in date order—is a 'creative re-description of the world such that hidden patterns and hitherto unexplored meanings can unfold' (Kearney, 2002, p. 12). To author a story is always a creative act (Coulter & Smith, 2009). As Lieblich, Tuval-Mashiach & Zilber (1998) have asserted, frequently the study of narrative 'has been criticized as being more art than research' (p. 1)—though why art has less value as knowledge is more often assumed than argued. Narrative enquiry originally grew out of literary theory (Zald, 1996) and, over the past two decades, has generated a 'narrative turn' in the social sciences (Atkinson & Delamont, 2006; Spector-Mersel, 2010). It is an interpretive approach that seeks to bring the reader closer to the phenomenon being studied (Bansal & Corley, 2011), allows an examination of social dynamics as process and enables understanding of human behaviour and the complex, relational quality of social interactions (Cope, 2005; Leitch, Hill & Harrison, 2010).

3.3 Three stage design and sample

Because I am looking at transformations over time, an ideal research design would be a longitudinal study. However, a PhD does not allow the luxury of a long period of time and so I have designed a 'tracks backwards' approach, from adults to students to school children; from committed experts to emergent students to novice children the choice of three different sets of participants was manageable. Different research indicates that identity development is heightened during the middle and late teens (Erikson, 1968) and, for some, maybe in later stages of life (Illeris, 2014). Moreover, Mezirow (2000) believes that transformation affects self (identity) in adulthood. With this in mind, I have shaped this three-phased research so that the samples chosen are from three different broad age groups: the average age of scientists and non-scientists was forty, for university students this was twenty five, and the secondary school girls were thirteen (Table 1.1).

I have used these three-phase transverse slices to collect a broad set of data first from participants from different phases of the life cycle. I began with professional scientists and non-scientists, all at Brunel University London, who have progressed well beyond their student lives and have quite clearly chosen and settled into science or non-science professions. At the time of interview their lives seemed fairly stable and the ability to make large-scale changes/ transformations at this stage of life was perhaps becoming increasingly less likely. The second sample, a voluntary survey sample of Brunel University London students, have chosen their broad field of study but not yet entered into any permanent professional role or responsibility. Through the questionnaires, these students showed a range of positions – understandably, some seemed quite fixed, some more fluid, towards their future employment destinations. Finally, the opportunistic sample of secondary school girls will be soon selecting science or non-science subjects for future studies at A-level and beyond. Again, quite understandably, this group of participants were found to be most fluid and quite open about their subject and career choices.

Interviews of the sample for Phase One (scientists and non-scientists) shaped the design of the questionnaires for Phase Two (Brunel University London students). These two phases in turn, formed the basis for designing Phase Three (secondary school girls) science education intervention plans, intervention evaluation questionnaires and interviews (Figure 3.1).

Phase One

Narrative styled semi structure interviews.	Twelve professional scientists and non-scientists from Brunel university London.

Phase Two

BOS questionnaires.	One hundred and twenty three students from Brunel university London.

Phase Three

Questionnaires Twelve selected narrative styled semi-structured interviews.	Thirty students from The Salehjee School for Girls.

Figure 3.1: Research design: three 'slices'

In Phase One I employed 'purposive sampling' or 'purposeful selection'. This type of sampling engages people who are professionals, experts or those who have particular experience and can give in-depth information on particular issues (Ball, 1990); therefore twelve current professional scientists and non-scientists were chosen as a sample who can communicate their part of the story while in their different stages of life. For the Phase Two study, one-hundred and twenty-three university students were voluntarily recruited through an invitation to participate advertised on the university's internal website, and through notification of the university's systems. For Phase Three study, thirty secondary school girls were chosen as an opportunity sample given by my own professional activities at the time. A further description of sampling used for the three different phases, are as follows:

Phase One: An equal number of male and female Brunel University scientists and non-scientists were approached. Initially the plan was to accommodate in total six participants (three male and three females). However, after conducting the first six interviews, a need for further data collection was felt necessary to achieve rich data. The twelve interviews took me around two to three months (February 2014 - May 2014) to collect and transcribe the tape recorded interviews. A 50:50 split of science and non-science academics, however, is glaringly unrepresentative; there are many more non-scientists (however classified) than there are those who have chosen a work-life within science. My choice of equal numbers here has more to do with my sense of symmetry than sample statistics.

Phase Two: The online survey with Brunel University London students did not show a 50:50 split; instead it gave ratios of male: female to be 1: 0.84, and science: non-science students of 1: 0.85 (Table 5.8 and Table 5.9). The online questionnaire was available for three months from 21st September 2014 – 21st December 2014 on the Brunel University London website, which all Brunel students could access. During this time I received only one-hundred and twenty-three responses from Brunel students. Despite its name and Brunel's strong science emphasis (Brunel Engineering is ranked top ten in the UK Times Higher Education World University Rankings in Engineering and Technology during 2014) this is not an entirely unbalanced picture, and the university has a substantial arts and humanities base. Brunel is comprised of broadly six colleges and institutes and identifies the College of Business Arts and Social Sciences (CBASS) as a non-science department in comparison to Engineering, Design and Physical Science, Health and Life Sciences and the Institute of Energy Futures, Institute of Environment, Health and Societies and Institute of Materials and Manufacturing – all of these are seen as science-oriented departments.

Phase Three: The Salehjee Girls School, thirty students aged 12-14/15 from UK's ethnic minority families were the subjects of Phase Three of my research. I believe that The Salehjee Girls School was the correct choice as firstly to date, I have not seen any published work that has been carried out on an independent all Muslim girls' school in the UK. Secondly, the school offers science GCSE single and double awards and does not offer triple science award or A-level sciences. Moreover, for the academic year 2015/2016 only five out of fifteen girls were doing the double award and the rest did single award science due to their low achievement and interest in science as compared to non-science subjects. A similar case is noted by IpSOS (2012) which demonstrates that the number of students taking up double science has fallen significantly. The reason for inappropriate KS3/KS4 science results mentioned by the science teacher and head teacher were that the girls are not scientifically able as they are not taught properly in KS3 (science teacher) and students like to do more non-science subjects rather than science subjects at A-levels (previous head teacher). Thirdly, the majority of the girls did not have any aspiration to study science(s) at A-level or were confused about science choices. As their science teacher, my intention was also to prepare the students for the new GCSE science 2017 examination curriculum in which single award science is completely eradicated from GCSE and all students in the UK are obligated to take double science or triple science awards.

In addition to the particular school setting, I believe, this study with Muslim girls is also appropriate as the students in the study are from ethnic minority families. Overall, Muslim's are a marginal number and make up 5% of the whole population though the population of Muslims in England and Wales has risen by 1.16 million in 10 years (from 2001-2011). By 2021, there are expected to be 300,000 Muslim teenagers; however, currently Muslim women are under-represented in the UK in terms of education and employment (Iqbal, 2016). In addition, 'girls and young women in general are not as well catered for by faith-based organisations, nor are those young people that are not interested in religion' (Communities and Local Government London, 2009). However, it has been reported in the Communities and Local Government London (2009) paper that Muslim girls (in the studied communities) are performing better than their male counterparts and that numbers of female Muslim students are successfully accomplishing careers. Even then, it is indicated by Elias, Jones & McWhinnie (2006) and Engineering UK (2014) that girls are under-represented in STEM education and careers. Wong (2015) believes that there is a need for research in the area of secondary schooling involving participants from minority ethnic backgrounds. For this reason my choice was The Salehjee Girls School, as this school consists of all Muslim girls from British Somali, Pakistani and Arab backgrounds belonging to the UK's ethnic minority groups according to Ethnicity and National Identity in England and Wales: 2011. Moreover, although similar research has been conducted by Ruthven, Mercer, Taber, Guardia, Hofmann, Ilie, Luthman and Riga (2016) and Topping, Thurston, Tolmie, Christie, Murray & Karagiannidou (2011) carrying out intervention studies in a science classroom, with students' aged around 12-14/15, however the studies are different from my study as both the studies chose mixed sex schools. I believe the participant age group was appropriate as science engagement and interest in science and technology is mainly needed in 14-year-old students (OECD, 2013). In addition, Bennett and Hogarth (2008), Osborne (2008) and Tai, Qi Liu, Maltese and Fan (2006) indicated that ages 11-14 are the crucial period where the students' interest is formed.

Moreover, I believe that my choice of school and targeted sample for Phase Three is appropriate because in the recent literature I was able to find only research by Archer et al. (2010) and Wong (2015) based on science education and UK based Muslim secondary school girls. Archer et al. (2010) highlighted that identities are interlinked with choices and Muslim girls perceive their personal choices, social and cultural factors to be central to their decision towards educational choices. To this argument, it would be worth questioning that if it is personal choices/ natural inclination (either way) - does it take a big dispositional transformation to move them? If they are not strongly inclined will a series of small nudges (science education interventions) work?

I believe that through my understanding of UK secondary school science educational policies, curriculum and assessment needs (which I gained from eight years of GCSE and IGCSE science teaching and tutoring experience) and being a science teacher in the school helped me to design and implement science education interventions according to the needs of the students. Moreover, I have been engaged in the necessary CPD such as teaching and learning workshops, courses, teaching observations, reading about science classroom strategies and publishing papers to understand and implement the interventions effectively. I originally planned to conduct six interventions over a three month period, however few interventions took longer than expected and it took me closer to six months (Year 8 and 9 November 2014-April 2015; Year 7 January 2015–June 2015) to complete the intervention study inside and/ or outside the science lesson time (Table 4.1 – Table 4.9).

3.4 Methods

The main methods that I used to collect the data were semi-structured interviews, descriptive questionnaires and 'intervention evaluation' questionnaires. These methods allowed me to capture participants' experience and self-perceptions associated with GF, SA, transformative and/or non-transformative learning experiences, natural inclination and in few instances IIA. The interview and questionnaires drew broadly on Facer and Manchester's (2012) 'dynamics of living': personal events, practicalities, participation, pleasures, and came in the form of brief narratives: 'I decided to . . . '; 'I think I needed to . . . '. In addition, the respondents chose, or were given, a pseudonym and, as might be expected, they disclosed only those details with which they were comfortable, resulting in a rich and varied, often lively, data collection. The stories written were in third person's voice about the scientists and non-scientists, university students and secondary school girls- rather than first person's voice by the participants, this allowed me to analyse the data at a subjective level as well as I was able to generalise the data using numbers and percentages. There was a need to ensure some direction in the interview obtained; the interview guide allowed any systematic collection of the data and closed any “logical gaps”. However, a fixed guide can alter flexibly in the delivery of the interview questions and in the pace of responses (Cohen et al., 2007, p. 353). For this reason, my questions were carefully designed in order to encourage interviewees wherever possible to expand on their experiences and elaborate on the points which they felt relevant. In the same vein, the questionnaire and intervention evaluation questionnaires provided a systematic collection of data, moreover, to incorporate flexibility; at the end of every question a comment box space was provided. I also did not restrict the time of response so that the participants could take as much time as they wanted to complete it; they were also allowed to change their responses later if needed.

I will now describe the narrative enquiry styled semi-structured interviews, descriptive questionnaire and intervention evaluation exercises separately with indications of similarities and differences in regards to the principal analysis Phase One (professional scientists and non-scientists) to Phase Two (Brunel University London students) and Phase Three (secondary school girls).

(i) Phase One: Professional scientists and non-scientists

As mentioned before, twelve oral stories were obtained through semi-structured interviews from the scientists and non-scientists. The interview questions were designed to find out and test a few reasons and solutions present in the recent literature, based on the scarcity of students going into sciences. The interview guide was in three sections including ‘biographical details’, ‘starting out’ and ‘staying in (or out) of science’. In total sixteen questions were asked of the Brunel University London scientists and non-scientists. A few important ethical concerns and validation issues including a piloting exercise were dealt with before the interview exercise (see section on ethical consideration and response validation) to rectify ambiguous or too structured interview questions, to identify places where probing was required, to check the recording system and average time of the interview. During the interview process all the scientists and non-scientists had undergone individual face-to-face semi-structured interviews which were audio-recorded over a period of some two months; each interview was conducted in the work office of the respondent and lasted between 40 and 60 minutes each. After each interview session transcripts were created (Appendix 5 and 6). These transcripts were at first written in full without adding, deleting or correcting responses. I repeatedly listened to the audio recording to gain a better sense of the interviewees’ responses. Then I aggregated and summarised individual interviews into stories which led into the generation of broadly three themes, or three 'life trajectories' (See below in analysis section). Later the data were subjected to thematic analysis approach, using both initial interview responses and summarised aggregated stories mainly looking at the influences from GF, SA and TL experiences.

(ii) Phase Two: Brunel University students

For Brunel University London students, I designed an online questionnaire using Bristol Online Survey (BOS). The questions were adapted from Phase One –scientists and non-scientists - with a few changes. Prior to use, the questionnaire was piloted with a small sample of Brunel students and amended accordingly. Based on this pilot, the questionnaire took, on average, between 10-15 minutes to complete. The questionnaire was in four sections; it was planned to investigate educational background, opinions of school science, perceptions and inclinations towards science and non-science disciplines, current and future career options. The first page acted as an information page about the survey's aim, the data protection policy and the last page provided opportunity to volunteer for a follow-up of one-one interview session (Appendix 4). Twenty questions were asked, and these were a mix of open, closed and four scaled questions (strongly agree, agree, disagree and strongly disagree). After reaching the three months point I closed the BOS system and started to repeatedly read the responses individually as well as combined percentages to gain a better sense of the questionnaire responses. Then I made my notes to summarise few individual questionnaire responses from the students who had written their responses in the comment box along with ticking the closed four scaled questions.

(iii) Phase Three: Secondary school girls

The secondary school girls were at first asked about their choice of studies at A-levels where some wanted to do science in combination with non-sciences, where the same number wanted not to do science at all. On the basis of this outcome, pre-intervention questionnaires (Appendix 8) were designed to facilitate clarity of communication using open-ended questions which allowed free expression of student views and resulted in both expected and unexpected outputs. I have not only taken into account the expected, I have also charted unexpected outputs as a reflection of the intervention research (Tables 5 - 13). These questionnaires included four scale evaluations (strongly agree, agree, disagree, strongly disagree) supplemented with open-ended questions to evaluate improvement, failure and perception alterations of the thirty girls towards or away from science education and career choices. Over time, the interventions were systematically monitored using six ‘intervention evaluative’ questionnaires (Appendix 9) during the six interventions and after the interventions, approximately at six and twelve months (Appendix 10). The main reason for collecting data at different time intervals was to observe the transformations in subject choices. I made sure that the same questions were asked twice either at pre-intervention and sixth month stage or sixth and twelfth month stage (Table 3.1). The time frames in asking the questions differ as few concepts came out during the intervention study like ‘natural inclination’. This was an important question in regards to asking their personal choices which was not asked in the pre-intervention stage, so it was asked later in the sixth and twelfth month.

In addition to the intervention evaluations, twelve willing students were selected on the basis of their subject selection and varying degree of their perception on science and/or non-science natural inclination. Interviews were conducted to confirm and/or clarify the intervention evaluation responses. In total eight questions were asked which were adapted from the sixteen interview questions, which were, originally designed for the scientists and non-scientists and from the twenty questionnaire questions, which were designed for the university students. A few important ethical concerns and validation issues including a piloting exercise were dealt with before the interview exercise to rectify ambiguous or too structured interview questions, to identify places where probing was required and the average time of the interview (see section on response validation). During the interview process all the twelve secondary school girls had face- to-face semi-structured interviews and instead of tape recording their voices, the students wrote the answers and in some instance I wrote their responses on printed interview sheets (Appendix 11). The reason for not recording (audio or video) was because the school management did not allow me to do so for confidentiality purposes (Appendix 2).

3.5 Ethical considerations

Silverman (2010) stated that, ‘qualitative research inevitably involves contact with human subjects in the field; ethical problems are not usually far away’ (p. 154). The research conducted at Brunel University London and at The Salehjee Girls School had been approved by the Brunel University Ethical Framework, Brunel University Good Research Practice Policy, Brunel University Code of Research Ethics, and the Universities UK concordat on research integrity, under Data Protection Act 1998. The following measures were taken to overcome ethical problems:

(i) Phase One: Professional scientists and non-scientists

Before conducting the interview I prepared the participant's information sheet and consent forms. Moreover, I also considered interview location/ room/office/laboratory as recommended by Cohen et al. (2004). Interviews were conducted in a non-stressful and non-threatening manner as they took place in the participant's office or in the science laboratories. In addition to the emailed information sheet, I answered any questions in relation to the interview process, publication and purpose of the study through email and/or in person to avoid communication barriers.

Before conducting interviews all the volunteer scientists and non-scientists were contacted by email and were sent the same participants' information sheet and an informed consent form (Appendix 1 and Appendix 3). Just before the interview, the consent form was signed by all twelve Brunel University London professionals as 'protection of human rights in qualitative research is achieved mainly by using the process of informed consent' (Carpenter & Hammell, 2000, p. 116). On the consent form first confidentiality and anonymity was offered for the scientists and non-scientists name, age, religion, ethnicity, social class and name of their Brunel colleges. During analysis and reporting all these aspects were kept entirely confidential. It was only reported if the scientists and non-scientists wanted to disclose it. Moreover, permission for (audio tape) recording interviews was obtained from the scientists and non-scientists in the consent form as well. After the interview and to date the recordings and transcripts have been kept safe. In addition, all the participants were given the right to terminate at any point. None of the scientists and non-scientists wished to leave during the interviews and none asked me not to report or publish their stories.

While analysing and reporting the data I have disclosed not only positive results, but also negative results and respected the autonomy of the scientists and non-scientists. For example, I did not hide the fact that the two scientists and non-scientists moved away from science due to failure in exams and/or because of poor teaching practices and at the same time acknowledged the way some of the scientists and non-scientists praised their teachers' teaching style and support.

(ii) Phase Two: Brunel University students

Before dispatching the online questionnaire on the Brunel homepage, I prepared a quite similar participant information sheet to that of the Phase One information sheet which became the first information page for students explaining the purpose of the research to avoid communication barriers (Appendix 4).

For confidentiality and anonymity reasons, I could not access the names, college, email addresses, religion, ethnicity and age of the participants. During analysis and reporting all these aspects were kept entirely confidential. It was only reported if the students disclosed it in the questionnaire comment boxes. The opportunity to volunteer for a follow-up one-one interview session was also indicated on the last page of the questionnaire (Appendix 4). However, no one agreed to give the interview, so I did not have any kind of communication (verbal, written or face-face) before, during and after the study with the participants. Moreover, all voluntary Brunel University London students were given the right to terminate at any point. However, none of the participants terminated while filling up the questionnaire and no one asked to do so after completing the questionnaire.

While analysing and reporting the data I have disclosed not only positive results but also negative results and respected the autonomy of the participants. For example the four scaled evaluation reported not only positive (agreed) statements but also negative (disagreed) statements and was later analysed looking at the both sides of the coin.

(iii) Phase Three: Secondary school girls

Before conducting the research I first obtained permission to conduct science education interventions at The Salehjee Girls School for six to twelve months. After receiving verbal permission I prepared the participant's information sheet explaining the purpose of the research to avoid communication barriers and a consent form which similar to Phase One form.

The school's head teacher was given the participant information sheet to read and sign the consent form before the pre-intervention questionnaire (Appendix 2 and Appendix 3). In addition to the head teacher, before conducting the research, the participant information sheet was read aloud and discussed as a whole class activity in my science lesson. In addition to the information sheet I answered any questions in relation to the interventions, questionnaire and interview process and publication and purpose of the study thoroughly in person before and during the research.

I did consider the location/ setting and other people involved during the intervention study. The study mainly took place in the school setting itself which included the girls and myself, as their science teacher. School visits took place outside the school premises in the presence of other science teachers and were conducted after obtaining verbal permission from the head teacher and written permission from the parents. Moreover, confidentiality and anonymity were also offered on the consent form; keeping the name of the school and names of the students, entirely confidential. To maintain confidentiality during analysing and reporting the data, I did not disclose the above; however, in an objective manner, religion, ethnicity and age of the students were disclosed as all the girls aged 12-14/15 in the study are Muslims and from ethnic minority families, however during analysis I did not group the girls into Pakistanis, Arabs etc. On the consent form the permission of video and/or audio recording was not given by the head teacher in accordance with the school policies (Appendix 2). Therefore, during data gathering only verbal and written communication methods were used.

While analysing and reporting the data I have disclosed not only positive results but also negative results and respected the autonomy of the participants. For example the data reported not only indicated those students who now wanted to do science A-levels but also reported those students who liked and/or disliked the interventions and still did not want to carry on with science at A-level.

After using the methods mentioned above and considering ethical issues I analysed the data using thematic analysis. The process of analysis that I followed for Phase One, Phase Two and Phase Three will be explained in detail in the next section.

3.6 Data gathering and initial analysis

In this research I am looking at interpretative commonalities in the narrative styled semi-structured interviews and descriptive questionnaire participant responses as they relate to personal events in the subject's social (scientific) world. In my view, stories, even diverse and complex ones, provide the context within which intelligible action is taken: they tell where we come from so that we can understand who we are and what we might do. Schank (1990) sees such storytelling as a form of intelligence; as ‘people remember what happens to them, and they tell other people what they remember. People learn from what happens to them, and they guide their future actions accordingly […] Intelligence is really about understanding what has happened well enough to be able to predict when it might happen again’ (p. 1).

In taking this route, I recognised that recalled experience is influenced and altered by memory and may not reflect the exact nature and sequence of events that took place (Powney & Watts, 1987). The mere act of participating in an interview is a transactional event that can alter the recall of experiences (e.g. Roth & Middleton, 2006). My orientation sees data analysis as a complex transaction between researcher and evidence, the ends of which are provisional and fallible. I probed the themes, hypotheses, categories and assertions that emerge from analysis to see how they stand up to the weight of evidence and counterclaims (Selvaruby, O’Sullivan, & Watts, 2008).

As can be seen in Figure 3.1, the research design involved three phases using a slightly different route (similar and/or different methods) to conduct the study according to the need of the research and availability of the participants. Therefore, I will now describe the process of analysis separately with indications of similarities and differences among Phase One (professional scientists and non-scientists), Phase Two (Brunel University London students) and Phase Three (secondary school girls).

(i) Phase One: Professional scientists and non-scientists

After transcribing the twelve stories (transcribing process, please see above) in March/April 2014 I have used the following steps to analyse the data:

Step 1:

At first codes were drawn from the interview questions and responses using word phrases, under three headings: ‘biographical details’ (4 codes: job title, qualifications, working years, start teaching) included one to two word structured questions to help the participants understand the background behind the upcoming questions which were mainly based on the lived academic and professional life in the experienced social settings. Second heading ‘starting out’ (5 codes: Am I able (or not able) to do science, subject choice reasons at 16 , subject choice fast or slow/ trigger moments’, teachers/ parents/ peers influence, school science or awareness of science in daily life affecting interest) included questions on their perception on science/ non-science ability, TL experiences, events and SA influences. The final heading 'staying in (or out) of science (8 codes: Factors that have kept your interest alive in science (or in your chosen field), like and dislike about chosen field, positive (and negative) features of the university study, knowledge (or ignorance) of science impact on your everyday life, positive (and negative) features of the school curriculum, transformation into and out of science, gained from the subject, important factor that would motivate more young people to take up science) included various questions regarding likes and dislikes about science and non-science from school life to current academic and/ or professional life, and their opinion as how to motivate students into science.

Step 2:

Then using an aggregation process - synoptic analysis, I constructed stories of the interview data, in third person voice about the participants rather than by the participant. I understand aggregation as the process of collecting and combining the data horizontally, vertically and chronologically and then expressed it in a summary to generate stories that presents transformation and change in individual's science or non-science lives. The stories comprised of individual's life journey specifically looking at the broad events, circumstances, meaning-making of science, preferences, natural inclination etc. These stories led me to group the participants into broadly three themes, which are as follows:

(i)Progressive TL and smooth transformation

(ii)Progressive TL and wavering transformation

(iii)Reconstructive TL and wavering transformation.

The description of each theme is noted in Chapter Five under the heading Transformation and change.

Step 3:

Later, the participant interview responses were pulled from twelve different Word documents into one, by copy and pasting the answers under the (sixteen) interview questions on the interview guide. I then adopted thematic analysis in which I compared and contrasted the participants based on scientists and non-scientists which remained as one of the main analysis distinctions. I made use of 'manifest items which are physically present' (Robson, 2002, p. 354) to count frequencies; I tried to locate words that resulted in positive, negative or neutral impact, the participants accepted or rejected such influences from GF, SAs, TL experiences. The resulting list consisted of three broad sub- categories which included the following: GF (gender, race, and class) and SA (parent, school science, and teacher) along with TL experiences. The first sub-themes emerged from the interview directly; this was not included in the interview questions. A detailed discussion on the findings and analysis is conducted in chapters Five and Seven.

(ii) Phase Two: Brunel University students

I began analysing the data in January 2015, and as mentioned before, the survey (questionnaire) questions were derived from the scientists and non-scientists interviews, with a few codes and related categories differing from the scientists and non-scientists. I took different measures to obtain the frequency. I compared questions between sciences and/or non-science subject choices and gender, also contrasted the students' response on the natural inclination towards or away from science with the percentage of responses to the choice at A-levels and university studies and professional choices after university. Furthermore, I compared the effects of SA (parents, school science and teacher,) influences on their choices of taking up science / non-science education and careers. I have used the following steps to analyse the data:

Step 1:

The recording units included manifest items in terms of percentage frequency. Eighteen word codes from the questions emerged, under the three headings:

First, is 'Demographic details'; the codes here were different from scientists and non-scientists (4 codes: student status, academic year, A-level subject choices and gender). These were in order to find out whether or not students are in science/ non-science colleges, the academic year of study (which helped me to ascertain the average age of the participants), their A-level subject choices which was an important question as it helped me to see the people moving in and out of science and gender to identify gender related preferences.

Second, 'My perceptions' (7 codes: science natural inclination, non-science natural inclination, parental influence, happy about choice at Brunel, science at school, daily life science, teacher, and interest through science curriculum). From scientists and non-scientists interview responses, I have found that few always wanted to opt for science and kept on doing it even after A-levels, but some were on the other extreme and some in the middle. For this reason, to confirm my findings, I added two opposing questions - one on natural inclination into science and the other one on natural inclination into non-science and later compared the percentages between science and non-science natural inclination against science and non-science choices, to further examine the transformation and the root cause of the decision. The majority of the scientists and non-scientists liked their teachers. To examine further as to whether teachers really had an impact in choosing subjects, two opposing questions on science and non-science teachers were asked and each question was compared against science and non-science students.

Finally a new section was introduced - 'Career opportunities' (5 codes: science career opportunities, non-science career opportunities, becoming a scientist, future career plan and employability skills). As university students within a few years' time will be looking for jobs. For this reason, two opposing questions were included in this section based on better science and/or non-science career opportunities, future career plans and comparison between science and non-science employability skills development.

Step 2:

I have used the above eighteen code words to further analyse the data. The main analysis included the percentage obtained using four scaled questions - strongly agree, agree, disagree and strongly disagree.

At first, in line with the scientists and non-scientists codes mentioned above, I used numbers to analyse the questionnaire data but later used percentages. Because, the number of science and non-science students' responses were not equal this makes it difficult to generalise the data with numbers. So I used percentages and converted 100% for science and another 100% for non-science students.

Moreover, where the whole number was not obtained I rounded the percentage to the nearest whole number that is 10.4 = 10, where 10.5=11.

Step 3:

Initially I compared and contrasted the participants based on science and non-science students, which remained as one of the main analytical distinctions to grasp the transformative practices in the participants. I also looked into individual questionnaires manually to find out the frequencies, for example: student choices and their perception of attaining science or non-science natural inclination and comments made. This resulted in the emergence of a new sub-themes, for example, 'both science and non-science natural inclination', as few students despite being in a science or non-science college believed to have both science and non-science natural inclination. However, I did not find a new theme(s) in addition to Phase One themes.

Step 4:
Then I constructed a few stories using aggregation process - synoptic analysis (as mentioned above) of the questionnaire data, in third person voice about the participants rather than by the participant. In order to summarize the life journey of the individual participants specifically looking at the broad events, circumstances, meaning-making of science, preferences, natural inclination etc. Although the descriptive data received through the questionnaire was not as rich as scientists and non-scientists. I have used the following themes to present the summarised stories:

i. Progressive TL and smooth transformation
ii. Progressive TL and wavering transformation
iii. Reconstructive TL and wavering transformation.

The description of each theme is noted in Chapter Five under the heading Transformation and change.

(iii) Phase Three: Secondary school girls

The mode of analysis used in this phase resembles to both Phase One (scientists and non-scientists) and Phase Two (university students). Three questionnaires were filled in at three different time intervals, which were then recorded manually on thirty separate spreadsheets and analysed. The questionnaire was based on codes that were used twice to confirm the data. All the codes were either compared from month zero to six months or from six months to twelve months (Table 3.1).

Influences	Pre-intervention zero months	After intervention six months	After intervention twelve months
Employment			
Parents			
Teachers			
Science curriculum			
Science in daily life			
Natural inclination			

Table 3.1: Questions asked at different time intervals

In addition to the above questionnaires, students filled in six intervention evaluation questionnaires that were based on six individual interventions. These intervention evaluation questionnaires asked questions on subject choices, level of enjoyment, like and dislike and feeling good and/or bad about science with respect to the particular intervention. This was carried out to compare the interventions, evaluate best teaching and learning strategy and to track the transformation/ change within the thirty girls.

Some of the data gathered has not been used, in order to emphasise more on the prominent issues and to avoid irrelevant and repeated questions. For example, questions about parental influence at university level, perception of scientists and science employability skills were found to be repetitive and did not give any particular information in relation to the research objectives.

The following steps were broadly taken to conduct the analysis of questionnaires and interviews of the secondary school girls.

Step 1:

At first, before choosing the recording system, the students were grouped on the basis of their science and non-science subject choices. When comparing the students on the basis of subject selection I utilised biology, chemistry, physics, maths, computer science/ICT as science subjects, whereas english, arabic, religious studies, sociology, psychology, physical education, citizenship, PSHE and design technology were taken as non-science subjects. I compared and contrasted the secondary school students based on four groups (C1-C4), which remained as one of the main analytical distinctions to grasp the transformative ability in the participants. The four groups and criteria grouping criteria are as follows:

(i)Science choices only (C1): where the students listed science only subjects. For example biology, chemistry, physics and related subjects

(ii)Both science and non-science choices (C2): where students want to opt for both science and non-science subject choices. For example, biology and English

(iii)Unsure about science choices (C3): the students can list prospective non-science subject choices, but are unsure of listing any science subject choices

(iv)Non-science choices only (C4): where the students listed only non-science choices and were quite confident in not pursuing science subjects at A-level.

Step 2:

Next the word codes were generated from the questionnaires as frequencies based on four scale responses (strongly agree, agree, disagree, strongly disagree) questions and additional comments made in the comment box - given at the end of all the twenty questions. However, the comments obtained were not as descriptive and different enough to warrant an additional category and/or theme. Instead the codes that emerged under the four headings are as follows:

First ‘Biographical detail’ (3 codes: year group, age, A-level subject choices) these codes obtained information to help me analyse in the average age of the participants and changes in subject choices with time.

Second ‘My perception’ and third ‘School science’. As the questions were designed according to Phase Two (Brunel University London students), therefore, the codes and questions that emerged were very similar as Phase Two (Brunel University London students) section on ‘my perception’ , except that the secondary school students were not asked about the current choice at Brunel. The ‘Career opportunities’ the codes and questions used in this section were the same as Phase Two.

Step 3:

The questionnaire responses obtained after every intervention mainly achieved a numerical data rather than a descriptive data and so I used codes highlighting the expressive side of the students after doing the interventions (5 codes: enjoy, like, feel good or bad about science, change in A-level choices and school science helpful in daily life).

Step 4:

In addition to the codes obtained from the questionnaires mentioned above, I conducted twelve interviews on the basis of subject choices and varying degree of natural inclination. The questions asked and phrase codes generated were mainly based on their perception on self-ability and future transformations/ changes in subject choices and why, as I did not gain enough information on that from the questionnaire. The codes are divided into two headings.

First 'starting out' (5 codes: Am I able (or not able) to do science, subject choice reasons in 16 , subject choice fast or slow/ trigger moments) included questions on their perception on science/ non-science ability and triggers.

Second heading 'staying in (or out) of science (5 codes: Factors that have kept your interest alive in science (or in your chosen field), like and dislike about chosen field, transform into and out of science, gained from the subject, important factor that would motivate more young people to take up science) included questions regarding like and dislike about science and non-science from school to present and their opinion as to how to motivate students into science (Appendix 11).

Step 5:

The aggregated pre-intervention, sixth and twelfth month questionnaire, intervention evaluations and (twelve) interview responses of the individual students helped me to write individual stories. The stories were constructed as synopsis, in third person voice about the participants rather than by the participant. In order to summarize the life journey of the individual participants specifically looking at the broad events, circumstances, meaning-making of science, preferences, natural inclination etc. I have used the same three themes mentioned above in Step 2 (Phase One) and Step 4 (Phase Two). The description of each theme is noted in Chapter Six under the heading Transformation and change.

3.7 Data accumulation and further analysis

After collecting the data and looking at the broad themes, the three phases of the data were accumulated for further analysis using the Sci-ID model ingredients; first separately for the each phase and then I accumulated the main outcomes from the three phases and discussed it in Chapter Seven.

The discussion of this study, also consists of coding what scientists and non-scientist, university students and girls say about the small (positive) gains of the experiences, circumstances, triggers and interventions, that created a greater ‘educational impetus’ towards gaining science or non-science subject choices and/or careers.

Moreover, from all the three phases I was unable to capture all the Sci-ID ingredients. Table 3.2 highlights the source of data gathering for each of the ingredient from the three phases of the study.

<table>
<tr><th>Sci-ID ingredients</th><th>Phase One</th><th>Phase Two</th><th>Phase Three</th></tr>
<tr><td>Global forces</td><td style="background:#8DB3E2"></td><td></td><td style="background:#8DB3E2"></td></tr>
<tr><td>Social agents</td><td style="background:#8DB3E2"></td><td style="background:#8DB3E2"></td><td style="background:#8DB3E2"></td></tr>
<tr><td>TL experiences
(events, triggers, interventions)</td><td style="background:#8DB3E2"></td><td style="background:#8DB3E2"></td><td style="background:#8DB3E2"></td></tr>
<tr><td>Meaning-making filter</td><td></td><td></td><td style="background:#8DB3E2"></td></tr>
<tr><td>Preference filter</td><td style="background:#8DB3E2"></td><td></td><td style="background:#8DB3E2"></td></tr>
<tr><td>IIA</td><td style="background:#8DB3E2"></td><td style="background:#8DB3E2"></td><td style="background:#8DB3E2"></td></tr>
<tr><td>Core</td><td></td><td></td><td></td></tr>
</table>

Table 3.2: Sci-ID ingredients- data accumulation from the three phases of study

The steps taken in the sections above on methods, ethical consideration and data analysis contribute to various validation questions that will be dealt in the next section on validation.

3.8 Validation

As a broad concept, validity pertains to the extent that a method investigates what it is intended to investigate (Kvale, 1989, p. 74).

I have utilised a five-part three–stage validation framework (Figure 3.2) as the approach of validity matches with the interpretative interaction (Pedrosa, Lopes & Watts, 2013). Moreover, it considers both internal and external validity (generalising) issues as it 'relates to whether the results of a measure can be extrapolated to other settings, times, etc.' (Neuendorf, 2002, p. 115).

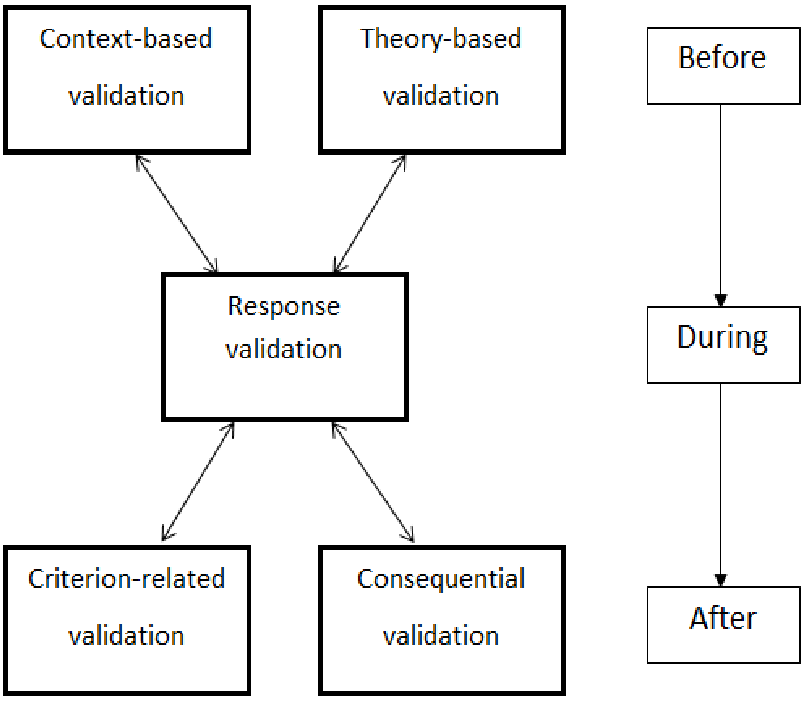


Figure 3.2: The validation framework, based on Pedrosa et al. (2013)

Now I will discuss the five parts of validation in accordance with this PhD research.

(i) Context Validation

In response to the problem mentioned in Chapter One based on the lack of STEM skilled workforce, I wanted to ascertain why some people decide to have their careers in science and others do not. What are the incidents in life that made them move into or out of science? So my research is aimed at exploring not only the limitations and solutions as described in Chapter One and Two, but also to examine the previous recommendations and other linked solutions for negligence in science education and future career choices (for example: positive/ negative teachers, parents, curriculum, influences). These aims were discussed with all the three groups before the data collection, by providing written participant information sheets to the Phase One scientists and non-scientists (personally) (Appendix 3), Phase Two university students (online) (Appendix 4) and the Phase Three secondary girls school head teacher (personally) (Appendix 2) and was discussed personally with the secondary school girls. At the end of the information sheet the participants were given the freedom to ask questions which I answered before conducting the interviews and interventions evaluation questionnaires. The same opportunity was given to the Brunel University London students but no one approached me (on my email address) to ask questions in relation to the survey (as mentioned above in the section on ethical considerations).

Next 'the form of research must be congruent with this broad context' (Pedrosa, et al., 2013, p. 9). The research project was required to be conducted by means of an interpretivist approach using participant's interpretations/ perceptions of the social world to explore the lived sciencey and/or non-sciencey stories. Therefore, I decided to choose two organisations (Brunel University London and The Salehjee Girls School) and as far as possible explored the self-perceptions of the participants by giving them enough space to talk through or write their responses. For this, interview questions were designed in a way that permitted participants to elaborate their ideology about themselves as an individual, their existence in social settings, real life conditions and influences that made them choose science or non-science education and/ or careers.

Moreover, Phase One (scientists and non-scientists) interview questions were designed after reading the literature on problems in association with under-representation of students in science education, career and related identity and transformative learning theories (see section below on Theory based Validation). Then Phase Two survey questions and Phase Three survey questions, interview questions and science education interventions mainly originated after analysing Phase One interview responses and a further reading of identity theories and other research into science education (see section below on Theory based Validation). These changes also kept the three different life phases in consideration. For example, the school girls were obviously not asked about their positive and/ or negative experiences at university as they have not been to the university; similarly university students were not asked about what they have gained or not gained from science or non-science careers. I believe the research question which originated from the background context and data developed comparable themes from three different methods of data collection. For example the notion of natural tendency and IIA emerged quite strongly in adults despite using different methods (interviewing and surveys), which reflect the main context of being a science or non-science person to a wider extent. Whereas parental and teacher involvement in decision making towards or away from science education and or a profession was found to be limited.

(ii) Theory Validation

The theoretical basis of this study involves the recent literature based on identity and identity transformations, GF, SA, TL experiences, natural inclination and IIA. The literature review along with the main aims of this research, explores the link between one's natural inclination and IIA, and TL experiences. This led me to first read general literature on science education and problems associated with high drop outs of students after the compulsory age for science education, including Archer et al.'s (2010, 2012, and 2015) various works on science education research. Later to accommodate transformation I selected Mezirow's TL theory (2000 - 2009). Finally, Illeris's definition of transformation in relation to identity constructs led me to adopt Illeris's identity model and linking it with TL. Later, through the concept of Illeris (2014) part identities, I understood the multiple identity theory and models as a key model that explains the meaning-making process from inside out. However, I found Illeris's model complex when I practically tried to fit in a theoretical story. The main reason for this was that it consists of complicated boundaries and I found difficulty in deciding the importance of one identity over another. Later on, through reading literature on multiple identities I came across Jones and McEwen's (2000) and later Abes, Jones and McEwen's (2007) model of identity, that included the meaning-making filter in my model. This theoretical understanding helped me to design Sci-ID model ingredients which I used to accumulate the data from the three Phases of the study.

In addition, this research also includes GF (for example: gender class and race) (to some extent), parents, school science and teachers as SA and natural inclination. There are various other factors in relation to the general distaste of science in public (like SEN, globalisation etc.), but it was quite impossible to study every influence/ factors in this study. In addition, it was impossible to read the wealth of literature on identity and transformation and include it in the study. For this reason, I have studied the articles and books that are available in the Brunel University London library and Google Scholar from around years 2006 to 2016. The identity models used in Chapter Two were from 2000 and onwards.

(iii) Response Validation

Response validation was based on two main confirmations - model validation (Figure 2.5, Figure 7.2, Figure 7.3 and Figure 7.4) and data collection validation.

The final theoretically-based model (Figure 2.5) was accomplished not only by reading and understanding the recent relevant literature on identity and transformations, but also through a discussion about the model with my supervisor, education-based journal peer reviewers and conference audiences ranging from education professors to PhD students. At first, the Phase One (scientists and non-scientists) study incorporated Mezirow's and Illeris's theory in relation to core identity using narratives which was not only appreciated by the conference audience at the London International Conference on Education 2014 and Brunel educational conferences (2013/ 2014) but also the International Journal of Science Education published the theoretical framework along with the results as a manuscript in 2015. Secondly, Phase Two study incorporated Mezirow/ Illeris TL relating self-perceptions to contextual influences and the data was first presented in the JRST journal for a peer review in 2015. The reviewers believed that the manuscript had the potential to make a contribution to the field of science education. However, the paper was asked to be resubmitted due to lack of justification based on empirical study, including design, validity, and data analysis protocols, which I have taken into consideration in this chapter. In contrast to JRST, my paper was accepted by the Australasian Science Education Research Association 2016 (ASERA), and later I received invites to publish the paper in different international education journals. The addition made at ASERA was that I incorporated Jones and McEwens (2000) identity model to support the data analysis from Brunel University London students. As a result, I continued using the same theoretical framework to justify Phase Three secondary school girls' data which was also accepted by the Czech Institute of Academic Education. In addition, I have currently employed Illeris (2014) general structure of identity and 'Reconceptualised Model of Multiple Dimensions of Identity', Abes, Jones and McEwen's (2007) model adopted from Jones and McEwen's (2000) Model of Multiple Dimensions of Identity as these models provide an advanced insight into the meaning-making process (Chapter Two). Moreover the model was approved by my supervisor.

Second, for data validation, the first phase was planning the interview guide and the interview protocol. At first, Phase One interview questions comprised of twenty two questions and were quite close ended, as at the beginning, I intended to test a lot of different specific variables. These variables were mostly adopted from The Relevance of Science Education Project (Sjøberg & Schreiner, 2010). However, later with the help of my supervisor interview questions ended up to be sixteen in total and quite open ended. Next, Phase Two survey questions originated with similar aims and objectives as Phase One. In addition to Phase One interview questions, four more questions were added based on the information on Brunel college, year of study, gender and A-level science subject and prospective career choices. Because it was an online survey (I acted as a complete outsider) I was not sure whether they were from science or non-science colleges, undergraduate or postgraduate students, male or female and prior science subject choices. In addition, Phase Three questions also originated from Phase One questions with few amendments, and interventions were designed from the recommendations given by the scientists and non-scientists (Phase One).

After making the interview guide, pilot studies were conducted to improve and confirm the validity of the chosen method. Initially, for Phase One, I answered the questions myself first and then piloted with a PhD student and with a part time lecturer from Brunel University. For Phase Two, I tested the online questionnaire myself and secondly a pilot study was carried out by two PhD students, one from science and the other from a non-science college. Finally, for Phase Three participants, before and after intervention questionnaires were piloted by two GCSE students who were not part of the science intervention study. The above mentioned pilot studies helped me to identify potential interview, questionnaire and intervention difficulties such as duration, data recording instrument (tape recorder) voice checks and Bristol Online Survey application areas where an alteration in questions was required or areas where probing was required that gave me 'a chance to modify practices, before the investigation proper begins' (Powney and Watts, 1987, p. 125). Before collecting the data, the modified interview guide was approved by my supervisor. In my opinion, two additional 'pilot' interviews with Phase Three participants would have further validated the approach.

Moreover, Cohen et al., (2007, p. 150) stated that 'the most practical way of achieving greater validity is to minimize the amount of bias as much as possible'. Therefore, during the interview/ questionnaire processes the following considerations were taken:

(i)The sequence and wordings of asking the questions were kept constant within each phase. During Phase One and Phase Three interview sessions, I probed some participants if something was not clear. For example, Danielle (Phase One non-scientist), was asked about her current profession, she mentioned a varied job description in relation to the profession. So I asked her again and we came to a decision that she identifies herself as a Reader in Education. Moreover, I asked Zikri (Phase Three C2 group) to elaborate about what she meant by 'growing up on her grandparents' farm' etc.

(ii)Phase One interviews were recorded and transcribed the same day, where Phase Three interviews were either written by the participants themselves or by me while they were giving answers (Appendix 11). I tried to be as truthful as possible by correctly transcribing (word by word) the interviews, recording survey questions as original data. The data collected and appeared stories were being discussed with the supervisor and a few willing participants to avoid further bias.

(iii)Similar to the suggestions of Kvale (1996), a part of the interview transcript was transcribed by a university librarian (from West London), and was later matched with the transcript that I transcribed. In addition, two academics were asked to read their own transcripts and summarised stories to further validate the data; both the participants were happy in the way they were addressed in the self-generated stories. In addition all the Phase One and Three interview participants were asked to read their stories and validate it. Necessary amendments were made after the review from these participants. A critical PhD friend was asked to match the BOS questionnaire response and summarised stories of the Phase Two participants.

(iv)Cohen et al. (2007) argues that the interpretation of the interviewer can be biased at the time of analysis. In addition, the interview and questionnaire included the same, but flipped science and non-science questions, for example 'I always had a natural inclination towards science subjects'/ 'I always had a natural inclination towards non-science subjects'. In my opinion, a few more of these flipped questions would have been useful for further analysis.

(v)The interviewer's bias in Phase One and Phase Three can still be present because of the absence of an accompanied observer at the time of the interview and science education intervention. Denzin (1989, p. 239) believes that 'observers remove the potential bias that comes from a single person'. Further replication of a similar research with similar or different participants and by a different interviewer can help to avoid the interviewer's bias further. The use of an observer was not undertaken in this research - another limitation of this study.

Insider and outsider researcher

The issue of subjectivity over objectivity is emphasised in the qualitative research. For this reason, the research stance taken to gather data from the sample participants mainly deals with the 'empathetic observer' which involves the objectivity position of the researcher, but at the same time being subjective to further understand the social actions taken by social actors (Blaikie, 2010). My understanding of subjectivity and objectivity relates to the literature on 'insider researcher' and/or 'outsider researcher'. Merton (1972) stated that insider researchers are members of specified groups and collectivises, or occupants of specified social statuses' being researched where the 'outsider researchers' are 'non-members' (p. 21). With an anti-positivist approach (mentioned above) I believe that 'complete objectivity is thus impossible' (Rooney, 2005, p. 7). Moreover, I have noticed that as a researcher I can position myself as an insider as well as an outsider, as these two elements overlapped each other due to its 'permeable' (Merton, 1972, p. 37) aptitude. My positioning as an insider and outsider varies from one phase to another, which is as follows:

Phase One: I had insider knowledge about the university as I am a student at Brunel University London. However, unlike me, the participants were professional scientists and non-scientists. In order to select a particular sample I had researched the participants before conducting the interview identifying their science or non-science discipline, research interest, job title etc. from the Brunel University London webpage. However, I believe I did not influence my viewpoints based on my interests and identity during data collection (by using the interview guide) which relied completely on the participant's perception. Moreover, I was not familiar with the academics extensional experiences and intentional perceptions based on family science/ non-science influences, school science, science teachers etc. Six of the participants were female, one of the participants was Asian like me and six participants (3 males and 3 females) were from a science background like me. However, they all started their educational and career journey in the UK, whereas, I started this journey in Pakistan and built on it in the UK. Moreover, none of the participants had the same biochemistry background as me. In addition, all the twelve scientists and non-scientists were sent the IJSE published article 'Science lives: school choices and natural tendencies', and none of the participants objected to the three broad categories (as smooth, wavering and transformative) and or summarised story, except Nikki (non-scientist) who was not entirely happy with the way she was portrayed in the summarised story. To deal with this issue, I listened to her recording again and took help from my supervisor to confirm the summarised story. No changes were made with the participant's permission. The analysis was also shown to two non-participating university students and to the twelve secondary school girls. No objections were made, although one female scientist indicated that I should have included the aspect of parental professions to better understand as to whether parents were influential in choosing the science/ non-science subject or not. These issues could be dealt in future. The justification for this could be that I consider the participants' perceived influences from the parents as truth at the point of data collection and analysis.

Phase Two: I had insider knowledge about the university as I am a student at Brunel University . Like me the participants are university students as well. However, unlike me the majority of the students were from the undergraduate level of study. Like me the majority of the students were females and belonged to the same department (Education) or college (CBASS). However, to my knowledge I have never personally met them and I am not familiar with their names, ethnic backgrounds, nationality, contact details etc. The biographical details I collected were gender, college and year of study in order to group them and compare. However, none of the university students questionnaire was verified, as I was completely unaware of the participants, in addition, almost all the students answered all the four scaled (strongly agree, agree, disagree, strongly disagree) questions, but very few (three students) added additional comments in the comment box given at the end of all the twenty questions and none of the participants showed interest in taking part in further follow up; another limitation of this study.

Phase Three: In The Salehjee Girls School I acted as a teacher researcher. For this reason I have been an integral part of the school environment and I was aware of school policies/ regulations and special measures/ protocol needed to conduct the research in an all-Muslim girl's school. Like all of the students I am Muslim and female and like a few others I am Asian and Pakistani, and then as their science teacher with a particular interest in the subject I could have altered the way students answered the questions. For this reason I avoided talking about the research work. I made sure that they completed the questionnaires in my absence and without consulting other students. I also could have input my personal interest in summarising the stories, therefore, to validate this I asked the twelve students to read their stories and all the students were happy with their summarised stories, except that Talat mentioned, that later she did not actually feel like, opting only science subjects at the sixth month of intervention studies. After carefully looking at the rest of the six intervention evaluations (questionnaires) filled by Talat, I moved her from C1 group to C2 group.

(iv) **Criterion Validation**

Criterion related validation 'considers the relationship of the research to interpretive frame of reference' (Pedrosa, 2013, p. 13). In contrast to the literature and this empirical study I have found few similarities, few differences and few insights that are not available in the recent literature. Examples are given in Table 3.3 below.

Few previous literature	My findings
Reports show high importance of employment choices in relation to subject choices post compulsory age of science education, where students perceive that science based employment is limited (for example: Macdonald, 2014).	For university and secondary school children, the main idea was to obtain a degree, whether science or non-science.
A quite strong parental influence in choosing science or non-science subjects and careers has been reported (for example: Archer et al., 2010; Sheldrake, 2016).	The majority did not experience specific parental influence in guiding science subject or career choices. On the other hand, few participants experienced positive/ or negative influence of parents.
The role of science teachers has been given considerable importance in the literature and by the UK government (for example Kellner, Gullberg, Attorps, Thorén & Tärneberg, 2010 ; Logan & Skamp, 2014).	High importance was given by the scientists towards teachers, whether science or non-science. In relation to the literature a few participants showed negative, few mixed, few none and few positive experiences. But the majority disagreed on having teacher(s) influence.
One-off science interventions have been unsuccessful (MacDonald, 2014).Series of micro-transformative experiences might result in big transformations (Hedy & Pugh, 2015). A series of mini transformative experiences might lead to transformative learning.	In accordance to the literature, a series of mini science based interventions helped the majority in deciding their science subject choices.

Table 3.3: Criterion related validation

(v) Consequential Validation

Besides adapting the three main theoretical models and designing a Sci-ID model to fit the aim and objectives of this research, the work/ part of the work was accepted and appreciated by the journal reviewers, conference attendees, the participant school, and participant secondary school students. The significance of this work will be further discussed in Chapter Seven.

3.9 Limitations

Even after considering validation of the research, there were limitations that will be needed to be considered for future research. Limitations of this research are discussed below:

(i) **Phase One: Professional scientists and non-scientists**

Ideally the sample size should be much larger to validate the ideas that appeared from the university academics' interviews, but this thesis is limited in terms of accessibility to other Brunel University London scientists and non-scientists due to their busy schedule and it was also not possible for me to collect data from a wide range of science and non-science colleges. I sent email requests to various professors and lecturers from science and non-science colleges, out of them only one agreed for an interview; the rest were approached as my own and my supervisor's contacts.

(ii) Phase Two: University students

The majority of the university students ticked the four scaled evaluation grid, however most did not comment further at all or very limited comments were given by a few students in the comment box. In this way I was unable to picture the complete story of the majority of the participants. In addition, I was unable to interview Brunel University London students, although on the last page of the online questionnaire all the students were invited for an interview, but none of them opted for it. I could not locate the participants as all the personal information like name, email address, phone number, student numbers were kept confidential and were not asked for unless the student wished to give them. In addition, through the questionnaire, I could not locate any gender-related specific information as the majority of the participants were females (68%) so while analysing the data I have converted and used equal percentages in order to compare male and female responses. However, I was unable to separate the male and female participants into science and non-science colleges for all the questions as the BOS did not gave me the luxury to cross tabulate three questions at the same time.

(iii) **Phase Three: Secondary school girls**

I was allowed to research with thirty Muslim secondary girls to whom I was teaching science. The school management did not allow me to research the 'GCSE exam girls' because of syllabus completion time. The other science teacher was not happy to conduct these sessions as she believed that it would add to their existing workload. In addition, as mentioned above, due to the school being a Muslim school, the girls were not able to be videoed and even their voice was not allowed to be recorded. In this way only written responses were taken into consideration, which could have not entirely pictured the real feelings of the girls while doing the interventions and giving the interviews.

3.10 Summary

This chapter has provided an overview of the research philosophy, research design, methods and procedures that I have used to carry out the three phase study to analyse ‘the making of a scientist’ - the preconditions that foster a 'science identity', the educational and 'life experiences' that move people towards - or away from - the study of science.

The chapter was divided into seven main sections (Figure 3.3). Within these sections I have addressed the main aim of gathering self-narrated stories from the participants themselves. To accomplish this aim I have used interpretative philosophy, three stage design, sample/ institution, and narrative enquiry styled interviews/ questionnaires to obtain depth from the stories from a wide range of people. In carrying out the research I have also dealt with ethical issues that could have misinterpreted the data collection procedures, reporting and analysis. Through the analysis process I was determined to understand the identity transformation over a period of time in a subjective as well as in an objective manner and in doing so I studied recent science education research and theories like identity and transformational learning theories. Moreover, in order to make my research acceptable enough to be replicated in future I have used the validation framework to deal with issues of Context, Theory, Response, Criterion and Consequential validation. In addition to the validation process, some of the limitations of the study have also being addressed in a way that provides opportunities for further research.

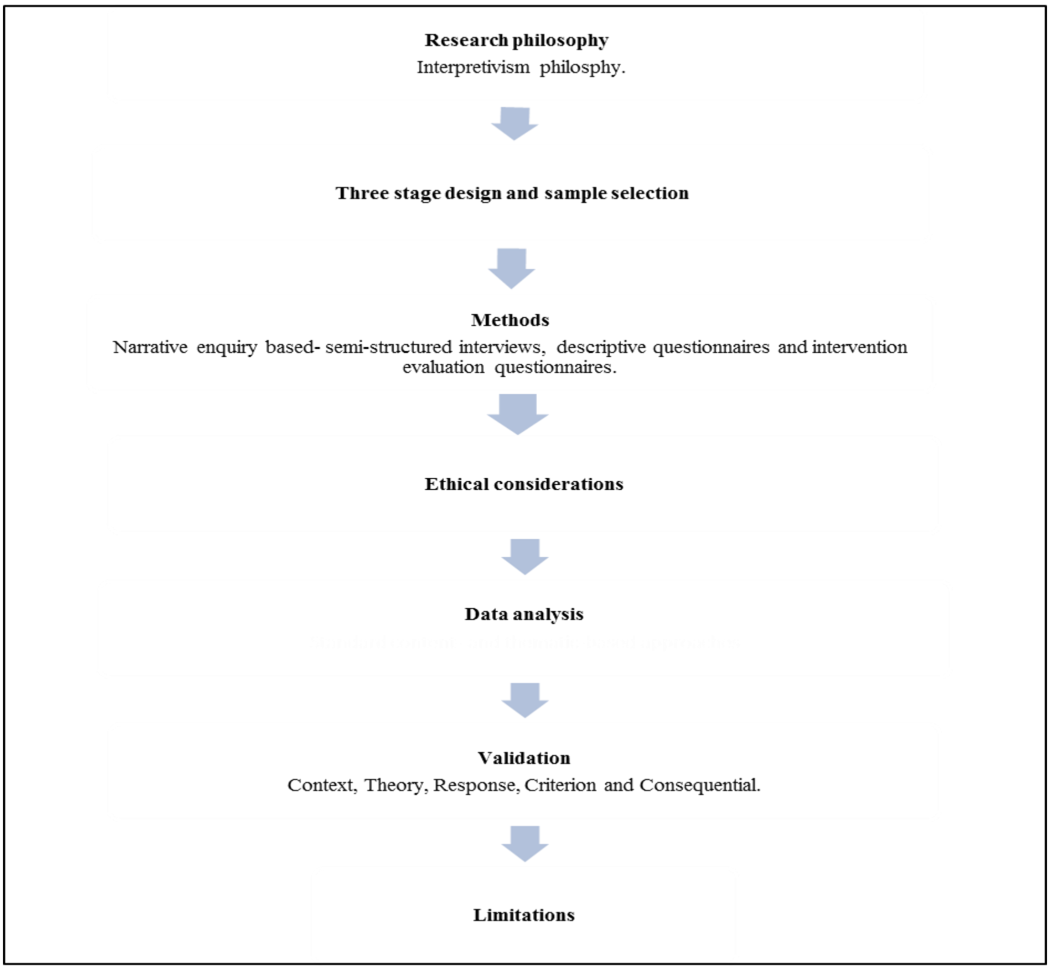


Figure 3.3: The empirical research flow chart

After looking at the above research practice, the next chapter will present the science education intervention activities which will provide an insight on the Phase Three part of the school based research conducted in The Salehjee Girls School. I will discuss the use of an enquiry based learning (EBL) strategy and Bell's (2014) model of successful intervention in the intervention design. Moreover, with the help of a few relevant literatures I will present the design of six interventions in the form of lesson plans with an intention of further improving and updating the design in the future, in accordance with the needs of students, availability of resources and time.

Chapter Four: Science education interventions

4.0 Introduction

As mentioned in the last chapter, I designed six science education interventions to enthuse more girls to choose science subjects at A-levels and beyond. In the English Collins Dictionary, intervention is the ‘action or process of intervening’. In addition, Schensul (2009) defines intervention as a

> systematically planned, conducted and evaluated social science based cultural products intercepting the lines of people and institutions in the context of multiple additional events and processes…. that may speed up, slow or reduce change towards a desired outcome (p. 241).

I understand science intervention studies to be along similar lines so I designed, conducted, evaluated, reflected upon and planned the next steps for six science education classroom interventions at The Salehjee Girls School. During these, I mapped the context of students’ SA influences, TL experiences and their engagement and disengagement with school science. The events and processes designed were integrated wherever possible with the curriculum and were dealt during standard science lessons, out of school visits and/or in home time and school holidays.

It is widely acknowledged that connecting science with the public, and girls in particular, are a ‘must’, and many organisations have put significant resources into doing so. The predicted demand for STEM subjects in the workplace over the next five to ten years has provided a major stimulus for a large number of interventions in this area. For example, the National Audit Office (NAO, 2010) reported that, in 2006, the Department for Education and Skills (now the Department for Education) identified some 478 intervention designs to improve young peoples’ experiences of STEM (as part of a review).

Moreover, to achieve my research purposes and to make the interventions successful, I critiqued recent literature on science education interventions. Here, though, there is a distinct paucity of published work and the ‘standout’ reading in this literature was Bell’s 2014 ‘successful intervention’ model that includes the main aspects required to design and implement science education interventions. Another model, ‘Response To Intervention’ (RTI), has been used in mathematics classrooms (by, for example, Marston, Lau, Muyskens & Wilson 2016; Xin, Chen & Kastberg, 2016), in literacy lessons (for example, Burns, Silberglitt, Christ, Gibbons & Coolong-Chaffin, 2016; Shapiro, 2016), in modifying behaviour (Shinn, Windram & Bollman, 2016), disability (Carta, McElhattan & Guerrero, 2016), to improve academic and behavioural aspects at an individual level. Unlike Bell's model, however, RTI does not help in the initial design of the intervention, only in making improvements in already existing systems. Similarly, in comparison to my intervention design, few recent research papers emphasise broad collaborative science intervention studies. Interventions such as Topping et al.'s (2011) collaborative learning with 12-14 year-olds, and Ruthven et al.'s (2016) dialogic physical science and maths teaching with student age groups from 11-12, are mild exceptions, but are essentially classroom-bound. Interesting research has also been conducted by Schütte and Köller (2015) in three German secondary schools, which involved science industry-based project work for primary-age students (grade five and six) which lasted for two years. Other than gender, age and test versus comparison group differences, Schütte and Köller's (2015) participants were already motivated towards science, and self-selected their entry to the programme. The authors accepted these limitations to their work because they found no increase in science motivation in the participating students and wanted to carry out further research 'with talented students who show (comparatively) less interest in science at the outset rather than with highly motivated students who self-select into the programme' (p. 2306). My selection criteria, in contrast, have involved both those who show early interest in doing science and/ or non-science subjects at A-level. I implemented science interventions because the majority of my target sample indicated less motivation in carrying out with science subject(s) in the future. To design and implement interventions I have incorporated an enquiry based learning approach and Bell's (2014) model for successful intervention which will be described in detail in the subsections below.

4.1 Enquiry-based learning (EBL)

In designing the six interventions I have incorporated an enquiry-based learning (EBL) approach to plan and implement in the science classrooms. The reason for choosing this approach is because in 2013, the Office for Standards in Education, Children's Services and Skills (Ofsted) conducted a survey of primary and secondary schools and showed concern for the lack of EBL in schools and strongly recommended an increase in the amount of science lesson time to incorporate scientific enquiry skills including practical social issues. In addition to Ofsted, the European Commission (2007) had also highlighted the importance of EBL. John Dewey's early 20th century edict was that 'education begins with curiosity of the learner' (Savery, 2015, p. 11) – first, science by doing and, second, through reflection (Kuhlthau, Maniotes & Caspari, 2015). Similarly, EBL is independent student-centred learning that involves 'any process of learning through inquiry [enquiry]' (Hutchings 2007, p. 11) and emphasis is on asking students to work as scientists designing, testing and critically concluding their results, rather than the correct results (Hepworth & Walton, 2009). Amongst its numerous benefits, EBL provides a logically assigned set of smaller units 'that guide students and draw attention to important features of scientific thinking' and the co-ordination of these units constitutes an enquiry cycle (Pedaste, Mäeots, Siiman, De Jong, Van Riesen, Kamp, Manoli, Zacharia & Tsourlidaki, 2015, p. 48). Minner, Levy and Century (2010) conducted a longitudinal study on enquiry-based science instructions impact on K-12 students (from 1984 to 2002) and reported that an 'investigation cycle' ('generating questions, designing experiments, collecting data, drawing conclusions, and communicating findings) and 'hands on experience' stimulated students' active thinking skills and, in turn, enhanced students' 'content learning, especially learning scientific concepts' (Minner et al., 2010, p. 20). There are other enquiry-based learning cycles like Bybee, Taylor, Gardner, van Scotter, Carlson & Westbrook (2006) five Es (Engagement, Exploration, Explanation, Elaboration, and Evaluation) cycle; Pedaste et al. (2015), conducted a literature review on thirty-two research papers and summarised existing EBL cycles into five main phases, which are 'Orientation, Conceptualization (questioning/ hypothesis generation), Investigation (exploration, experimentation, data interpretation), Conclusion, and Discussion (communication and reflection)'. Justice, Warry, Cuneo, Inglis, Miller & Rice (2002) believe that the order of these phases in the cycle is not fixed. In accordance with Science by Doing (Australian Academy of Science, 2013) the forms of enquiry instructions include closed, guide and open enquiry. Open enquiry involves only students in generating questions, designing methods and drawing conclusions. Closed enquiry involves only teachers for all the three enquiry-based processes and guided-enquiry is a combination of both student and teacher led participation and mode of instructions. I have mainly incorporated open ended or guided enquiry approaches which are indicated in the lesson plans Table 4.1-4.9. In addition, The Fibonacci Project (2012) emphasised the current need to integrate science enquiry across the curriculum, because it is noted that the secondary school system exhibits integration only within the sciences (biology, chemistry and physics) and not outside of the sciences – principally because secondary science teachers commonly teach only science (Artigue, Dillon, Harlen & Léna, 2012; Borda Carulla, 2012). Science linked to mathematics, english, computing etc. is rare but important since ‘science is not an island to be taught on its own’ (Barnett & Feasey, 2016, p. xi). A cross-curricular link is beneficial because (like religion) it makes connexions between science and future citizens and specialists (Billingsley, Brock, Taber & Riga, 2016). For example, through mathematics integration in science ‘pupils are more likely to develop creativity, critical thinking and problem solving abilities as they become more familiar with recognising the complex demands of problems requiring knowledge and skills from more than one subject’ (The Fibonacci Project, 2012/2013, p. 6). Moreover, the Fibonacci Project listed benefits of integrating literacy in science lessons in developing speaking, listening, reading and writing skills. Taking the EBL approach along with social, cultural contexts and interlinking subjects I will now move on to the intervention exercises that I implemented in the school.

4.2 Intervention exercise

So, returning to Bell (2014), his work is apposite because it not only refers specifically to broad classroom and non-school-based science education, but also deals with groups rather than simply with individuals. He believes that such intervention in science education can be used to engage students in learning in order to improve their skills, knowledge and conceptual understanding, both ‘generally and in specific science disciplines’ (Bell, 2014, p. 21). McDonald (2014) argued that one-off interventions do not work and that constant practice is needed to gain positive effects. Her argument is based on the fact that, after many decades of ‘worthy’ interventions, very little progress has been made in encouraging more girls towards science. While her approach certainly has some force, her comments do not draw attention to what might have been the case - had there been no interventions at all? One of the recommendations given by Bell (2014) is that ‘consideration should be given to testing and refining such a model for developing interventions in order to explore in more depth ways in which interventions of all types can be made more successful’ (Bell, 2014, p. 44). I also believe in ‘constant practice’ and accordingly ‘testing and refining’ of the interventions in science classrooms according to the needs of the students. In this vein, I have incorporated Bell’s (2014) model for successful interventions which consists of seven elements that ‘all interact and contribute to the success of an intervention’ (p. 8), but together, can be considered to form three intersecting axes, as set out in Figure 4.1, in which:

(i)'The clarity of, and commitment to, the purpose lead to tangible impact and outcomes
(ii)Suitable people working in the right context results in measurable and demonstrable outputs
(iii)Robust processes lead to effective implementation' (Bell, 2014, p. 8).

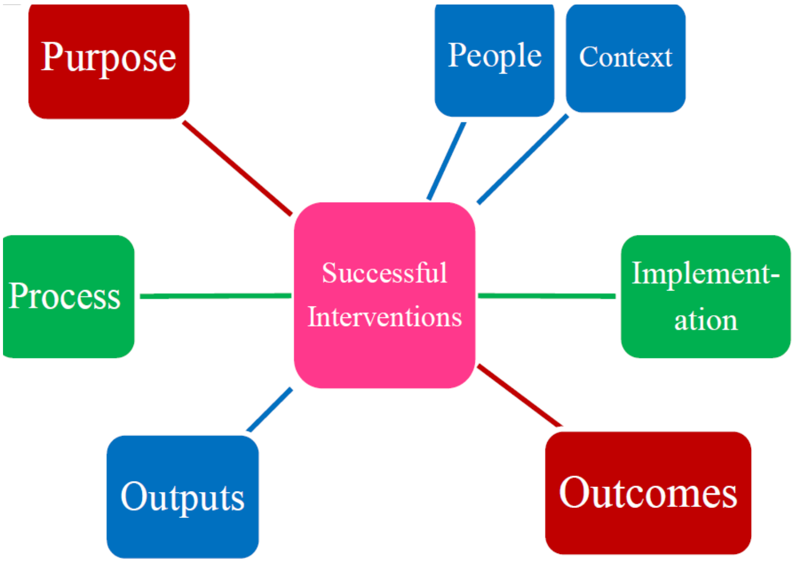


Figure 4.1: A model for successful interventions (Bell, 2014, p.8)

I will now describe the journey of the intervention programme that I have conducted in The Salehjee Girls School, using Bell's (2014) model for successful interventions.

(1) The purpose leading to outcomes

The purpose of school based science interventions is to increase a positive approach towards science in order to integrate willingness within the thirty girls to opt for at least one science at A-levels. To achieve this I wanted to incorporate better teaching and learning practices by avoiding traditional teaching and learning procedures in order to make girls think of themselves as 'a kind of person' who can do science. Moreover in doing that I wanted to build up an understanding that science is not studied in isolation - instead the aspects of science are present in almost every subject and in daily life practices.

To accomplish this I designed teaching and learning strategies in order to expose the girls (from UK ethnic minority families) to enjoyable in-school and out-school co-curricular (like literacy and numeracy) and real world (like social contexts) linked science enquiry (guided and open) based lessons. These interventions were conducted to improve the existing practices; later these practices were also evaluated for future intervention practices (Reflection and Next stage section on Tables 5-13). However, one of the challenges in implementing interventions at the school was finance. While the school allowed me to carry out the interventions, there was no budget allowance for this. A second limitation was that the school did not allow me to carry out an intervention study with the Year Ten or Year Eleven pupils (age group fifteen to sixteen) because of limited syllabus time and examination pressures.

(2) People, context and outputs

As mentioned in Chapter Three, the people involved in the study were mainly the thirty girls and myself in a school context. Occasionally other science teachers and science educators were also involved during out of school visits. As mentioned before, The Salehjee Girls School is a Muslim faith school and those students are from a minority population as compared to other multi-religion mainstream schools. The question then was 'how to make interventions successful in a secondary school?' I strongly believe that the lesson strategies and processes should be 'school appropriate' but not be too fixed and to some extent cater for an open form of enquiry strategy as well. For example, in 'learning in-depth' intervention project one restriction was that the topic must be chosen from 'nature' (teacher led), the research topic though was open (student led) to all the students. Similarly, in 'treasure hunting' and 'problem solving experiments', the open-ended (student led) process of decoding and conducting the experiments was followed closely but the hypothesis was provided by the teacher and the experiments were differentiated slightly according to the age group of the students (teacher led). A further detail on the intervention processes design and implementation can be seen in lesson plans (Tables 5-13).

The main outputs are expected to engage girls into science-based activities leading to the possible continuation of studying science subjects over the age of sixteen and/ or be influential to others. If possible, the girls would continue with science-related career opportunities and/or encourage others within a social – and educational - setting. The evidence I have gathered to observe whether the interventions were successful or not include: (i)reporting level of enjoyment and understanding of scientific concepts in the intervened science lessons and (ii)reporting movement of the girls into or away from science. The outcomes of these evidences can be seen in Chapter Six.

The six interventions were implemented in the three classrooms over approximately six months, using different teaching strategies like discussions, group work, hands on activities, individual work and activities mainly linking to literacy and numeracy and social and cultural aspects to introduce quality science teaching instructions (Shelton, 2016). For every intervention the aspect of EBL was highlighted.

(3) Process and Implementation

The guided enquiry used in The Salehjee Girls School included science fiction, visits outside school, 'meeting a scientist' and also employed speaking, listening, reading and writing skills through open-enquiry-based learning through science poetry writing, the 'treasure hunt' and learning in depth. For example, students were shown science fiction videos and were asked to look for answers themselves as to how these related to science; for the learning in depth intervention study, students were asked to collect primary evidences such as pictures or samples and explain the natural phenomenon behind them; the students themselves performed the problem solving activities. At first, students were given hypotheses to plan the investigation and later students modified the practical according to the secondary data collection and availability of resources. Their conclusions were made and shared with the other team members. I also included societal and cultural aspects linked to science topics and also took personal help from Dr. Jane Essex, who is a secondary science PGCE tutor at Brunel University London. Recently, Dr Essex published 'Cultural Inclusion in Science Education' (2016) giving examples in linking science to society and culture. Literacy and Numeracy and other interlinking topics can be seen in the lesson plans (Tables 4.1 – 4.9).

Other than the above interventions, I am aware of the extensive literature on formal/ informal learning, collaborative learning, group work, differentiation and other related strategies. However, my aim is not to include in-depth research on the advantages and disadvantages of these teaching and learning approaches. I have utilised science pedagogical interventions to improve teaching and learning strategies (like group work, independent work, and linking science to literacy, numeracy and real/daily life experiences) and Enhancement & Enrichment interventions through career talks and university life experiences to scaffold girls' enthusiasm towards science. In Bell's 2014 paper, pedagogical and enhancement and enrichment (E&E) interventions are categorised as a separate typography of interventions, however Bell (2014) himself pointed out that the boundaries identified are not rigid and can be interlinked. I also believe that a separation made between pedagogy and E&E is not suitable as even in the E&E intervention study, the impact of pedagogy is quite prevalent. Moreover, after conducting the lesson I realised that not only careful planning is important, but reflecting on it is also integral in making the process repeatable. I have included a short reflective report (few ideas for the next stage can be seen in lesson plan Tables 4.1 – 4.9) based on Kolb's learning cycle depicted by Roffey-Barentsen and Malthouse, to avoid researcher biases and assumptions (Roffey-Barentsen & Malthouse, 2013) and I believe this also helped me to improve my teaching practice by reviewing my own ability and pitfalls as a science teacher. vanVondel, Steenbeek, vanDijk, and van Geert (2016) reported that the assessment of students' performance during group-based interventions in enquiry learning have been given much attention in the recent years, while the influences on individual student learning gains over time have been relatively low.

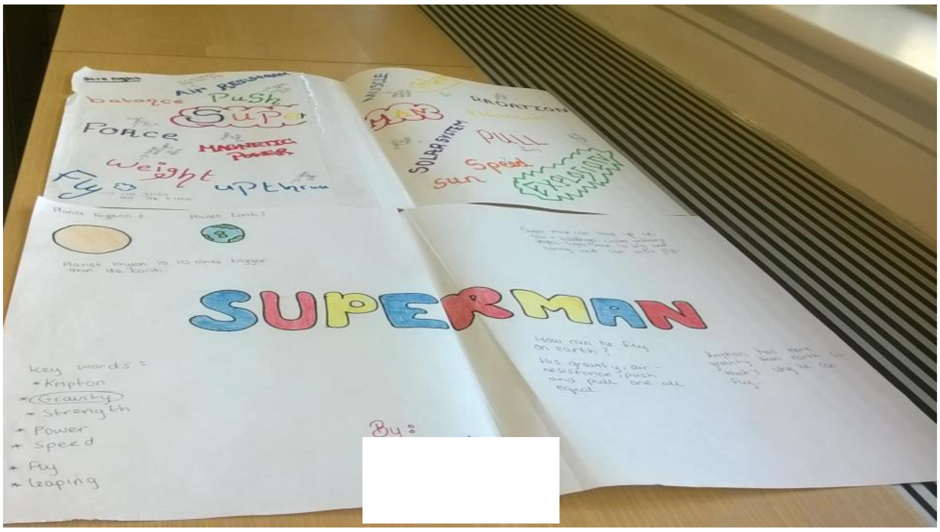
At this point, I tried to interpret individual student gains through their own perception on enjoyment and feelings in science. A more thorough data collection through observation would have been better. The accompanying literature, process of interventions, few photographs, reflection, and the future practices based on the six main science education interventions are given below.

i) Science fiction

Science fiction stories help project ideas into the future and aid discussions about the future direction of science and technology (Piggott, 2014). Some recent literature indicates the benefits of using science fiction stories in the classroom. Hewlett (2016) believes that reading science fiction stories make students link scientific concepts with their own daily life experiences and in turn can relate the characters of the story with their own understanding of the world. Although, in the first instance a book called Z for Zachariah was given to the students I found that they were not engaged so I googled the movie on YouTube and played it for them. Students looked quite interested so I changed my strategy and used films instead. The chosen films (*Superman* and *Z for Zachariah*) were silent for the first 5 minutes as I wanted the students to give scientific voice to it (during group discussions). Later, students looked at the films with sound as 'when words and visual elements are closely tied, students are better able to comprehend and synthesize new information' (Vaquez, 2012, p. 8). Similarly, researchers in the field of product design have reported that students were found to perform better using science fiction films (Lin, Tsai & Chien, 2013; Yu, Fan, Tsai & Chu, 2013).

Surmeli, (2012) examined the influence of science fiction films on second grade students' attitude towards a Science Technology Society University course at Mersin University Science Teacher Education department. They found positive results in the attitude of the students and students themselves also liked this teaching strategy in the science course. However, Barnet, Wagner, Gatling, Anderson, Houle and Kafka (2006) conducted similar research in an eighth grade lessons, where students viewed the film 'Core' and found a negative effect as stated that 'we found that a single viewing of a science fiction film can negatively impact student ideas regarding scientific phenomena. Specifically, we found that the film leveraged the scientific authority of the main character, coupled with scientifically correct explanations of some basic earth science, to create a series of plausible, albeit unscientific, ideas that made sense to students' (p. 179). At this point I believe that teachers should be vigilant enough to clarify the misconceptions in the classroom and for this reason a discussion on the aspects of science which cannot be answered or are incorrect were also emphasized in the discussion with the students. For example: how Superman unlike humans can fly and like humans can walk as well?

Another reason for introducing science fiction in science lessons was that Adam and Norman, the two english non-scientists from the Phase One study (Table 5.1) pointed out that they connect themselves to the world of science through writing and reading science fiction books. For this reason I approached Adam to advise me on few science fiction based films. A list was provided by Adam, out of which I managed to implement two in the classrooms in six lessons (approximately). The movies were ‘Science behind Superman’ and ‘Z for Zachariah’ (Photograph 1 and 2). A brief science fiction related enquiry activity lesson plan is given in Tables 4.1 and 4.2.



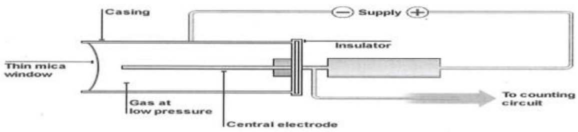
Photograph 1: Science fiction 1- Science behind Superman

Science and Z for Zachariah:

There is a lot of science behind z for Zachariah. Anna's father tells her to look after her dog and her brother joseph, while he searches for food.He says he will return in a few hours. Without anyone noticing Joseph sneaks into the back of the truck so he can go with his father.As soon as they set off, her dog runs. So, she chases after him. He runs very fast into the greenery land. There was grass and mountains, all around. There were also a few puddles on the way.

Then, she gives up and returns home in the state of depression. It's all a 'biome' (a very large eco-system) she comes to the river to collect some water, she notices it's all contaminated. All the fish in the sea are slowly dying. There were also a lot of chemicals in the water. When he arrives back home all the electricity has gone. So she decides to draw pictures whilst listening to the news. Then she hears something on the news and suddenly runs outside. She destroys any possible signs of life. She hurries all the animals away into a barn, Terminates all the crops, breaks all the branches. Now all the trees and crops looked dead and the area was as if nobody was even living there. In addition, she helped a cow give birth.

Anna then goes to a local shop to buy a few necessities (tinned food, clothes) she then sees a scientist who has come to investigate the area.He tests the water, detects the ground, sky, and air. He uses a Geiger Muller which is a special machine that identifies radiation. The scientist was wearing an astronaut outfit, including a helmet. It was contaminated with radioactive materials. The Geiger Muller was invented in 1908.TheThe GM tube is a hollow cylinder filled with a gas at low pressure. The tube has a thin window made of mica at one end. There is a central electrode inside the GM tube. A voltage supply is connected across the casing of the tub.



Photograph 2: Science fiction 2- Science behind Z for Zachariah

Learning objectives (LO)

1. To be able to compare Krypton’s Earth and Moon's gravity resulting in Superman’s strength and ability to fly.
2. To be able to analyse the force of magnetism and the ability to leap tall buildings in one bounce.

Resources

Film 1: www.youtube.com/watch?v=WScaWdl6TEk Film 2: www.youtube.com/watch?v=Kcj4TAvKxq8

Duration (1lesson=45mins)

Yr9- 3 lessons, Yr8- 4 lessons, Yr7- 3 lessons.

Do it

<table>
<tr><th>Teaching instructions</th><th>Interlinking subject(s)</th><th>Enquiry based learning (EBL)</th><th>Guided enquiry</th></tr>
<tr><td>Watching silent films 1 and 2 for the first 5 minutes, later with sound as a whole class. Followed by questions, practical, discussion on a scientific theory/ scientific facts and discussion on possible scenes that contradict the theories.</td><td rowspan="2">Literacy
Watching SF and writing reports/ flow chart. Relating daily life use of the english language in describing scientific literacy.
Numeracy
Using different formulas and values. Force, gravity, mass, weight etc.
Using masses and force meter to measure the force of a falling object.</td><td>Orientation
Introducing the topic by showing a picture of Superman while flying, and asking them to talk in pairs as to why I have chosen this picture in the science lesson.</td><td>Student</td></tr>
<tr><td>Type of student engagement
Students watching scientific phenomena of force, magnetism and X-ray.</td><td>Conceptualisation
(Argue) Why Superman can fly and we cannot?
(Predict) Is there science behind superman?</td><td>Student</td></tr>
</table>

Students manipulate the formula (like f=ma or a=f/m). Students predict and evaluate the non-science phenomena that do not follow the scientific theory/ principles. Students use secondary data- researching on the internet, pair/ group/ whole class discussion.	**Social and Cultural context** Quran teachings on moon and gravity (Religious study, Literacy and Numeracy). Playing football involves different kind of forces (Physical education and Numeracy). Al-Biruni's ideas about the rotation of the Earth (History and geography and Numeracy) Computing (video, photographs, internet, power point, recording voice).	**Investigation** Experimenting: Force related experiments, including push, pull, gravity, gravitational potential, and magnetic power.	**Teacher/ Student**
		Drawing conclusions Answering the questions asked at the conceptualisation stage.	**Student**
		Communicating findings Making poster/ spider diagram based on the science behind science fiction films.	**Student/ teacher**
Observation/Reflection Students' achieve the objective of the topic in a fun and scientific way (Monitored through thumbs up, down and neutral). Students enjoyed the films and, to some extent, did not like pausing and talking about it. Few students did not know about the Superman character and asked 'Is Superman for real?' Where few also stated that 'I did not like writing about science behind Superman. The lesson time took over the expected time allocated.			
Next stage Watch half of the film in one lesson and other half in the next lesson. Asking students to watch the film before the lesson to manage the allocated time. Adding more group work activities like quiz games. Asking students to write (in their science note books) the linking subjects with the lesson on forces. Incorporating other videos in class like 'Back to the Future' in relation to time machine and forces involved to speed up the time machine			

Table 4.1: Science fiction 1

Learning objectives (LO)

To be able to define and explain different types of radiation.

To be able to identify and describe the process of the measuring device which is used to detect radiation (Geiger Muller counter) and evaluate theafter effects of radiation.

Resources

Z for Zachariah BBC Play for Today (1984), https://www.youtube.com/watch?v=JtqaOdO-91I

Duration (1lesson=45mins)

Yr9- 2 lessons, Yr8- 2 lessons, Yr7- 2 lessons.

Do it

Teaching instructions	**Interlinking subject**	**Enquiry based learning (EBL)**	**Guided enquiry**
Watching silent film for the first 5 minutes, later with sound as a whole class. Followed by questions, practical, discussion on a scientific theory/ scientific facts and discussion on possible scenes that contradicts the theories.	**Literacy** Watching SF and writing reports/ flow chart. **Numeracy** Using different formulas and values like alpha, beta, gamma speed and penetration power. Researching on measuring device- Geiger Muller counter.	**Orientation** Introducing the topic by showing a silent film for the first five minutes and asking students to identify the topic that we will study today.	**Student**
		Conceptualisation (Predict) Why the fish was still alive at the top of the water stream but not downstream? (Judge) What scientific knowledge is behind Z for Zachariah?	**Student**

<table>
<tr>
<td rowspan="3">Type of student engagement
Watching scientific phenomena of different types of radiations.
Using formula to calculate half-life.
Predict and evaluate the non-science phenomena indicated in the movie, which do not follow the scientific theory/ principles.
Use secondary data- researching on the internet, pair/ work and whole class discussion.</td>
<td rowspan="3">Social and Cultural context
Linking to adverse effects on humans, such as
Hiroshima and Nagasaki wars (History and Literacy).
Emotional association of science with nuclear war (PSHE, Literacy).
Marie Curie came from Poland but worked in France (History, female scientist image).
The positive and negative effects of chemotherapy in relation to patient’s well-being (Sociology, Psychology).</td>
<td>Investigation
Modelling: Using a carom board to see the unstable atomic structure releasing radiation, isotopes and types of radiation deflection, density idea (Marie Currie invention).
Secondary and Primary data collection.</td>
<td>Teacher/
Student</td>
</tr>
<tr>
<td>Drawing conclusions
Revisiting the questions asked at the conceptualisation stage.</td>
<td>Student</td>
</tr>
<tr>
<td>Communicating findings
Writing an individual essay on Z for Zachariah and later presenting in the class.
Research on Geiger Muller counter in pairs and presenting as groups of four in the classroom.</td>
<td>Student/
teacher</td>
</tr>
<tr>
<td colspan="4">Observation/Reflection
Students enjoyed the film but to some extent, did not like pausing and talking about it. A few scenes in the film were quite depressing for a few students.
The majority of the students understood the process of radiation and decay in one lesson. A few students did not bring the essay on Z for Zachariah in time.</td>
</tr>
<tr>
<td colspan="4">Next stage
Give a general brief on the video.
Watch half of the film in one lesson and the other half in the next lesson or watch the film in one go and replay it a second time to allow better understanding.
Adding more group work activities like quiz games. Motivating students to write the essay/ ask them to work as a group (keeping lesson time in mind).</td>
</tr>
</table>

Table 4.2: Science fiction 2

Moreover, intervention evaluation questionnaires were collected after completing the above two science fiction related lessons (Chapter Three).

Later on I introduced 'Frankenstein' and linked it to the topic of stem cells, 'Back to the Future' linking to physics and time machines, 'Inside Out' linking to psychology, brain and emotions, 'Wizard of Oz' in relation to Sulphur and hazardous effects when the witch leaves the city of Oz and 'Charlie and the Chocolate Factory' relating to the physical and chemical properties and associated reactions of the main ingredients of chocolate including short and long chains of sugars (disaccharides and polysaccharides). In the latter stages, I noticed that these stories are helping students to understand the scientific concepts at a faster pace and I was able to manage the lesson time. I believe that over time, the science teacher (me) and the students devised a better way of implementing and practicing science fiction stories in the classrooms.

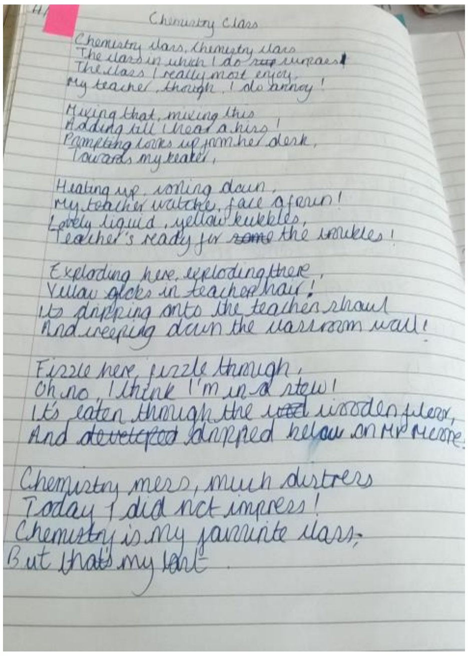
(ii)Science poetry

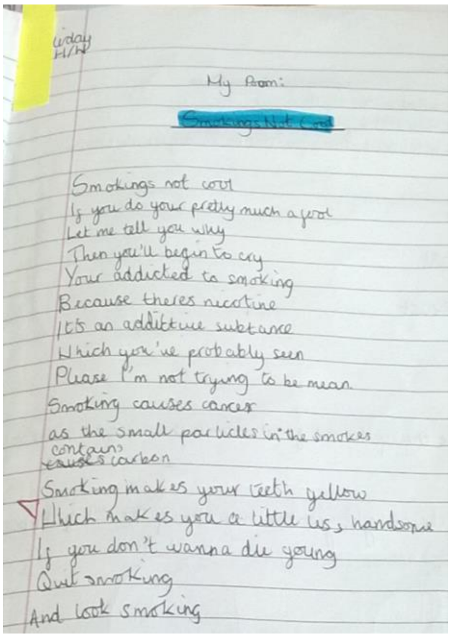
> Science is, or ought to be, the inspiration for great poetry, but I do not have the talent to clinch the argument by demonstration and must depend instead on more prosaic persuasion' (Richard Dawkins, 2006, p. ii).

In addition to Richard Dawkins, Bass.Midgley (2013) criticised the isolation between science and arts. She also believes that science and poetry should be placed 'within the whole that has a place for both of them' (p. 1). Garcia-Matosand Carrasco, (2014) reported a successful competition called 'Let's write science tales', organized by Barcelona's Science Museum to relate science to poetry; the students that took part were from year group nine to twelve. In addition, competitions like a 'School of Ants poetry competition 2015' was organised in Australia in order to inspire, especially, primary students into the world of ants through story telling. Bradbury believes that combining science with arts enhances achievement in both fields of study (Bradbury, 2014).

Similarly, I wanted to fuse science and poetry in the classroom to relate science to literacy, targeting girls who like to write and read poetry. Similarly, work in schools has been reported by Frazier and Murray, (2009), which involved elementary school students in Viginia US, where students successfully learned about science based investigations with the aid of poetry as 'poetry can be used during science instruction to foster interest, excitement, and wonder among elementary level students' (Frazier & Murray, 2009, p. 58). Barbosa, Fonseca, Dal-Farra and Lopes (2014) reported that writing science poetry with the students ranging from fifth to eighth grade inspired 'imagination, integrating knowledge' and engaged students because of the fusion of science to the arts. Other research (older than 2006) has also documented a similar positive result, for example in 'Creative Trespass' (2000) published by The Association for Science Education. In addition to primary and secondary schools, Brown (2015) also reported the similar benefits of integration among science and poetry in medical students.

Therefore, I asked my students to express their imagination through poetry writing in their own space and time. For this reason an open choice on the science topic was given and students were asked to write during the half term holidays, due to limited classroom teaching time. Few example poetries were smoking, rain, Ebola virus, etc. (Photographs 3). A brief science poetry related enquiry activity lesson plan is given in Table 4.3.





Photographs 3: Science poetry on 'chemistry class' and 'smoking not cool'

<table>
<tr><td colspan="4">Learning objectives
To be able to write a poem on any topic linking to science.</td></tr>
<tr><td colspan="4">Resources
Students, Poetry book- Creative Trespass: fusing science and poetry in the classroom. ASE Edited by Mike Watts (2000), Prize- CGP books.</td></tr>
<tr><td colspan="4">Duration
Yr9- Winter break homework (December 2014), Yr8- Winter break homework (December 2014), Yr7- Half term holidays (February 2015) homework.</td></tr>
<tr><td>Teaching instructions</td><td>Interlinking subject</td><td>Enquiry based learning (EBL)</td><td>Open enquiry</td></tr>
<tr><td rowspan="2">To create original poetry linking to science with a title.
Voting for the best poetry.
Presenting it in the whole school assembly.
The winner received CGP chemistry/physics books and the names were posted on the school's web page.</td><td rowspan="4">Literacy
Reading, writing, listening, rhyming.

Computing
Using Microsoft Word to type (uploaded on the school web page).

Social and Cultural context
Gertrud Kolmar (1894-1943) - Jewish poet during World War 2 (History, Literacy).
Science and its relationship with emotions/ feelings (Psychology).</td><td>Orientation
Sharing poems in the classroom written by students from the book Creative Trespass.</td><td>Student</td></tr>
<tr><td>Conceptualisation
(Identify) What science has to do with poetry writing?</td><td>Student</td></tr>
<tr><td rowspan="2">Type of student engagement
Students listening to the poetry
Students use individual imagination skills, research on the topic and produce poetry.
Students predict and evaluate the non-science phenomena indicated in the poetry if it does not follow scientific theory/ principles</td><td>Investigation
(Create) To write an original poem on any topic in relation to science
(Exploring) The history behind writing poetry (secondary research).
.</td><td>Student</td></tr>
<tr><td>Drawing conclusions
Revisiting the broad questions asked at the conceptualisation stage.</td><td>Student</td></tr>
</table>

		Communicating findings Writing, reading and representing science poetry in the classroom. After voting presenting in a whole school assembly.	**Student/ teacher**

Observation/ Reflection Students liked the homework, as it was creative and different from usual science homework. I think it was very encouraging for them, plus it gives an idea to the english poetry lovers that they can write poetry while studying science in future. Some students find it hard to rhyme. Few students mentioned that they had to do hours of research on the topic before writing the poetry. Some students wrote very long poems covering a big part of the selected topic and a few wrote very short.
Next stage Introducing more opportunities for writing science poetry and organising related competitions. As starters or plenaries asking groups of 2 -3 to use key words of the topic and create a poem. To make them aware that rhyming the words is not necessary. In the beginning, decide word limit with the students.

Table 4.3: Science poetry

Later on, I tried to incorporate more poetry writing in the classrooms as topic starters. Year 7 and a few Year 8 students found it interesting and were enthusiastic about writing it while Year 9 students were not taking it seriously in the last few months. A thorough planning, rewarded competition (eg with house points) and involving english department could enthuse them more towards science poetry writing.

(iii) Treasure hunt/Problem solving

'Problem solving skills are prerequisites to solving engineering problems' (Moore, 2014, p. 5). These problem solving skills play a vital role in preparing for science and/or non-science future careers (Nasereddin, Clark and Konak, 2014). In the other intervention designs, problem solving skills were also incorporated. A treasure hunt intervention is adapted from a CaSE study which first involved decoding the codes, then design, conduct and evaluate an investigation for the hypothesis provided. Students were not given any clues on how to decode the numbers. This problem solving activity was designed as a goal where the solver had to devise their strategies (Watts, 1991). I have utilised 'goal strategy', with an open ended nature of solving problems. Students came up with plans and I made sure to arrange equipment for the next lesson. In the next lesson students, with minimum help, were allowed to conduct the practical and write conclusions. This game can be linked to EBL as treasure hunt activity allowed students to calculate, use equations, find the solutions and finally get the reward (Iuculano, Rosenberg-Lee, Richardson, Tenison, Fuchs, Supekar & Menon, 2015).

I replicated the same due to the benefits reported in the CaSE study as well as in recent literature. For example, Economou, Bouki, Kounenis, Mentzelopoulos & Georgalas (2015) valued the treasure hunt games and stressed the gamified elements and its role in enhancing the visiting experience. Moreover, Via Mineralia, a treasure hunt game, was used to find a different location in the mineral exposition museum, which not only motivated the students to find the place and read the placards, but also motivated the group of students through competition (Heumer, Gommlich, Jung & Mueller, 2007). Similarly, I instigated three groups in each class and the groups competed with each other to find five treasures (Kit Kat chocolate bars) which were hidden in the science laboratory, assembly hall and near student lockers.

Jagoda, Gilliam, McDonald and Russell (2015) also discussed the importance of gaming named as Alternate Reality Games (ARG) and reported positive effects of ARG in promoting STEM along with literacies and social justice and they suggested that 'although designers determine the challenges in an ARG, the players shape the experience and shared game world through collaborative actions' (p. 74). Similarly, I used a collaborative teaching strategy to enhance the experience and enjoyment among the girls plus incorporated specific literacy, numeracy, social and cultural knowledge links to the three science experiments. I believe that the social and cultural context understanding gave students the space to add to their prior knowledge and enabled them to 'apply the process to real-world situations' (Greenspan, 2015, p. 33) (Table 4.4).

In researching the literature, I found that in addition to the above mentioned treasure hunt, others similar (with technical differences) games have been incorporated and appreciated in arts, mathematics and geography lessons as well. For example, Ke (2008) used it to plot graphs, Ihamäki (2014) in teaching geography, Brown, Hughes, Crowder and Brown (2015) in science and maths. The last two researchers used Geocaching, a game where treasures are hidden in caches (small containers) and students used a GPS device (compass) to find the treasure. In addition to Geocaching, other recent research has also indicated the use of technical software and/or devices as treasure hunt devices. For example, Falloon (2013) used an app to enthuse and enhance literacy, numeracy and problem-solving skills in five year old students.

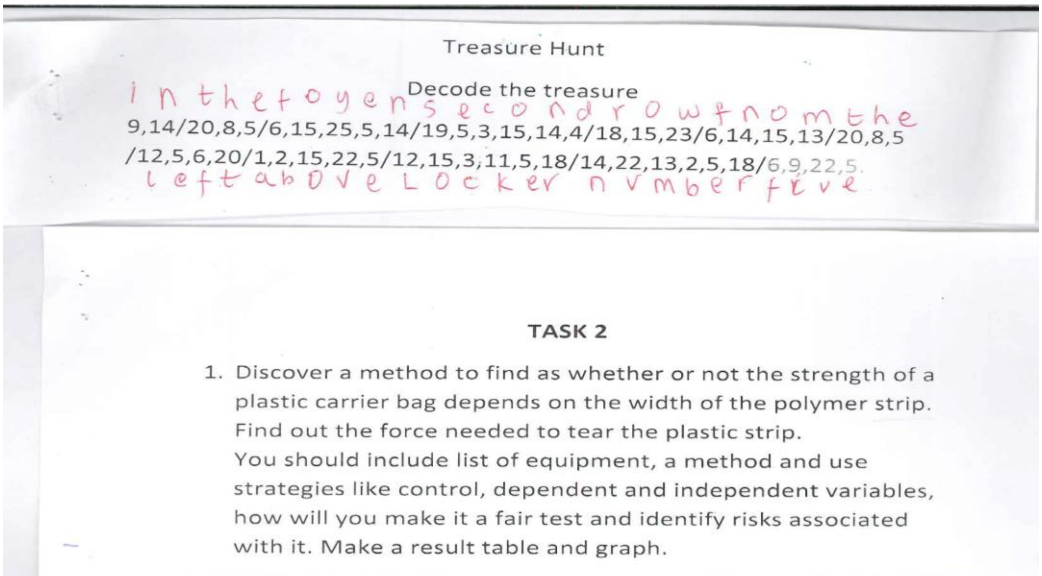
Findings reveal a complex matrix of influencing factors. These include the effect of embedded pedagogical scaffolds (eg. modelling, reflection time), corrective and formative feedback, text-to-speech functionality, imposed interaction parameters, impediments (eg. web links, advertisements, buying content) and the entertainment/ education balance. (Falloon, 2013, p. 505).

In the actual treasure hunt practice, I believe that the pedagogical scaffolding indicated above involved around 25 minutes designing and reflection time. Increasing this time would have provided better designing time. However, I believe that the time allocated was sufficient enough to plan a draft; extra time would have acted as a disruptive factor.

In contrast to Browns et al.'s (2015) work with gifted and talented (described above), Brezinka (2014, p. 100) reported that

Therapists used Treasure Hunt for a broad range of diagnoses. They judged the game as helpful in the explanation of cognitive-behavioural concepts, used it as reinforcement and reported it enhanced child motivation for psychotherapy and strengthened the therapeutic relationship with the child.

A science treasure hunt related enquiry activity (Photograph 4) lesson plan is given in Table 4.4.



Treasure Hunt

Decode the treasure

9,14/20,8,5/6,15,25,5,14/19,5,3,15,14,4/18,15,23/6,14,15,13/20,8,5
/12,5,6,20/1,2,15,22,5/12,15,3,11,5,18/14,22,13,2,5,18/6,9,22,5.

TASK 2

1. Discover a method to find as whether or not the strength of a plastic carrier bag depends on the width of the polymer strip. Find out the force needed to tear the plastic strip.
   You should include list of equipment, a method and use strategies like control, dependent and independent variables, how will you make it a fair test and identify risks associated with it. Make a result table and graph.

Photographs 4: Treasure hunt/ Problem solving practical on the strength of a polymer carrier bag

Learning objectives

To be able to use mathematical skills to decode the codes. Relate the hypothesis with real life situations.

To be able to plan investigations based on the given hypothesis. Carrying out the investigations, collecting data and evaluating the data using graphs.

Resources

Practical 1: Polymer strength: polythene bags, weights, balance, force meter, stand and clamp and basic stationary.

Practical 2: Pendulum: strings and pendulum balls stand and clamp, basic stationary.

Practical 3: Diffusion: Glucose solutions (0.1M, 0.3M, and 0.5M), potatoes cubes, knife, petri dishes and basic stationary.

Duration

Yr9- 3 lessons, Yr8- 3 lessons, Yr7- 4 lessons.

Teaching instructions	**Interlinking subject**	**Enquiry based learning (EBL)**	**Open enquiry**
Decoding the given code, design the investigation and find treasure. (Lesson 1) Designing investigations- in 3 teams based on the given hypothesis by listing equipments, a method and use strategy like control, dependent and independent variables, fair test and identify risks associated with the chosen experiments. Thinking and finding out context of the investigation (Lesson 2). Carrying out investigation (Polymer strength, pendulum, Diffusion, Data collection and graph making (Lesson 3).	**Literacy** Reading, writing, listening, discussing the experimental design. **Numeracy** Collecting numerical data. Looking for patterns. Using formulas to calculate- average, force, speed, surface area to volume ratio, moles). Using measuring instruments (force meter, ruler, stop watch, weighing machines etc.) Constructing graphs. **Social and Cultural context** Tesco polythene bag handles width (Chemistry). Muslim work on tents and bridges (History and Engineering). Chinese invention of papermaking using the cellulose in plant cells (History and Engineering).	**Orientation** Break the code. Find the location of the hidden treasure by decoding the complete code in two steps.	Student/Teacher
Type of student engagement Students solving problems. Students using three different hypotheses to design experiment. Students predict and evaluate the non-science phenomenon that does not follow scientific theory/ principles. Students use secondary data- researching on		**Conceptualisation** (Solve) How to break the code? Is it in the periodic table? Is it someone's name? (Judge, Design, Plan) What this hypothesis states? How to develop context? What materials are needed? What are the depended, independent and control variables? What are the associated risks?	Students

internet, pair/ group/ whole class discussion		**Investigation** Carrying out investigations (Polymer strength, pendulum, Diffusion) collecting data and graph making. Using secondary resources to design the experiments.	Students
		Drawing conclusions Revisiting the questions asked at the conceptualisation stage.	Students
		Communicating findings Doing, talking, writing, reading and demonstrating experiments to the whole class in groups.	Students
Observation/ Reflection 1. Treasure hunt activity went quite well in the class as there was a competitive environment and students wanted to find the treasure before others. 2. I believe that the activities were planned well. Worksheets, chocolates hidden appropriately, equipment ready for the practical. But a variety of other experiments should have been included. 3. I experienced problems in staying out of the process of understanding the hypothesis and designing the practical. Students kept on asking for my help although it was instructed in the beginning that help provided will be minimal. For this reason I kept on reminding them of the ground rules of the activity. 4. I have experienced how creative students can be while working in groups, even Yr7 students (youngest participants) were able to perform and carry out KS4 levelled experiments. 5. The pace was a little rushed for a few students. This requires more time to be given to the students. 6. Students did very well as they could decode the code, find treasure, design investigation, carry out experiments, make result tables and graphs. 7. A variety of designs were drafted by the students which were later modified after conducting internet research.			
Next stage Making the hypothesis simpler and clearer. Giving choice on experiments and introducing more variety of activities. Give extra time to research the experiment online (2 days) which could help them in designing the experiment with limited teacher help and to avoid a rushed pace. I could have given choices between the experiments and introduced a variety of different experiments.			

Table 4.4: Treasure hunt/Problem solving

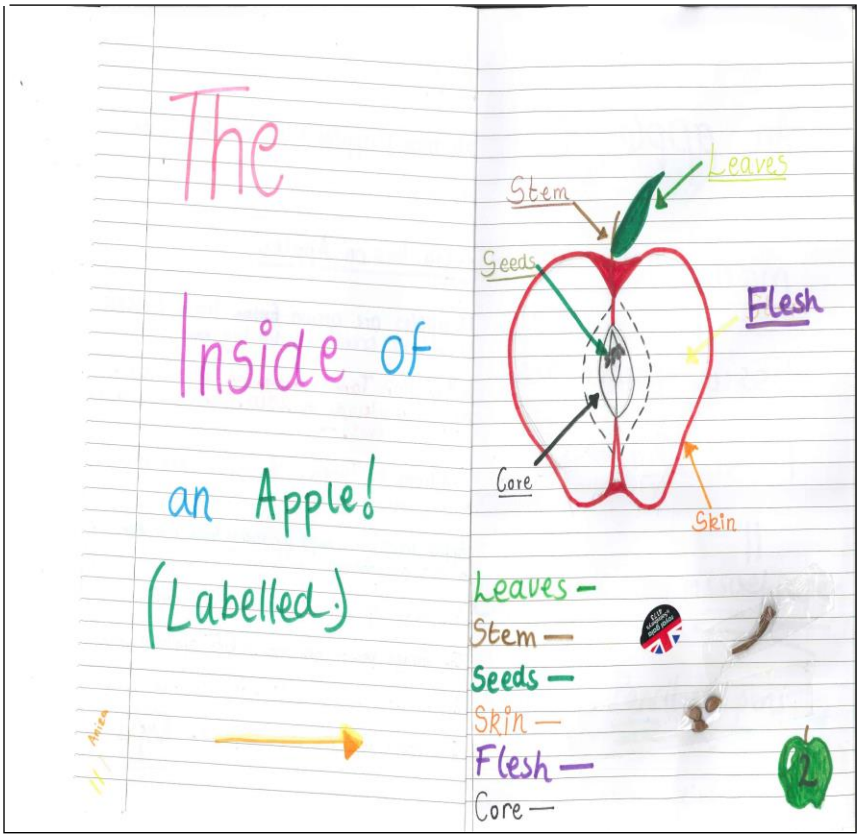
(iv)Learning in Depth (LiD)

'Students no longer have teachers to serve as their executive control' (Kitsantas & Cleary, 2016). The initial idea of this intervention is taken from Learning in Depth (LiD) described in Kieran Egan's Educated Mind (1997) and Future of Education (2008). LiD work is based on the Vygotsky learning theory viewpoint on stimulation of imagination through learning in depth, although a few alterations to the LiD project have been made to enhance students' participation, stimulate imagination and deeper understanding resulting in a sense of self (Egan, 2009, 2010, 2013).

Egan (2013), in conjunction with other philosophers, believes that an image of an educated person is not someone who has a breadth of knowledge about the world or depth of knowledge of something specific, but a combination of both. An example of depth of knowledge has been given by Bergtrom, Sadler and Sonnert (2016) who reported that students who have spent their out of school time in 'observing stars, tinkering with mechanical or electrical devices, or reading/watching science or science fiction' were more likely to be interested in choosing an astronomy career as compared to fellow students who do not spend their time in such extra-curricular activities. Piersol (2013, p. 11) criticised the in-school system as she believes, schools are like 'prison-houses' where children experience boredom rather than wonder based teaching and learning processes. She also believed that Egan's LiD (2010) practices can awake wondering, curiosity and enormous learning opportunities in children.

During the two week Easter holiday break (28-03-15 to 13-04-15), students were asked to make a scrap book on any topic of their choice. The LiD project aim is to develop an expertise of students on a given topic by the end of schooling with continuous mentoring from the teacher along the way (Egan, 2010). First, students were asked to choose a topic from the world of nature (Photograph 5), as Egan believes that topics based on nature enable students to wonder and think about the place of humans (and other living and non-living) in nature. Secondly, mentoring from me as their science teacher happened just once because of limited time and my part time commitment to the school. I did not design it to be a very long 2-3 years project because of the busy teaching schedule. Lack of mentoring support resulted in problems in looking for primary specimens, moreover, a few students wanted to change their topic and even after changing the topic, they did not complete the scrap book.

Finally, I am not entirely sure as to whether this work incorporated deep understanding of the student-selected topic, transformed their out of school experience and/or emotionally satisfied their science learning which includes independent choice and is not enforced. Further research is needed. The science LiD related enquiry activity lesson plan is given in the Table 4.5.



Photograph 5: LiD on 'Apples'.

<table>
<tr><td colspan="4">Learning objectives
To be able to prepare a scrapbook on any topic linking to science on the theme Nature</td></tr>
<tr><td colspan="4">Resources
Students, computers-internet, specimens (like flowers, leaf, pebbles), scrapbook, CGP book for the winner.</td></tr>
<tr><td colspan="4">Duration (28-03-15 to 13-04-15)
Yr9- Easter break homework, Yr8- Easter break homework, Yr7- Easter break homework.</td></tr>
<tr><td>Teaching instruction</td><td>Interlinking subject</td><td>Enquiry based learning (EBL)</td><td>Guided to open enquiry</td></tr>
<tr><td rowspan="3">Scrapbook on any topic related to nature.
To do secondary research using the internet and library books.
Make and present power point recorded presentations to the class.
Best presentation will receive a special prize.</td><td rowspan="5">Literacy
Reading and writing (while accumulating the research data).
Numeracy
Indicating facts and figures.
Computing
Internet research.
Social and Cultural context
Traditional medicinal plants- Indian Hakeems (Business, Medicine).
Cash crop (Business, Health Science)
Staple food (PSHE-poverty, health science- nutrition, agriculture, business, genetic engineering).
Life past, present and future (Zoology, Botany, health science, climatology).</td><td>Orientation
Find my topic: Students were asked to imagine a park to give a list of things which are in the park children’s area. The list was enormous. For this reason clues like Net, Animal springers, Teeter totter, Umbrella, rings, and Exercising machines were given. So that they come to the word NATURE.</td><td>Teacher/Student</td></tr>
<tr><td>Conceptualisation
(Decide) What will be my topic? (The topic was open ended)
(Devise) What primary and secondary data to collect?
(Arrange) How will I present my findings?</td><td>Student</td></tr>
<tr><td>Investigation
To create a scrapbook on any topic in relation to nature.
Primary and secondary data collection.</td><td>Student</td></tr>
<tr><td rowspan="2">Type of student engagement
Choosing a topic from nature (open choice).
Students’ collecting primary (specimens) and secondary data (internet, pair/ group/ whole class discussion).
Students arranging the information in a logical and presenting manner.
Students working individually.</td><td>Drawing conclusions
Answering the questions asked at the conceptualisation stage.</td><td>Student</td></tr>
<tr><td>Communicating findings
Writing, reading and representing the scrap book.</td><td>Student</td></tr>
</table>

Observation/Reflection 1. Students were happy to see that the homework was open ended. 2. All students (except three) managed to complete the homework, but mainly secondary computing resources were researched. Only a few used apple, flowers and pebbles specimens in the scrapbook. 3. It was completely independent work and I believe that the aim of giving them space to research a topic of their interest was achieved as can be seen in the questionnaire. 4. Presentation – The students were involved, but did not take the project very seriously and just finish it in order to get over it. Extra time was given to a few students so they could finish the scrapbook. 5. The students came up with different projects like flowers, pebbles, butterflies, waterfall, etc. Their used good scientific vocabulary and new ideas in the field of nature**.** 6. After the deadline mostly students brought secondary data from internet sources. Students were further probed to collect primary data, including pictures and items themselves. Later, students were asked to make a short presentation on power point, in a way that their siblings/ cousins/ neighbours currently studying in primary school can understand. Next, record their younger/older sibling's voices presenting the slides (using tab on the power point). By doing this I wanted my students to communicate their work and research with the wider community- starting from home. Similar research on a larger scale is recently published in ASERA by Forbes and Skamp (2016). Their research involved secondary school teachers and grade nine students as mentors to primary school students and found positive results in filling the transition gap between primary to secondary as well as mentors confidence building of the topic that they helped primary students to learn through community practising.
Next stage The idea was taken from LiD project, but due to time limitation I was unable to support the students as I should have in deciding and collecting the primary item. A more thorough planning and more teachers' mentoring support are required for the future. I will take the girls to the nearby park or grocery store and ask them to collect a few nature based items, draw the pictures, take pictures on a camera or if possible use the item itself to give them an idea of collecting primary resources. Moreover, linking individual topics like flower and a river and asking students in groups to record their presentations in the classroom.

Table 4.5: Learning in Depth (LiD)

After evaluating the LiD project, I carried out similar work with new Year 7s in September 2016. The only difference was that they were allowed to choose any topic in relation to science, so students choose subjects such as mobile phones, bubble gum, balloons, and teeth. Unlike previous work, the majority used a specimen and the research conducted was better than before; although again the project was planned for a short time. So instead of in depth learning, I believe it turned out to be an independent project work on a topic of the student's choice.

(v)Out of school visits

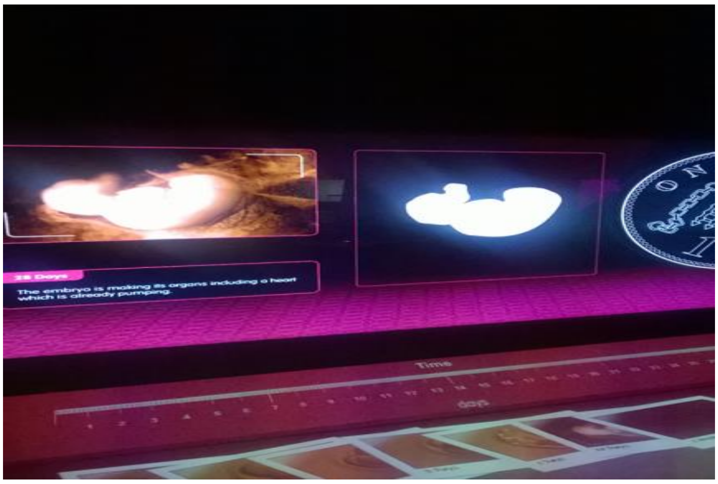
Over the last few years, there has been a major expansion in the quantity and quality of science outreach material (Adamson & Lane, 2016). When Amos and Reiss (2011) examined the influence of a five year residential field work programme on inner city UK students, they found that collaborative skills, interpersonal relationships 'social and affective domains" were enhanced in 11-14 year old students' (p. 485).

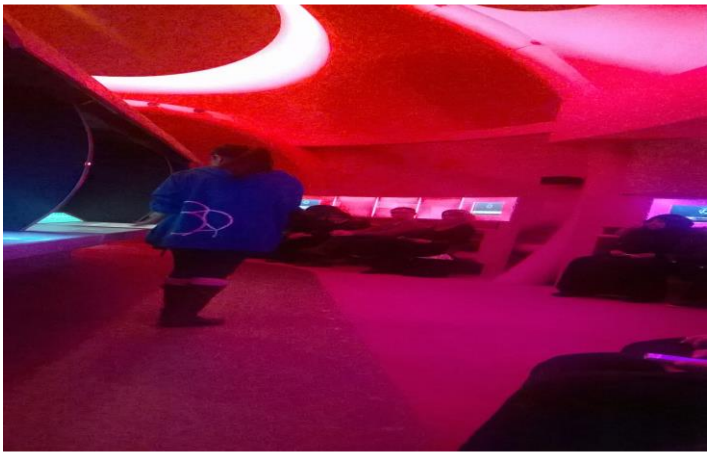
While, at the time of writing, the sector will be under greater pressure than ever to demonstrate the impact of out of school learning and access initiatives it is not entirely clear how to evaluate the success of such efforts. As Bell (2014) points out in a report to the Wellcome Trust, the majority of interventions in science and technology education lack high quality evidence about their effectiveness. University outreach programmes in STEM that address the career interests and academic readiness of potential students take on a wide variety of formats. The term outreach itself has misty degrees of acceptance and it tends to imply one of a number of interchangeable concepts including 'extension activities', 'service to the community' as well as 'service to special groups'. Alongside the pragmatics of filling places on university courses, 'girls' outreach' carries a tinge of social activism, attaining true significance in the context of reaching out a 'service to the disadvantaged'. There are commonly off- and on-campus activities, some short one-day events while others can be weekend or residential 'summer camp' programmes.

'Impact', too, is a term with multiple meaning and implications. To measure impact requires some evaluation of both the generation of particular kinds of knowledge and the value of the knowledge generated. 'The holy grail is to find short term indicators that can be measured before, during or immediately after the research is completed and that are robust predictors of the longer term impact … from the research' (Buxton 2011, p. 260). That said, knowledge itself is only vaguely measurable, at best observed through expressions of knowledge such as publications, papers, patents, and, in this case, students' perceptions. A key dimension of impact relates to whether the activity is intended to change awareness about a particular range of issues or understanding, or promotes decision-making of, say, one policy alternative over others. The latter is easier to measure than the former, not least because it is possible to observe whether decisions have been taken or not. In this way, such evaluative research is much more than mere numbers. While statistics play a role in the reality of educational impact, they provide an incomplete picture of the outcomes of an exercise such as outreach. Analysing the success of outreach efforts is not just a simple matter of unambiguous 'numbers through the door', and any meaningful demonstration of value must go beyond simple quantification.

A 'combined physical adventure and real-world experiences proved to be popular with students and their teachers, and opened up opportunities for learning and doing science in ways not often accessible in urban school environments' (Amos and Reiss, 2011 p. 485). In comparison to boys, girls exhibit gender gap, identity differentiation that prohibits them in joining out of school physics clubs and activities (Sadler, Sonnert, Hazari & Tai, 2012). However, Bergtrom et al. (2016) found a gender gap in an interest in taking up astronomy after secondary schooling. He found that girls who spent time in certain astronomy based activities (like star gazing) out of school hours encouraged more of them to take up astronomy based careers in the future as compared to their male counterparts.

During the period of approximately six months, three visits were organised by me and/or other science teacher. School visits for three different year groups were organised in relation to age appropriateness, topics being taught in school and exposing the students to science related career opportunities. In addition, these trips were finalised after a certain number of students brought approved consent forms from their parents. A few students did not attend the trip(s) as parental consent was not received by the school. Students did not have a say in selecting the trips, but students and parents had the freedom of sending and/or not sending them on the trips. Tal (2012) pointed out the importance of students' choice, strategies used in conducting a visit and student learning. Where, Faria and Chagas (2013) discussed that guided visits to Lisbon (Portugal) aquarium were beneficial for students and teachers, but did not give enough space and choice on the learning outcomes because of the lecture style guided visits. To avoid this, the visits planned for The Salehjee Girls School were not lecturing only; there were more hands on activities and at the same time, students were allowed to choose tasks during the visit to the planetarium. Tal's (2012) third point is to look at student learning - the students did worksheets along with the trips, but these worksheets were not assessed in terms of students' learning rather the aspects of like/dislike, enjoyment and general feeling about science were taken into consideration. A brief science school visit 1, 2 and 3 related enquiry activity lesson plans are given in Tables 4.6 – 4.8 along with few photographs (Photographs 6).





Photographs 6: Out of school visit (1) at the Centre of the Cell- the pod

<table>
<tr><td colspan="4">Learning objectives
To be able to promote scientific interest, knowledge and career aspirations in the field of microbiology and pathology (Photographs 6).</td></tr>
<tr><td colspan="4">Resources
Visits to the ‘Centre of the Cell’ (which is located above the Blizard Institute at Barts and The London School of Medicine and Dentistry) accompanied by three teachers, where students paid £5 each, and we used buses, trains and tubes which cost around £2 per child.</td></tr>
<tr><td colspan="4">Duration (March 2015)
A one day visit</td></tr>
<tr><td>Teaching instructions</td><td>Interlinking subject</td><td>Enquiry based learning (EBL)</td><td>Guided enquiry</td></tr>
<tr><td>Year group 7, 8 and 9 visiting Centre of the Cell research institute.
Students visit the Pod and involve with various computer generated quiz activities.
To observe working scientists.
To converse with a male and a female medical/ research student.</td><td rowspan="3">Literacy
Answering quiz questions and asking medicine related questions of the medical students.
Numeracy
Maths based interactive activities (increasing the number of pathogenic cells and its effects).

Computing
Using computers and computer generated devices to attempt activities.
Social and cultural context (discussed after the trip)
Smoking in relation to lung cancer (PSHE- personal and social effect of smoking).</td><td>Orientation
Observing scientists working in the labs.</td><td>Student</td></tr>
<tr><td rowspan="2">Type of student engagement
Students combining the past and future image of the scientist.
Students applying previous knowledge to answer the questions and assessing their own answers using the answer tab.</td><td>Conceptualisation
(Judge) How scientists work in the labs?
(Identify) What are the different types of cells?
(Determine/ look for evidence) How pathogenic cells affect health?
(Applying knowledge) Can cancer be treated now?</td><td>Student/Instructor</td></tr>
<tr><td>Investigation
Answer the questions (combination of MCQs or descriptive audio and video based questions).</td><td>Student</td></tr>
</table>

<table>
<tr>
<td rowspan="2"></td>
<td rowspan="2">Organ transplanting and religion (religious studies and Endocrinology)
The spread of cholera, malaria and jaundice in refugee camps. (PSHE, medicine)
Basic health requirements in poor countries (Economics, health sciences).</td>
<td>Drawing conclusions
Answering the questions that rose at the conceptualisation stage.</td>
<td>Student</td>
</tr>
<tr>
<td>Communicating findings
Doing computer generated activities, talking to the scientists during the visit to the Centre of the Cell.
After the visit, selected students were asked to share their experience with the whole school in the afternoon assembly.</td>
<td>Student/ instructor</td>
</tr>
<tr>
<td colspan="4">Observation/Reflection
Students enjoyed the visit.
Time spent inside the pod was 30 mins, the students found it too short.
Some of the scientific words like endocrinology, etc. were difficult for the girls to understand.
A few girls spent too long on the same activity and did not have a chance to explore other activities.</td>
</tr>
<tr>
<td colspan="4">Next stage
To incorporate more of these visits.
Ask students to research about the place before the trip.
Encourage students to ask questions/ difficult terms from the teachers and/or instructors.
Teachers need to be actively engaged with the students, so they do not spend too little or too long on an activity.</td>
</tr>
</table>

Table 4.6: Out of school visit 1

Learning objectives- To be able to promote scientific interest, knowledge and career aspirations in astronomy and physics.			
Resources Visits to planetarium and astronomy centre at the Royal Museums Greenwich accompanied by three teachers, where students paid a discounted fee of £7 each.			
Duration (April 2015) A one day visit			
Teaching instructions	**Interlinking subject**	**Enquiry based learning (EBL)**	**Guided enquiry**
Planetarium and astronomy centre visit (Yr8 and 9), where students were instructed: To attend the planetarium show To attend a physics based maths workshop.	**Literacy** Expressing their verbal and written thoughts after visiting the planetarium and working with a PhD science student. **Numeracy** Using formulae to calculate speed of car, racing cars, aeroplanes, and planets movement around the sun. **Social and cultural context** Muslim teachings about the	**Orientation** Observing and listening to the commentary on the solar system during the planetarium show.	**Student**
Type of student engagement Students observe the wonders of the universe. Students to integrate maths and physics in relation to daily life situations like driving cars to finding the speed of planet movements in the		**Conceptualisation** (Judge) How scientists work? (Identify) What are the different mechanisms operating the universe? (Determine/ look for evidence) How difficult/ long it takes to become a physicist? (Analyse) How we use skills in daily life activities that scientists use in their research?	**Student/ instructor**

solar system.	moon and universe in Quran (Religious studies/ literacy). Hindus pray to Sun (Religious studies). Cultural myths about falling stars indicating love, sun indication of power. Star orientation astrology and numerology concepts and myths.	**Investigation** Observing past, present and future research (inside the gallery). Solving physics problems.	**Student**
		Drawing conclusions Answering the questions asked at the conceptualisation stage.	**Student**
		Communicating findings Doing activities and worksheets, asking and answering the questions from the medical research students during the visit to the planetarium and astronomy centre. After the visits, selected students were asked to share their experience with the whole school in the afternoon assembly.	**Student/ instructor**
Observation/Reflection Students enjoyed the visit. Time spent for the above mentioned two activities was appreciated by all. Students were very engaged in doing the speed calculations.			
Next stage To incorporate more of these visits. Ask students to research about the place before the trip. Encourage shy students to ask questions/ difficult terms from the teachers and/or instructors. Teachers need to be actively engaged with the passive students.			

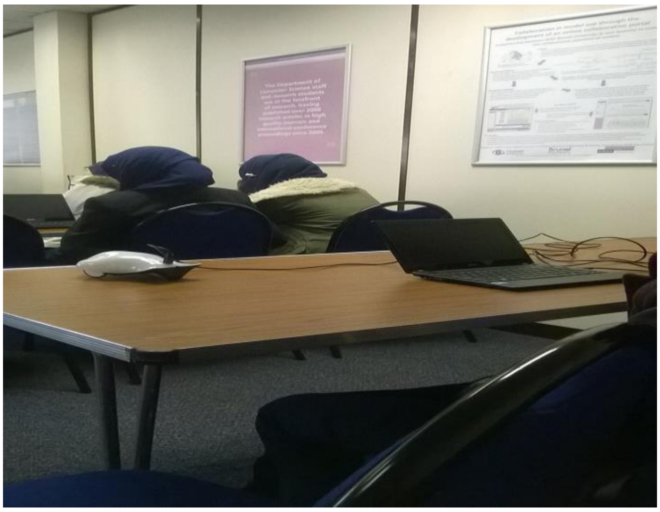
Table 4.7: Out of school visit 2

In addition to the above trips, in the same academic year 2014/2015, Yr7 and Yr8 students visited the Emirates cable car and Crystal Museum on the 25th May 2015 accompanied by three teachers. The Crystal Museum trip was lecture based at first and then free choice was given in choosing the activities. The students paid £1 for a single journey, later students were asked to fill in TfL designed worksheets linked to KS3 curriculum based on the topic of Motions and Forces.

Lastly, all year groups attended Thorpe Park on 27th April 2015 as an end of year trip accompanied by all non-science teachers. This trip was not guided at all as it was an end of year trip organised by the school. Later on the trip was linked to the topic of energy transformations (including gravity, inertia, acceleration, speed). After the visit the researcher discussed the science behind the roller coaster using 'The science of roller coaster' slides available at: https://www.thorpepark.com/.../thorpe-park-resort-pre-visit-science-slide. Later, students were also asked to complete a worksheet based on Kinetic energy, potential energy, gravitational potential energy etc.

Very few exercises in public engagement, such as the Brunel programme, have been subjected to strong evaluations of their impact. This programme is run largely as an educational exercise, but having direct access also allows researching a variety of internal questions. In this case, they define impact by two broad categories: (i) augmentation of curriculum provision, and (ii) enrichment of educative practice. Augmenting the curriculum focuses predominantly on improving students' understanding of the content of their studies, whereas enrichment of teaching and learning activities focuses on a broader range of outcomes, such as changing students' appreciation, attitudes and awareness of the processes of higher education. These two distinct rationales are important because the successful definition of impact may vary depending on what questions are being asked. As teachers, students, and other relevant audiences (parents, volunteers, etc.) work through the programme, it is important to know how they interact with it, what they thought of it, and what they 'got out' of it. A brief description on science university outreach related enquiry activity lesson plan is given in Table 4.8 along with few photographs (Photographs 7 and 8).

Photograph 7: Out of school visit (3) at Brunel University - chocolate welding activity



Photograph 8: Out of school visit (3) at Brunel University - robotics activity

<table>
<tr><td colspan="4">Learning objectives- Out of school visit 3
To be able to expose girls to university life and budgeting
To understand the science behind robotics (Photograph 8) and chocolate welding (Photograph 7).</td></tr>
<tr><td colspan="4">Resources
These students visited an all-day STEM event hosted by Brunel University London. They were not charged and the students used their student Oyster cards to travel from school to Brunel University London along with three science teachers. The other year groups did not attend the event as according to the organisers it was appropriate for an age fourteen plus group of students.</td></tr>
<tr><td colspan="4">Duration (10th December 2014).
Yr9- 6 hours (9am-4pm) and Yr8- 6 hours (9am-4pm).</td></tr>
<tr><td rowspan="4">Teaching instructions
Learning outside the classroom experience of interactive science learning and university exposure.
Chocolate welding, robotics, university student life, budgeting.
10.00 am Arrive on Campus.
10.10 am Campus Tour – Starting at the Wilfred Brown Building and ending at St. John's Building at 10.55 am.
11.00 am Welcome by Professor Dany Nobus, Pro Vice-Chancellor – St. John's Room SJ050. 11.10 am Designing Robots (Computer Activity) – St. John's Room SJ050.

12.20 pm Lunch – Lecture Centre,</td><td>Interlinking subject</td><td>Enquiry based learning (EBL)</td><td>Guided enquiry</td></tr>
<tr><td rowspan="3">Literacy
Conversing with the scientists, university students and organisers.
Numeracy
Using numerical codes using data programming to move/change colour of the robots.
Making a chocolate bridge and predicting the maximum mass it can resist.
Civil Engineering
Designing bridges based on the strength.
Business studies</td><td>Orientation
A tour to Brunel University London.</td><td>Student</td></tr>
<tr><td>Conceptualisation
(Arrange and analyse) How to arrange the correct codes resulting to command the robot.
(Predict and Design) How to make the strongest bridge with chocolate.
(Evaluate) How to save money for future studies. What Brunel University London offers in terms of STEM courses, funding, loan, accommodation etc.</td><td>Student</td></tr>
<tr><td>Investigation
Arranging codes to move/ change colour etc. of a robot using computers and app.
Making the strongest bridge with chocolate, Chocolate</td><td>Student</td></tr>
</table>

Room 211. 12.30pm Budgeting for University. 13.00 pm Leave for prayers. 13.30 pm Welding with Chocolate 14.50 pm Evaluation sheets. 15.00 pm Visit close and students depart campus.	Preparation for future budgeting (University lifesaving and expense) **Social and cultural context** (Discussed after the visit) Pros and Cons of robots (Debate). Flintstones vs The Jetsons (Debate). The UK's lowering labour cost vs UK employment.	welding. Successful budgeting for future.	
		Drawing conclusions Answering the questions asked at the conceptualisation stage.	**Student**
		Communicating findings Doing activities and worksheets, asking and answering the questions from the Brunel team of teachers and students during the visit to Brunel University London. After the visits, selected students were asked to share their experience with the whole school in the afternoon assembly.	**Student/ teacher**
Observation/Reflection 1. The visit went very well, students enjoyed the visit very much especially robotics and chocolate welding activities. 2. It was very well organised by Brunel University London STEM department. The team comprised of 4-5 STEM ambassadors and a team leader. 3. It was hands on and student centered, for example students were allowed to move the robots in different directions and change colour by giving computer generated commands to the robots. Students learned the engineering aspects of welding using chocolates. 4. I have learnt that how we can teach difficult aspects of robotics and engineering in a fun manner. 5. For preparation I contacted the STEM team leader at least 3-4 times to arrange a suitable time and date. I sent letters to the parents about the trip and collected the returned slips back. Filled out school visit forms, health and safety forms.6. After the visit, students were asked to fill in the questionnaire regarding the trip; all the students enjoyed the visits and learned about university life, budgeting in university, robotics and chocolate welding.			
Next stage 1. Introduce more of these sorts of visits in Brunel.2. It would be nice to do another activity relating to the microscope.			

Table 4.8: Out of school visit 3

In the academic year 2015/2016, Yr7 students visited Brunel University London again to attend Salters festival competition. The students won the treasure hunt competition. More of these trips will be organised in the future.

(vi) Meeting a scientist

The idea of meeting female scientists arose when I was asked to analyse 2013 Brunel Girls Allowed data. According to the students' feedback the most enjoyed activity turned out to be 'meet a scientist/engineer', as 55% of students rated it as 'Excellent'. Later, along with two engineers and a Professor of Education, I wrote an article entitled 'STEM sell: evaluating a university's outreach programme' which is under a review process for a science education based journal. Hazari et al. (2013) examined female interest in physics. She concluded that an awareness and discussion with female students based on the underrepresentation of women had shown a positive impact. Both the visiting scientists not only talk about their work as a scientist but also used strategies like identifying scientists using descriptions and pictures, discussed the under-representation of female scientists in the UK, the availability of funding in STEM especially for females and so on. One of the scientists was invited by the school on a voluntary basis; she shared her passion and enthusiasm for astrophysics and related fields. A brief description of meeting a scientist related enquiry activity lesson plan is given in Table 4.9 8 along with a photograph (Photograph 9).

Photograph 9: Meeting a scientist- an Astrophysicist

Learning objectives

This intervention was designed to expose girls to different science related professions and to enthuse them about careers in science.

Resources

Students, teachers, scientists (accompanied by resources)

Duration (January 2015 and 3rd June 2015 11:15am-11:45am)

<table>
<tr><th>Teaching strategies</th><th>Interlinking subject</th><th>Enquiry based learning</th><th>Forms of enquiry</th></tr>
<tr><td>External female speaker 1 and 2
To attend workshops (in-school and out-school) with an Astrophysicist and an Engineer about career choices in STEM and women’s choice.</td><td rowspan="3">Literacy
Expressing ideas and asking questions while meeting the scientists.
Numeracy
Doing verbal calculations in relation to the particle theory, demonstration by the scientist.

Social and cultural contexts
Under-representation of female scientists (PSHE).
Negative image of scientists (PSHE)
Pressure from society.
Gender stereotype.
Availability of jobs in STEM (Career counselling)</td><td>Orientation
My life journey into science.</td><td>Instructor</td></tr>
<tr><td rowspan="2">Type of student engagement
Students to use prior knowledge on science career options and arrange the puzzles, answer question asked by the Astrophysicist. And build new knowledge about female scientists
Completing the tasks: to identify the scientists, 10 types of scientists.
Asking questions on subject choices and career options after school.</td><td>Conceptualisation
(Applying knowledge) Out of ten which scientist, I can be?
(Questioning) Do we need A’s in science to get into science at university?
(Interpreting) Which subjects to choose in A levels?
(Judge) Why female scientists are under-represented?
(Analysing) What can us as females do to come out from this gender stereotype?</td><td>Student/ Instructor</td></tr>
<tr><td>Investigation
Grasping the positive experiences from the two scientists.
Researching on female scientists and their work not being</td><td>Student</td></tr>
</table>

		recognised. Clarifying misconceptions about science scientists and gender.	
		Drawing conclusions Answering the questions asked at the conceptualisation stage.	**Student**
		Communicating findings Doing, talking, writing, reading and representing on female scientists and their work.	**Student/ teacher**
Reflection Students were highly inspired by the female scientists' personalities and achievements. They listened to them very interestingly. Students asked questions on particle physics, astrophysics and comets. More of these sessions are needed to inspire more girls into science careers.			
Next stage Introduce more of these sorts of visits in and out of school. Encourage students to research the scientist's profile and think of questions before meeting them.			

Table 4.9: Meeting a scientist 1 and 2

After the above visits, I was unable to invite other scientists in the school. However, meeting scientists using virtual modes of communication would be a better option to keep them motivated in science (Lapka, Aguirre, Hill, Beni, N., Szillasi, Alexopoulos, Hochkeppel, Petrilli, Goldfarb and Bourdarios, 2016). As indicated by Goldfarb, Marcelloni and Shaw (2016) who describe that virtual visit are one of the programmes started in 2011 implemented by ATLAS Education and Outreach. This consists of audiences in the classrooms as well as not all students can reach CERN for geographical, economical and social reasons.

4.3 Summary

In summary, I believe that the use of an Enquiry Based Learning (EBL) strategy and Bell's model of successful intervention has made a contribution in achieving the purpose of an increasingly positive approach towards science and integrating willingness within the thirty girls in opting for at least one science at A-levels. The willingness to continue with science in the majority of the girls with time provides evidence of a successful study.

Moreover, I believe that I have achieved the purpose of incorporating better teaching and learning practices in the school. Firstly by incorporating mainly guided (teacher and student led) and open (student led) enquiry techniques, secondly incorporating numeracy and literacy in science lessons and thirdly by incorporating social and cultural context and linking with other school subjects such as religion, PE, history, geography, computing etc. Moreover, by incorporating other subjects and general issues, I believe helped the students realise that school science is not an isolated subject but instead it makes a big contribution in the world, with its involvement in everything from films to solving problems of health and pollution.

Furthermore, in accordance with MacDonald's (2014) and Bell's (2014) recommendation, constant practice and continuous testing/ refining was incorporated and became quite manageable as firstly I did not follow a strict lesson plan, changed teaching and learning strategies where needed while carrying out the intervention study and even after a year-long study I managed to incorporate similar interventions with variations where needed with a new year group and the work is in progress.

Chapter six will provide results to the above mentioned intervention design and implementation. First the next chapter – Chapter Five will provide findings from the university based research mentioned in Chapter Three. Chapter five is divided in two sections; the first section will present the findings from the narrative enquiry styled semi-structured interviews from the scientists and non-scientists (Phase One) presenting stories, numbers and a few quotes. The second section will present the findings from the descriptive questionnaires presenting percentages, a few quotes and summarised stories.

Chapter Five: Findings

Section One

Phase One: Scientists and Non-Scientists

5.0 Introduction

The twelve participants in this first phase are six male and six female, of whom six are scientists and six non-scientists. Scientists' and non-scientists' pseudonyms, gender, category and roles are listed in Table14 below. The respondents were not asked their age, although the majority were 'senior' in the university and therefore over the age of forty (Table 1.1). A note is needed here on the UK school science at the time - young people forty or so years ago studied a fairly common curriculum consisting of a range of school subjects at secondary level, from ages eleven to fourteen. At that point they were offered a choice in preparation for their Ordinary Level (O-Level) examinations at age sixteen. Depending on the school, for the next two years they focused on between seven and ten subjects, wherein science may have been offered as a single integrated subject, or as separate biology, chemistry and physics. Taking three separate sciences would constitute some third of the possible curriculum time at this level, and would already indicate a positive inclination towards science in later study. Success in subjects at sixteen would then herald study in the next two years of post-compulsory education to Advanced Level examinations (A-Level), which act, amongst other routes, as preparation for university entrance. The implication here is that 'science or non-science' can be set fairly solidly within the curricular science as young as an age of twelve or thirteen.

	Participant	Category	Academic roles
1	Dennis	Male scientist, PhD	Senior Lecturer in Computer Engineering
2	Parker	Male scientist, professor	Professor and Deputy Head of School
3	George	Male Scientist, professor	Professor and principal researcher
4	Adam	Male non-scientist, PhD	Senior Lecturer in Education
5	Norman	Male non-scientist, PhD	Senior Lecturer in English Literature
6	Philip	Male non-scientist, professor	Professor of Music, Head of Music Research
7	Jane	Female scientist, PhD	Lecturer in Experimental Particle Physics
8	Daisy	Female scientist, PhD	Senior Lecturer in Education and researcher in Experimental Particle Physics
9	Grace	Female scientist, PhD	Lecturer in Mathematics Education
10	Greta	Female non-scientist, PhD	Lecturer and Course Leader in Education
11	Nikki	Female non-scientist, professor	Associate Professor in Education
12	Danielle	Female non-scientist, professor	Associate Professor in Education

Table 5.1: Interview participants (with pseudonyms), category (scientists or non-scientists) and their roles

Now I will present my findings in broadly four sections which are as follows:

(i)Transformation and change: where I will present the summarised stories of the scientists and non-scientists under three themes (ii)Perception of GF: where I will use a few quotes and main outcomes of the GF that emerged from the interviews

(iii)Perception of SA: where I will use a few quotes and main outcomes of the SA that emerged from the interviews

(iv)Summary -Phase One: where I will apply the seven Sci-ID model ingredients to summarise the key outcomes.

5.1 Transformation and change

As mentioned in Chapter Three, aggregation process - synoptic analysis was employed to construct summarised stories of individuals. These stories are about the participants using 'third person' voice by me. This gave me the understanding of individual's transformational life journey into and away from science. The stories given below are published in IJSE (Salehjee & Watts, 2015). The data focussed on the following three themes or three 'life trajectories' (Table 5.2):

(i)Progressive TL and smooth transformations, where scientists and non-scientists 'always knew what they were going to do': they never questioned their ability or career direction; they were always going to do science or arts exhibiting stability in their identities from a young age. The movement away from their respective inclination was either very small or negligible. Therefore for them the meaning-making filter, their preferences and natural inclination were open for what they wanted to study (science or non-science). From a young age they exhibited a certain drive/push (IIA) that go against GF, SA, triggers or interventions (TL experiences) or go with them.

(ii)Progressive TL and wavering transformation, where there was some ambivalence, indecision, non-commitment and happenstance but no single major 'shaping event' one way or the other, into or out of science. Scientists and non-scientists could have chosen either route but 'ended up' in one. Exhibiting fluid identity and the TL experiences had an intermediate impact in their movement into or away from science. Therefore for them, the meaning-making filter, preferences and natural inclination were open for both science and non-science choices. The drive/ push (IIA) of either going against or go with the GF, SA, triggers or interventions (TL experiences) exhibited ambivalence. Later, TL experience(s) after the age of seventeen, exhibited medium movement into science or non-science.

(iii)Reconstructive TL and wavering transformation, where respondents identify clear moments or periods in their lives, particular events or 'twists of fate' when decisions were arrived at, their choices made, they became resolute in what they were doing. Exhibiting fluid identity where the TL experiences had a high impact resulting in movement towards or away from science. These clear moments in life established a certain drive/ push (IIA) that goes against or with the GF, SA, triggers, events or interventions (TL experiences).

Now I will present the twelve stories under the three themes mentioned above (Table 5.2).

	Into science	**Away from science**
Progressive TL and Smooth transformation	Dennis George Grace Parker	Adam Danielle Greta
Progressive TL and Wavering transformation	Daisy Jane	Nikki
Reconstructive TL and Wavering transformation	No scientist from this category	Norman Philip

Table 5.2: Transformation and change – Phase One

(i) Progressive TL and smooth transformation

Into science

Four of the six scientists interviewed (Dennis, George, Grace and Parker) never really considered doing anything else other than science. For scientists the very suggestion that they might not do science seems not to have arisen. It is not clear in their stories quite how the initial interest and commitment arose, but it seems to have been consolidated around the early age of eight (mentioned by two). These scientists could recall TL moments (experiences) in their childhood that seem confirmatory exhibiting progressive TL and smooth transformation. For example:

> Dennis never questioned his ability towards science exhibiting a strong IIA. For instance, he was always interested in astronomy and space flight, rather than biology or chemistry. Even as a young boy he was obsessed with space and rockets, and—if there was a (mild) transformative moment, then the *1986 appearance of Halley's Comet* was a confirmatory hinge point for getting into sciences. Exposure to science-related topics in newspapers, science fiction magazines and an inspirational physics teacher made him progress easily on a science path. Another mild TL experience (trigger) at the age of 17 occurred when his maths teacher doubted Dennis's ability, but he took this as a challenge and excelled in the subject. He never had to make an extra effort in doing science as compared to other subjects because he was *naturally quite good at it*. Denis believes that one of the most important factors in motivating students into science is the awareness of science career opportunities which to some extent depends on the career choices made by the parents themselves.

> George did not remember asking himself about his ability into science and he knew that he wants to do science, from childhood. He found school science to be *great fun* he was good at it and *would not even take 20 seconds*, to make the decision to study science in school and beyond. There was no particular inspiration for sciences from out-of-school experiences, and he *purely and simply enjoyed school science experiences*. There were no trigger moments and, like other respondents in this theme, George, believes that it was purely his will and not the influence of teachers, parents or peers to carry on with science. However, he really appreciated an inspirational maths teacher because he would *rarely stick to the curriculum; just did what he wanted—and that was super*. He believes that *nothing in this world can make him move from sciences at all*. His involvement in sciences and related fields has helped him to *understand a complex organisation and how they change and how they won't change*. Now, after 25 years, he has become the head of research and *you can't do better than that*. Like Dennis, he also emphasised the need of better science career counselling to motivate students in science.

> Grace's, believes that she chose to study maths as her father was a mathematician who ran after school maths clubs for her and friends, her step-father an engineer, who helped her with physics. When she turned 16 she

chose maths because it was *easy* and a *lighter subject* as compared to the arts. She studied english at A-level, but did not continue with this because she was *not much good at it as compared to maths*. Grace was clearly influenced by parents in her decision towards mathematics. She cannot imagine moving away from mathematics and believes that the single most important factor to motivate more young people into maths and sciences will be incorporating relevance of science from daily life experiences.

Parker, too, was ‘always destined’ to work in the sciences and always believed in himself, who can do physical science. Again, this was a smooth transition, and he found all the physics, chemistry and maths teachers inspiring and fairly influential throughout A-level study. He grew up in the era of space age; moon landings, computer advancements etcetera, and public interest towards these innovations were very high and built his interest. His (mild) transformative moment came in rejecting medical sciences in favour of the physical sciences: he was put off medical sciences because *both parents were in medicine*. He never wanted to work with patients and so crossed off medicine as an option, still retained his enthusiasm for physical science. Working on fundamental science on current long-term projects and working towards achieving ‘grand goals’ has kept his interest alive. Then he added, *it’s always been my job and therefore, by definition, it’s my interest*. Parker perceives that as a scientist, his awareness towards daily life science makes him better informed *so you will be a little more-informed spectator*. He also believes that his full journey in sciences from the age of 15 to 50 was highly positive which has helped him to choose a career and stated, *I am extremely fortunate. I couldn’t have wished for a better outcome*. One of his main recommendations to improve the uptake of science careers was to diminish the negative perception of scientists’ especially female scientists.

Not into science

Similarly, there are three non-scientists (Adam, Danielle and Greta) who never really contemplated doing science; their interest always lay elsewhere (for example, in literature). For example:

Adam began to think about as whether he can do science or not at the age of 13–14. He was required at school to choose at least two of the sciences, so decided to opt for biology and physics, but not chemistry, because he *hated chemistry*. He found both his science and non-science teachers influential, but stopped studying sciences at the age 16 because he particularly always loved reading english literature and history, much more so than any of the sciences, or anything else for that matter. He was good at maths, continued to pre-university level, but believes that studying english is much rewarding and generous as compared to maths. However, as far as he could see, mole calculations had no conceivable benefit, were utterly and completely pointless: 'Case closed'. Why had he hated chemistry so much? The immediate reply was *MOLES!* And he declared that mole calculation completely *switched me off from chemistry*.

Danielle's home environment was very philosophical not least because her father had studied theology and philosophy and had numerous philosophy books in his study that created a love for arts, music and drama at a very early age, *so this is where my heart is, I suppose*. Her parents, siblings, nephews and nieces are all artists, and she stated *that there is obviously no hope for any of us* where the sciences are concerned. Moreover, Danielle believes that, in comparison to science, non-science studies were highly stimulating towards her imaginative thinking and the she found freedom of expression rather than right and wrong answers in science. She also stated that *I really hated mathematics more than I can possibly say even from a very young age*. She really doubted her science ability, as completely agrees that she was *quite hopeless in science*, despite the efforts of science teachers, could not even grow mushrooms and does not even like gardening because *it ruins my finger nails*. Finally mentioned that science teacher should relate the content with real life/ daily life experiences to motivate young people towards science.

Similarly, Greta, a non-scientist, was *not naturally inclined towards sciences and did not achieve high grades in it*. Rather, she was fully inclined towards english and arts. There is no single trigger that turned her away from sciences to take up english, she simply had a 'feeling' at a young age that she was not good at science, she did not work well with the science teacher, progressed without difficulty, with her english teacher and decided to choose humanities at A-level and university. Her parents were not influential; *they encouraged me to do whatever I wanted to do*. So, she was never pushed to study sciences, had no particular guidance as to what to choose and so continued with the subjects in which her interests were stronger. Greta's grumble was that secondary school science entailed a *huge emphasis on subject knowledge*, and any focus on practical activities in the class diminished rapidly in secondary school as compared to primary school teaching and learning. Continuing with science was simply 'not for her'. The only way Greta, links to science is through her daughter and husband who are in science related professions which made her balances the science and english backgrounds. Finally, Greta's research interest lies in finding about girls science stories, which she relates to her own negative science experiences at school.

In summary, the above scientists and non-scientists exhibit quite smooth transformation and seem to have reached stability in either science or non-science at a quite an early age. Therefore, studying science for scientists and non-science for non-scientists was 'always' their intended goal in life.

(ii) Progressive transformational learning and wavering transformation

The transformative moments here seem more marked, more significant but fall short in our sense of being sharply transformative.

Daisy had always performed much better in physics and maths than other subjects. Even early in school, she thought she would take a degree in sciences. While her teachers were good, the subject itself was not particularly inspiring: *I think school science was just school science nothing particularly stands out*. One problem was that she enjoyed music and wanted to combine this with physics, perhaps taking a degree in *music technology or sound engineering or something like that*. Unfortunately, there was no such university degree available at the time. Her (mild) transformative moment came to 'close' her wavering when her teacher organised work experience during her A-level course, planning satellite observations in Oxford for two weeks. The experience was so positive, and she completed the two weeks, even though her classmate decided not to continue after the first day. She made up her mind to opt for astrophysics and now Daisy is part of the High Energy Particle Physics experiment, the Compact Muon Solenoid (CMS), at the Large Hadron Collider (LHC) at CERN, Geneva: one of two general purpose detectors at the LHC, which has been optimised to search for the predicted Higgs Boson. Daisy, also mentioned that if because of certain circumstances, she will ever move away from a science career wise, she might pursue music, but still that change will not transform her completely away from sciences.

Similarly, Jane was always able to do science. Even now she is never bored of it, *It still gets me up from the bed in the morning*. She completed her doctorate whilst at Imperial College London working on the ZEUS experiment at Deutsches Elektronen-Synchrotron (DESY, the German Electron Synchrotron) in Hamburg, Germany. Like Daisy, she too is an active experimental particle physicist, for 7 years a member of the CMS experiment on the Large Hadron Collider at CERN. Her story, demonstrates a sense of puzzlement during the time she was making choices for A-level at age 16. She had chosen three subjects, *chemistry, because my father was a chemist; physics because physics goes along with chemistry, and maths* (here she gave a shoulder-shrug, no reason given). She declared, *I did not like biology even before I was 14. It did not float my boat (laugh), I was really not interested!* However, she found herself *sitting on crossroads* at decision time between science and languages, and she was equally good at both She was sure, though, that she liked sciences more than languages and opted for these at A-level. She soon found she was very good at maths, preferred physics to chemistry and opted to take double maths in the second year of the programme. As a result, she began to look forward to a career in maths. But, then a small twist: the physics teacher pressured her to enter a ‘special examination’, Physics S-level a higher level examination above A-level. She hesitated and there followed an intense argument with the teacher, she was afraid she was not capable of tackling a physics exam at this exalted level. In the event, she relented, sat the special paper and passed. That decided her future to become a physicist. She said, *after passing the exam my confidence level was boosted up*. Jane also mentioned that in A-level, in her school there were only four girls who were studying physics, but that did not put her off from physics. However, she acknowledged her concern that the majority of the secondary/ A-level girls drop physics studies, which can be due to the lack of female role models. For this reason she runs workshops and programmes to motivate girls into physics.

Nikki did not remember asking about her science ability, but she did think about the different branches of science at the decision making age of fourteen. Nikki took physics at A-level due simply to school pressure. She *hated physics teachers and the physics book* and opted for maths at university, but struggled in the first year of undergraduate studies because of the physics components in the course. She believes that her mother incorporated interest towards maths at pre-school level, by the use of quiz and rod technique and through these techniques Nikki was able to make sums and work out the problems at a very early age. She did not find the experience *worthy enough for undertaking a PhD* *and so I did a PhD in maths Education*. These days she enjoys the cooperative, vast and unlimited structure of the working environment in maths education rather than in mathematics itself, and views herself to be moving progressively away from even this contact with mathematics as she becomes increasingly sociological in my outlook.

In summary, the above scientists and a non-scientist exhibits wavered transformation after the age of sixteen. They mentioned specific act of indecision towards selecting their science or non-science subjects, where few principal progressive TL experiences helped them to decide their science or non-science future.

(iii) Reconstructive transformational learning and wavering transformation

Two of the twelve, Norman and Philip (non-scientists) are grouped under this category. As these non-scientists can recall 'sharp' regressive TL moments after the age of seventeen, which decided their education and career. These regressive TL experiences/ moments helped them to recognise and accept non-science progressive TL experiences. This form of regression and then progression was not experienced by the scientists.

Norman had not questioned his route into science, and he simply took sciences at school. None of Norman's parents and/or other family members studied at university, and for them it was a very privileged entity to study at university, science or non-science was not a problem. However, his parents through conversations always encouraged him to choose a degree that provides a better future (career wise). Norman continued to study science till the age of 20, enrolled in a marine biology degree. At this point his life took a 'U-turn' because he failed a second-year marine zoology examination. He was 'confronted by failure', began to wonder and asked himself the question: *What do I really want to do? Have I really chosen this wisely?* He was very interested in the history of science, reading popular science works such as those by Steven J Gould, and always enjoyed science fiction. He did not, though, enjoy laboratory work and disliked the idea of working in labs for hours and hours as a scientist. At school his 'sciences friends' were quite influential whereas, at university, he made friends with english students. He took 'time out and, after 3 or 4 years of self-examination' he began a degree in english literature and philosophy. At present, he lectures in english using science fiction in his own writing. He is not, he says, *completely science illiterate, but my limits are to read and write science fiction* *and understand the issues published in newspapers* and cannot consider reverting back into science education and career.

Philip was *just expected to do science*, reflecting his subject choices at the age of 14 and 16: maths, physics and chemistry. He was never very sure, always in a state of *continuous nervousness* but with a sort of the underlying pressure from my father to do sciences. He attended a technical school, in an under-represented Liverpool area, where there was more direction towards science subjects (because of the mining industry), and a prevailing sense that only the 'weaker' students opted for art subjects. He wanted to be with the *trendy and clever people, but struggled to the limit*, failed physics and chemistry exams at 17 and, at the same time, discovered his love for music through a beautiful piano at school. Without any formal piano training he would play the school piano in his free time. After his failure in science exams, the deputy principal of the school asked him *what was it Philip? Too much music? I said yes and he said, right, you can do music this year. Brilliant! He saved my life.* As a result, he relinquished chemistry, took up music in the second year of the programme*. Unbelievably, I got a B in maths and B in music, even after studying only one year of Music* (Appendix 6). He continued with maths in his first year of university (B is a good grade), but then *escaped the sciences*. Now Philip, is one of the prominent UK musicians, and believes that as a Buddhist he admires scientific knowledge based on energy transfers and nature. His school science was taught in a very *old-fashioned way . . . it was certainly not a question of nurturing talent*.

In summary for Norman and Philip, stability was achieved after confronted with failure (regressive TL) in exams resulting in transformation away from science.

After looking at the three life trajectories, I will now present GF and SA influences that emerged from the interviews.

5.2 Perception of global forces (GF)

I did not ask scientists or non-scientists direct questions in relation to their perceptions on GF. Half of the scientists and non-scientists did not mention their experiences in relation to GF, while the other half mentioned their experiences as shown in Table 5.3.

Responses	Main outcome
I was quite abnormal to be a girl who really likes mathematics. There weren't many girls in my A-level class. *I honestly don't think this affected me (Grace).*	Gender: Two of the twelve (female scientists) sensed it but rejected the influence.
It is much about me being a girl, but not just looking physically like a girl, but looking like a girl in a way I did in mathematics, the way I portrayed myself (Nikki).	Gender: Two of the twelve (female non-scientists) sensed it and accepted the influence.
The typical male response is that I always thought that I could do whatever I want to do, there was nothing particularly implied that I couldn't (Dennis). (See Appendix 5).	Gender: One of the twelve (male scientist) indicated gender based IIA.
Yes I am from Liverpool working class family, …I am also a Buddhist and a lot of Buddhism is to say it's quite scientific like how energy moves how energy transfers so there are so many things in it that links to science and nature (Philip).	Class and religion: One of the twelve (male non-scientists) mentioned a link between class and his religion.
Maybe one of the things is that people don't see appropriate next progression career role models. Therefore it is not that they are put off doing science at school, so I think the [gender] bias in schools is probably gone now. But, looking ahead, young women say "Ok, I Can do physics or mathematics but I do not see any female physicists who have done these degrees in any position in any company" (Parker).	Gender: Three of the six (scientists) observations were based on gender inequality in sciences.

Table 5.3: Global forces - Phase One

5.3 Perception of social agents (SA)

This section will present the findings based on the scientists and non-scientists perception on TL experiences that they gained from parents, school science experiences and teachers.

(i) Parents

Question 8 asked the participants how influential, from the age of sixteen onwards, were their parents in making decisions towards science or non-science subjects? Eleven of the twelve scientists and non-scientists found parental support to be quite internalised. One of the twelve, Adam (non-scientist) did not mention whether his parents were supportive or not and completely denied parental influence. As he stated: *Not- no. it was my decision completely!*

A few responses and main outcomes based on parental influences can be seen in Table 5.4.

Responses	Main outcome
I think [parents were] relatively influential, I think it's difficult to kind of classify that exactly because neither of them never went to university … I think it was perceived that if you go (to university) and do something… they did not put any pressure on me (Norman).	The majority of the scientists and non-scientists, parents were non-influential in deciding science or non-science future.
My dad was hugely influential, he was a secondary school teacher… he taught in teacher education for secondary teachers (Grace). *My parents, siblings, we are all artists…. So there was no hope for us obviously (Danielle).*	Two female scientists and one female non-scientist adopt the same profession as their parents.
I suppose not overtly, but they were always, like, "whatever you want to do - as long as you do your best - we are happy". (Jane). *My mum hated mathematics, still hates mathematics, but she was a primary school teacher..in pre-school she gave me a lot of attention and she helped me with this and I became very interested in doing sums … I don't know where it comes from exactly, partly from family. I don't believe in its inside us, although I did at one stage (Nikki).*	Two females- one scientist and one non-scientist retention towards positive parental influence became weaker in later years.
Well both my parents are scientists, so I suspect that might have put me off, but at least I had, I guess, a reasonably realistic idea what science was like. Although they were both in the medical sciences rather than Physical sciences (Parker). *There was a kind of latent pressure from my father and from the school that you opt to do science and if you are slightly weaker or indulgent, then to do Arts. (Philip).*	One male scientist and one non-scientist rejected parental influence.

Table 5.4: Parents - Phase One

(ii)School science curriculum and relevance of daily life science

Question 9a asked the scientists and non-scientists how school science or awareness of science in daily life had affected their interest in science. This question is compared and contrasted to detect whether it is learning through school science curriculum or it is science learning in relation to daily life experiences that has or has not engendered any interest in the sciences.

Nine of the twelve Daisy, Dennis and Parker (scientists), and all the six non-scientists, were more influenced through the awareness of science in daily life as compared to school science curriculum, which they experienced through personal out of school science experiences. The different daily life, social events/ artefacts that acted as triggers and means for keeping an interest alive in science included science innovations (Dennis, Parker) media, books and/or magazines (Dennis, Danielle, Greta and Norman), public interest (Parker), science fiction (Adam and Norman), Victorian journals (Adam), mushroom propagation (Danielle) and nature (Philip). A few example responses and main outcomes based on parental influences can be seen in Table 5.5.

Responses	Main outcome
I remember quite enjoying school science. *We did some interesting things where you could choose to cover certain topics ... I suppose I was aware of stuff but did not go out my way to read New Scientist and stuff. So I was aware but not massively influenced by it (Jane).* *Yeah, it was quite influential I was quite interested in school science I enjoyed it. Not daily life experiences –* *it was purely 'school' (George).*	Only two scientists became interested in science through science curriculum.
It didn't have a particularly negative effect, but kind of … I can't say that it was particularly inspiring, NO! I think school science was just school science, nothing particularly stands out. It did not put me off doing it but neither did it inspire me to do it (Daisy).	One scientist had no effect of the school science curriculum.
TV programmer(s) like Horizon and things to do with space with the news were always that I was interested in, I wanted to find more about, so I used to get astronomy books for Christmas and things like to keep me interested (Dennis).	The majority believed that they are interested in science through their awareness with daily life science and media.

Table 5.5: School science and relevance of daily life science - Phase One

Question 13 (in addition, to the above) asked an open-ended question on the positive and or negative perceptions of the (current) school curriculum. I asked this question to find out their perceptions of the science curriculum currently taught in schools. The majority of the scientists and non-scientists were not entirely sure about what is taught in the schools nowadays, so attempted to answer this question in relation to their interactions with first-year undergraduate students (Dennis), their own children's experiences (Parker and Greta) and through other personal observations and interpretations. Danielle did not answer the question at all. In answering the question, scientists and non-scientists suggested a few solutions to improve science curriculum. The majority, eight of the twelve, Dennis, Jane, Daisy, George, Grace (scientists) and Adam, Norman and Nikki (non-scientists) perceived science curriculum as assessment-driven from their past and/ or present experiences. Two of the twelve, Parker (scientist) and Greta (non-scientist), mentioned the lack of experiments/ practical work in the current school curriculum. Four of the twelve, Dennis (scientist) and Nikki, Norman, Philip (non-scientists) mentioned that the science curriculum provides too limited set of knowledge that does not include diversity and cross-curricular links. In order to deal with this issue, Philip, saw that science should not be learned in isolation, for example, the inclusion of science in teaching music could be beneficial. A few example recommendations from the scientists and non-scientists can be seen in Table 5.6.

Responses	Recommendations
I think the school curriculum is too assessment-driven. It is perfectly clear that it's too concentrated on getting people through assessments. It is not about raising inspiration and I think that's a big worry. I don't think much of the National Curriculum in a way (George).	Assessment driven.
I think the experimental side is the weak part. I think health and safety issues are completely made up. I think it's a good excuse to not to do things. The Royal society of Chemistry some years ago looked at a number of experiments that were part of curriculum that had been removed or the schools had not doing on the grounds of health and safety. I think, from memory, there were about 60 of these, one they found was covered by health and safety, four or five with some fairly trivial change met in the current guidelines and all the other ones were an excuse (Parker). *I think it's really sad that teachers see, in my view, a lot of teachers did not want to set up practical science because it is obviously time consuming, the children are more likely to mess about, there are behaviour issues in class rooms, health and safety issues and all that, I know it definitely put off one of my daughters (Greta).*	Lack of experiments/ practical.
I have a fairly limited knowledge about what happens now but there is sort of different ways of answering that so what I think is limited in school curriculum at the moment in terms of what I see students coming to university I am the admissions tutor for electronic computing and engineering (Dennis). *National Curriculum is always kind of prescriptive of how lessons are structured and I think it's too prescriptive seems to be a problem across the subjects. I think that's probably the problem (Norman).*	Science curriculum provides too limited set of knowledge/ too prescriptive.
Before starting my music lecture *'I usually put up a picture of Einstein (he is wondering) and the answer is BOTH… I think there is a third way and it must apply to science as well as the arts where you learn both facts and imagination research exploration that would be my comment on current education (Philip)* (Appendix 6).	A need for cross-curricular links.

Table 5.6: Recommendations for school science

(iii)Teachers

Question 8, also asked the participants whether or not teachers were influential in their decision of choosing science and or non-science subjects. A range of responses from school to university teaching experiences was obtained. Ten of the twelve, Dennis, Daisy, Grace, George, Jane and Parker (scientists) and Nikki, Danielle, Norman and Adam (non-scientists) perceived to have been inspired by at least one science teacher - despite their eventual science or non-science education and career choices. A few example responses and main outcomes based on parental influences can be seen in Table 5.7.

Responses	Main outcomes
Fairly, I think I had a great Physics teacher - I am still in touch with him and he was great. And, in a way, if he hadn't set up the work experience then it would have been very different. It was people like my Physics teacher who were very inspiring, but not just because he teaches Physics (Daisy). *I mean, when I started in secondary school, I went to clubs; one of the clubs I went … was Physics Club - although I never did Physics after 16. It was just something at that time that was quite good, they made an effort to engage you if you were first year, which not all the clubs in after school activities did, so that is something I did that got me quite interested (Norman).*	The majority perceived to have science as well as non-science teacher(s) influence.
You could do Physics A-levels and then you could do S level (more advanced levels) and one day he held back a group of us and you lot are going to do s level physics, so I waited till the end and I said no I am not, don't be ridiculous, he said yes you are SHUT UP! You are doing it and I am putting you in for it. And then of course I passed it and saw him on the day I got the result. He was I told you so, at your face. Possibly he was right. (Jane).	A few scientists and non-scientists mentioned teachers involvement in directing their science or non-science future.
We had a very frightening Physics teacher, there were days where we could throw things at you, so he threw chalk if he saw someone talking, he'd throw chalk from 20 yards and hit you here (pointed mid forehead) … certainly made the whole situation more tense … It was quite an old-fashioned environment (Philip). (Appendix 6).	A few non-scientists mentioned particular science teacher who had a negative influence.
I did not get along with (mathematics teacher) and, when he was annoyed at me, it just made me want do better just to rub his nose in it and prove the point. So, it works both ways (Dennis).	One male scientist experienced negative influence from mathematics teacher, which he rejected.

Table 5.7: Teachers - Phase One

The last three points indicate that in comparison to Nikki, Greta, and Philip (non-scientists) Dennis took the negative experience/ events as a challenge and fought back to prove that he is capable of doing mathematics. In contrast, one of the twelve, Greta (non-scientists) had non-science teacher's influence only; where three of the twelve, Adam, Norman and Danielle (non-scientists) were influenced by both science and non-science teachers. One of the twelve, Philip (non-scientist) did not mention non-science teacher(s) positive or negative influence, but along with Nikki and Greta (non-scientists) mentioned perceived negative experiences from a particular science teacher.

5.4 Summary- Phase One

The findings from the university-based scientists and non-scientists have provided a wide range of data revealing important features based on different aspects of GF, SA, TL experiences (events, triggers and interventions), natural inclinations, IIA and transformations that moved scientists into science or non-scientists into non-science education and careers. I will now summarise the key outcomes using Sci-ID model ingredients (Figure 2.5).

1. Global forces (GF): As mentioned in Chapter Three, I did not ask any question on global forces, like ethnicity, gender, race, class, religion etc. Only a few scientists and non-scientists mentioned it in relation to their personal experiences. Few accepted such forces and the majority rejected exhibiting a certain drive/push (IIA) that either influences them to go with it or against it.

2. Social Agents (SAs): As mentioned in Chapter Three, I have principally looked at broadly three out of the various social agents indicated in the literature, that can have a high impact on an individual's science or non-science future which are: (i) parents - the majority of the scientists and non-scientists indicated parental support in whatever they wanted to do. A few female scientists indicated the high impact of parental influence that has been retained till today. However, male scientists and non-scientists rejected such influence while deciding their subject choices, (ii) school science - the majority of the scientists and non-scientists preferred learning science through daily life science experiences rather than through the science curriculum and (iii) teachers - the majority believed that their teachers were influential despite their future science or non-science choices. A few female scientists and non-scientists even mention additional support from their teachers that resulted in their science or non-science choices. However, a few also criticised science teachers because of traditional style teaching and/or lack of support and encouragement from a particular science teacher.

3. TL experiences (triggers, events, interventions): A few examples: into sciences are Haley's Comet, science fiction magazines, computer, influences from GF and SA etc. Into non-sciences are piano, music, science fiction books, and philosophy books. Away from science are science education being too factual or working in labs with soil, ants, rats, worms etc.

4. Meaning-making filter: There was no specific data generated.

5. Preference filter: The scientists discussed their preferences for science education and careers because it involves new challenges, new scientific discoveries and, as a result, science is not static and provides opportunities to share new/ revised discoveries at a local as well as at an international level. A few non-scientists preferred reading about the role of science in society, culture, music, religion, environmental issues, writing science fiction books; however, they have no preference for studying science at all at any substantive level.

6. Individual Internal Agency (IIA): The majority of the scientists and half of the non-scientists were naturally inclined towards a science or non-science education and career due to self-interest and their perception of self-ability which acted as a drive or push (IIA). Exhibiting IIA a few even rejected certain TL experiences as mentioned above, which exhibits a push in relation to their agency.

7. Core: I did not obtain any direct data. The above data represents that at this current time they exhibit a quite stable core. Looking back at their lives, the majority of the scientists and half of the non-scientists were relatively stable from a young age of approximately eight, where the rest exhibited turbulence in their lives towards science or non-science choices, exhibiting fluid core identities.

The above findings resulted in the generation of three themes presenting transformations and changes which includes (i) Progressive TL and smooth transformation- the majority exhibiting small or no movement away from their choices, showing stability from a young age, exhibiting low impact of GF, SA and TL experiences that goes against their IIA, displaying strong IIA either towards science or non-science education, (ii) Progressive TL and wavering transformation- similar stability was achieved after certain indecision and ambivalence, principally after the age of seventeen exhibiting medium movement towards or away from science and (iii) Reconstructive TL and wavering transformation- towards reaching stability a few male non-scientists experienced regressive TL which had a high impact in their decision making. This regression actually helped them to recognise their interest in non-sciences.

Now I will move on to explore the insights from Phase Two of my research, which includes university students. These university students have undergone the process of selecting subject choices at A-levels and at university, but have not yet entirely entered the professional stage of their lives.

Section Two

Phase Two: University students

5.5 Introduction

Brunel University London is modern, campus-based, and lies on the western outskirts of London. Chartered in 1966, the university has become a major force both within the UK higher education sector and on the international stage. The university's 2014/2015 figures for all programmes (data collected from SITS Data Management on 21/12/2014), shows some 13,000 under- and post-graduate students (Table 5.8):

Gender	Science	Non-Science	Total
Male	4297	2814	7111
Female	2707	3166	5873
Totals	7004	5980	12984

Table 5.8: Brunel University London student population: indicating gender and science and/or non-science current subject choices

This gives ratios of male: female to be 1: 0.84, and science: non-science students of 1: 0.85. Despite its name and Brunel's strong science emphasis (Brunel Engineering is ranked in the top 10 in the UK by The Times Higher Education World University Rankings in Engineering and Technology, 2014) this is not an entirely unbalanced picture, and the university has a substantial arts and humanities base.

In this study, more female (68%) students responded to the questionnaire than male (31%) students. The male to female ratio was 1: 2.2. 61% of students who completed the questionnaire were from non-science colleges which include business, arts and social sciences students and the remainder, 39%, were from science colleges, including students from engineering, design and physical science, health and life sciences, Institute of Energy Futures, Institute of Environment and Health and Societies and Institute of Materials and Manufacturing. 3% more male students opted for science subjects at A-levels as compared to female students, which could be because 4% more male students are studying science subjects at Brunel University, London (Table 5.8). The total ratio of science to non-science participation was 1: 1.56. As can be seen in Table 5.9, overall the majority of females were from non-science colleges. To overcome the percentage differences between science and non-science university students, I calculated science and non-science as 100% each.

Gender	Science (%)	Non-science (%)	Totals (%)
Male	18	13	31
Female	21	47	68
Other	00	01	01
Totals	39	61	100

Table 5.9: Students population: indicating gender and science/non- science current subject choices at Brunel University

Question 2 asked students their current science or non-science university choices, which I will now compare with question 4 that enquired students as whether or not participants had one or more science subjects at A-levels. 60% of the students studied sciences till A-level, where 40%, did not took sciences at A-level (Table 5.10). In comparing science and non-science university choices out of 60%, almost half of the students (32%) carried on with science. Whereas almost the other half (28%) dropped science either at the age of sixteen or nineteen and chose non- science subjects at university. On the other hand 40% of the students did not have science at A-levels, out of which the majority 33% students carried on doing non-science subjects at the university as well. The remaining 7% students found a way into science qualifications. These students mainly belong to design (4%), life sciences (2%) and other science based research institutes (1%).

Science at A-level	Science at university (%)	Non-science at university (%)
Yes (60%)	32	28
No (40%)	07	33

Table 5.10: Subject choice differences at A-level

Moreover, the majority with 87% (35% strongly agree and 52% agree) are looking forward to working in the same field as university study, whereas 14% wish to move out of the current field of study (Figure 5.1).

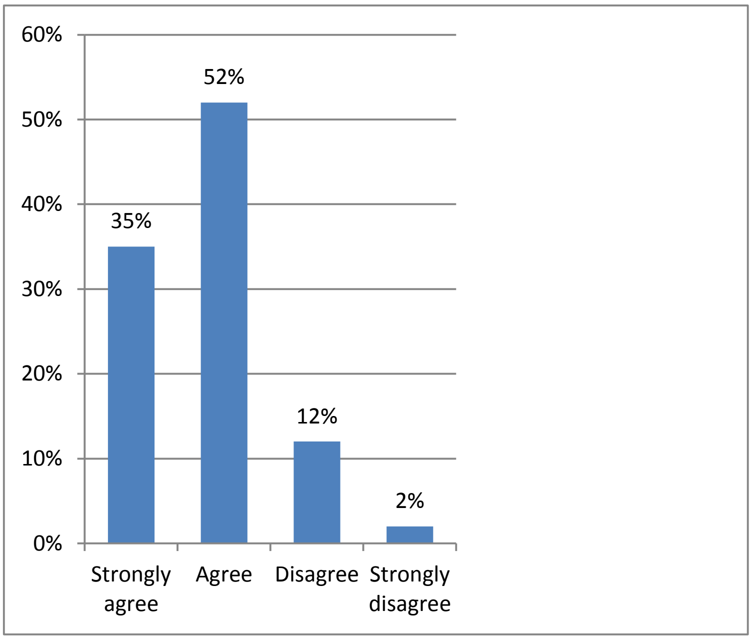


Figure 5.1: Prospective career choices – Phase Two

Out of the 87%, almost 6% more non-science students than science students are determined to find a job in the current field of university study (Table 5.11). This could be because a few students are completely moving away from science, or they are thinking of changing their future career in the same science or non-science field of study. The reasons for the 14% (Figure 5.1) of students changing employment is not evident, where Helen's story (given below) of combining both science and non-science careers can be taken as an example.

	Science (%)	**Non-science (%)**
Strongly agree	29	39
Agree	54	50
Overall agreed	**83**	**89**
Disagree	15	10
Strongly disagree	02	02
Overall disagreed	**17**	**12**

Table 5.11: Prospective career choices: science vs non-science – Phase Two

Question 16 and 17 asked the students about their perception on the availability of science and/or non-science career opportunities. The majority believed that doing a degree in science or non-science unlocks opportunities into diverse and exciting jobs. The majority, 83%, (23% strongly agree and 60% agree) believed that a degree in science can provide better opportunities, where only 18% (4% strongly disagree and

14% disagree) did not believe the same. On the other hand, 70% (16 % strongly agree and 54% agree) of the students believed that a non-science degree can provide better opportunities where 30% (6 % strongly disagree and 24 % disagree) disagreed (Figure 5.2). 13% (science 83% - non-science 70%) more importance was given in achieving a degree in science as compared to non-science degrees in relation to future career opportunities.

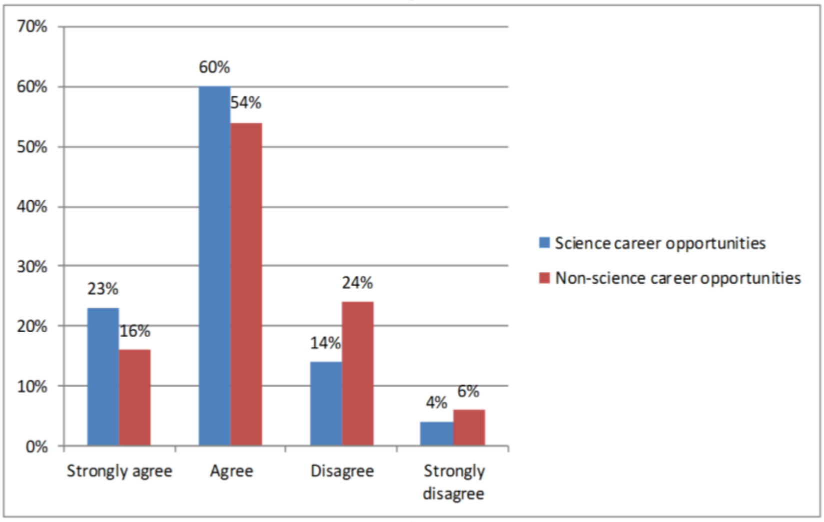


Figure 5.2: Career opportunities – Phase Two

Overall, 91% of science students agreed and only 9% disagreed and 78% non-science students agreed and 22% disagreed that a science degree provides better job opportunities (Table 5.12).

	Science (%)	Non-science (%)
Strongly agree	36	14
Agree	55	64
Overall agreed	**91**	**78**
Disagree	08	17
Strongly disagree	01	05
Overall disagreed	**09**	**22**

Table 5.12: Science career opportunities – Phase Two

In addition, 55% of science students agree, 45% disagree and 79% of non-science students agree and 21% disagree that a non-science degree provides better job opportunities (Table 5.13).

Therefore, 36% (91% science - 55% non-science) more science students perceive that science degrees provide better career opportunities as compared to non-science degrees. Whereas the non-science students were quite neutral, showing only 1% (79% non-science - 78% science) difference, that both science and non-science degrees unlock diverse and exciting jobs. This 36% difference shows that the perception on science career opportunities could be one of the main reasons that incorporate students into science studies.

	Science (%)	Non-science (%)
Strongly agree	12	18
Agree	43	61
Overall agreed	**55**	**79**
Disagree	35	17
Strongly disagree	10	04
Overall disagreed	**45**	**21**

Table 5.13: Non-science career opportunities – Phase Two

In addition, the evidence is that 34% (55% science – 21% Non-science) more science students, in comparison to non-science students, perceive that a science degree, as compared to non-science degree, can provide better employability skills (Table 5.14).

	Science (%)	Non-science (%)
Strongly agree	20	03
Agree	35	18
Overall agreed	**55**	**21**
Disagree	33	60
Strongly disagree	12	19
Overall disagreed	**45**	**79**

Table 5.14: Better employability skills – Phase Two

After looking at the students' subject and prospective career choices, I will now present the rest of the findings in broadly five sections which are as follows:

(i)Perception of GF: where I will use percentages and main outcomes of the GF that emerged from the questionnaires

(ii)Perception of SA: where I will use percentages and main outcomes of the SA that emerged from the questionnaires

(iii)Perception of natural inclination: where I will use percentages and main outcomes of the science and non-science natural inclination that emerged from the questionnaires

(iv)Transformation and change: where I will present summarised stories of the university students under three themes

(v)Summary- Phase Two: where I will apply the seven Sci-ID model ingredients to summarise the key outcomes.

5.6 Perception of global forces (GF)

The students did not mention GF in the questionnaires.

5.7 Perception of social agents (SA)

A series of questions were asked to find out the perceptions of the university students about parents, school science, teachers and careers. I was expecting to receive brief description of their choices. However, the majority filled the scaled questions and did not write in the comment box, leaving me with mainly percentages which are discussed below.

(i)Parents

The university students have been confronted with the decision of subject choices in two, quite recent, instances (after A-level and school). For this reason the same question was asked twice. Question 8 asked the students whether or not they experienced parental influence at the time of choosing subjects at A-level and question 9 asked the same question on parental influence at the time of choosing subjects at university (Figure 5.3).

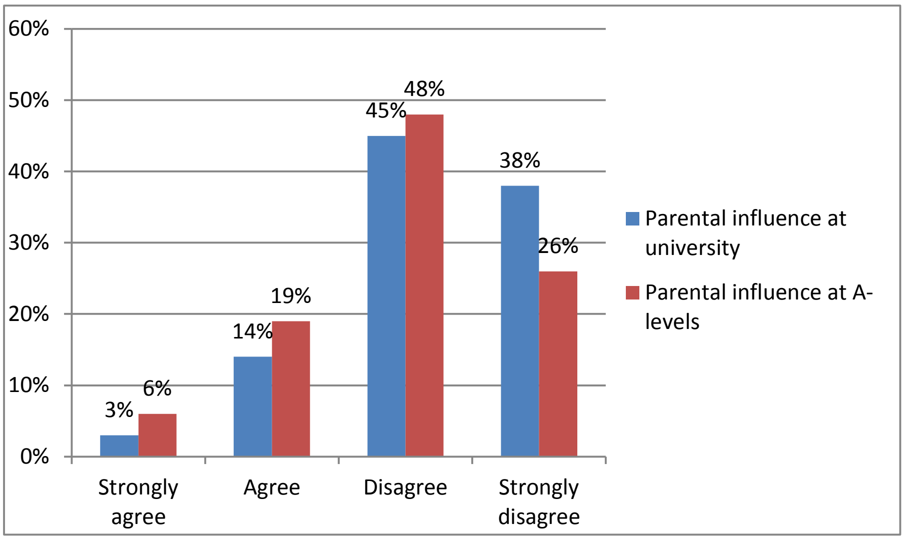


Figure 5.3: Parents – Phase Two

As can be seen in Figure 5.3, the majority declined parental influence at A-level, and at university. This decline further builds up at university, as students' option for strongly agree declined from 6% to 3% and agree from 19% to 14%. Whereas, on the disagreement side a slight 3% decline was observed from 48% to 45%. Moreover, for the strongly disagree option a 12% rise from 26% to 38% was seen.

In comparing science to non-science students (Table 5.15), despite the majority declining to have experienced parental influence in taking up science or non-science subjects, science students retained parental influence a little longer than non-science students. Because at university and at A-levels, 6% (university- 21% - 15%; at A-level- 30 % - 24%) more science students agreed to having had parental influence as compared to non-science students. Moreover, 6% (university 79%-85%, A-levels 70%-76%) less science students disagreed as compared to non-science students (Table 5.15).

	University		A-level	
	Science (%)	Non-Science (%)	Science (%)	Non-Science (%)
Strongly agree	01	05	04	09
Agree	20	10	26	15
Overall agreed	**21**	**15**	**30**	**24**
Disagree	50	42	44	52
Strongly disagree	29	43	26	24
Overall disagreed	**79**	**85**	**70**	**76**

Table 5.15: Parents – Phase Two

(ii)School science curriculum and relevance of daily life science

Question 12 asked the university students about science learning in school in relation to everyday life and question 15 asked whether or not their school science curriculum had influenced their interest in science?

Looking individually at questions 12 and 15, it is clear that the majority with 54% (7% strongly agree and 47% agree) liked the school curriculum which influenced their interest in sciences. The majority with 74% (15% strongly agree and 59% agree) also believed that awareness of daily life science has helped them in school science. On the other hand, a little less than half of students also disliked the science curriculum (35% disagree and 7% strongly disagree). There were comments on disliking the curriculum including the lack of relevance of school science and rote learning adapted syllabus design. Whereas, overall 26% (7% strongly disagree and 21% disagree) disagreed that school science had helped them in making a decision on day to day life activities.

While comparing the two variables, I found that more students indicated that relevance of daily life science was helpful as compared to the positive influence attained from the school science curriculum. As 8% more strongly agreed, 12% more agreed, 14% less disagreed and 2% less strongly disagreed that awareness of daily life science had helped them in school science learning (Figure 5.4). However, 4% of students did not answer question 15 on school science curriculum.

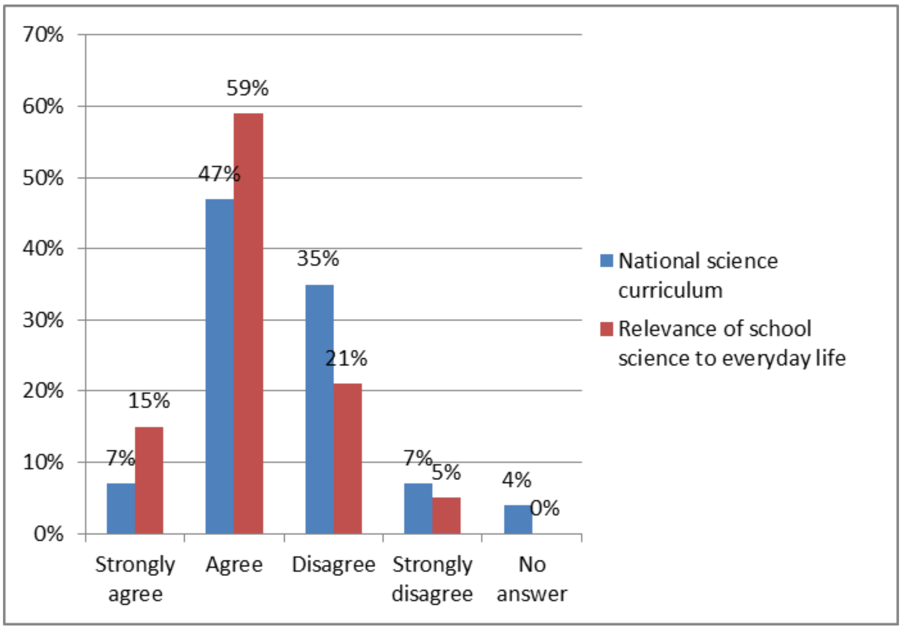


Figure 5.4: School science curriculum and relevance of daily life science- Phase Two

In addition to the overall picture, a comparison between science and non-science students indicated that 60% (5% strongly agree and 55% agree) of science university students and 53% (8% strongly agree and 45% agree) of non-science university students agreed to have been influenced by the science curriculum. Similar results were obtained on the disagreement side, as 36% (8% strongly disagree and 28% disagree) of science and 44 % (5% strongly disagree and 39% disagree) of non-science university students believed to be on the disagreement side. Moreover, 4% of science and 3% of non-science students skipped question 15 on school science curriculum (Table 5.16).

	Science (%)	**Non-science (%)**
Strongly agree	05	08
Agree	55	45
Overall agreed	**60**	**53**
Disagree	28	39
Strongly disagree	08	05
Overall disagreed	**36**	**44**
No answer	04	03

Table 5.16: School science curriculum- Phase Two

Accordingly, the majority of both science and non-science students agreed to attain interest in science through the school science curriculum. As predicted, science university students had a slightly higher rate of interest as compared to non-science university students. In comparison, 7% (from science 60%- non-science 53%) more were found to be on the agreement side and 8% (from science 36% to non-science 44%) less science students were found to be on the disagreement side as compared to non-science university students. Towards science curriculum, 53% agreement from non-science students indicates that these students, despite their education and career choices, did not have a particular problem, whereas approximately the other half did not find the curriculum interesting. This needs further investigation and probing.

I cannot say for certain whether it is the science curriculum that has inspired the majority of the university students to grasp or drop science education and/or careers, because there are a large percentage of university students who declined the positive impact of science curriculum, but carried on doing science at university; the non-science students who were interested in sciences through science curriculum but dropped sciences at university level. It could be because the students were satisfied or unsatisfied about the A-levels science curriculum that actually made them decide to choose science or non-science at university. I did not ask questions in relation to A-level choices - a limitation of this research - or it could be other external or internal factors that made their future one way or another.

Amazingly, 73% of science students and 74% of non-science students agreed, where 28% science and 26% non- science students disagreed that school science learning is helpful in daily life (Table 5.17).

	Science (%)	**Non-science (%)**
Strongly agree	14	15
Agree	59	59
Overall agree	**73**	**74**
Disagree	24	20
Strongly disagree	04	06
Overall disagree	**28**	**26**
No answer	00	00

Table 5.17: Relevance of school science to daily life – Phase Two

(iii)Teachers

Question 13 asked the students whether or not their decision of opting and/or declining science subjects was influenced by science teachers and question 14 asked the same but with respect to non-science teachers.

34% (7% strongly agree and 26% agree) reported some influence from science teachers, but the majority with 66% (16% strongly disagree, 51% disagree) disagreed they were influenced by science teachers in taking up/declining science subject choices (Figure 5.5). On the other hand, 24% (5% strongly agree and 19% agree) agreed overall and the majority with 77% (15% strongly disagree and 62% disagree) disagreed to have gained influence from non-science teachers. In comparison, after looking at the overall trends, 10% (science teacher 34% - non-science teacher 24%) more students recalled science teachers to be influential as compared to non-science teachers in taking up science or non-science subjects.

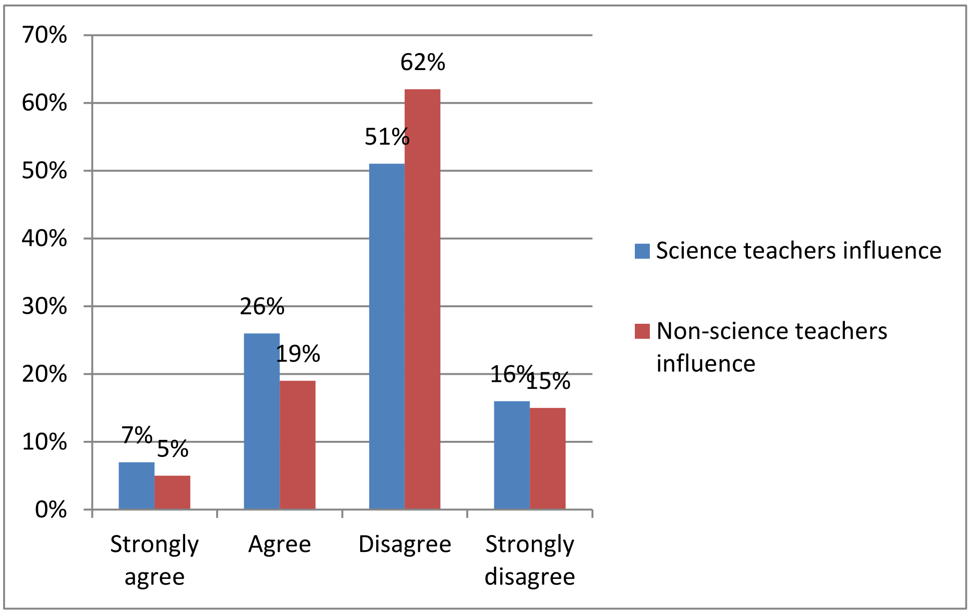


Figure 5.5: Teachers – Phase Two

In addition, 26% (5% strongly agree and 21% agree) of science students agreed and the majority with 74% (16% strongly disagree and 58% disagree) disagreed to have experienced science teachers' influence. Similarly, of non-science students, 37% (8% strongly agree and 29% agree) agreed and the majority with 63% (17% strongly disagree and 46% disagree) disagreed (Table 5.18).

	Science (%)	Non-science (%)
Strongly agree	05	08
Agree	21	29
Overall agreed	**26**	**37**
Disagree	58	46
Strongly disagree	16	17
Overall disagreed	**74**	**63**

Table 5.18: Science teacher(s) – Phase Two

Despite overall disagreement towards science teachers' influence, it can be seen from the above results that 11% (science 74%- non-science 63%) more non-science students, in comparison to science students, were influenced by the science teacher(s). Then why are these students studying non-science subjects at university? Does this mean that these 11% of students experienced a negative impact from their science teachers or positive impact from them? Or was the influence less dominating and/or short lived? Or it could be that these non-science students liked school science teachers, but disliked college science teachers. This needs further investigation for future research.

Next, as mentioned above, question 14 asked about the effect of non-science teachers in the approval/ disapproval of non-science subjects. The majority of university students did not perceive influence by non-science teachers. Only 27% (9% strongly agree and 18% agree) of science students agreed and the majority with 73% (58% strongly disagree and 15% disagree) disagreed. Similarly, 21% (2% strongly agree and 19% agree) of non-science students agreed and the majority with 79% (14% strongly disagree and 65% disagree) disagreed (Table 5.19).

	Science (%)	Non-science (%)
Strongly agree	09	02
Agree	18	19
Overall agreed	**27**	**21**
Disagree	58	65
Strongly disagree	15	14
Overall disagreed	**73**	**79**

Table 5.19: Non-science teacher(s) – Phase Two

An opposite attraction can be seen as science students, had overall 6% more non-science teacher's influence in choosing the non-science subjects. But again, it is not clear from the results as to why the science students did not pursue non-science subjects in the future. It could be that the science students experienced a negative or positive influence from the non-science teachers, and further investigation and probing is required.

5.8 Perception of natural inclination

After asking specifically past, present and future decision making questions from the university students, the questionnaire asked whether they perceived themselves to have a science or non-science inclination. Question 6 asked the students whether or not they perceived themselves to have a science natural inclination and question 7 asked whether or not the students perceived themselves to have a non-science natural inclination.

The answer revealed that the majority with 68% (29% strongly agree and 39 % agree) agreed to have a natural inclination towards science which is only 3% more than the students believing themselves to have non-science natural inclination at 65% (20% strongly agree and 45% agree). The rest of the 32% (4% strongly agree and 28% agree) do not perceive themselves to have a natural inclination towards science and 34% (5% strongly disagree and 29% disagree) towards non-science (Figure 5.6).

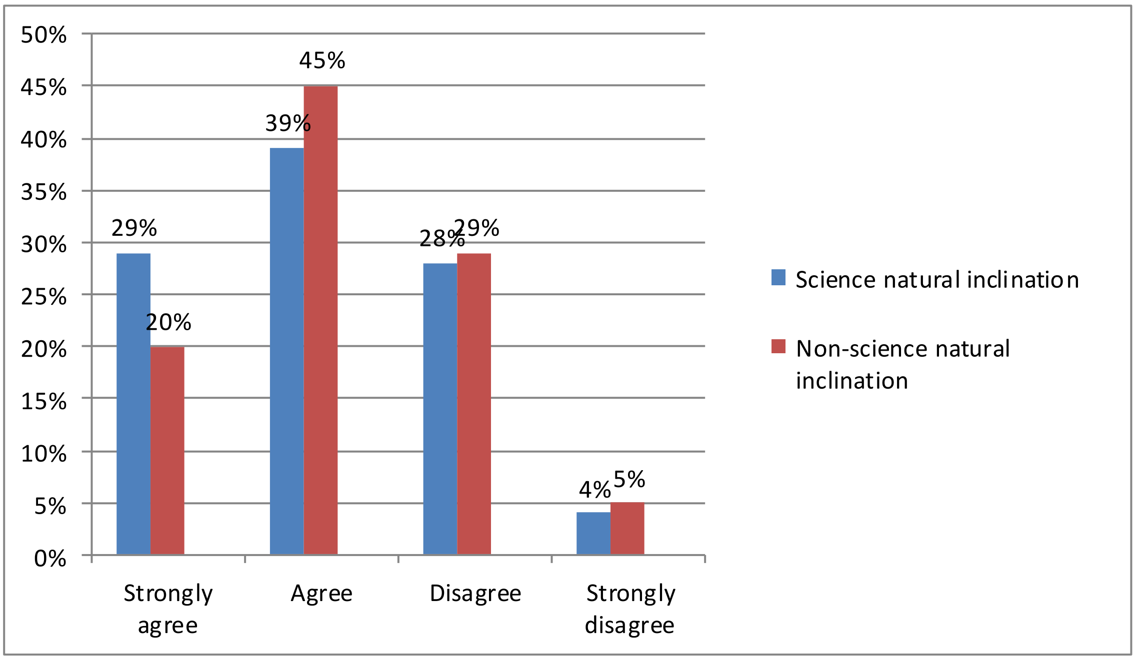


Figure 5.6: Natural inclination- Phase Two

The overall natural inclination result was a little unexpected, as the majority believed themselves to have a science natural inclination; however, the majority of my participants (60%) belong to non-science colleges/institutes. For this reason, I then examined the responses of science and non-science students separately. I found that the majority, with 88% (41% strongly agree and 47% agree), of science students believed themselves to have a natural inclination towards science exhibiting a certain drive/push (IIA) towards science education. Whereas 12% (00% strongly disagree and 12% disagree) declined. The reason for this decline is not clear; it could be that the students might have experienced certain TL experiences (events, triggers, interventions) that resulted in their uptake of science subjects. The results also revealed that 32% (88% science – 56% non-science) more science students believed themselves to have a natural inclination towards science, as compared to non-science students.

56% (23% strongly agree and 33% agree) of non-science students indicated a science natural inclination, whereas the rest of the 44% (6% strongly disagree and 38% disagree) of non-science students disagreed (Table 5.20). Therefore, despite a science natural inclination, 56% of non-science students backed off from sciences. As mentioned above, it seems that the students might have experienced certain TL experiences that resulted in their uptake of non-science subjects.

	Science (%)	**Non-science (%)**
Strongly agree	41	23
Agree	47	33
Overall agreed	**88**	**56**
Disagree	12	38
Strongly disagree	00	06
Overall disagreed	**12**	**44**

Table 5.20: Science natural inclination - Phase Two

In addition to science inclination, I also examined the perception of students towards non-science inclination. 24% (74% non-science – 50% science) more non-science students, as compared to science students, exhibited inclination towards non-science. In contrast, 50% science students agreed and 50% disagreed to have natural inclination towards non-science inclination. The majority of the non-science students with 74% (28% strongly agree and 46% agree) believed themselves to have a non-science natural inclination and 25% (3% strongly disagree and 22% disagree) disagreed (Table 5.21).

	Science (%)	Non-science (%)
Strongly agree	06	28
Agree	44	46
Overall agreed	**50**	**74**
Disagree	42	22
Strongly disagree	08	03
Overall disagreed	**50**	**25**

Table 5.21: Non-science natural inclination - Phase Two

Looking at the other side, half of the science students perceived themselves to have both a science and non-science inclination, and later in life choose science specialisms, which could be due to a larger inclination towards science or due to aggregated TL experiences that led them to gain a science-based education. The other half disagreed to having a natural inclination towards non-science and 12% (Table 5.21) also declined to have a science inclination. Therefore, 38% of science students exhibited a straight forward inclination into sciences only, exhibiting strong IIA towards gaining a science based education and career. 12% disagreed to have a science as well as non-science inclination, but chose sciences at university. The reason for these students of taking up science is not clear; however, it could be that TL experiences mediated by SA (for example institutions) and/or GF might have guided them to gain a science education. Further investigation and probing is required.

5.9 Transformation and change

The above data on science inclination and non-science non-inclination was then compared and contrasted with subject choices focusing on the following three themes (Table 5.22):

(i) Progressive TL and smooth transformations - they exhibit stability, as they always had either science or non-science inclination. Therefore, for them, the meaning-making filter, their preferences were open for what they wanted to study (either science or non-science), resulted in no movement or very small movement from either stable science or non-science extremes. This relationship exhibits a certain drive/ push (IIA) that goes against GF, SA and TL experiences (events, triggers and/or interventions) or goes with them.

(ii) Progressive TL and wavering transformation - they exhibit fluidity despite their subject choices, as they perceive themselves to have both science and non-science natural inclination. Therefore, for them, the meaning-making filter and preference filter were open for both science and non-science choices. The drive/ push (IIA) of either going against or to go with the GF, SA and TL experiences (events, triggers and/or interventions) exhibits ambivalence.

(iii) Reconstructive TL and wavering transformation - they exhibit fluidity, and mild transformation towards science or non-science. They experienced a few distinctive/ sharp small, medium or large number of TL experiences that marks their movement towards or away from science. Therefore, after these experiences, the meaning-making filter and preference filters sizes were readjusted and natural inclinations are quite determinative towards either science or non-science choices. It seems that these clear moments in life established a certain drive/ push (IIA) that goes against or with the GF, SA, TL experiences (triggers, events and/or interventions).

	Into science (%)	**Away from science (%)**
Progressive TL and smooth transformation	46	40
Progressive TL and wavering transformation	44	43
Reconstructive TL and wavering transformation	10	17

Table 5.22: Transformation and change- Phase Two

(i)Progressive TL and smooth transformation

As can be seen in Table 5.22, the majority (46%) of the science students fall into this category of smooth transition. 40% non-science participants fall into this category as well, which is only 3% (43% -40%) less than the non-science highest theme of incremental wavering transition. For both science students and non-science students the suggestion of whether to do science or not has not dominantly arisen. For example:

Ben, a full time Master's science student, continued to opt for sciences after the age of 16. He successfully completed biology, chemistry, maths and psychology at A-level and later at university carried on with life sciences. He is naturally inclined towards science and strongly disagrees to having a natural tendency towards non-science, exhibiting no movement away from sciences. His long term inclination towards science can be seen through his belief in making science compulsory until the age of 19 and his intention of carrying on with a science career in the future, exhibiting a drive/ push (IIA) towards science. He has been influenced by his parents in choosing science subjects at A-level, but the influence diminished at university level. He has not been influenced by science and or non-science teachers, in comparison, school science curriculum and relevance of school science to daily life activities acted as TL experiences that triggered his interest in sciences. In terms of career opportunities, Ben believed that science and non-science degrees are equally important and can provide a better career. Next in support of a science degree, Ben believes that a degree in science offers better employable skills than a degree in non-sciences.

(ii)Progressive TL and wavering transformation

44% of science students come under this category of fluid transition. These students are naturally inclined for both science and non-science, but then chose to do science at a degree level. In addition, I have also noticed that 2% of the students chose to do science at university with a belief of having neither a science nor non-science natural inclination. Moreover, from the data I have found that the majority with 43% of non-science students believed themselves to have an inclination for both science and non-science learning (Table 5.22). Even with an inclination for both, the students chose a non-science specialism rather than a science specialism at university. In addition, I also noticed that 3% of students who believed themselves to have neither a science nor non-science inclination, chose to do non-science at university. This group of students exhibits ambivalence. For example:

> Helen, a full time year one health and life sciences PhD student studied psychology and mathematics at A-level. She believed herself to have a strong inclination towards non-science and mentioned that she always *loved to write and read and has never been scared or put off by these* (english and geography) *subjects*. At school, Helen, thought of science subjects as *too difficult for me* especially topics like the big bang theory that actually moved her away from science. Helen's parents were not at all influential in her decision making, however, her non-science teachers, especially the psychology teacher was greatly influential and the teacher's encouragement helped her to carry on studying psychology all the way to degree level. On the other hand, chemistry and biology teachers, *dusty textbooks, confusing symbols and lack of real-worldness* moved her away from science. Now thinking back, Helen strongly disagrees that school science is relevant to daily life, but after school life her perception changed and now Helen believes that *science is for everyone* and

> it's not as problematic and dreadful as she used to believe during her secondary school days, exhibiting medium movement into science. However, Helen strongly disagrees that science should be compulsory till the age of 19 as she believes that people could be interested in other subjects as well. In addition, now she prefers that some aspects of science should be taught up to A-levels like *how to think logically, how to research on the internet, critical appraisal of sources, etc.* This change in perception happened after reading books and understanding (meaning-making) history of science, for example reading *Bill Bryson's short history,* which has great ideas *on big bang theory*. Moreover, as she carried on with psychology at undergraduate level, during this time she really liked/ preferred a neurology module that motivated her to carry on with scientific research on brain functioning in relation to psychology. Although, Helen did not even study biology at A-levels, she progressed quite well during masters and is hoping to conduct a PhD in the same field. Helen's future plans seem to incorporate science and non-science careers, as although she wants to carry on with research work in neurology she later mentioned that she wants to work as a researcher in civil services. She stated that *if you do a BSc you can go into research, engineering, design, physics, etc. and a lot of business careers like the scientific way of thinking*.

(iii)Reconstructive TL and wavering transformation

The data exhibits that 10% of university students had a natural inclination towards non-science but chose science subjects at university (Table 5.22). Similarly, 17% of non-science students agree to have a natural inclination towards science only, but still choose non-science subjects at university. This category displays the effect of TL experiences (events, triggers and interventions) gained through social agents that impacts on an individual's subject choices. I believe that these students have undergone transformation in order to gain a respective science or non-science education and career. For example:

> Amani, an undergraduate full time non-science student, studied a combination of science, maths and history subjects at A-level and carried on doing undergraduate studies in history as a major subject which she is happy to proceed with in the future. She actually rejected all the other sciences, although she holds a natural inclination towards science only. The only reason that can be viewed at this stage is that to become a medical doctor was her dream job from the age of seven and she never thought of pursuing a non-science degree

or career. But then slowly the interest in becoming a doctor diminished after the age of seventeen. The reason of rejecting her interest in medicine is not clear as she found her science teachers, school science curriculum and school science environment very positive. There is something that happened during her college life (A-level) that made her drop out of the science career decision. Her final responses on career opportunities, exhibits the main possible reason behind dropping out, which is her belief that a non-science degree unlocks better career opportunities as compared to a science degree. In addition, she strongly disagrees that through science studies students can gain more employability skills (like communication, team working, self-reliance and generalist skill, etc.) as compared to arts and humanities subjects. It seems that the students in this category have chosen education and future careers against their natural inclination. Amani's drive of becoming a doctor faded away and it could be that she was not able to enter a science university course due to poor grades at A-level.

There can be other TL experiences in life but it is not clear as she did not elaborate her reasons for opting for science or non-science subjects. A further follow up with these students could provide a better understanding.

5.10 Summary- Phase Two

The findings from the university-based science and non-science students have provided a wide range of data revealing important features based on different aspects of SA and TL experiences (events, triggers and/or interventions) and personal transformation/ change that moved them into science or non-science education. I will now summarise the key outcomes using Sci-ID model ingredients (Figure 2.5).

1. Global forces (GF): There was no data generated for this ingredient.

2. Social agents (SA): I have looked at broadly into the three avenues, the main outcomes are (i) parents - the majority did not feel that their parents had an influence towards choosing their science or non-science subject choices. In comparing science and non-science students, students from a science background seemed to be more influenced by parents than non-science students, (ii) school science - an almost equal percentage of students agreed and disagreed that they became interested in science through science curriculum. The majority perceived that school science has helped them towards their awareness of daily life science. The science curriculum had a

more positive impact on science students as compared to non-science students and (iii) teachers - the majority of the participants declined science and non-science teacher influence. Slightly more reported to be influenced by science teachers than non-science teachers. A reverse perception was obtained as more non-science students perceived to be influenced by the science teachers and more science students perceived to be influenced by non-science teachers.

3. TL experiences (triggers, events, interventions): For example - into science Bill Bryson's short history book and away from science: dusty text books, confusing symbols.

4. Preference filter: No direct data, only the extent to which students could assign themselves as science-orientated or not.

5. Individual Internal Agency (IIA): The majority of the students were fluid whereby showing educational and professional stability towards science or non-science. As half of the science students and little more than half of the non-science students perceived themselves to have inclination for both, exhibiting ambivalence.

6. Core: No direct data generated, only the extent to which students could assign themselves as science-orientated or not.

The above findings resulted in the generation of three themes presenting transformation and change which includes (i) Progressive TL and smooth transformation: The majority exhibited progressive TL and smooth transformation into science, (ii) Progressive TL and wavering transformation: The majority of the non-science students exhibited progressive TL and wavering transformation into non-science and (iii) Reconstructive TL and wavering transformation: Very few science and non-science students exhibited reconstructive TL and wavering transformation.

Now I will move on to Phase Three of the research, to discover the perceptions of the thirty secondary school students who are still in the compulsory age of science education and yet in a few years' time they will be deciding their A-level subject choices. In the next chapter, I will be highlighting the changes in the attitudes, preferences, meaning-making and natural inclination, through the impact of social agents, events, triggers and six school based interventions (Chapter Four).

Chapter Six: Phase Three - The Salehjee Girls School

6.0 Introduction

The third and the final phase of data collection involved the youngest participants of my research. As discussed in Chapter Three, this sample was chosen from The Salehjee Girls School (a pseudonym) located in the London Borough of Ealing. The six science education interventions were designed and conducted with thirty secondary school girls aged eleven to fifteen. These six interventions, design and implementation in science classrooms are described in detail in Chapter Four.

After each intervention, the girls completed short questionnaires to help me to reflect and improve on the designed interventions, and to examine whether or not the girls enjoyed the interventions (question 4) and whether these series of intervention experiences encouraged them to consider science education (question 3) as an area of study or even as a future career. The 'readings' at the end of each intervention were positive about the science interventions, the majority acknowledged that there were very few of the components that had nothing to offer as an improvement to their experiences of science.

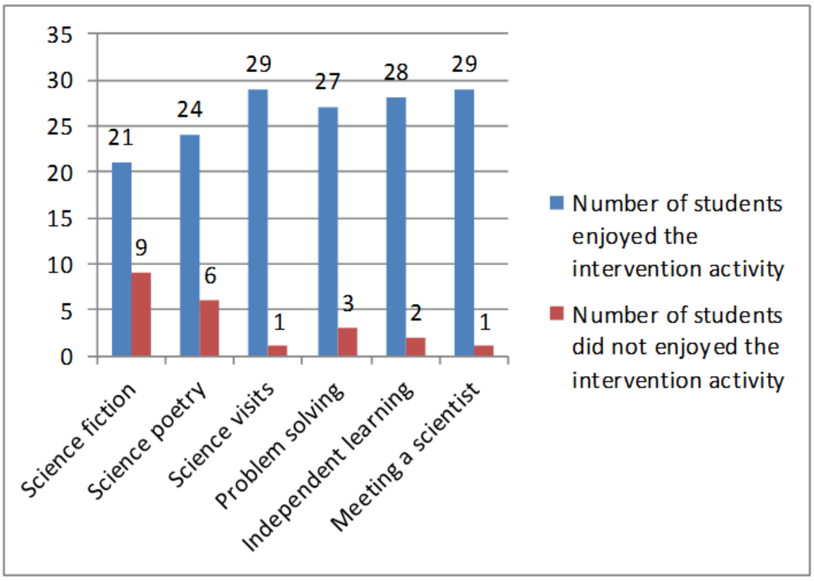


Figure 6.1: Activity ratings of the six science interventions

Overall, in combining strongly agree and agree as enjoyed intervention activity, and disagree to strongly disagree categories as not enjoyed intervention activity (Figure

6.1), I found that the most enjoyed activities were ‘science visits’ and ‘meeting a scientist’ with twenty-nine of the thirty responses – while only one of the thirty did not find these two interventions enjoyable. Following this, ‘independent learning’ constitutes the highest scores for *strongly agree* category with twenty-eight of the thirty responses, although two of the thirty girls disliked it. Next was the problem-solving activity, which twenty-seven of the thirty enjoyed and three of the thirty did not enjoy it. Twenty-four of the thirty girls enjoyed science poetry, in contrast to six girls. And in the last place, was science fiction, which was enjoyed by twenty-one of the thirty whereas nine did not enjoy the activity.

From this result I can comment here that – on the whole - the intervention was quite successful (after amalgamating these ratings) as the least liked science fiction activity is more than half, with highest to lowest category ranges from 29 – 21.

6.1 Changes in attitudes towards science

Question 9 asked the girls as whether or not their decision in making science or non-science subject choices has changed with respect to these six intervention activities. The ‘final’ results after all of the interventions show that the majority, twenty-seven of the thirty, stated that their decision towards science and/or non-science had not changed. Three of the thirty Zaki, Isra and Maha (pseudonyms) mentioned that their decision to take subjects had changed after particular interventions. Zaki (Year 9), for example, believed that the interventions based on ‘science fiction’, ‘visits’ and ‘problem solving’ has changed her view on doing more science subjects. Moreover, Isra (Year 8) viewed ‘science poetry’ and ‘independent learning’ as transformative interventions and Maha (Year 9) believed that after ‘meeting a scientist’ she now would like to take up more science subjects at A-level.

So, did ‘enjoyment’ translate into a more positive attitude towards science? Did the interventions generate change in these thirty girls? The timeline summary given below indicates that the girls can be grouped in one of four ways (C1, C2, C3 and C4) to indicate any change in attitude at different points, at the sixth month and/or at the twelfth month period. These overall changes are listed below:

> (i)Before intervention, none (0) of the thirty girls intended to carry on with ‘science subjects *only’* at A-level. This changed to two of the thirty at the sixth month point, and then four of the thirty after twelfth month point. This group of girls is referred to as C1.

(ii)Before intervention, eleven of the thirty girls wanted to choose a combination of 'both science *and* non-science subjects' at A-level. At the end of the year, this number increased to twenty-two of the thirty. This group of girls is referred to as C2.

(iii)Before intervention, eight of the thirty girls were quite unsure about their decision towards science subjects at A-level. However, these girls were really quite sure about their non-science subject choices. Later, at the twelfth-month point, this turned out to be none (0) of the thirty because these eight girls, through the intervention studies, decided to undertake a combination of both science and non-science subjects. This group of girls is referred to as C3.

(iv)Before intervention, eleven of the thirty girls wanted to choose 'non-science subjects *only'* at A-level. After interventions, however, only four of the thirty still intended to carry out with non-science subjects only. This group of girls is referred to as C4.

The distribution of all the thirty girls in accordance to C1-C4 groups can be seen in Appendix 12.

From Appendix 12 data, I will now discuss one example each from the above four categories and discuss the changes in the light of the interventions.

Category C2- C1:

Sarmin (year group nine student), exhibited small movement from C2 to C1 and achieved an intermediate impact from the interventions. After the first intervention she agreed that she would like to do biology and chemistry because she liked/ preferred (i) science behind superman (to some extent), (ii) meeting the scientist to a much larger extent as it was 'fascinating' and she could relate herself to the scientist, *because she (the scientist) had experienced what we were experiencing now*, (iii) watching science fiction made meaning of something new about forces, gravity etc. (iv) science poetry because it provided her better opportunity to express her ideas, (v) chocolate welding practical as *it was creative* and (vi) problem solving activities were *beneficial for life*. A few disadvantages like science fiction were dragged too long, and too much writing for the scrap book was also indicated. At the end of interventions, I believe that Sarmin had an intermediate effect from a series of small TL experiences because she was sitting in crossroads before the intervention and in the end crossed off all the non-science subjects and exhibited her inclination into sciences only.

Category C3-C2:

Hadi (year group seven student), also exhibited small movement from C3 to C2, she liked/ preferred (i) science fiction lesson as *it was fun*, (ii) she liked writing science poetry and understood more of the scientific vocabulary, (iii) visiting 'centre of the cell' made her interested in science, (iv) conducting independent work made her learn more about flowers. She really liked meeting the scientist; however, she stated that *I did not understand exactly what she was talking about*. At the end of the intervention she only wanted to carry on with biology at A-level. I believe that Hadi's movement into science is very small, with an intermediate to low impact from the series of interventions.

Category C4- C2:

Star (year group eight student), exhibited a slightly bigger jump as compared to Sarmin and Hadi. She did not like/ preferred doing the first three interventions as they were *boring*, later the rest of the interventions were *interesting, cool and fun*. And at the end of the interventions she wanted to do one science (mathematics) at A-levels. I believe that all the interventions had a small to intermediate impact towards her movement into science and not just the last three, as by the time she did the fourth intervention her dispositions away from science was softened. Although she is inclined to do only one science subject and did not actually mention her understanding of the topic, however, I believe that Star's movement into science exhibits intermediate impact of the series of small interventions.

Category C4-C2- C4:

Iqra (year group nine student), exhibited a medium movement away from science and the impact of interventions at one point was intermediate that actually encouraged her to do applied science. She liked/ preferred the interventions as (i) science fiction lesson was fun and she did not have to write much, it seems that understanding element was missing, (ii) Brunel University visit opened her *eyes to more fun side of science* (iii) poetry writing was humorous which gave her the liberty to express her personal opinions, however at the same time she mentioned that *because I have made a poem does not mean that I like science. I still think science is a complex subject that I will easily get bored in*. After this intervention her opinion changed and she indicated that she would like to consider science. But then after six months she moved back to the C4 category. I believe that the movement into science was very small, the impact of fun through these activities made her like science however when it comes to understanding and making-meaning of science she finds it difficult to adapt. Therefore she prefers the fun side of science rather than the understanding side of science.

In summary, these small, classroom interventions can be shown to have been successful. They have been successful first in terms of their perceived enjoyability. While not all were seen to be equally enjoyable, only very few of the girls saw some of the interventions as disagreeable. I take encouragement in this at two levels: first, the interventions were not a waste of time, and as I show below, they were successful at other levels too. Most teachers take professional pride in designing activities at classroom level that they want to be successful – in this case enjoyability was high on the aims I had for these sessions. Second, the C4 group described above, the four girls who were 'non-movers-towards science' illustrate quite markedly that there are some students who will really not move towards science. For whatever reason (the strength of social forces, natural inclination, lack of meaning, strong anti-preference, a lack of personal agency) these girls resisted the enjoyment of the interventions and were adamant in retaining their non-science attitudes.

Moreover, in addition to academic choices, only seventeen of the thirty girls were able to indicate their career choices. The results of the findings are given below in Table 6.1.

	Pre-intervention	After 12 months	Student	Prospective career choice
1	C2	C1	Sarmin	Doctor
2	C2	C1	Sitara	Astronomer/ Radiologist
3	C2	C1	Samray	Doctor/ Pscychologist
4	C2	C1	Saira	Scientist/Chemist/Geologist/
5	C2	C2	Hijir	Biologist, Psychologist, IT technician
6	C3	C2	Zikri	Doctor/ photographer
7	C3	C2	Sabah	Doctor
8	C3	C2	Samar	Astronomy/ Psychology
9	C4	C2	Hadi	Vet then English teacher
10	C4	C2	Hajra	Artist/ Dentist
11	C4	C2	Rukhsana	Writer/ Doctor/ Pharmacist
12	C4	C2	Mahnoor	Lawyer
13	C4	C2	Samia	Public service.

Table 6.1: Prospective career choice – Phase Three

In addition to the above thirteen girls, an interesting trend can be seen that the four C4 girls seemed to have inclination towards studying non-science subjects only; moreover they also exhibit a drive towards gaining a non-science career. For example: Anushka wants to become an english teacher, Bano a dress designer, Mehtab a psychologist/ english writer and Iqra writer/ singer/ poet. Therefore, even though they preferred most of the interventions, however, the impact of the series of small TL experiences were low and the movement into science was very small or even negligible.

In addition to looking at the future career decisions, pre-intervention questions 7 and 8 and post sixth month intervention, questions 13 and 14 asked the girls as whether or not a science degree provides a better career opportunity (as compared to a non-science degree).

At pre-intervention, twenty-eight of the thirty (9 strongly agreed, 19 agreed) girls believed that a degree in science unlocks the opportunities for diverse and exciting jobs. Two of the thirty disagreed (00 strongly disagree and 02 disagree) (Figure 6.2).

The overall distribution of the thirty girls within four groups is as follows (no particular comment was given by the girls):

C1- Science *only*: None of the student belongs to this category at pre-intervention stage

C2- Science *and* non-science: The majority agreed (10/11 agree and 01/11 disagree)

C3- Unsure: All agreed (08/08 agree, 00/08 disagree)

C4- Non-science *only*: The majority agreed (10/11 agree, 01/ 11 disagree).

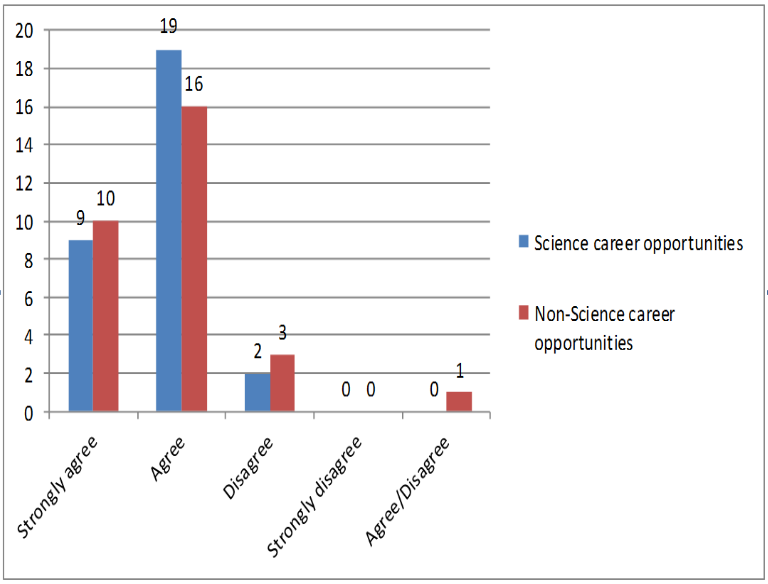


Figure 6.2: Career opportunities (pre-intervention period) – Phase Three

Comparing pre-intervention science and non-science data, the majority agreed that a degree in science as well as a degree in non-science provide better job opportunities, despite their future subject choices. However, two more (science career) girls (one from subject category C3 and C4 each) agreed that a degree in science provides better career opportunities as compared to a degree in non-science.

Post-sixth month non-science career choices, equal number of girls (26/30, 6 strongly agree and 20 agree; pre-intervention 26- sixth month 26) agreed. Where, almost equal number (02/30: 00 strongly disagree and 2 disagree; pre-intervention 3 – sixth month 2) disagreed and one more student (2/30; pre-intervention 1– sixth month 2) agree/disagree (Figure 6.3). The overall agree and disagree distributions of the thirty girls within four groups, in relation to non-science career opportunities is as follows along with a few comments:

C1- Science only: Equal number agreed and disagreed (01/02 agreed and 01/02 disagreed). For example: *Agree because arts and humanities is everywhere* (Sarmin)

C2- Science and non-science: The majority agreed (22/25 agree and 01/25 disagree and 02/25 agree/disagree). For example: *Yes because it seems fun'* (Sitara), *taking more subjects are good rather than science ones only* (Samia)

C3- Unsure: None of the student belonged to this category at sixth month (00/00)

C4- Non-science only: All agreed (03/03 agree and 00/03 disagree). For example: *my PSHE teacher motivates me* (Bano).

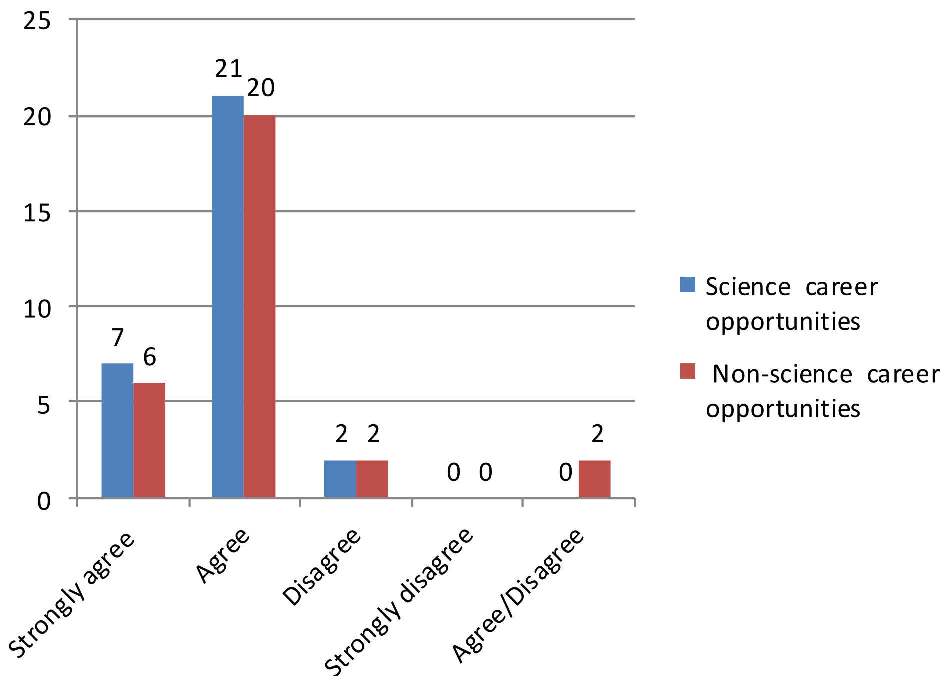


Figure 6.3: Career opportunities (post-sixth-month intervention period) – Phase Three

The majority actually believe that a degree is important to acquire a better career, maybe this is the reason that the most of the girls (twenty-five of thirty) wanted to carry on with both science and non-science subjects at A-level as they believe that both science and non-science degrees provide a gain in future career. While comparing the responses based on subject grouping, I have observed only one student response difference between C1 category and two responses between C2 categories in favour of a science degree.

Now, after looking into the girls' changing attitudes, I will present my findings in broadly five sections which are as follows:

(i)Perception of GF: where I will use numbers, a few quotes and main outcomes of the GF that emerged from the questionnaires

(ii)Perception of SA: where I will use numbers, a few quotes and main outcomes of the SA that emerged from the questionnaires

(iii) Perception of natural inclination: where I will use numbers and main outcomes of the science and non-science natural inclination that emerged from the questionnaires

(iv)Transformation and change: where I will present a few summarised stories of the girls under three themes

(v) Summary- Phase Three: where I will apply the seven Sci-ID model ingredients to summarise the key outcomes.

6.2 Perception of global forces (GF)

Only, Saira from C1 category indicated in the interview that the only reason she could move away from science will be if she had to go and live in Somalia where education (science) for girls is quite impossible. The rest of the girls did not mention the impact of GF like ethnicity, race, gender, religion etc.

6.3 Perception of social agents (SA)

I have asked a series of questions to find out the influences from parents, school science, and teachers that has shaped them to choose science or non-science subjects in future. The findings are presented below using C1, C2, C3 and C4 groups.

(i)Parents

At sixth and twelfth month, question six, asked the girls whether parents have an influence towards their decision of taking up science or non-science subjects at A-level.

At sixth month, only six of the thirty (3 strongly agree and 3 agree) girls believed that their parents were influential in their decision towards taking up science or non-science subjects at A-level and beyond (Figure 6.4). Where the majority; twenty-one of the thirty (9 disagree and 12 strongly disagree) believed that parents are non-influential.

The majority believed that to take up science or non-science subjects are their personal choice. Three of the thirty opted for both agree and disagree options.

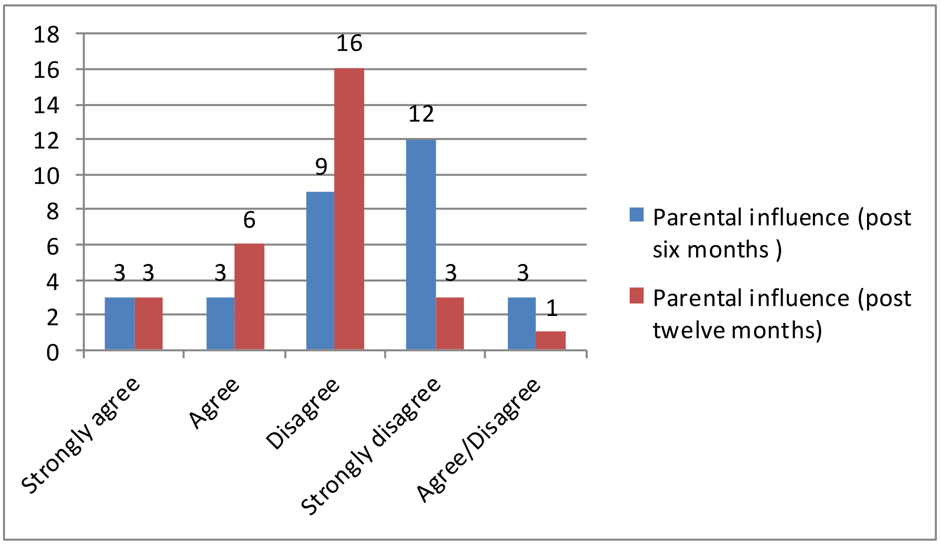


Figure 6.4: Parents- Phase Three

The overall agree and disagree distributions of the thirty girls within the four groups, in relation to parental influence, is as follows along with a few comments:

C1- Science only: Equal numbers of girls' agree and disagree (1/2 agrees and 1/2 disagrees). For example: *my parents want me to be a doctor* (Sarmin), *I wanted to do it myself* (Tabu).

C2- Science and non-science: The majority disagreed (4/25 agree and 18/25 disagree). For example: *I make my own choices usually* (Zaki), *My mother would like me to become a doctor so I do as well* (Zikri).

C3- Unsure: None of the student belongs to this category at sixth month.

C4- Non-science only: One more student disagreed (1/3 agrees and 2/ 3 disagree). For example: *I'll pick what I want* (Mehtab), *My mum wants me to be an english teacher* (Hadi).

Overall, the majority disagreed from all the above categories except from C1, where one half agreed and the other half disagreed.

At twelfth month, in comparison to sixth month, three more (9/30; 03 strongly agree and 6 agree) girls agreed. Moreover, two less (19/30; 16 disagree and 3 strongly disagree) disagreed (Figure 6.4). However, one student opted for both agree and disagree options.

The overall agree and disagree distributions of the thirty girls within four groups, in relation to parental influence(s), is as follows along with a few comments:

> C1- Science only: The majority disagreed (1/4 agree, 2/4 disagree and 1/4 agree/disagree). For example*: My siblings all did one or more sciences at A-level* (Sarmin).
>
> C2- Science and non-science: The majority disagreed (08/22 agree, 13/22 disagree and 1/4 agree/ disagree). For example: *It's my choice what I do* (Mahnoor).
>
> C3- Unsure: None of the student belongs to this category at sixth month
>
> C4- Non-science only: All disagreed (0/4 agree and 4/ 4 disagree). For example: not parents it's m*ainly media* (Iqra).

On the agreement side, from sixth month data to twelfth month data, four of thirty girls Hajra (C2), Sabah (C2), Samray (C2-C1) and Tabu (C2-C1) changed their view from disagree to agree. In addition, Roshan (C2) and Sitara (C2-C1) from agree/disagree to agree options exhibiting the influence of parents.

On the disagreement side, from sixth month data to twelfth month data, Sarmin (C1) and Zaki (C2) changed their view from agree to agree/disagree, in addition, Hijir (C2) changed her view from agree/disagree and Saira (C2-C1) from agree to disagree, exhibiting individualistic decision towards the up taking of subjects.

In summary, it seems that the girls with science only subject choices indicated parental influence as Samray, Sitara and Tabu moved from C2 to C1 category and with this movement agreed to have parental influence. However, it could be an aggregated influence from other GF, SA and/or TL experiences that have made them choose science. Like, Saira also showed the same transition from C2-C1 and Sarmin remained under C1 category but did not believe to have parental influence anymore. Moreover, Anushka declined science completely (C2 – C4) through 'non-sciencey' home environment. Further investigation is needed to understand the salience of parental influence on the girls.

(ii)School science curriculum and relevance of daily life science

Question 12 at post sixth month intervention and question 7 on the post twelve month questionnaire asked the girls as to what extent their school science curriculum has influenced their interest in science.

At sixth month, thirteen of the thirty (2 strongly agree and 11 agree) girls believed that the curriculum has a positive impact in encouraging their interest in science. Whereas, sixteen of the thirty (4 strongly disagree and 12 disagree) disagreed and one student agreed and disagreed (Figure 6.5).

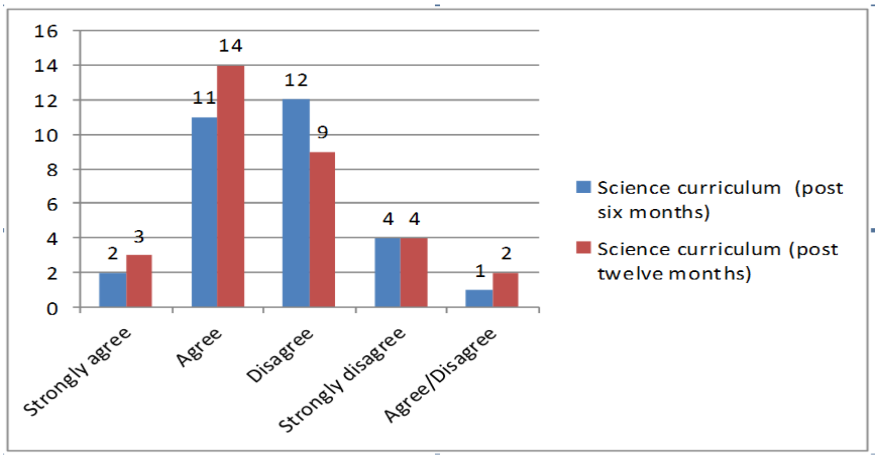


Figure 6.5: School science curriculum – Phase Three

The overall agree and disagree distributions of the thirty girls within four groups, in relation to the school science curriculum, is as follows, along with a few comments:

> C1- Science only: All disagreed (0/2 agree, 2/2 disagree). For example: *I think I need to learn more to influence myself into science* (Sarmin).
>
> C2- Science and non-science: The majority (with a difference of two) disagreed (11/25 agree, 13/25 disagree and 1/25 agree/ disagree). For example: *The book is not interesting* (Huma), *I really like the way how we are taught' through science curriculum* (Sabah).
>
> C3- Unsure: None of the student belongs to this category at sixth month.
>
> C4- Non-science only: The majority (with a difference of two) disagreed (2/3 agree and 1/ 3 disagree*).* For example: Agree because *it was interesting* (Bano).

At twelfth month of the intervention, in comparison to sixth month, four more (17/30; 3 strongly agree and 14 agree; science 13- non-science 17) girls believed to have been interested in science through the science curriculum (Figure 6.5). Whereas, three less (13/30; 4 strongly disagree and 9 disagree; science 16- non-science 13) girls disagreed as compared to sixth month data.

The overall agree and disagree distributions of the thirty girls within four groups, in relation to the science curriculum, is as follows along with a few comments:

C1- Science only: A mixed view was obtained (1/4 Agree, 2/4 disagree and 1/4 agree and Disagree). For example: *It is very interesting* (Sarmin).

C2- Science and non-science: The majority agreed (14/25 agree, 08/25 disagree). For example: *I always liked science regardless* (Sana).

C3- Unsure: None of the student belongs to this category at sixth month.

C4- Non-science only: The majority disagreed (0/3 agree and 3/4 disagree and 1/4 agree/disagree). For example: *I still do not like science* (Anushka).

On the agreement side, from sixth month data to twelfth month data, five girls Hajra, Iqra Q, Rakhi, Roshan and Star, while staying in the same C2 subject group, switched their view from disagree to agree in six months time. Moreover, a little positive effect of the science curriculum was viewed by Sitara as she moved from disgaree to agree/disagree option and Samray changed her view from disagree to agree/disagree and both moved from C2 to C1 subject group. At this point there is a possibility that Sitara and Samray now want to take up science subjects only as they have gained interest in science curriculum, but it is not certain as moving into C1 group could be an aggregated imapct from various GF, SA and TL expereinces. Further probing from these girls is required for future study.

On the disagreement side, from sixth month data to twelfth month data four girls Humaira (C2), Hijir (C2), Iqra (C2-C4) and Anushka (C2-C4) changed their view from agree to disagree. The first two stayed in the same subject group C2, where the last two moved from C2 category to C4 category showing a lack of interest in up taking science at A-levels. Here, for Iqra and Anushka, science curriculum acted as one of the main cause of declining science but this does not mean that it is the only cause.

In summary, the majority disagreed that science curiculum has a positive effect at sixth month despite of subject grouping from C1 – C4. However, at twelfth month 50:50 girls believed to have an effect, where the majority of the girls agreed from C2 group and all disagreed from C4 subject group. The improvement could be linked to the science interventions or it could be that the topic been taught at the twelfth month questionnaire period is liked by the majority (topics: Yr 7 Respiration, Yr8 Periodic table and Yr9 Hydocarbons). Moreover, as discussed before that any particular influence is not the only cause of opting for science and/or non-science choices, instead it is an aggregated effect from various GF, SA and TL expereinces.

In addition, to the science curriculum, pre-intervention questionnaire question 4 and question 9 in the sixth month questionnaire, asked as whether school science has affected their interest in daily life science.

At the *pre-intervention study*, twenty-three of the thirty (23/30) (3 strongly agree and 20 agree) agreed that school science has affected their interest in daily life science. Whereas, seven of the thirty (00 strongly disagree, 07 disagree) disagreed (Figure 6.6).

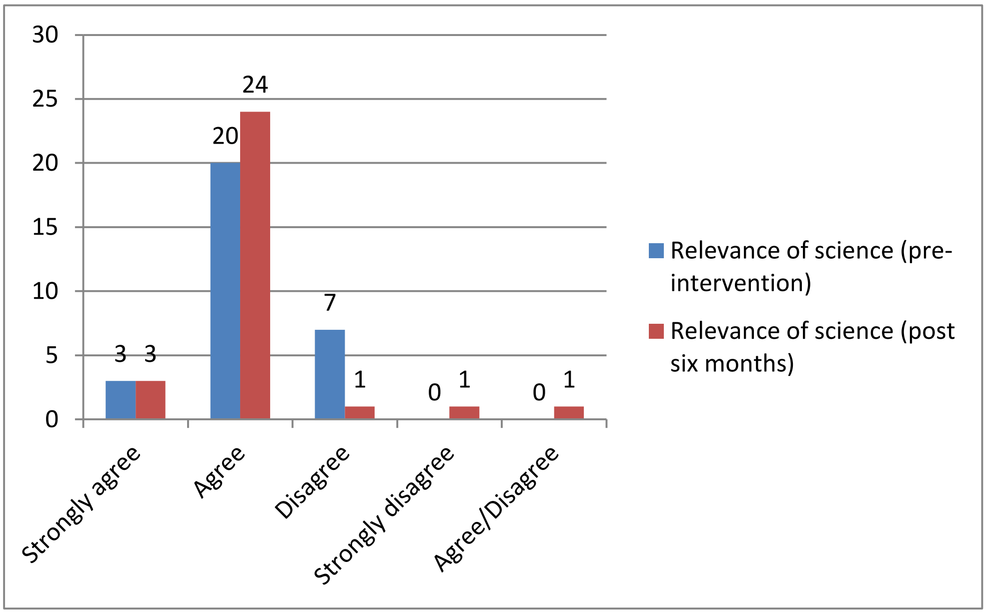


Figure 6.6: Relevance of school science to daily life – Phase Three

The overall agree and disagree distributions of the thirty girls within four groups, in relation to relevance of daily life science, is as follows, along with a few comments:

C1- Science only: None of the student belongs to this category at sixth month
C2- Science and non-science: The majority agreed (09/11 agree and 02/11 disagree). For example: *mostly the things I learn I use in my daily life* (Hijir).
C3- Unsure: The majority agreed (06/08 agree and 02/08 disagreed). For example: *it helps to know how to keep healthy* (Roshan).
C4- Non-science only: The majority agreed (08/11 agree and 3/11 disagree). For example: *not every single day but mostly* (Hajra).

At sixth month of the intervention, four more (27/30; 03 strongly agree and 24 agree) agreed and five less (02/30; 01 strongly disagree and 01disagree) disagreed. However, one of the thirty opted for both agree and disagree (Figure 6.6).

The overall agree and disagree distributions of the thirty girls within four groups, in relation to relevance of daily life science, is as follows:

C1- Science only: All agreed (02/02 agree and 00/02 disagree). For example*: I wish to learn more* (Sarmin).
C2- Science and non-science: The majority agreed (22/25 agree and 02/25 disagree and 01/25 agreed and disagreed). For example: ..*hygiene and health* (Star).
C3- Unsure: None of the student belongs to this category at sixth month.
C4- Non-science only: All agreed (03/03 agree and 00/03 disagree). For example: *Its cool. Yeah, I guess it does sometimes* (Mehtab).

On the agreement side, from sixth month data to twelfth month data, seven girls changed their view on the relevance of daily life science from disagree to agree option, including girls Samray (C2), Zeenat (C2), Mehtab (C4), Huma (C3-C2), Zikri (C3-C2), Isra (C4-C2) and Rukhsana (C4-C2). The first three girls stayed in the same subject group where the last four girls showed a step ahead towards the uptake of science at A-levels. Moreover, Sana (C2) changed her viewpoint from agree/disagree to agree. It shows that the change in their view about school science could be because of the positive impact from the interventions for example: through 'chocolate welding' activity the idea of making strong bridges, polymerisation and cooking process could have given an incentive as what they learn in science at school is linked to daily life. In addition it is noted that C4 girls agreed to the option however, a few indicated that not everything that is learnt in science is helpful.

In summary, it seems that effect of school science is viewed to be quite helpful in daily life science despite of being in any group from C1-C4. Moreover, the impact of interventions seemed to be worked as well as after six months four more students opted for an agree option.

(iii)Teachers

Questions 5 and 6 at pre intervention questionnaire, asked the girls about science and non-science teachers' positive influence in choosing more science and/or non-science subjects at A-level.

At pre-intervention, twenty of the thirty (4 strongly agree and 16 agree) agreed to have been influenced by science teachers in deciding towards the uptake of science subjects. Where, eight of the thirty (2 strongly disagree and 6 disagree) and two of the thirty opted for both agree/disagree option (Figure 6.7).

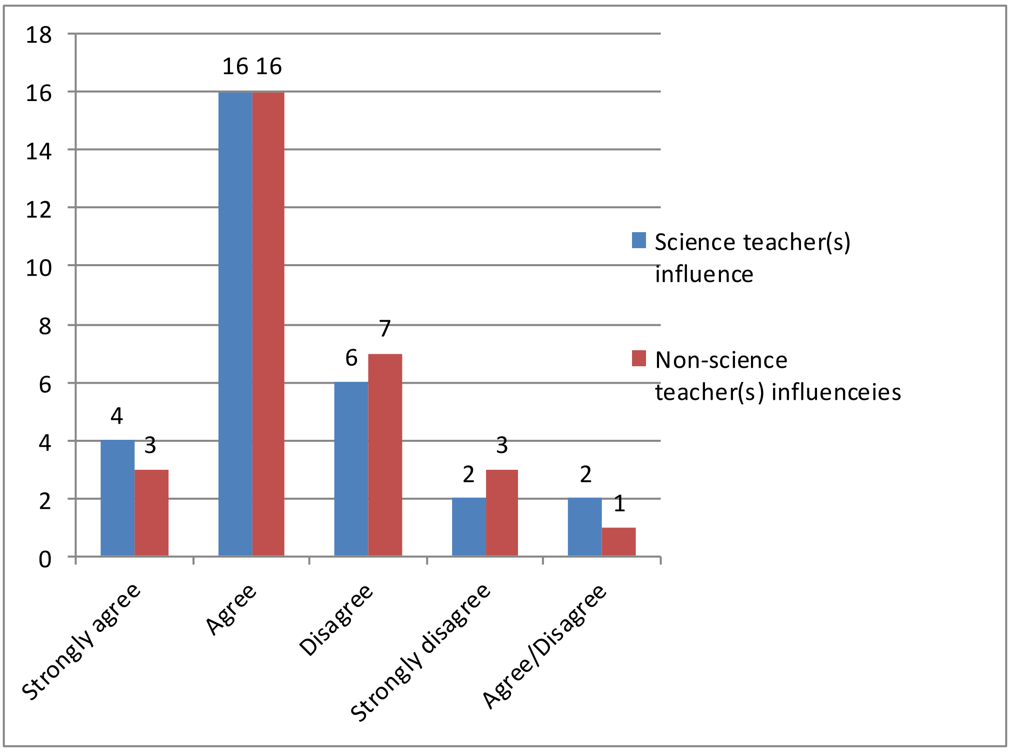


Figure 6.7: Teacher(s) (pre-intervention) – Phase Three

The overall agree and disagree distributions of the thirty girls within four groups, in relation to science teacher's positive influence, is as follows along with a few comments:

> C1- Science only: None of the student belongs to this category at sixth month .
> C2- Science and non-science: The majority agreed (10/11 agree and 01/11 disagree). For example: An appropriate comment was not given.
> C3- Unsure: The majority agreed (05/08 agree, 01/08 disagree and 02/08 agree/disagree). For example: *Not sure* (Samar). *My science teacher helps me a lot; she makes sure we understand* (Sabah).
> C4- Non-science only: Majority disagreed (05/11 agree, 06/ 11 disagree). For example: An appropriate comment was not given.

Similarly, nineteen of the thirty (3 strongly agree and 16 agree) agreed to have experienced positive, non-science teachers influence in carrying on with non-science subjects. Where ten of the thirty (3 strongly disagree and 7 disagree) disagreed and one of the thirty opted for both agree/disagree option (Figure 6.7). The overall agree and disagree distributions of the thirty girls within four groups, in relation to non-science teacher's positive influence, is as follows:

> C1- Science only: None of the student belongs to this category at sixth month.

C2- Science and non-science: The majority agreed (07/11 agree and 04/11 disagree). For example: no appropriate comment.

C3- Unsure: The majority agreed (06/08 agree, 02/08 disagree). For example: no appropriate comment.

C4- Non-science only: The majority agreed (06/11 agree, 04/ 11 disagree and 1/11 agree/disagree). For example: no appropriate comment.

In summary, the majority of the girls believed to have science and/ non-science teachers' positive influence in the uptake of subjects. However, the science teachers influence was little higher than non-science teachers. Overall only one more (science teacher 20 – non-science teacher 19) student believed that science teachers are influential as compared to non-science teachers. Where two less (science teacher 8 – non-science teacher 10) disagreed and one more (science teacher 2 – non-science teacher 1) agreed/disagreed.

In addition to pre-intervention, questions 10 and 11 at the sixth month of the questionnaire, also asked the girls about science and non-science teachers' positive influence in choosing more science and/or non-science subjects after GCSE's.

At sixth month, in comparison to pre-intervention, six less (14/30, 2 strongly agree and 12 agree; pre-intervention 20 – sixth month 14) believed to have science teachers' influence in choosing science subjects. Where seven more (15/30: 6 strongly disagree and 9 disagree; pre-intervention 08 – sixth month 15) disagreed and equal number (1/30) agreed/disagreed (Figure 6.8).

The overall agree and disagree distributions of the thirty girls within four groups, in relation to science teacher's positive influence, is as follows along with a few comments:

C1- Science only: Equal number agreed and disagreed (01/02 agreed and 01/02 disagreed). For example: *Because I want to be a dentist and I need triple science* (Tabu).

C2- Science and non-science: The majority agreed (14/25 agree and 5/25 disagree and 01/25 Agreed and Disagreed). For example: *They didn't influence me to not choose science subjects (Talat), my teacher has made me see so much more in science* (Zikri).

C3- Unsure: None of the student belongs to this category at sixth month (00/00).

C4- Non-science only: All disagreed (00/03 agree and 03/03 disagree). For example: *Strongly Agree I just find it (science) too difficult* (Iqra).

On the other hand, three less (16/30, 2 strongly agree and 14 agree; pre-intervention 19 - sixth month 16) agreed to have been positively influenced by non-science teachers in their decision of choosing non-science subjects. Where, two more (12/30: 4 strongly disagree and 8 disagree; pre-intervention 10 – sixth month 12) disagreed and one more (2/30; pre-intervention 1 – sixth month 2) student agree/disagree (Figure 6.8).

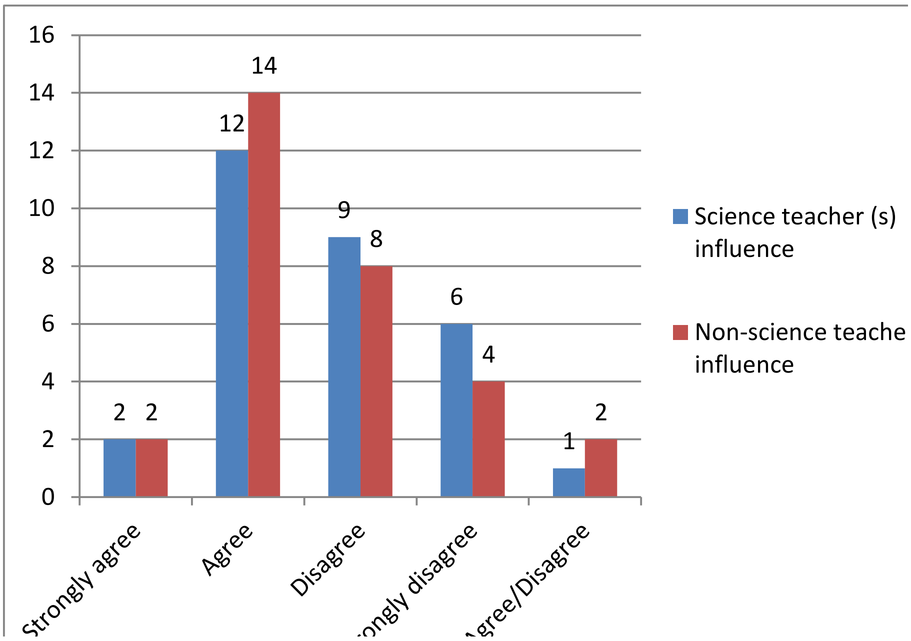


Figure 6.8: Teacher (post-sixth-month intervention period) – Phase Three

The overall agree and disagree distributions of the thirty girls within four groups, in relation to non-science teacher's positive influence, is as follows along with a few comments:

C1- Science only: All disagreed (00/02 agreed and 02/02 disagreed). *Disagree as I want to become a dentist* (Tabu).

C2- Science and non-science: The majority agreed (13/25 agree and 10/25 disagree and 02/25 agreed and disagreed). *I don't understand my teacher most of the time* (Samray).

C3- Unsure: None of the student belongs to this category at sixth month (00/00).

C4- non-science only: All agreed (03/03 agree and 00/03 disagree). For example: *My PSHE teacher motivates me* (Bano).

Quite a lot of fluctuations were also observed towards girls' view on science teachers' positive influence. As, on the agreement side, from sixth month data to twelfth month data, Rakhi changed her subject grouping from C4 to C2 and moved from disagree to agree/disagree option and Humaira from agree/disagree to agree options with a change in subject grouping from C3-C2.

On the disagreement side, from sixth month data to twelfth month data, six girls, Zeenat (C2), Anushka (C2), Samray (C2), Rukhsana (C3-C2), Isra (C4-C2) and Maha (C4-C2), liked to choose science and non-science subjects at A-level but without science teachers influence showing fluctuation from agree to disagree. The first three declined science teacher's positive influence towards subject choice and stayed under the same C2 subject group, where the last three has shown interest to take up science in addition to non-science. Moreover, Samar, while staying on the same C2 subject group was unsure before, but later disagreed and Sitara (C2) agreed and then later becomes unsure. These six girls' perception of science teacher has fallen, but the good thing is that the effect on science subject choices retained and for Isra and Maha even become better.

Quite a lot of fluctuations were also observed towards girls' view on non-science teachers' positive influence as well. As, on the agreement side, from sixth month data to twelfth month data, five girls, Saira (C2), Sabah (C3- C2), Isra (C3-C2) Rukhsana (C3-C2) and Rakhi (C4-C2) moved from disagreed to agreed options. Saira changed her view, but stayed in the same subject group of C2, where the rest moved from C3 or C4 to C2. It might be that non-science teachers were dominating, that made the girls opt for non-sciences, but at the same time not dominating enough as these girls want to pursue science subjects along with non-science subjects; or it could be other factor(s) affecting their interest into science and non-science subject choices.

On the disagreement side, from sixth month data to twelfth month data, another five girls Tabu (C1-C2), Maha (C3-C2), Roshan (C3-C2), Samar (C3-C2) and Zikri (C3-C2) moved from agree to disagree options. Except Tabu, all the other four girls later disliked the non-science teacher(s), as maybe because later, they wanted to choose science subjects along with non-science subjects or it could be that non-science teachers' negative influence has made them think of science subjects along with non-science subjects. Moreover, three girls Zaki (C2), Hijir (C2) and Iqra (C2-C4) moved from agree/disagree option to agree options and at the same time stayed or moved into both science and non-science group. Rakhi, in comparison to Iqra, demonstrates same transition of subject grouping (C2-C4) but opted for opposite non-science teacher options.

In summary, the influence of science teachers as well as non-science teachers slightly declined over the period of science interventions, however the enjoyment towards interventions and willingness to take up at least one science at A-levels has improved. To some extent it shows that the influence of science teachers does not play a big role in influencing these girls to take up sciences at A-level and beyond.

6.4 Perception of natural inclination

Questions 4 and 5, at the post-sixth and twelfth-month period, asked the secondary school girls whether they perceived themselves to have a science or non-science 'natural inclination'.

At the *sixth month* period, fourteen of the thirty (5 strongly agrees and 9 agrees) girls perceived themselves to have a science natural inclination from the time they were in primary school. Fifteen of the thirty (6 strongly disagree and 9 disagree), disagreed to have a natural inclination towards science (Figure 6.9). One of the thirty was unsure about as whether she has a science inclination or not. The overall agree and disagree distributions of the thirty girls within four groups, in relation to science natural inclination, is as follows along with a few comments:

C1- Science only: Equal numbers agree and disagreed (1/2 agree and 1/2 disagree). *Agree: I enjoy it* (Sarmin).
C2- Science and non-science: Almost half agreed and half disagreed (11/25 agree, 12/25 disagree and 1/25 agree and disagree). *Agree- more about space; however I am slowly losing my interest* (Iqra). *Strongly Agree- In (through) high school experiments* (Zaki).
C3- Unsure: None of the student belongs to this category at sixth month.
C4- Non-science only: One more student disagreed (1/3 agree and 2/ 3 disagree). *Disagree: I didn't like science* (Hadi).

On the other hand, twenty-seven of the thirty (10 strongly agree and 17 agree) agreed and only three of the thirty (1 strongly disagree and 2 disagree) disagreed to have a non-science natural inclination (Figure 6.9). The overall agree and disagree distributions of the thirty girls within four groups, in relation to a non-science natural inclination, is as follows:

C1 – Science only: All agreed (02/02 agree and 00/02 disagree). For example: *I want to learn about the … social world* (Sarmin).

C2 – Science and non-science: The majority agrees (22/25 agree, 03/25 disagree). For example: *Strongly Agree towards english* (Anushka).

C3- Unsure: None of the student belongs to this category at sixth month.

C4- Non-science only: All agreed (03/03 agree and 00/00 disagree). For example: *I loved art and english the most*.

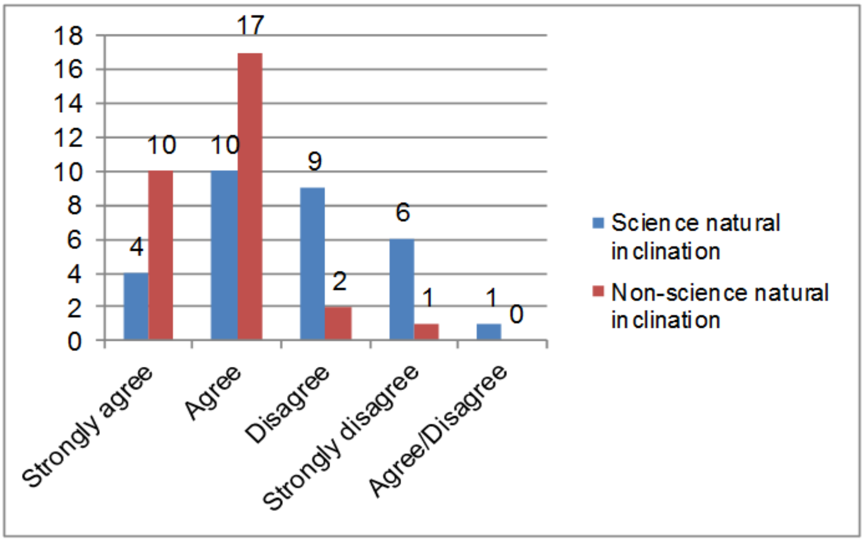


Figure 6.9: Natural inclination (post-sixth-month intervention period) – Phase Three

In comparison to natural inclination into science, thirteen more (non-science 27 – science 14) girls indicated to be naturally inclined towards non-science subjects and twelve less (science 15- non-science 3) disagreed. One more C1 student, who wanted to opt for sciences only, agreed to have a non-science natural inclination but later opted for a science natural inclination option. In addition, the majority of the C2 girls agreed to have a non-science natural inclination more than a science inclination. The results from C2 showed that the girls' intention to take up science is less prevalent than taking up non-science subjects. Moreover, the majority of the C4 girls agreed to have a non-science natural inclination as compared to science natural inclination.

At twelfth month, in comparison to sixth month, two more (16/30; 5 strongly agree, 11 agree; sixth month 14- twelfth month 16) girls agreed having a natural inclination towards science and two less (13/30; 00 strongly disagree, 13 disagree; sixth month 15- twelfth month 13) disagreed (Figure 6.10). The overall agree and disagree, distributions of the thirty girls within four groups, in relation to science natural inclination, is as follows along with a few comments:

C1 - Science only: The majority agreed (3/4 agree, 0/4 disagree and 1/4 agree/disagree). For example: not an appropriate comment received.

C2 - Science and non-science: Half of the girls agreed and half-disagreed (11/22 agree, 11/22 disagree). For example: *when I was a little girl I always wanted to be a scientist* (Sabah).

C3- Unsure: None of the student belongs to this category at sixth month.

C4- Non-science only: Equal number of girls agreed and disagreed (2/4 agree and 2/ 4 disagree). For example: *I used to like but now I do not* (Anushka).

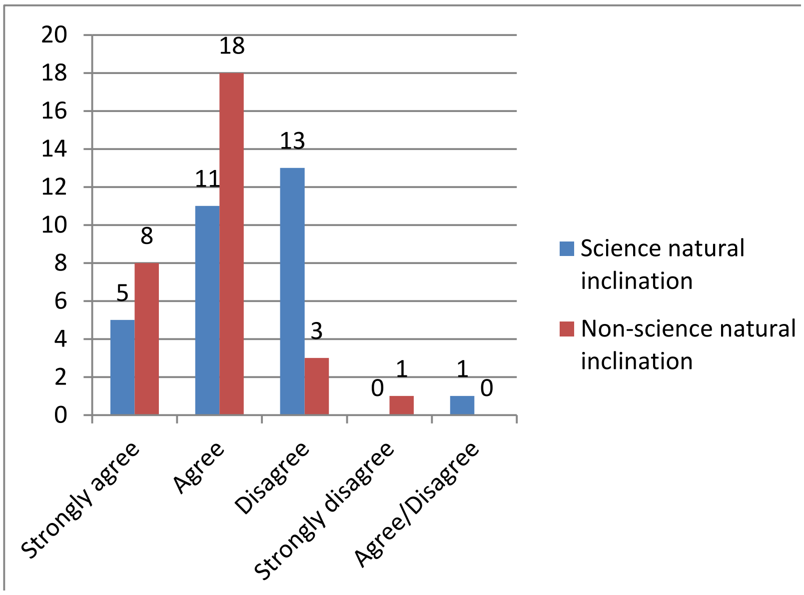


Figure 6.10: Natural inclination (post-twelfth month intervention period) - Phase Three

Moreover, overall one less (26/30; 03 strongly agreed and 13 agreed; sixth month 27-twelfth month 26) agreed and one more (4/30; 01 strongly disagrees and 3 disagree; sixth month 4 - twelfth month 3) disagreed having a non-science natural inclination between sixth and twelfth month of study (Figure 6.10). The overall agree and disagree distributions of the thirty girls within four groups, in relation to non-science natural inclination, is as follows along with a few comments:

C1- Science only: The majority agreed (3/4 agree, 1/4 disagree). For example: *I am not very artistic* (Sarmin).

C2- Science and non-science: The majority agreed (19/22 agree, 03/22 disagree). For example: *I really like to draw* (Sabah).

C3- Unsure: None of the student belongs to this category at sixth month.

C4- Non-science only: All agreed (4/4 agree and 0/ 4 disagree). For example: *I am becoming more interested* in science (Iqra).

For science natural inclination, on the agreement side, from sixth month data to twelfth month data Hajra (C2), Hadi (C4-C2), Sitara (C2-C1) and Roshan (C2) changed their view from disagree to agree. On the disagreement side, from sixth month data to twelfth month data Talat (C2) disagrees and Samray (C2-C1) became unsure from strongly agree. This gives an indication that with time, their science or non-science inclination might have transformed- further investigation is needed for future research.

6.5 Transformation and change

The above data on science inclination and non-science inclination was then compared and contrasted with subject choices focusing on the following three themes:

(i)Progressive TL and smooth transformations- they exhibit stability, they knew what they wanted to do from an primary school age and even TL experiences, resulted in no movement or very small movement from their stable science or non-science extremes. Therefore, for them, the meaning-making filter, their preferences and natural inclination were largely open for what they wanted to study either science or non-science. Even at their present age (12-14 years) they exhibit stable natural inclination and a certain drive/ push (IIA) that goes against certain GF, SA and TL experiences (events, triggers or interventions) or goes with them.

(ii)Progressive TL and wavering transformation - they exhibit fluidity, they want to carry on with both science and non-science subjects at A-level, for some the TL experiences, resulted in a kind of intermediate impact and a medium movement towards science. Therefore, for them, the meaning-making filter, preferences and natural inclination are open for both science and non-science choices. For some natural inclination is ambivalent or stable but the drive/ push (IIA) of either going against or to go with the GF, SA and TL experiences (events, triggers, interventions) exhibit ambivalence.

(iii)Reconstructive TL and wavering transformation - they exhibit fluidity, and mild transformation towards science or non-science. They have experienced a few distinctive/ sharp small, medium or large number of TL experiences that marks their movement towards or away from science. Therefore, after these experiences, the meaning-making filter and preference filter have readjusted the filter sizes and their natural inclinations are quite determinative towards either science or non-science choices. It seems that these clear moments in life established a certain drive/ push (IIA) that goes against or with the GF, SA, TL experiences (events, triggers or interventions).

The distribution of students in the above three themes can be seen in Table 6.2.

	Into science	**Into both**	**Away from science**
Progressive TL and Smooth transformation	01	00	01
Progressive TL and Wavering transformation	03	22	01
Reconstructive TL and Wavering transformation	00	00	02

Table 6.2: Transformation and change – Phase Three

The three themes mentioned above will be supported with the twelve example stories; at least two from each theme. These stories include a discussion on GF, SA, TL experiences (events, triggers, interventions) and future plans. The selection criteria were to show a range of personal and social TL experiences and its impact on their choices towards or away from science.

(i)Progressive TL and smooth transformation

Only two of the thirty girls fall into this category, one into science and the other one away from science. For example:

Saira, a twelve-year-old, year seven student always wanted to take up science subjects at A-level and beyond. She accepted that she has a natural 'science inclination' principally because *science is my favourite subject*. Like the other smooth transition participants from Phase One and Two, she never asked herself as whether or not she wants to do science *all I know is that I am willing to do science for my GCSE, A-levels and finally to become a pharmacist/ scientist*, exhibiting small movement further into science. Further evidence is that in the beginning Saira opted for science and non-science subjects (C2) -

and later, strictly showed interest in choosing science subjects only (C1) exhibiting movement towards becoming a scientist. Saira's perception on 'social agents' is that her decision of taking science has a low or no impact. For example: no influence from parents, science teacher has an influence, which was seen before and after the intervention, whereas non-science teacher influence diminishes in this period of scientific intervention. The science based 'trigger' for Saira arose at age nine, after watching a few chemistry videos which showed mixing chemicals together, forming new compounds, showing colour change and explosions, *it's just so amazing*. The science interventions were praised by Saira, but seem that were not very much liked as she showed mixed feeling towards science interventions, for three interventions she felt good and for the other three she did not and the reason for feeling good or bad was not mentioned. Moreover, Saira agrees before, during and after interventions that school science is relevant to daily life. In the future she wants to carry on with science based employment as she believes that a degree in science provides better career opportunities. The only life occurrence that might make her decision away from science will be moving to a different country (Somalia), where education as a girl to achieve is quite impossible. She exhibits stable science identity as she stated that *I want to become a scientist and that's it*. This statement indicates a drive/ push (IIA) towards becoming a scientist (Appendix 8, Appendix 9 and Appendix 10).

Mehtab, a thirteen year old student never wanted to take up any science subject at A-levels and beyond. A complete decline towards science is evident, as she believes to have 'non-science inclination' only. She stayed in C4 category before and after intervention exhibiting no movement towards science and away from non-science subjects. Mehtab exhibits low impact of 'social agents' for example: parental or science teachers influence towards choosing subjects. She finds non-science teachers influential because *I do not like science*. However, she prefers school science as it is fun and she learns things that are relevant to daily life activities but does not prefer and make meaning of science content knowledge. The TL experiences provided through interventions did not also change her subject choices, even though she preferred the last four interventions as it was *fun* and *something new and challenging*. However, she did not enjoy and preferred science fiction and poetry writing as she found science fiction boring and did not like writing poetry in general. In terms of future plans Mehtab is clearly very persistent and exhibiting a certain drive (IIA) that she will continue with islamic studies, psychology and english. She mentioned that it is not quite possible, but the only way that can make her do science is *if I find it interesting*.

As can be seen, only two girls exhibit progressive TL and smooth transformation. The movement away from their preferred or inclined choices are either very small (Saira) or no movement at all (Mehtab). Both enjoy science at school when it is in relation to daily life where Saira likes science curriculum where Mehtab does not. Therefore, both girls exhibit a kind of drive and willingness (IIA) to gain science (Saira) or non-science (Mehtab) education and careers in the future.

(ii)Progressive TL and wavering transformation

The majority with twenty-six of the thirty secondary school girls are grouped under this category, out of which, twenty-five, are willing to study at least one science, and one student does not want to study science at all. This theme exhibits broadly six variations which are as follows:

1.Three of the thirty girls exhibit both science and non-science inclination at sixth and twelfth month, however the subject choice, progressed from both science and non-science group (C2) to science only subject group (C1). Even with fluidity this group prefers to gain more science based education and career. For example:

> Sitara, a thirteen-year-old, year eight student agreed that she has 'science and non-science' inclination'. She exhibited medium movement towards science subject choices only. Sitara's perception on 'social agent' becomes less influential towards her tuition science teacher and school science curriculum influence became stronger after twelfth month of intervention study, exhibiting intermediate impact of TL experiences. The 'trigger' that motivated her interest was at the age of six, when she was taught about human body mechanisms using human dummy and related experiments in the primary school. Moreover, before, during and after intervention she believes science at school is helpful in carrying out her daily life activities.
>
> Sitara experienced poor science exam results during the period of science interventions which acted as a negative trigger for some time as it made her critically think on her science ability and subject choice preferences. Still she went against it exhibiting a drive/ push (IIA) and worked harder towards the understanding or meaning-making of science, and progressed in the tests and exams. She enjoyed all the interventions except science fiction because it was not enjoyable for her. The rest of the interventions were fascinating (poetry),

interesting (visit), entertaining (problem solving), fun (independent learning) and the most liked intervention turned out to be was meeting a scientist, she felt good about science because the scientist described exactly how scientists work in real life.

Sitara's 'future plan' is to study science and mathematics and become an astronomer/ radiologist. She further believes that a degree in sciences will be helpful for her to achieve better job opportunities.

2. Eleven of the thirty girls also showed both science and non-science inclination. Their view of carrying with both science and non-science (C2) remains the same over the six month period. With fluidity they exhibit turbulence towards gaining science and/or non-science education and career. For example:

Maha, a fourteen-year-old, year nine student strongly disagrees that she had a 'science inclination', later at twelfth month; she agreed to have 'science and non-science inclination', exhibiting medium movement towards science. Maha exhibits low impact of SA: for example, parents and teachers influence became diminished after intervention. Moreover, she remained persistent that school science and curriculum has affected her *interest for science negatively*. Despite of un-liking school science she preferred 4 out of 6 interventions exhibiting intermediate impact of the interventions, she found science fiction relevant to everyday life, Brunel visit provided hands on experience on bridge making and robots, meeting a scientist made her realise the importance of physics in life and the interesting side of physics. However, for poetry and independent study, scrapbook making, did not impress her as for her verses comes randomly, but *for this, I had to sit and think and write it also science isn't my favourite subjects so I couldn't find inspiration*; where independent study was too much dragged on for her. The participant felt good about science interventions, the main reason of positive feeling about the interventions were related to everyday life, *it was fun and interesting*, it incorporated diversity in science beyond human science and nature but the negative aspect pointed out was the complex and difficult features of science knowledge. The most powerful trigger for her I believe was 'meeting a scientist' or maybe it is a later intervention study which might have strengthened her science inclination. As throughout the intervention study no change was observed in her decision, only after 'meeting a scientist' intervention study, she mentioned that *I may do science because you actually discover new things each day* then later at twelfth month she wanted to opt for chemistry along with mathematics, english and psychology at A-level. Still, it is not certain as to whether she will continue with science university education and career or not.

Sana, a fourteen-year-old year nine student even before the interventions always wanted to do science and still wants to carry out science at A-levels and beyond. She believes that she decided her science education and career in life very quickly at an early age. At the same time she exhibits ‘non-science inclination’. Though, Sana disagreed with the question as whether or not ‘intervention changed the way of taking one or more sciences in A-level because *I would have taken science as A-level anyway and it had not changed my decision*. This comment shows that she has an inclination towards science and she also exhibit preferences. The impact of social agents is low for parents as according to Sana she is free to take her decisions. However, her GCSE science teacher is influential and at the same time non-science teachers and her tuition teachers are influential as well because they have taught her well. The likeness towards school science curriculum becomes less influential with time because of its lack of relevance to everyday life. She did not mention any particular trigger, although just simply interested in the subject because *it is challenging*. The only occurrence in life that can move her away from science could be failing science exams. She liked/preferred all the interventions, disliking comments were not given. She also felt happy about science as she found science interventions *different*, *fun*. She liked analysing science fiction film, finding scientific conclusions, *challenging activities*, problems were solved in a challenging manner and guest speaker answered her questions in *an interesting way*. Sana’s future plan is to take up biology, chemistry, astronomy and non-science subjects for example english literature and psychology. I believe that Sana’s future is in sciences as in the interview she mentioned science education acts as a backup even for almost all the jobs (science or non-science), exhibiting a certain drive/push (IIA) towards science preferences.

Zikri, a-twelve-year-old, year seven student believes to have ‘science and non-science inclination’. Zikri has an interest in the arts subject especially photography, but wants to become a doctor. As she exhibits intermediate to high impact of TL incorporated by social agents for example: her mother (acting as ‘social agent’) wants her to be a doctor and always encourage science in the family, science teacher’s influence became stronger with time as she stated that *my teacher has made me see so much more in science*. In the beginning Zikri agrees to do non-science subjects alongside with science subjects due to the positive influence from non-science teachers which after intervention turned out to be disagreed. Moreover, she agreed that science curriculum is relevant to everyday life, but mainly denied that school science helps her in living a better life, although in two instances (independent learning and after intervention) she believes that science at school in sometimes helpful at home and understanding of human life cycle. I believe that other than parents and teacher's positive influences, the main agent in producing science trigger in her life were her grandparents and their farm. As she stated that for quite a while (when she was around 5-6 years) she lived on a farm in Algeria, where she liked to be *surrounded by plants and animals* as her grandmother used to take care of the family farm and grandfather had a business of selling animals. She also agreed to have non-science natural inclination as she loves photography. Moreover after doing science fiction, visits and independent learning interventions she was unsure as whether to take up science or not, while after poetry and problem solving she agreed and after meeting a scientist strongly agreed that she wants to take up biology and chemistry at A-level. She excluded the physics option, although she loved meeting a scientist who was an engineer. The interventions were enjoyed by Zikri as it involved comparing superman and science behind its existence, finding new words while writing science poetry, learnt about environment on a trip to crystal museum, learnt through problem solving practical which turned out to be beneficial rather than boring but sometimes a few practical's based on problem solving got a bit longer, liked decorating and researching the self-chosen topic and was able to ask questions on engineering that bothers her, from the scientist. In accordance to her inclination, with the influence from her mother she wants to become a doctor/pharmacist and her belief that science related jobs are more beneficial in terms of skill development as compared to non-science jobs grew stronger within six months' time.

I believe that the science education and career preferences are quite promising for Maha, Sana and Zikri. Out of all the three only Zikri presented family exposure into science.

3. Another sub-theme includes a student who perceived to have 'science and non-science inclination' but never intended to do any science subject at sixth and/or twelfth month. The story of Bano below will highlight the reasons of not wanting to do science at all after school.

Bano, a twelve-year-old, year seven student is the only student in wavering transformation theme who does not want to opt for any science subjects at A-level and beyond, although she is inclined towards both science and non-science inclination, where, non-science inclination is stronger. The impact of SA is low, for example: parental influence towards taking up science or non-science was not clear; however, her parents do want her to do a university degree and get a better job. Science teachers influence faded away after the intervention. In contrast, Bano mentioned PSHE teacher to be highly influential in choosing non-science subjects. She agreed that school science and school science curriculum has helped her in understanding (or making meaning) of the world better and sometimes also help her in daily life practices. The main TL experience (trigger) that has made her to move away from science is her struggle towards writing and remembering. On the other hand, she prefers the practical side of science. She liked/preferred all the science interventions except science fiction and visiting 'the crystal museum' however, did not mention the reason of dislike. The rest of the interventions were enjoyed/ liked and made meaning of science in a few occasions. Bano felt good about science interventions because she liked: creating rhyming words, her journey on emirates cable car, problem solving practical and handling crystal and lenses. In future, Bano likes to opt for PSHE, DT and PE at A-level and a career as a fashion designer exhibiting quite strong drive/push (IIA) towards non-science education and career preferences. Bano believes that both science and non-science degrees can help to achieve better job opportunities and with an intention of working in non-sciences, she disagrees that a science degree helps to attain more employability skills as compared to a degree in non-science.

From the above story, despite the fluid inclination the chances seem to be quite slim for Bano to take up science at A-levels and beyond.

4. Next sub-theme includes Zeenat. She believed to have a science natural inclination only (both at sixth and twelfth month study). However, unlike stable girls (Saira and Mehtab), she wanted to explore a combination of science and non-science subjects at A-level and beyond. According to Zeenat there is an equal opportunity of gaining science or non-science education and career in future.

5. Another, sub-theme includes seven of the thirty secondary school girls -who like Mehtab from smooth transition theme, believed to have non-science natural inclination only till the twelfth month study, but surprisingly they do not only want to opt for non-

science subjects but also for science subjects at A-level. A few sample stories belonging to this sub-theme are given below.

> Mahnoor, a fourteen year-old, year nine student, also agrees that her inclination was and still is in law and arts related future choices. In comparison, she strongly disagrees that her natural inclination is towards science as she stated that *science is boring*. TL experiences had a low impact on her for example: her parents, teachers and science curriculum have no influence in her decision of choosing subjects and she will follow her dreams towards taking up non-science subjects. Mahnoor after the first intervention (science fiction) stated that *I have not noticed any change because science has nothing in common with what I want to be* that is a lawyer. But her comments after second (poetry writing), fifth (independent study and sixth (meeting a scientist) interventions were optimistic about science choices as she stated three times that her interest is in biology and at one instance in physics subject. In supporting her preference/interest in biology, she agrees that school science is helpful in daily life, mainly to maintain a healthy lifestyle. Her mild positive movement towards biology and/or physics could be as a result of the interventions. As she preferred doing all the interventions except problem solving because she *couldn't guess any of the activity right* and felt bad as *it was hard to solve*. Meanwhile, I believe that her enjoyment towards science started to grow stronger as she liked the fun activities in science fiction and learned *different aspects of science*- although sometimes it got little boring and meaningless for Mahnoor. Next, she liked writing science poetry not only because it was fun, but also because it made her view the non-serious part of science, although disliked the fact that it was hard to make the poetry rhyme which also made her feel less bad about science. Mahnoor also liked her visit to Brunel University where she learnt about chocolate welding, robotics- which made her feel good about science, although did not like the speeches from the university managers. She liked independent research, taking pictures and making scrapbooks; she felt positive about science because of independent research as she *learnt more information about different animals* in her own time, but did not like too much writing. Finally, after meeting the scientist, she liked the talk on how scientists work and it made her feel good about Quantum physics, but found some part of the talk less interesting. In future, Mahnoor wants to become a lawyer, exhibiting a certain drive/push (IIA). The positive point here is that now she wants to do biological science at A-levels. Moreover, Mahnoor agrees before

intervention that science as well as non-science degrees are helpful in providing better job opportunities like doctor and architect. But after sixth month intervention questionnaire her view towards a science degree changed to disagree (as then she believes that it's not only science it can be other non-science degrees too) where the belief for non-science job perspective grew stronger.

Tabu, a thirteen-year-old, year eight student is not naturally inclined towards science, but is always liable for non-science practices. The impact of SA for Tabu grew stronger for parental influence, science teacher's influence and science curriculum interest, where non-science teachers' influence became weaker in six months' time. The reason behind these positive influences was that she wants to take up triple science and become a dentist. Tabu enjoyed four of the six interventions as she preferred doing the activities in the 'centre of the cell' and disliked the fact that the duration in the pod was very short, liked problem solving activities, independent study and meeting a scientist interventions as it was fun. Although the first two interventions (science fiction and poetry writing) were not enjoyed as it was not fun lessons, she also did not feel good about science after conducting these two interventions, but from the third intervention the enjoyment and positive feeling about science showed irregularities with an improved pattern. In future she wants to become a dentist. She mentioned throughout the intervention study that 'the way she thinks about subject choices has changed' but did not elaborate it further. However, in the after intervention questionnaire and after the current verbal conversation she is inclined to opt for science and mathematics at A-level and beyond. Tabu's positive viewpoint on attaining better job opportunities through a science degree remained the same before and after six months of ongoing interventions, but changed for non-science degree employability perspective from agree to disagree. The employability emphasis on becoming a dentist is further evident as Tabu believes that a science degree employs better employability skills than a degree in non-science, indicating a certain drive/ push (IIA) towards becoming a dentist.

In both the above stories a certain drive/push towards becoming a lawyer (Mahnoor) and becoming a dentist (Tabu) was observed and the movement away from their desired preferences is small.

6. The last sub-theme include three girls who at first (sixth month) believed to be naturally inclined to non-science only, but later (at twelfth month) believed to have inclination for both science and non-science. Two of the three girls, even before changing the view, wanted to opt for both science and non-science subjects. Where, one student inclination changed along with subject choices. They exhibit a small movement into science. An example story belonging to this sub-theme is given below.

> Roshan, a fourteen-year-old year nine student - believed not to be naturally inclined towards science as she disagreed and added *I did not like science in the beginning* and showed a strong inclination towards non-science and commented *I have always been fascinated* into arts and humanities. Later during six months' time she believed to have both science and non-science inclination. Roshan believes that her parents are influential in a way that they respect her decision towards subject choices and career options. In terms of teachers, science teachers' influence remained due to influential science lessons where non-science teacher's influence drifted away with time. Roshan disagreed that school science curriculum helps her in daily life activities, but preferred and made meaning of school science in relation to relevance of science to daily life for example: keeping healthy, understanding the world more, creation and processes of living and non-living. For Roshan, it seems that the interventions worked well that made her thinking to take up science. As in the beginning before and after the first intervention she was not sure, then after second and third intervention she witnessed a positive change in the making a decision towards science and in the next three interventions and even in the final intervention she agreed to do science at A-level and beyond. She liked *how super heroes were shown in a scientific way*, the creativity part of poetry writing, solving science problems by doing science practical and making a scrapbook. She also felt good about science throughout the interventions because she stated that through interventions she was able to *understand science more*, helped her science understanding (meaning-making) in school and beyond and also helped her to express the creative side. I believe that her future is bright towards science as she would like to take up mainly science subjects biology, chemistry, computer science and sociology a non-science subject. Finally, Roshan believed before intervention both science and non-science degree is beneficial in finding better jobs, but later the view changed and Roshan now believes that a science degree is more advantageous as

compared to a non-science degree in achieving better career opportunities in the future.

(iii)Reconstructive TL and wavering transformation

The two girls Anushka and Iqra, exhibited mild transformation, small movement into science at one point but then reverted back to non-science subject choices. Their stories are given below.

Anushka, a twelve-year-old, year seven student always exhibited non-science inclination only. However along with english she wanted to opt for mathematics (C2) at the six month but slowly the impact of mathematics seemed to fade away (C4). At first she exhibited low impact of SA for example: at six months she strongly disagreed that her parents influenced her to do science at A-levels and beyond, she believed that her parents *are like friends and never have or will force her to choose* science or non-science *subjects*. Later at twelfth month she disclosed that the main reason for her to continue with english is that *it runs in the family*, her brother and parents have a good interest in it. So she wants to 'live up to them'. Moreover, she likes her science teacher, but did not find her influential enough to change her decision. At the sixth and twelfth month stage of intervention study she does not find science curriculum interesting enough to motivate her towards science. Her strong inclination towards english was apparent as she declined after every intervention that her decision of not doing science after GCSE has changed, as she stated that *because I have done some activities, does not mean I automatically like science; making me want to do it for A-level*. Although she preferred and liked all the six interventions, for example she liked problem solving intervention because *it was fun and I enjoyed unscrambling the words and finding the things*, although she found a few other interventions *bit boring sometimes*. Anushka had mixed views on feeling good or bad about science as a result of specified interventions. For science fiction, independent study and problem solving she felt good about science, but for the other three interventions she neither felt good or bad about science. She also believes that science at school is helpful and important, although during science visits and problem solving interventions she found science boring, finds difficulty in understanding (meaning-making) and memorising formulae. In future, she likes to do english for certain at A-levels and wants to become an english teacher. On later conversation, she became unsure about mathematics and believes that she will only continue with subjects which compliments english like history. Furthermore, she believes that a degree in science is important, but believes that other subjects are also equally important in getting a desirable job.

Iqra, a fourteen-year-old, year nine student agreed to be naturally inclined towards science (space), but believes to lose interest slowly and agrees to have a non-science inclination only. Parental impact is low, where science teacher's influence strengthened after interventions, but still Iqra finds difficulty to cope up with science learning and understanding (meaning-making). Moreover, she agrees that science curriculum and overall science in school is helpful and relevant to daily life activities, but at twelfth month survey, she strongly disagrees that science curriculum has influenced her interest in science. The most likely reason for disagreement is due to poor exam results which acted as a negative TL experience (trigger). Through later conversations she mentioned that she likes to *sing all the time* and loved to watch BBC dramas with great interest and believes that media acted as a main agent in directing her interest in non-sciences. Along with these TL experiences, Iqra enjoyed all the interventions in science fiction lesson on forces she liked the linking of science to superman and felt good about physics but not for entire science, less work which opened her eyes towards the fun side of science, although she disliked the disruption (discussion) between the clips, she liked the humorous side of writing science poetry on smoking, enjoyed the chocolate welding during the visit although did not like the long walk during the tour. She enjoyed thinking about science outside the box and liked discovering nature during independent study; meanwhile for these two interventions her feeling for science remained neutral. After meeting the scientist Iqra realised that *science outside the school is not as bad as I thought of* which made her even consider to become a scientist at one point. At the beginning after the first three interventions (science fiction, poetry, visits) she wanted to do non-science subjects only then after problem solving intervention she became undecided and then after independent study and meeting a scientist interventions she started to consider science and finally at sixth month declared that she will do applied science alongside with non-science subjects at A-level. At this point I am not certain that it is the problem solving intervention that has changed her viewpoint about science or it is an aggregated TL experiences (triggers) from all the interventions. In the future Iqra does not want to do science, as repeated failure in exam made her feel an incapable science student, moreover, she was put into lower set science which actually extinguished the science intervention triggers experienced by Iqra. As she stated *I dislike science because it is very complicated and personally I do not want to have a job related in science*. She wants to gain a career as a writer/singer/ poet. Moreover, in supporting her career choices Iqra thinks that science only trains a person intellectually, but does not much polish employable skills.

Both Anushka and Iqra exhibited a reconstructive transformation. They exhibited a small swinging movement. Then the large movement back to non-science subject choices occurred due to failure (Iqra) and strong family environment (Anushka). At this point they exhibit a certain drive/push (IIA) that goes with the TL experiences, they resemble to the smooth transformation category, but differs in a way that at one point in life they actually preferred science and non-science both.

6.6 Summary- Phase Three

This chapter presented results from The Salehjee Girls School, where I conducted broadly six interventions. ‘Science visits’ and ‘meeting the scientists’ interventions were liked the most. At this point it is possible that both these interventions involved people outside the school; however, I believe that the other interventions were enjoyed as well. I also believe that the aggregated impact from interventions has helped the girls in choosing science after the age of sixteen. Although the majority declined that interventions has changed their science preferences; however, after looking at individual questionnaires a positive change towards science is noted.

The above findings have provided a wide range of data revealing the impact of SA and TL experiences and natural inclination that has shown movement of girls into or away from science. I will now summarise the key outcomes using the Sci-ID model ingredients (Figure 2.5).

1. Global forces (GF): Only one student mentioned that moving to Somalia would possibly prevent her doing science because she is a girl, in a culture that would not recognise girls as scientists

2. Social agents (SA): The three main SA mentioned above included (i) parents - the majority of the students declined to have parental influence, a slight increase in parental influence was observed after twelve months. The majority believed that choosing subjects and/or career are their personal choices. A few girls indicated that their mothers want them to be doctors or an english teacher.

A few students later agreed to have influence from parents and also moved from C2 to C1 category; however a few students declined parental influence still moved to C1. One student moved to C4 from C2 while agreeing to parental influence, (ii) school science - overall the likeness towards school science curriculum increased after the intervention. For a few girls their school science curriculum is one of the main causes of moving from C2 to C4 category. Overall likeness towards daily life science taught through the science curriculum increased after the intervention from all the four categories and (iii) teachers - overall the influence of science teacher declined. This decline was principally reported from the students from the C4 category. Overall the non-science teachers' influence also declined as well

3. TL experiences (triggers, events, interventions): A few examples into sciences are - living on a family farm, chemistry videos, human body dummy, science magazines. In addition, all the science interventions especially meeting a scientist and science visit. A few possible examples into non-sciences are - Zain Malik from One Direction, music band, Science text book etc.

4. Meaning-making filter: Through intervention study, I was able to observe the understanding (meaning-making) of science among the girls. The majority understood the science contents and its application in the daily life through incorporating social and cultural aspects linking to the taught science topics

5. Preference filter: From my observations and from students' verbal and/or written responses, it is quite clear that the majority of the girls enjoyed all the interventions. They also preferred doing similar activities in the next term

6. Individual Internal Agency (IIA): The majority of the students perceived to have natural inclination for both, exhibiting ambivalent IIA. Little less than the majority perceived themselves to have a non-science inclination only, exhibiting non-science IIA. A few students exhibited transformation from a non-science natural inclination only to both science and non-science inclination after six months, exhibiting ambivalent IIA

7. Core: No direct data generated, only the extent to which students could assign themselves as science-orientated or not.

Moreover the stories presented under the three themes includes: (i) Progressive TL and smooth transformation-very few girls exhibited smooth and progressive transformation into science. The movement for these girls into or away from science was very limited, (ii) Progressive TL and wavering transformation - the majority of the girls exhibited wavering and possibly progressive transformation into science and non-science exhibiting fluid movement and still in an undecided state and (iii) Reconstructive TL and wavering transformation- very few girls exhibited wavering and reconstructive transformation. These girls exhibited a low to medium movement into science but then due to a kind of regressive TL experiences, they moved into non-science choices, exhibiting a certain kind of drive/push (IIA) towards non-sciences.

Chapter six has provided an introduction to my sample participants and familiarised with the impact of certain GF, SA and TL experiences (events, triggers, interventions) in their life that had low, intermediate or high impact in their preferences towards science or non-science education and career. Moreover, this chapter also helped to explore other Sci-ID ingredients like meaning-making of science, preferences, natural inclination, IIA.

Chapter Five and Chapter Six have provided an extensive findings and analysis of the collected data from the participants from the three different phases of life. This will now enable me to accumulate the three phases of the data and answer the research questions stated in Chapter One and discuss the findings in relation to the recent relevant literature in the next and the final chapter of this thesis.

Chapter Seven: Discussion

7.0 Introduction

This chapter will conclude this study by discussing the key answers to my research questions in Chapter One, by relating them to previous literature on identities, principally ‘science identities’, in order to develop the key ingredients that can help in the ‘making of a scientist’. This chapter will discuss and interlink the main outcomes and importance of conducting this study, by first restating the purpose of this research, then restating the research questions, data used and brief outcomes of this research in the form of a table. Then I will discuss the key outcomes in relation to the literature.
Later, I will also discuss the limitations of data gathering methods, three phased study, sample size and future implications. Moreover, I will discuss the validity of the empirical work.
Next in concluding the thesis, I will indicate unique contributions of knowledge and generalisability of this study in a wider context. This will be followed by a few future research questions and finally I will suggest a few recommendations to the policy makers, educators and researchers principally from the field of science education.

7.1 Purpose of the research

The main purpose of the research has been to identify the key ingredients needed in the ‘making of a scientist’ and, in the process, explore the main real-life circumstances, events and experiences that transform individuals’ identity both towards and away from the study of science. To achieve this purpose, I first examined some of the issues, theories and models of identity, science identity in particular, along with forms of identity transformation. This reading of the literature helped me understand the boundaries between individual internal agency (IIA) and global forces (GF), social agents (SA) and TL experiences. This has eventually led me to design a model based principally on Illeris’s (2014) and Abes et al.’s (2007) models of identity.
The purpose of the literature review and the empirical research has directed me to explore the life journeys of people from the three stages of their educational and career life, which included Phase One: established scientists and non-scientists; Phase Two: university students and Phase Three: secondary school girls.

7.2 Research Questions

The aggregated outcomes to answer the four broad research questions are given in Table 7.1 below, which I will use to discuss the research questions separately under four sub-sections.

Research Questions	Data generated	Main outcomes
What are the main TL experiences that generate transformations in peoples' identity towards and away from science?	Interviews, 'stories', questionnaires and 'intervention evaluations' from Phase One, Phase Two and Phase Three.	The TL experiences, triggers, events, interventions differ in number (small, medium, large) and its impact (low, intermediate, high) in transforming one's identity towards and away from science.
What kind of model of identity can represent the social forces, the social agents, the triggers, the transformations, the personal meanings, inclinations and agency that impact upon an individual's choices in relation to science?	Theoretical literature research, supported by empirical substantiation through the data generated in Phase One, Two and Three.	The Sci-ID model. Indicating principally seven divisions. This model presents a link between GF, SA incorporating TL experiences and person's understanding, preferences and IIA.
Can a model of Science Identity be used to illustrate progressive, regressive and reconstructive transformation(s) in individuals?	Testing with actual examples using data from interviews and questionnaires.	Progressive and Reconstructive TL examples incorporated in Sci-ID model. Regressive TL incorporated within the Progressive and Reconstructive models.
In what ways are a series of mini-transformative experiences (multiple classroom intervention activities) sufficiently persuasive to alter secondary school Muslim girls' self-perceptions and perceptions of science, for the future?	'Intervention evaluations', questionnaires interviews and 'stories'.	Simple and easy EBL activities incorporated in the learning of science (inside and outside the school).Science content made meaning with fun. A few exhibited persistence towards further science education and career. A few were non-movers. The majority exhibited fluidity towards science and non-science. A small number of interventions aggregates to show an impact, by gradually soften one's dispositions. Intervention evaluations acted as a reflective account.

Table 7.1: Summary of the research outcomes from the research questions and the data used

7.3 Research Question One

What are the main circumstances and events that generate transformation in peoples' identity towards and away from science?

To answer this question I will make use of the Figure 7.1 below. The people on the extreme poles can be seen to have either stable science or non-science identity. The people who populate the space between have more fluid identities. The movement (transformation) of people towards or away from science depends on a series of external transformational learning (TL) experiences (events, triggers and interventions) incorporated by SA and GF. These TL experiences have a low, medium or high impact on different people.

The TL experience variations are as follows:

(i)Large number generating a low, intermediate or high impact of TL experience (triggers, events, interventions)

(ii)Medium number generating low, intermediate or high impact of TL experiences (triggers, events, interventions)

(iii)Small number generating a low, intermediate or high impact of TL experience (triggers, events, interventions).

These variations depend on the stability of one's identity. Therefore, (i) people either have stable science or non-science IIA exhibiting very small movement away from their respective extremes, unless exposed to a large, medium or small number of TL experiences that generates a high impact. While (ii) people with ambivalent IIA exhibit medium or large movement towards or away from science because, they probably have an intermediate to high impact from a large, medium or small number of TL experiences.

For example:

1.Phase One non-scientist, Philip, exhibited ambivalent inclination and later moved out of science. A few key impacts of TL experiences are as follows:

High impact: Failure in chemistry exams.

Medium impact: Peer pressure from students (as science are for people who are clever), hall piano, deputy principal.

Low impact: No formal training in music.

Philip exhibits large movement (transformation) away from science through an exposure to regressive TL experiences.

2.Phase Two university science student, Helen, exhibited science and non-science natural inclination. At present studying science at university. A few key impact of TL experiences are as follows:

High impact: Psychology teacher, neurology topic.
Medium impact: Biology and chemistry books, Bill Bryson's book on big bang theory
Low impact: Parental influence.
Helen exhibits medium movement (transformation) towards science as she was sitting in crossroads to choose science or non-science subjects and eventually decided to choose science subject(s) at university.
3.Phase Three secondary school girl, Saira, exhibited stable natural inclination. A few key impacts of TL experiences are as follows:

High impact: Amazing chemistry videos.
Medium impact: Science education interventions (science fiction, visit and meeting a scientist).
Low impact: Science education interventions (Poetry, problem solving independent study).
Saira exhibits small movement (transformation) from C2-C1.

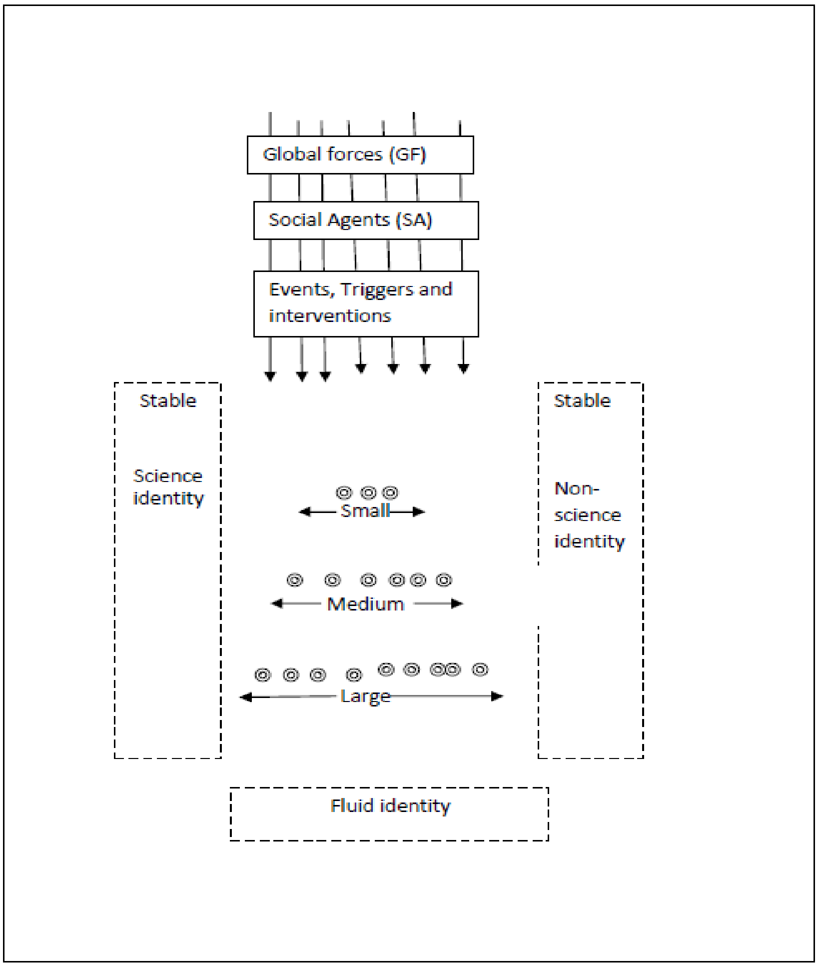


Figure 7.1: The migration of the people

7.4 Research Question Two

What kind of model of identity can represent the social forces, the social agents, the triggers, the transformations, the personal meanings, inclinations and agency that impact upon an individual's choices in relation to science?

To answer this question I have generated a model of 'science identity' (Sci-ID), initially as a theoretical model that represents TL experiences that is incorporated by the GF, SA, and that interact with the personal meanings, preferences, inclinations and agency that form the core of the model (Figure 2.5). The model allows for a variety of TL experiences that permeates the making of meaning and the more affective preferences of the individual. I have based this model on identity models such as those by Illeris (2014) and Abes et al. (2007).

This theoretical model then became the mode of analysis throughout my empirical data. While I have not been able to capture each and every nuanced aspect of this model (Table 3.2), I do believe that I have sufficient data to support this as a generalised form, and from which further research questions can be based. I now discuss the key research outcomes in some detail.

1. Global forces (GF) and TL experiences

As mentioned previously, the broad approach to this research has taken as read that there exists a range of 'global forces' (GF) that act to shape the making of a scientist. The works of Archer et al., (2010, 2014) has shown how clear and comprehensive are these forces, and the general trends that shape science education – not just in the UK but in many (most) countries around the world. My research reported here did not ask the participants any detailed questions on GF such as ethnicity, race or gender. Very few scientists and non-scientists mentioned these forces, and one secondary school girl did talk about it, as I illustrate in Chapter Five, Chapter Six and in Table 7.2 below.

Phase	Main Outcomes
One	**Gender:** The majority of the scientists and non-scientists did not mention any personal advantage and/or disadvantage of being a male or female in relation to subject and career choices A little more than half of the female scientists and non-scientist mentioned gender related perceptions in relation to science subject choices. Interestingly, such negative perceptions were accepted by the female non-scientists and rejected by the female scientists Only one male scientist mentioned the advantage of being male in relation to subject and career choices. **Religion/ Class:** Only one male non-scientist mentioned positive relation of religion to the science of energy and natural surroundings. The same non-scientist mentioned his under-represented class identity and societal pressure in choosing science which he rejected The remainder of the scientists and non-scientists did not mention such perceptions.
Two	No responses were generated.
Three	**Gender:** Only one student mentioned that moving to Somalia would possibly prevent her doing science because she is a girl, in a culture that would not recognise girls as scientists.

Table 7.2: Global forces- summary

In relation to the literature in Chapter Two (for example Archer & Dewitt, 2015[a,b]), a few female non-scientists in Phase One believed that science is "just not for me" and exhibited an unwillingness and 'inability' to participate in sciences. In keeping with Brickhouse and Potter's (2001) 'Ruby', and Carlone and Johnson (2007) 'disruptive scientists', a small minority of females fought against their disposition. From my perspective here, they challenged these GF (gender), along with other aggregated SA influences, and developed strong science IIA to gain a science-based education and career. However unlike Archer and Dewitt's (2015) and Carlone and Johnson's (2007) respondents, these women did not (i) belong to African backgrounds and (ii) mention any extra additional challenges in their lives. As mentioned above, one secondary school student did believe that changes in her circumstances (for example, moving to Somalia) would prevent her doing science.

The issue of positive or negative GF was not only perceived by the female participants, as has been widely indicated in Chapter Two but also by the male participants. On the male side, one scientist mentioned a form of extra effort in mathematics because he believes that one main reason he persisted with the study of mathematics (despite the negative influence from his teacher) was because of his gender - because, being a man, he was able to eventually achieve whatever he set out to do. In addition, one of the male non-scientists rejected the imposition of cultural forces, he fought unwanted parental influences. This rejection exhibited a kind of reflection (for example, Mezirow (2000) and Giddens (1991)) on the ways that GF interact with IIA. Therefore, with strong IIA, some respondents rejected these GF.

2. Social Agents (SA) and TL experiences

(i)Parents

As mentioned in the literature review chapter that the grand longitudinal study on ASPIRES project and a few other recent studies have indicated that science aspirations and career aspirations are quite considerably influenced through parental science capital. However, in line with Huston (2015) the majority of my participants' from all the three phases declined parental influence towards science or non-science subjects' uptake. The act of parental intrinsic support has been indicated to be a powerful tool in the literature (for example: Gilmartin et al., (2006) and Ing (2014)). In a similar vein the majority of the scientists and non-scientists and a few secondary school girls indicated that parents were (or are) supportive in whatever they want to choose after the compulsory age of science education (Table 7.3).

Phase	Main Outcomes
One	The majority of the scientists and non-scientists parents were positively supportive in whatever choices they wanted to make. The majority of the scientists and non-scientists parents were not influential in deciding science or non-science future. Half of the female scientists and non-scientists adopt the same profession as their parents. The other two female scientist and non-scientist retention towards positive parental influence became weaker in later years. Two male scientist and non-scientist rejected parental influence.
Two	The majority did not feel that their parents had an influence. Students from a science background seemed to be more influenced by parents than non-science students.
Three	The majority of the students declined to have parental influence, a slight increase in parental influence is observed after twelve months. The majority believed that choosing subjects and/or career are their personal choices. A few girls indicated that there mother want them to be doctors or English teacher. A few students later agreed to have influence from parents and also moved from C2 to C1 category; however a few declined parental influence still moved to C1. One student moved to C4 from C2 while agreeing to parental influence.

Table 7.3: Parents - summary

Moreover, in line with the work of Archer et al., a few female scientists and non-scientists followed and a few secondary school girls desired to follow the same career path as their parents. For scientists and non-scientists mainly father's influence was noted where for the girls' mothers influence was noted. Mother's influence could be linked to the concept of 'Chinese mother' exhibiting strong cultural power. It does show to some extent the females are little more receptive to parental influence than male, however, only girls were included in the Phase Three study. This small sample did not actually implicitly inform as fathers are more influential or mothers of the female participants. In future I will be interested to view the influence (section below on future research questions).

In line with Archer et al., slightly more scientists and science students portrayed parental influence as compared to non-science participants which were indicated due to parental support in completing homework and assignments or even due to parental careers. However these reasons were also mentioned by a few non-scientists. In contrast, it is difficult to indicate for sure as whether at the moment the secondary school girls belong to science or non-science group (the majority belongs to ambivalent C2 category). Though, if we look at the two extremes C1 (science only) and C4 (non-science only) the majority of the students disagreed despite their education and career choices.

A slight decline in parental influence was noted around the age of 17 to 18 in scientists, non-scientists and university students. Whereas a slight increase in parental influence was observed between the ages 13-15 among secondary school girls. Similarly, Blenkinsop, McCrone, Wade and Morris (2006) and Rodeiro (2007) also indicated that the choice of science subjects varies with time, which cannot only be influenced by parents, but there can be other factors (like teachers, school environment etc.) as well.

(ii)School science curriculum and everyday life science

In line with the positive impact of NoS and 'scientific literacy for all' in producing science literate citizens (for example: Hassard & Dias, 2009).

For the majority of my participants (Phase One, Phase Two and Phase Three) the daily life activities linking to the science curriculum made meaning of the science content despite their subject and career choices. I believe that among Phase Three secondary school girls the incorporation of daily life science through science intervention activities declined their rejection towards school science curriculum.

Moreover, scientists, non-scientists and university students' results indicate that the interest in school science curriculum is evident more in participants who are in science studies and careers as compared to non-science studies and careers (Table 7.4). To some extent this indicates that it could be as they are more inclined to do science later in lives. At this point I cannot for certain conclude that the interest in science curriculum have actually decided sciencey participants to take on science, as mentioned before that influences aggregate to create a greater educational stimulation towards subject and career choices.

Phase	Main Outcomes
One	The majority believed that they are interested in science through their awareness with daily life science. Only two scientists became interested in science through science curriculum. One scientist had no effect of the school science curriculum. One scientist did not find the effect of both that affected her interest in science.
Two	Almost equal percentage of students agreed and disagreed that they became interested in science through science curriculum. The majority perceived that the awareness of daily life science has helped them more in learning school science. The interest in school science curriculum is evident more in participants who are in science studies as compared to non-science studies.
Three	Overall the likeness towards school science curriculum increased after intervention. Where little less than half disagreed. For a few girls science curriculum is one of the main causes of moving from C2 to C4 category. Overall likeness towards daily life science increased after intervention from all the four categories.

Table 7.4: School science – summary

(iii)Teachers

The influence of teacher was seen to be positive among the majority of scientists and non-scientists, however the science and non-science university students and secondary school girls exhibited a reverse outcome (Table 7.5).

Phase	Main Outcomes
One	The majority perceived to have science as well as non-science teachers influence. A few scientists and non-scientists mentioned teachers (SA) involvement in directing few scientists and non-scientists to a particular exam, sending student to satellite observation in Oxford university and giving permission to join A-levels music classes. A few non-scientists mentioned particular science teacher who had a negative influence due to traditional style teaching and lack of support and encouragement from the science teacher. One male scientist experienced negative influence from maths teacher, which he rejected.
Two	The majority of the participants declined science as well as non-science teacher's influence. Slightly more reported to be influenced by science teachers than non-science teachers. More non-science students perceived to be influenced by science teachers. More science students perceived to be influenced by non-science teachers.
Three	Overall the influence of science teacher declined. This decline was reported from the C4 category students. Overall the non-science teachers' influence also declined.

Table 7.5: Teachers - summary

Moreover, the majority of the university students exhibited a reverse picture, that science teachers influenced more non-science students and vice versa. The question here is then why did these students choose non-science subject at the university level. Because a few students perceive to be influenced by both science and non-science teachers and later moved into either science or non-science degrees. However, there were still a few who exhibited a complete reverse story. It could be because of the other circumstances and events like institutional pressure, exam results etc. Further investigation through probing could give a better answer.

In line with the university students and secondary school girls, a few scientists and non-scientists did mention negative influences from a particular science teacher due to poor teaching, limited support and lack of encouragement. Such limitations have been indicated in the recent literature as well (For example: Hassard & Dias, 2009; Carambo, 2015). However, a few scientists and non-scientists indicated positive influence through teacher's support through dialogue, recommendations, encouragements and good teaching practice which actually were the solutions to the limitations mentioned above.

Secondary school students indicated a decline in teachers influence after the intervention mainly from the C2 group (both science and non-science subject). The reason might be that their inclination is into non-sciences as well and so the boundary for sciences is hardning. A few reasons were that the student does not understand the teacher or because the non-science teachers are more influential. Moreover, a few reasons included the overall picture rather than specified teachers influence such as science is difficult or the ‘science teacher did not influence not to do non-science subjects’ (Talat). Talat’s comment gives me a hint that may be that the incorporation of cross-curricular links might have made them equally influenced into non-sciences along with sciences. Further investigation is needed for future research.

3. The meaning-making filter and TL experiences

The making of meaning, and preferences into science (Table 7.6), was difficult to dis-aggregate for scientists, non-scientists (Phase One) and university students (Phase Two). For example, for Dennis (scientist) Haley’s comet was a hinge point in his life at a very early age - it might have made meaning about the science behind the comet but I believe to a limited extent, later the meaning broadened with age. However, he was fascinated about it and preferred/liked it quite strongly from an early age. For this reason for scientists and non-scientists the aspect of meaning-making is not taken into account at this point of discussion. Moreover, due to limited descriptive data from the university students’ questionnaire I cannot figure out as how they make meaning of science.

Phase	Main Outcomes
One	No data generated.
Two	No data generated.
Three	Through intervention study, I was able to observe the understanding (meaning-making) of science among the girls. The majority understood the science contents, its application in the everyday life through incorporating social and cultural aspects behind certain science topic.

Table 7.6: Meaning-making filter- summary

The only way I could witness the understanding (meaning-making) of science was through science interventions. The majority of the secondary school girls exhibited understanding of the science through the six interventions. For example: they understood about the kinds of forces, including gravity and magnetism through

‘Science behind Superman’ (Table 4.1). The girls were excited and a few girls even in the end believed that ‘Superman is for real’. They were also able to understand as how Islamic teachings on the moon and gravity links to the science taught in the classroom. Through ‘Z for Zachariah BBC play’ they made meaning of the process of radiation and decay, they made meaning as why the fish in the upper stream were alive but not on the lower level. They could also understand the harmful effects of these nuclear wars, scientifically as well as socially in relation to the main character, the girl, who was alone in the village, the way she handled certain adverse situation (like contaminated water) using scientific ideas.

Unlike, Abes et al., (2007), I cannot indicate the varying complexity of the filter at an individual level. However, I believe that the topics taught through interventions made the meaning-making filter less complex (thin layer with large grid openings) for the majority of the students at quite an individual level because all the students reached their respective targeted level at school in science.

4. Preference filter and TL experiences

The majority of the established scientists not only mention that science ‘wakes them up in the morning’ (Jane-scientist), but also mentioned as how they can commit and contribute to scientific research in a wider, international context. On the other hand, the non-scientists preferred their learning and understanding in science to link to any personal interest in relation to the immediate, social world. In terms of the school pupils, their enjoyment through intervention activities was quite visible (Table 7.7). For example, the ‘chocolate welding’ activity was arresting not just because it was a fun, sticky, messy activity that also led to eating chocolate in class, it ‘hit’ a number of preferences to the extent that they wanted to repeat the activity back at school again. They were intrigued by the engineering: it involved designing the strongest bridge, evaluating why the bridge was strong (or not), developing explanations including the limitations of their design and the search for further solutions and, eventually, presenting of the data to the whole class.

Such preferences as mentioned by scientists and the secondary school girls’ actually deserve special consideration. Both ‘life-wide triggers’ and educational interventions can make impacts that serve to strengthen, weaken or changes people’s science IIA. The established scientists can look back through their own biographical narratives and recount the various events or interventions that led them to science; and quite possibly a series of such interventions could also develop science identity within the girls. From the data, this can be seen to happen – certainly for some of them. This broad approach resembles Illeris's (2014) idea of the 'energy and dedication' that brings change at this layer of identity, 'where no special consideration or efforts are involved' (p. 73). The sense here is that events, experiences, interventions within life and schooling only have the possibility of impacting on a person's core identity if they are seen preferentially or not. Acceptance and rejection of ideas, activities and experiences aggregate and build with time, forging an individual's Sci-ID along the way.

Phase	Main Outcomes
One	The scientists discussed their preferences for science education and careers because it involves new challenges, new scientific discoveries and, as a result, science is not static and provides opportunities to share new/ revised discoveries at a local as well as at an international level. A few non-scientists preferred reading about the role of science in society, culture, music, religion, environmental issues, writing science fiction but had no preference for studying science at all at any substantive level.
Two	No direct data, only the extent to which students could assign themselves as science-orientated or not.
Three	From my observations and from students' verbal and/or written responses, it is quite clear that the majority of the girls enjoyed all the interventions, and the majority of the students expressed preferences in doing these activities.

Table 7.7: Preference filter – summary

5. Individual Internal Agency (IIA) and TL experiences

The established scientists in Phase One believed that they are sufficiently competent to do science (like Carlone and Johnson's (2007) competence) and exhibited self- interest (like Hazari's interest component). I believe both these components enforces science IIA and, in turn, science identity. In contrast, the majority of the non-scientists exhibited the reverse. That is, some made clear negative dispositions about scientists and scientific work, their distaste, disinterest and – therefore –their lower competence in sciences.

Phase	Main Outcomes
One	The majority of the scientists were naturally inclined towards science education and career due to self-interest and self-ability exhibiting a certain drive or push (IIA). A few non-scientists were not naturally inclined towards science over non-science education and career because of dis-interest, perception of inability, science education being too factual, offers working in the labs and working with soil, ants, rats, worms etc. Rejecting science education and career (IIA). A few scientists even rejected certain TL experiences exhibited a force against or IIA.
Two	The majority of the science students perceived to have natural inclination for both. A little more than half of the non-science students perceived to have inclination for both. Exhibiting ambivalent IIA.
Three	The majority of the students perceived to have natural inclination for both. A few students exhibited transformation from non-science inclination only to both science and non-science inclination after six months. Exhibiting ambivalent IIA. Little less than the majority perceived to have non-science inclination only. This could lead to non-science IIA.

Table 7.8: IIA - summary

Similar to scientists and non-scientists, the majority of the university science students in Phase 2 exhibited science natural inclination and non-science students exhibited non-science inclination which exhibits a drive/ push. I believe, like scientists and non-scientist, this would be due to self-interest and perception of competence as well. However, there were a few who demonstrated inclination towards both, therefore it is difficult to illustrate their IIA. Similarly the element of both science and non-science natural inclination increased in the secondary school girls, after the intervention study making up the majority, this fluidity conform the past researches (for example: Heddy and Pugh (2015) and Nohl (2015)) that identity formation requires various TL experiences to become stabilised (Table 7.8).

The IIA here is seen as the personal 'drive', the ways in which people can go against TL experiences, SA and/or GF – or go with them. People need 'drive', ambition, energy in what they do, even if that is in line with – or opposed to – the TL experiences, SA and/or GF in their lives. For example: Adam's (Phase One) obsession on reading and writing about Victorian journals. Dennis, Philp (Phase One), Helen (Phase Two), Mehtab and Saira (Phase Three) rejecting parental, societal, school interventions, triggers that did not align with their personal drive.

6. Core

In this study, I cannot distinguish the exact metrics of core identity construct. The only way I can relate this it is through discussion on natural inclination, IIA in relation to stable or fluid identities.

My understanding of a 'stable core identity' is when a person has reached a certain 'coherent identity' (Erikson, 1973) and maintains 'ontological security' (Giddens, 1991). Such stable identities were apparent in the majority of scientists and non-scientists (as might be expected), in a few of the university students' responses, and in a few of the secondary school girls. My sense of a more 'fluid core identity' is when a person demonstrates 'identity confusion' (Erikson, 1973), existential anxiety (Giddens, 1991), undergoes 'critical reflection' of self and 'transformation of meaning schemes and meaning perspectives' (Mezirow, 2000). These are 'wavering transformations' in order to attain greater stability in the core. In line with others, I believe that people exhibit greater 'fluid core identity' during the stages of adolescence, with increasing stability over time after experiencing various TL experiences in life.

Along with the understanding of stable and fluid identity core, my indications of approximate age-related change is as follows:

- The adult group (average age 40) has reached a strong degree of stability as they quite clearly identify themselves as engineers, chemists, philosophers, writers, musicians etc. Moreover, they discuss their unwillingness to transform their science or non-science stable identities any time soon in the future
- At the other extreme, the youngest group (average age 13), the secondary school girls results resembles Erikson's adolescence stage (age between 13-19) where identity construction reaches maximum fluidity
- The middle group, with average age 25, the university students resemble Illeris's (2014) view on youth in modern society. As he believes that a considerable 'coherent identity' might reach 'in the middle or late twenties, sometimes not until to thirties, and for some it may be debateable whether such a stable identity formation ever takes place' (p. 86).

7.5 Research Question Three

Can a model of Science Identity (Sci-ID) be used to illustrate progressive, regressive and reconstructive transformational learning in individuals?

Extending the above work on the stable (smooth transformation) and fluid (wavering transformation) core identity, I have illustrated TL processes using Illeris's (2014) concept of 'kinds of transformations' (Figure 7.2, Figure 7.3 and Figure 7.4), to test as whether or not my Sci-ID model can explain these processes. I now discuss briefly the three main themes with examples to respond to this research question.

(i)Progressive TL and smooth transformation

As mentioned above, the majority of the scientists and half of non-scientists, majority of the university science students and very few secondary school girls fall into this category. In aggregating this result it seems that this category of transformation is mainly evident among science people (Table 7.9).

Phase	Main outcomes
One	The majority of the scientists and half of the non-scientists exhibited smooth (from approximately age 8) and progressive transformational learning into science or non-science from a very young age.
Two	The majority of the university students exhibited smooth and progressive transformational learning into science.
Three	Very few girls exhibited smooth and progressive transformational learning into science.

Table 7.9: Progressive TL and smooth transformation – summary

For example Dennis (scientist) might be represented as below (Figure 7.2).

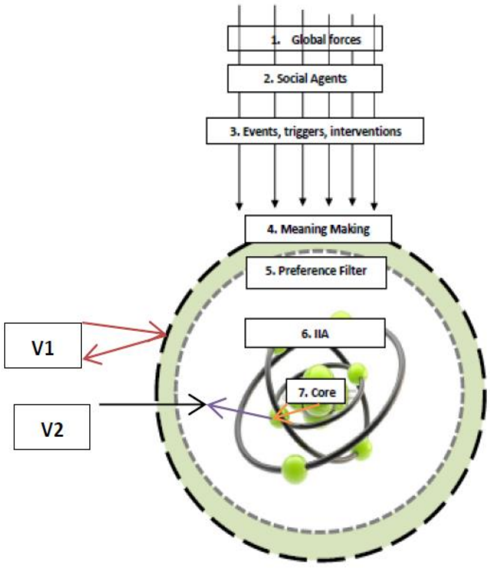


Figure 7.2: Progressive TL and smooth transformation

> Instance 1 (V1): Rejected negative influence from his mathematics teacher at the meaning-making filter (SA-red arrow).
>
> Instance 2 (V2): (i) Inspired by Haley's Comet at a young age (Trigger - black arrow) which passes through to the preference filter which is directed by his (ii) feeling of competence in science, obsession with space and rockets, generating a force (IIA- purple arrow) (iii) directed by the sciencey core (core- orange arrow).

Therefore following his long-standing obsession, he became a computer engineer in the field of astronomy.

(ii)Progressive TL and wavering transformation

A few female scientists and non-scientists a majority of the university students of whom a majority of the female students and the majority of the secondary school girls fall into this category. This exhibits the ways and opportunities for TL interventions to help these students continue with science education and career in the future (Table 7.10).

Phase	Main outcomes
One	A few female scientists and non-scientists exhibit wavering (after the age of sixteen) and progressive TL into science or non-science.
Two	The majority of the non-science students exhibited wavering and progressive TL into non-science.
Three	The majority of the girls exhibited wavering and possibly progressive TL into science and non-science.

Table 7.10: Progressive TL and wavering transformation - summary

Diagrammatic representation with an example is given below. For example Zikri (C2 category):

Instance 1 (V1): Rejected problem solving longer activities (event-red arrow)

Instance 2 (V2): Preferred meeting an engineer (event, SA) however rejected to opt for physics/ engineering (blue arrow)

Instance 3 (V3): (i) Grandparents farm in Algeria (Event- black arrow) (ii) mother wants her to become doctor (SA- green arrow) (iii) likes science as she has been surrounded by plants and animals (IIA- purple arrow).

Instance 4 (V4): (i) Grandparents' farm in Algeria (Trigger - black arrow) (ii) decorating (pictures) and researching scrapbook on 'nature' (iii) loves nature photography (IIA- purple arrow).

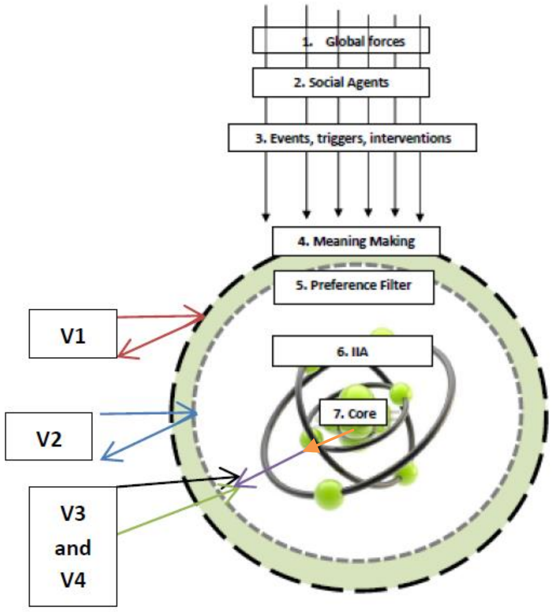


Figure 7.3: Progressive TL and wavering transformation

Therefore she exhibits progression towards both becoming a doctor and a photographer, where exhibiting ambivalent IIA and core (orange arrow) seems to be fluid in nature.

(iii)Reconstructive TL and wavering transformation

Of the three, this theme represents the lowest number and percentage of participants from all the three phases of study. One similarity that emerged is 'failure in exams', which first resulted in rejection and then acceptance of other very different TL that is satisfying (Table 7.11).

Phase	Main outcomes
One	A few male non-scientists exhibited wavering (after the age of seventeen) and reconstructive transformation away from science.
Two	A very university student exhibited wavering and reconstructive transformation.
Three	Very few girls exhibited wavering and reconstructive transformation.

Table 7.11: Reconstructive TL and wavering transformation- summary

Diagrammatic representation with an example is given below. For example Iqra (C2-C4):

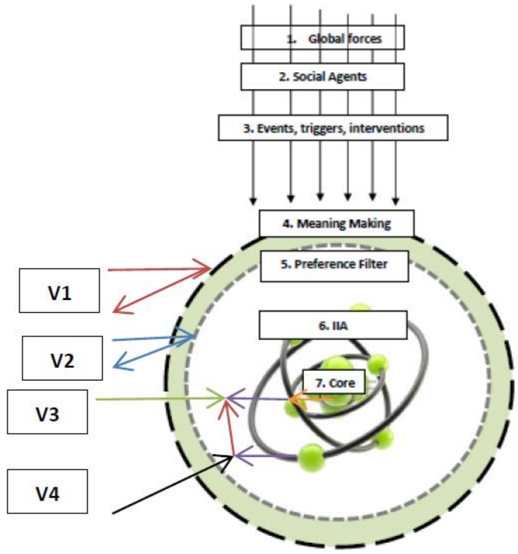


Figure 7.4: Reconstructive TL with wavering transformation

Instance 1 (V1): She does not make meaning of science content and exam questions (event- red arrow) and rejected at the meaning-making filter.

Instance 2 (V2): Science teachers influence (SA), all science interventions (events -blue arrow) rejected at the preference filter.

Instance 3 (V3): BBC dramas, Zain Malik (SA) (green arrow) interests her to become a singer, poet or writer (IIA- purple arrow accepting the green arrow)

Instance 4 (V4): poor exam results (event- black arrow), resulting in a feeling that science is hard, inclination towards learning about 'space' is fading away (IIA- purple arrow), rejected science (red arrow) and reconstructing TL in accordance to the non-science IIA (V3- purple arrow).

Therefore she exhibits reconstruction towards becoming a singer, poet or writer as the fluid core is stabilising towards non-sciences exhibiting wavering transformation. Where, failure in exam (red arrow) becomes a bridge between V3 and V4.

In summary, I am quite confident that the Sci-ID model is suited to illustrate progressive and reconstructive transformational learning process. Where regressive transformational learning can be incorporated within progressive and reconstructive models as indicated in red arrows. Moreover, a complete regression as indicated in the literature review is not evident from my data, an issue that requires further research with people who have moved completely away from science as well as non-science education.

7.6 Research Question Four

In what ways are a series of mini-transformative experiences (multiple classroom intervention activities) sufficiently persuasive to alter secondary school Muslim girls' perceptions of science?

The mini-transformative learning experiences which I called science interventions turned out to be quite progressive. I believe that these lessons fulfilled students and my expectations, as the girls' questionnaires indicate enjoyment and fun along with understanding of the scientific concepts for example: forces, gravity, magnetism, coding and decoding, cells, diseases, long chain polymers etc. At different occasions they worked scientifically involving the three main steps mentioned by Osborne (2014) indicated in the literature review. The persuasion of girls into sciences is evident as after the intervention a very high majority (C2 category) of the girls wanted to do at least one science subject at A-levels which was previously not evident. Moreover, the majority of the girls who were able to indicate their career choices wanted to explore science careers; this exhibits a determination (IIA) towards future science and education careers. Along with this determination there is a large possibility that, in future, they will accept TL experiences (events, triggers, interventions) that could help them in accomplishing their goals (science career) and reject those which are against their intentions. Similarly, the non-movers-towards science (C4); predominantly wanted to opt for non-science careers only, reflecting their drive/ push (IIA) towards their goal.

The change towards enjoying and learning science could be due to a particular intervention that results in a large impact however I strongly believe that a small number of various interventions (big or small) exhibit an aggregated impact on the students. Because a few girls after the third or fourth intervention indicated their enjoyment towards these mini-interventions and started to feel 'good' about science content they learnt in these intervened lessons.

Moreover, I also believe that these interventions have softened a few negative self-perceptions of students towards science education and career. Although it is not evidenced directly, however, the terms that I can pick from their questionnaires, interviews and verbal feedback demonstrated a positive impact. For example: science is broadly incorporated with every taught subject at school (Sabah) and the science degree acts as a backup for a variety of science as well as non-science careers (Sana).

I strongly recommend that these small school science interventions should be implemented according to the interest of the students. Moreover, responses from the questionnaires after every intervention acted as a reflective strategy for the girls- which I believe further made them acknowledge the understanding of the topic, their preferences and that at the same time studying science is enjoyable. For example *it was fun and I learnt more about the environment* (Zikri). Furthermore, the collection of these reflective questionnaires helped me to alter my teaching practices and design more interventions in the future as well.

7.7 Some limitations

There are, of course, some limitations to the research I have reported here. For instance, the research design can be questioned in terms of linking the three Phases of the study: the participants were from different ethnic groups, race, gender, and religion backgrounds – all of which I have discussed in terms of Global forces (GF). However, in this study, (i) I did not ask the participants' a direct question on the extent to which ethnicity, race and/or religion 'triggered' their identity, (ii) a few scientists and non-scientists mention gender, race, ethnicity-based identity constructs and (iii) this allowed me to link this limited data with the recent previous literature on GF. Moreover, the main outcomes from the three-phase design were linked through 'data accumulation processes' using the Sci-ID model ingredients. This accumulated summary provides a broader, wider picture to be discussed along with the recent literature (Table 7.2 – 7.8). My future research will consider differences between ethnicity, race and class (for example Wong, 2015; Brickhouse & Potter, 2000) and pupil's subject choices.

The questions can be asked, 'Why a UK-based all-Muslim girls' school was chosen for this study? - Why not a mixed mainstream school or single sex grammar or Catholic school? There are two clear reasons: first, this was a 'un-missable' opportunistic sample, the chance to work with a cohort of thirty young women for a protracted period of time (one year) and evaluate the extent to which my educational interventions might shape their attitudes to science. The idea behind conducting this research was to explore transformations - or at least change the negative science-based predispositions - within a particular community of Muslim Pakistani, Somali and Arabic girls. Second, the majority of the girls were (i) not much interested in taking up science(s) at A-level (that I found out at from the pre-intervention data), (ii) the literature gives especial attention in raising girls science education and career aspirations (for example Archer et al. 2010, 2015), (iii) moreover, they belong to a group of students who are from ethnic minority groups and are underachieving and (iv) such a particular type of school in the UK has been neglected by the researcher as through my literature research, from the leading journals like Science Education, IJSE, JRST; google search and science education based books, I could find little research on UK-based secondary Muslim schooling. For future research I would like to compare the different types of school to generate a comparative study.

As mentioned in Chapters One and Chapter Three, the methods to collect the data involved semi-structured narrative-styled-interviews and descriptive questionnaires. The interviews generated a depth of data involving participant's lived stories. This data allowed me to aggregate the responses to generate 'stories'. At this point one can argue (as indicated in the literature) that stories recalled from the past are re-constructions that might not reflect actual experiences (for example: Powney & Watts, 1987; Roth & Middleton, 2006). Therefore, ideally a follow-up interview session might have given a more 'corroborative' picture. However, I believe that (i) an approximate 40-minute interview with Phase One scientists and non-scientists provided me sufficient time to probe, (ii) few summarised stories exhibited description of Phase Two university students' life journey in choosing science and/or non-science subjects after the age of sixteen and (iii) a follow-up interview session with the willing Phase Three secondary school girls allowed me to gather substantial amount of data. However, an observer, especially during the conduct of the interventions with secondary school girls, might have been given greater in-depth information.

Further arguments could be raised about the response validation of the stories generated, because I, as a researcher, presented these stories about the participants in third-person rather than first-person 'voice' and aggregated the stories from selective parts of the narratives. I am confident about the aggregated stories because (i) the stories were given back to the scientists, non-scientists and secondary school girls for comment, (ii) the scientists and non-scientists were happy with their generated stories, a few secondary school girls indicated some changes that were then made to the stories, and the participants were asked to read them again and confirm, and (iii) a 'critical friend' read the questionnaire responses and related summarised stories as well.

7.8 Unique contributions to knowledge

From this study I believe the major contributions to science education are as follows:

(i)The Sci-ID educational model as expressed here is a unique and useful contribution to the discussion on the movement of pupils into and away from science. This model gives a structure to key aspects of 'science identity' that combines aspects of external and internal forces. It can be used as a tool to give an overview of youth as well as adult identity and the gaps that need consideration not only in science education but in other disciplines as well

(ii)The progressive, reconstructive smooth and wavering transformation models are also unique contributions to the impacts of learning in science. Using the empirical research with the Sci-ID model is a useful way to map a person's life journey from one point to another, and chart TL experiences, events, circumstances etc. along the way that move people into and away from science

(iii)The three phased research design used is also a strong contribution in the field of science education, which involved aggregation to generate stories and accumulation of the data from the three sets of participants and finding common ground to discuss the seven Sci-ID model ingredients that could help the making of scientists in the UK. This kind of study involving university scientists, non-scientists and students has not been conducted before (certainly not in Brunel University!). Moreover, studying Muslim girls from a UK-based Muslim faith school is also a unique contribution in science education and I believe it was not an easy task to undertake – not least because it involved a number of restrictions from the school management and teaching team.

7.9 Generalisability

I believe that this study has wide applicability in the field of education, in the following ways:

(i)The science identity based model utilising IIA, GF, SA and TL experiences (events, triggers and interventions) can be used by the other researchers to critique, compare and contrast with other models/ theories (ii)The generated Sci-ID model in its present state can be used by researchers to design and conduct empirical research not only in the field of science education but it can also be used in other fields

(iii)The generated progressive, reconstructive smooth and wavering transformation models can be used by anthropologists, ethnographers to design and evaluate real life transformative journey of people

(iv)The three-phased research design can be used to design a similar research in the future to overcome some of the limitations of a longitudinal research

(v)The style of aggregating the data and presenting stories in third person form can be adapted by the researchers to present lived stories

(v)The six intervention exercise, lesson plans, reflections and limitations can be adopted by the primary and secondary teachers from single sex or co-ed, independent or main stream schools, especially, if the availability of resources is limited.

7.10 Future research questions

From conducting this study, the following questions arise – and constitute some of my next ‘research steps’ for the future:

(i)Through the self-perceptions of the participants, I was able to illustrate their dispositions, natural inclinations and their subject and career choices and determined as to whether they have a smooth or fluid core identities. Therefore for future study the interview and questionnaire questions need to be re-phrased to understand the exact nature of the core. This might give rise to such questions as: In what ways can the ‘fluid nature’ of Sci-ID in a sample of secondary school girls be directed towards science education at pre-university/A-level? How might their fluid identities be transformed at A-level? What kinds of planned transformational learning experiences can be designed in A-level and beyond? Can there be a model that illustrates Reconstructive TL with smooth transformation? Can a complete regression from education happen in one’s life?

(ii)Which of all the social agents within a person’s life prove to be the most influential on Sci-ID? Are mothers or fathers more influential in directing their (female) children towards science education and careers? What are effects of teachers, peers, siblings, career councillors on students’ science or non-science futures? Is there an impact of fathers influence in Asian and African families in deciding girls' science education and career?

(iii)I was able to understand to some extent as how scientists, non-scientists and secondary school girls make meaning of science through their interaction with the interventions. However, I was unable to gather this data from the university students. Therefore for future study, I believe interview sessions would be of much benefit.

(iv)Is it possible that linking science with other non-science subjects allow students to prefer both science and non-science more? Can science interventions successfully be incorporated in arts and humanities lessons? Can these six science interventions be useful for SEN children?

(iv)How do science aspirations affect secondary school girls' achievement performance? What were the circumstances and events that persuade Muslim female scientists and non-scientists into and away from science? Does gender, ethnicity, race, religion identities overlap with science identities in the secondary school Muslim girls? How might, for example, the Salehjee Girls School be compared with a Sikh school (which is in the close vicinity)?

7.11 Recommendations

From the above findings and analysis it is quite clear that there in a gap in promoting lifelong learning in science. As the pupils' pass the age of compulsory education and later gain science or non-science based careers their identities becomes quite stable towards science or non-science. Therefore, some are anti-science, some pro-science and the institutions, society and government identify them as 'sciencey' or 'non-sciencey' people. Moreover, to cater for this various intervention strategies have been employed in the UK for example ASPIRE's project. However, I believe that the vast majority- the fluid people have been neglected. For example, a person who is 38 years old and did not have a university degree, works in a local shop, hated science in school, however, follows Tim Peake's journey to the International Space Station and fascinated by space and rockets. This person's fascination in a way is similar to Dennis (the scientist from Phase One). However, he did not have the same opportunity as Dennis, and his fascination could not translate into a force that could have allowed him to become a scientist. Even though he is not in the field of science his fascination is well and alive. Therefore, what could be done about it? I believe that the UK's government should promote mechanisms and provide funding for enabling lifelong learning in local communities such as local churches, mosques, libraries, community centres, science fairs in the local parks etc. This strategy will not only potentially make every person a scientist in the community but this public awareness could encourage local people to gain more scientific knowledge in their field of interest and it could encourage a few more towards gaining a qualification/ degree. Moreover, this will encourage people to actually challenge and eradicate their anti-science predispositions that ‘science is not for them’ because they belong to a certain under-represented backgrounds (and/) or they are females or even that science is not a cool subject.

Moreover, researchers in the area of science education also need to promote public understanding in science and evaluate ways that stop students closing doors too soon in their lives. I would also recommend the researchers to use the Sci-ID model and adapt it to explore the duality aspects of external forces and agency in individual’s from schools, colleges, universities, science and non-science-based professional workplaces etc.

Teachers need to find simple ways in implementing such science interventions to cater students with stable or fluid identities. They should device strategies/ interventions to encourage fluidity into non-science stable students and further working towards incorporating stability in sciences among the fluid students- which is one of my next steps as well. They also need to consider the meaning-making of science content along with the preferences, enjoyment and the fun element of laboratory work, out of school visits etc. Therefore, I strongly recommend that primary and secondary schools should incorporate such a strategy in their ‘school improvement plan’ on a long term basis and encourage science teachers to carryout action research involving not only designing and implementing interventions but also evaluating and modifying their plans. At this point, I believe that the Local Education Authority (LEA) also has a responsibility to make teachers communicate from different schools and share best practice considering differentiation in terms of science or non-science stability and fluidity aspects, rather than labelling students as high or low ability students.

Moreover, educators here also have a big responsibility in catering for the fluid people not only at a school level but also at a higher level. They need to identify stable and fluid people which, requires effort towards talking to people or communities - understanding their stories, life journey, finding out what are the things that moves them away or towards science and design simple interventions accordingly for the schools and teachers. Therefore, we need to find and help people to switch-on their ‘motivational fuse’ into sciences by talking to people about their ‘science lives, school choices and natural tendencies’ (Salehjee & Watts, 2015).

As Watts (2015) researched on a small sample of people who were excellent gardeners, self-taught botanists, through their understanding of plant biology but described themselves as non-sciencey people.

> *Once the ‘motivational fuse’ was lit, these respondents became forcefully active learners, pursued personal lines of enquiry, undertook typical IBL and became autodidactic (Watts, 2015, p. 353).*

References

Abes, E.S., Jones, S.R. and McEwen, M.K. (2007). Reconceptualizing the model of multiple dimensions of identity: The role of meaning-making capacity in the construction of multiple identities. *Journal of college student development*. *48*(1), pp.1-22.

Abes, E.S. and Jones, S.R. (2004). Meaning-making capacity and the dynamics of lesbian college students' multiple dimensions of identity. *Journal of college student development*. 45(6), pp.612-632.

Adamson, K. and Lane, T. (2016). The science of science outreach: methods to maximise audience engagement. In *EGU General Assembly Conference Abstracts*. Vienna: Austria. 18, p. 15830.

Albright, J., Towndrow, P.A., Kwek, D. and Tan, A.L. (2008). Identity and agency in science education: reflections from the far side of the world. *Cultural Studies of Science Education*. 3(1), pp.145-156.

Amos, R. and Reiss, M. (2011). The benefits of residential fieldwork for school science: Insights from a five-year initiative for inner-city students in the UK. *International Journal of Science Education*.*34* (4), pp.485-511.

Archer, L. and DeWitt, J. (2016). *Understanding Young People's Science Aspirations: How students form ideas about 'becoming a scientist'*. New York, N: Routledge.

Archer, L., Dawson, E., Seakins, A., DeWitt, J., Godec, S. and Whitby, C. (2016). "I'm Being a Man Here": Urban Boys' Performances of Masculinity and Engagement With Science During a Science Museum Visit. *Journal of the Learning Sciences*, (just-accepted).

Archer, L. and DeWitt, J. (2015). Science aspirations and gender identity: Lessons from the ASPIRES project. In Henriksen, E.K., Dillon, J. and Ryder, J. *eds. Understanding student participation and choice in science and technology education.* Dordrecht: Springer, pp. 89-102.

Archer, L., Dewitt, J., Osborne, J. (2015[a]). Is science for us? black students' and parents' views of science and science careers. *Science education*. 99 (2), pp. 199-237.

Archer, L., Dawson, E., DeWitt, J., Seakins, A. and Wong, B. (2015[b]). Science capital: A conceptual, methodological, and empirical argument for extending bourdieusian notions of capital beyond the arts. *Journal of Research in Science Teaching. 52*(7), pp.922-948.

Archer, L., DeWitt, J. and Willis, B. (2014[a]). Adolescent boys' science aspirations: Masculinity, capital, and power. *Journal of Research in Science Teaching*. *51*(1), pp.1-30.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. & Wong, B. (2014[b]). *ASPIRES. Young people's science and career aspirations, age 10 –14.* London: Kings College.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B. & Wong, B. (2013). Not Girly, not sexy, not glamorous: Primary school girls' and parents' constructions of science aspirations. *Pedagogy, Culture & Society*. 21 (1), pp. 171-194.

Archer, L., DeWitt, J., Osborne, J., Dillon, J. Willis, B. & Wong, B. (2012). Science Aspirations, Capital, and Family Habitus: How Families Shape Children's Engagement and Identification With Science. *American Educational Research Journal*, 49(5), pp. 881-908.

Archer, L., DeWitt, J., Osborne, J., Dillon, J., Willis, B., & Wong, B. (2010). ''Doing'' science versus ''being'' a scientist: Examining 10/11-year-old schoolchildren's constructions of science through the lens of identity. *Science Education*. 94(4), pp.617–639.

Artigue, M., Dillon, J., Harlen, W. and Léna, P. (2012). *Learning through Enquiry. The Fibonacci Project*. [Online]. [Accessed 09/01/15]. Available from: www.fibonacci-project.eu.

Aspires (2013) *Young people's science and career aspirations age 10-14. Department of Education and Professional studies*. London: Kings College. Available from:http://www.kcl.ac.uk/sspp/departments/education/research/aspires/ASPIRES-final-report-December-2013.pdf

Atkinson, P. and Delamont, S. (2006). Rescuing narrative from qualitative research. *Narrative enquiry*. 16(1), pp. 164-172.

Australian Academy of Science (2013) *Science by doing: Engaging students with science. Enquiry based learning*. [Online]. [Accessed 08/01/207]. Available from: https://www.sciencebydoing.edu.au/portal/teacher/teacher-guide.html#footerMenu

Ball, S.J. (1990) Politics and Policy-Making in Education. London, UK: Routledge.

Bandura, A., 1990. Perceived self-efficacy in the exercise of personal agency. *Journal of applied sport psychology*. 2(2), pp.128-163.

Bansal, P., & Corley, K. (2011). The coming of age for qualitative research: Embracing the diversity of qualitative methods. *Academy of Management Journal*. 54(2), pp. 233–237.

Barbosa, L.M., Fonseca, B., Dal-Farra, R.A. and Lopes, L.A. (2014). Teaching science education with poetry. *Creative Education*. 5(19), pp.1745.

Barnett, J. and Feasey, R. (2016). *Jumpstart! Science Outdoors: Cross-curricular Games and Activities for Ages 5-12*. London and New York: Routledge.

Beauchamp, G. and Parkinson, J. (2008). Pupils' attitudes towards school science as they transfer from an ICT-rich primary school to a secondary school with fewer ICT resources: Does ICT matter?. *Education and Information Technologies*. *13*(2),pp.103-118.

Becker, F.S. (2010). Why don't young people want to become engineers? Rational reasons for disappointing decisions. *European journal of engineering education*. 35(4), pp.349-366.

Bell, D. (2014). *The perceived success of interventions in science education*. London, UK: Wellcome trust. [Online]. [Accesses 08/01/2016]. Available from: https://wellcome.ac.uk/sites/default/files/wtp056459_0.pdf

Bennett, J., & Hogarth, S. (2008). *Would you want to talk to a scientist at a party?: Students' attitudes to school science and science*. York: Department of Educational Studies at the University of York.

Bergtrom, Z., Sadler, P. and Sonnert, G. (2016). Evolution And Persistence Of Students' Astronomy Career Interests: A Gender Study. *Journal of Astronomy & Earth Sciences Education (JAESE)*. *3*(1), pp.77-92.

Billingsley, B., Brock, R., Taber, K.S. and Riga, F. (2016). How students view the boundaries between their science and religious education concerning the origins of life and the universe. *Science Education*. Willey Online Library. 100(3), pp.459-482. [Accessed 08/12/2016]. Available from: doi 10.1002/sce.21213

Blaikie, N. (2010) *Designing social research*. 2nd edition. Cambridge, Malden: Polity Press.

Blenkinsop, S., McCrone, T., Wade, P. and Morris, M. (2006). *How do young people make choices at 14 and 16*. London: Department for Education and Skills.

Block, D. (2013). The structure and agency dilemma in identity and intercultural communication research. *Language and Intercultural Communication*.*13* (2), pp.126-147.

Borda Carulla, S. (ed.) (2012). *Tools for Enhancing Enquiry in Science Education. The Fibonacci Project*. [Online]. [Accessed 12/12/15]. Available from: www.fibonacci-project.eu.

Bourdieu, P., & Passeron, J. C. (1990). *Reproduction in education, society and culture*. 2nd edition. London: Sage.

Bourdieu, P. (1990) *In other words: Essay towards a reflexive sociology*. Cambridge: Polity.

Bourdieu, P. (1986). The forms of capital. In J. C. Richardson. ed. *Handbook of theory and research for the sociology of education*. New York: Greenwood Press, pp.241-258.

Bourdieu, Pierre (1986). The Forms of Capital. In John Richardson, Ed. *Handbook of Theory and Research for the Sociology of Education*. New York: Greenwood Press, pp.241-258.

Bourdieu, P., & Passeron, J. C. (1977). *Reproduction in education, society and culture*. Beverly Hills: Sage.

Bradbury, L. *(*2014*).* Linking science and language arts: A review of the literature which compares integrated versus non-integrated approaches*. Journal of Science Teacher Education.* 25*(*4*),*pp.465–488*.*

Brezinka, V. (2014). Computer games supporting cognitive behaviour therapy in children. *Clinical child psychology and psychiatry*.19 (1), pp.100-110.

Brickhouse, N.W. and Potter, J.T. (2001). Young women's scientific identity formation in an urban context. *Journal of research in science teaching*.38 (8), pp.965-980.

Brickhouse, N.W., Lowery, P. and Schultz, K. (2000). What kind of a girl does science? The construction of school science identities. *Journal of research in science teaching*.*37*(5), pp.441-458.

Brown, K.B., Hughes, A.J., Crowder, I.G. and Brown, P.M. (2015). Hunting for Treasures Through Learning Using Geocaching to Motivate Young Adolescent Learners. *Gifted Child Today*. *38*(2), pp.95-102.

Brown, S.A. (2015). Creative expression of science through poetry and other media can enrich medical and science education. *Frontiers in neurology*, *6*. [Online]. [Accessed 28/11/2016]. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4302945/

Burke, P. J. & Stets, J. E. (2009). *Identity theory*. New York NY: Oxford University Press.

Burns, M.K., Silberglitt, B., Christ, T.J., Gibbons, K.A. and Coolong-Chaffin, M. (2016). Using Oral Reading Fluency to Evaluate Response to Intervention and to Identify Students not Making Sufficient Progress. In Cummings, K. D. and Petscher, Y.ed.*The Fluency Construct*. New York: Springer, pp. 123-140.

Buxton, M. (2011). The payback of 'Payback': challenges in assessing research impact. *Research Evaluation*. 20(3), pp.259-260.

Carambo, C. (2015). Social, Cultural and Emotional Contexts of Transformative Learning Environments. In Milne, C., Tobin, K. and DeGennaro, D. eds. *Sociocultural Studies and Implications for Science Education*. Netherlands: Springer. pp. 155-180.

Carlone, H. B., & Johnson, A. (2007). Understanding the science experiences of successful women of color: Science identity as an analytic lens. *Journal of Research in Science Teaching.* 44(8), pp.1187–1218.

Carpenter, C. and Hammell, K. (2000). Evaluating qualitative research. *Using qualitative research: A practical introduction for occupational and physical therapists*, pp.107-119.

Carta, J.J., McElhattan, T.E. and Guerrero, G. (2016). The Application of Response to Intervention to Young Children with Identified Disabilities. In Reichow, B., Boyd,B.A., Barton, E.E. and Odom, S.L. *Handbook of Early Childhood Special Education*. Springer International Publishing, pp. 163-178.

Chapman, A. and Feldman, A. (2016). Cultivation of science identity through authentic science in an urban high school classroom. *Cultural Studies of Science Education*, pp.1-23. DOI 10.1007/s11422-015-9723-3.

Claussen, S., & Osborne, J. (2012) Bourdieu's notion of cultural capital and its implications for science curriculum. *Science Education*. 97(1),pp. 58-79.

Codiroli, N., 2015. *Inequalities in students' choice of STEM subjects*. [Online]. [Accessed 01/01/2017]. Available from: http://s3.amazonaws.com/academia.edu.documents/39490917/CLS_WP_20156_-_Inequalities_in_students_choice_of_STEM_subjects_-_N_Codiroli_-_September_2015.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1483916323&Signature=ISWFCN3gU14VBzzp8FrhA%2F8NUZI%3D&response-content-disposition=inline%3B%20filename%3DInequalities_in_students_choice_of_STEM.pdf

Cohen, L., Manion, L. and Morrison, K. (2007) *Research methods in Education*.6th Ed. London New York: Routledge.

Cohen, L., Manion, L. and Morrison, K. (2004). *A guide to teaching practice*. 5th Ed. London and New York: Routledge.

Communities and Local Government: London (2009) *Understanding Muslim Ethnic Communities*. [Online]. [Accessed 02/08/2016]. Available from:http://webarchive.nationalarchives.gov.uk/20120919132719/http:/www.communities.gov.uk/documents/communities/pdf/1203896.pdf

Confederation of British Industry (CBI) (2014). *Engineering our Future: Stepping up the urgency on STEM*. [Online]. [Accessed 02/11/2015]. Available from: www.cbi.org.uk

Cope, J. (2005). Researching entrepreneurship through phenomenological enquiry philosophical and methodological issues. *International Small Business Journal*. *23*(2), pp.163-189.

Coulter, C.A. and Smith, M.L. (2009). The Construction Zone Literary Elements in Narrative Research. *Educational Researcher*. *38*(8), pp.577-590.

Cranton, P. (2001) Interpretive and critical evaluation. *New directions for Teaching and Learning*. 2001(88), pp. 11-18.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Los Angeles, London, New Delhi, Singapore, Washington DC: Sage.

D'Amato, L. G., and Krasny, M. E. (2011). Outdoor adventure education: Applying transformative learning theory to understanding instrumental learning and personal growth in environmental education. *Journal of Environmental Education*. 42(4), pp.237–254.

Davies, P [a] (2015). The nature of Science. In Toplis, R. ed. *Learning to teach science in the secondary school: a companion to school experience*. 4th Ed. Milton Park, Abingdon, Oxon; New York, NY: Routledge. pp. 36-42.

Davies, P [b] (2015). Science 11-14. In Toplis, R ed. *Learning to teach science in the secondary school: a companion to school experience*.4th Ed. Milton Park, Abingdon, Oxon; New York, NY: Routledge. pp. 43-52.

Dawkins, R. (2013). *An appetite for wonder. The making of a scientist*. London: Transworld Publishers.

Dawkins, R. (2006). *Unweaving the rainbow: Science, delusion and the appetite for wonder*. Penguin Books. [Online]. [Accessed 12/12/2014]. Available from:https://books.google.co.uk/books?id=T1HVsIuAQwIC&printsec=frontcover&dq=unweaving+the+rainbow&hl=en&sa=X&redir_esc=y#v=onepage&q=science%20poetry&f=false

DBIS (2014) *STEM research with young people*. [Online]. [Accessed 28/12/16]. Available from:https://www.gov.uk/government/publications/science-technology-engineering-and-maths-research-with-young-people

Denzin, N.K. and Lincoln, Y.S. (2011). *The SAGE handbook of qualitative research*. Los Angeles, London, New Delhi, Singapore, Washington DC:Sage.

Denzin, N.K. (1989) *The Research Act*. 3rd edition. Englewood Cliffs, NJ: Prentice Hall.

Department for Education (2013). *National curriculum in England: citizenship programmes of study for key stages 3 and 4*. [Online] [Accessed 22/03/2014]. Available from:https://www.gov.uk/government/publications/national-curriculum-in-england-citizenship-programmes-of-study/national-curriculum-in-england-citizenship-programmes-of-study-for-key-stages-3-and-4.

Department of Business Innovation and Skills (BIS) (2014). *Project STEM – Book of Insights. Research with young people, their parents and teachers*. London: Department of Business Innovation and Skills and Mindshare, BIS/ 14/899, pp.77.

deVilliers, M. (2016). An explanatory, transformation geometry proof of a classic treasure-hunt problem and its generalization. *International Journal of Mathematical Education in Science and Technology* . 48(2) pp.1-7.

Dillon, J. (2009). On scientific literacy and curriculum reform. *International Journal of Environmental & Science Education*. 4(3),pp. 201–213.

DiMaggio, P. (1982). Cultural capital and school success: The impact of status culture participation on the grades of US high school students. *American sociological review*. 47(2), pp.189-201.

Drake, C., Spillane, J.P., and Hufferd-Ackles, K. (2001). Storied identities: Teacher learning and subject matter context. *Journal of Curriculum Studies*. 33(1),pp. 1–23.

Duit, R. and Treagust, D.F. (2003) Conceptual change- a powerful framework for improving science teaching and learning. *International Journal of Science Education*. 25(6),pp. 671 – 88.

Economou, D., Bouki, V., Kounenis, T., Mentzelopoulos, M. and Georgalas, N. (2015). Treasure hunt pervasive games in cultural organisations. In *Interactive Mobile Communication Technologies and Learning (IMCL), 2015 International Conference on* (pp. 368-372). IEEE.

Egan, K., Cant, A.I. and Judson, G. eds. (2013). *Wonder-full education: The centrality of wonder in teaching and learning across the curriculum*. New York and London: Routledge.

Egan, K. (2010). Learning in depth: *A simple innovation that can transform schooling*. Chicago: University of Chicago Press.

Egan, K. and Madej, K.R.Y.S.T.I.N.A. (2009). Learning in depth: Students as experts. *Education Canada*, 49(2), pp.18-23.

Elias, P., Jones, P., and McWhinnie, S. (2006). *Representation of ethnic groups in chemistry and physics: A report prepared for the Royal Society of Chemistry and the Institute of Physics*. London: Royal Society of Chemistry/Institute of Physics.

Elmesky, R. and Seiler, G. (2007). Movement expressiveness, solidarity and the (re) shaping of African American students' scientific identities. *Cultural Studies of Science Education*. *2*(1), pp.73-103.

Engineering UK (2014). The State of Engineering. In MacDonald, A. *“Not for people like me?” Under-represented groups in science, technology and engineering*. Wise Campaign. [Online] [Accessed 09/01/2017]. Available from:https://www.wisecampaign.org.uk/uploads/wise/files/not_for_people_like_me.pdf.

English Oxford Living Dictionaries (2016). *Definition of inclination in English: Inclination. Oxford: Oxford University Press*. [Online]. [Accessed 21/0/17]. Available from:https://en.oxforddictionaries.com/definition/inclination

English Oxford Living Dictionaries (2016). *Definition of inclination in English: Intervention. Oxford: Oxford University Press*. [Online]. [Accessed 21/0/17]. Available from:https://en.oxforddictionaries.com/definition/intervention

Erel, U. (2010). Migrating cultural capital: Bourdieu in migration studies. *Sociology*. *44*(4), pp.642-660.

Erikson, E. H. (1982) *The lifecycle completed*. New York, USA: Norton.

Erikson, E. (1973) Eight ages of man. In Bowman, C.C., 1973. *Humanistic sociology; readings*. McGraw-Hill Primis Custom Publishing. p. 68 -82.

Erikson, E. H. (1968). *Identity: Youth and crisis*. New York: Norton.

Essex, J. (2016) Cultural Inclusion in Science Education. In Abels, Simone and Markic, Silvija, *Inclusion in Science Education*, New York: US, Nova Publishing, pp. 67-90.

Estrada, M., Woodcock, A., Hernandez, P. R., and Schultz, P. W. (2010). Toward a model of social influence that explains minority student integration into the scientific community. *Journal of Educational Psychology*. [Accessed 09/10/14]. 103(1),pp. 206–222. doi: 10.1037/a0020743.

European Commission (2007) *European Commission Science education now: A renewed pedagogy for the future of Europe*. [Online]. [Accessed 09/01/2016]. Available from: http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf

Facer, K., and Manchester, H. (2012). *Mapping learning lives: Final Report. Education and social research institute*. Manchester: Manchester Metropolitan University.

Falloon, G. (2013). Young students using iPads: App design and content influences on their learning pathways. *Computers & Education*. 68, pp.505-521. [Online]. [Accessed 09/10/15]. Available from: https://www.researchgate.net/profile/G_Falloon/publication/262358029_Young_students_using_iPads_App_design_and_content_influences_on_their_learning_pathways/links/55e78e6b08ae65b638995b53.pdf

Faria, C., Chagas, I., Machado, A. and Sousa, J. (2013). A science teacher education course in a science centre: a successful strategy to empower teachers to master museum resources exploration?. *Electronic Journal of Science Education*.16(2), pp. 1-13.

Forbes, A. and Skamp, K. (2016). Secondary science teachers' and students' involvement in a primary school community of science practice: How it changed their practices and interest in science. *Research in Science Education*. 46(1), pp.91-112.

Frazier, W. and Murray, K. (2009). Science poetry in two voices: poetry and the nature of science. *Sci Educ Rev*. *8*(2), pp.58-78.

Garcia-Matos, M. and Carrasco, S. (2014). Light on the Waves: Science, music, poetry… and light! In *12th Education and Training in Optics and Photonics Conference* (pp. 92892E-92892E). International Society for Optics and Photonics.

Gee, J.P. (2000). Identity as an analytic lens for research in education. *Review of research in education*, *25*, pp.99-125. [Online] [Accessed 09/10/16]. Available from:http://rre.sagepub.com/content/25/1/99.full.pdf+html

Gerstner, H. P., Neubauer, T., and Lehmann, A. (2014). 'Bildung as a transformation of self-world-relations', paper presented at the Interrogating transformative processes in learning and education: an international dialogue: a new European Society for Research on the Education of Adults (ESREA) Network 1st Conference, Athens, Greece, 27th – 29th June.

Giddens, A. (1991). *Modernity and self-identity: Self and society in the late modern age*. Stanford: Stanford University Press.

Gilbert, J.K (2006). On the nature of context in chemical education. *International Journal of Science Education*. 28(9), pp. 957–976.

Gilmartin, S.K., Li, E. and Aschbacher, P. (2006). The relationship between interest in physical science/engineering, science class experiences, and family contexts: Variations by gender and race/ethnicity among secondary students. *Journal of Women and Minorities in Science and Engineering*, *12*(2-3). [Online] [Accessed 20/11/2014]. Available from:10.1615/JWomenMinorScienEng.v12.i2-3.50.

Goldfarb, S., Marcelloni, C. and Shaw, K. (2016). Innovating science communication: the structure supporting ATLAS Education & Outreach. *Nuclear and Particle Physics Proceedings*. 273, pp.1276-1283.

Greenspan, Y. F. (2015). *A Guide to Teaching Elementary Science*. Rotterdam, NL:SensePublishers. [Online]. [Accessed 22/11/2016]. Available from:http://site.ebrary.com/lib/alltitles/docDetail.action?docID=11136408.

Grix, J. (2010). *The Foundations of Research*. New York: Palgrave Macmillan.

Guba, E.G. and Lincoln, Y.S. (1989). *Fourth generation evaluation*. Newbury Park, London, New Delhi: Sage.

Hampden-Thompson, G. and Bennett, J. (2013). Science Teaching and Learning Activities and Students' Engagement in Science. *International Journal of Science Education*. 35(8), 1325-1343.

Hassard, J. and Dias, M. (2009) *The Art of Teaching Science: Enquiry and innovation in middle school and high school.* 2nd Ed. New York and London: Routledge.

Hattam, R. and Zipin, L. (2009). Towards pedagogical justice. *Discourse: Studies in the cultural Politics of Education*. 30(3), pp.297-301.

Hazari, Z., Cass, C. and Beattie, C. (2015). Obscuring power structures in the physics classroom: Linking teacher positioning, student engagement, and physics identity development. *Journal of Research in Science Teaching*. *52*(6), pp.735-762.

Hazari, Z., Potvin, G., Lock, R.M., Lung, F., Sonnert, G. and Sadler, P.M. (2013). Factors that affect the physical science career interest of female students: Testing five common hypotheses. *Physical Review Special Topics-Physics Education Research*. 9(2),pp.020115.

Hazari, Z., Sonnert, G., Sadler, P.M. and Shanahan, M.C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*. *47*(8), pp.978-1003.

Heddy, B. and Pugh, K. (2015). Bigger is not always better: Should educators aim for big transformative learning events or small transformative experiences?. *Journal of Transformative Learning*. 3(1), pp.52-58.

Hepworth, M. and Walton, G. (2009) *Teaching Information Literacy for Enquiry-Based Learning*. Oxford, Cambridge, New Delhi: Chandos Publishing.

Heumer, G., Gommlich, F., Jung, B., and Mueller, A. (2007). Via Mineralia—A pervasive museum exploration game. *In Proceedings of PerGames 2007*. Salzburg, Austria, pp. 159–160.

Hewlett, C. (2016). *Why use Fiction?. In Teaching Science in the Primary Classroom*. [Online] [Accessed 23/12/2016]. Available from:https://books.google.co.uk/books?hl=en&lr=&id=3T1DCgAAQBAJ&oi=fnd&pg=PT135&dq=science+fiction+ofsted&ots=r5xYO-HVGJ&sig=IRulqL-54TGrW7TKkPk_kzNUSG0#v=onepage&q&f=false

Higher Education Funding Council for England (HEFCE) (2014). *Submission to the House of Lords Select Committee on Science and* Technology: Enquiry on International STEM students, Higher Education Funding Council for England, February 2014. [Online]. [Accessed 21/10/15]. Available from: http://www.scienceinparliament.org.uk/wp-content/uploads/2013/12/SELECT-COMMITTEES-HoC-LIBRARY-POST.pdf

Hofstein, A., Eilks, I., and Bybee, R. (2011). Societal issues and their importance for contemporary science education: A pedagogical justification and the state of the art in Israel, Germany and the USA. International Journal of Science and Mathematics Education. 9(6), 1459–1483.

Holbrook, J. (2008). Introduction to the special issue of science education international devoted to PARSEL. *Science Education International*. 19(3), 257–266.

Holbrook, J. (2005). Making chemistry teaching relevant. *Chemical Education International*. 6(1), pp.13–16.

Holbrook, J. (2003). Increasing relevance of science education: The way forward. *Science Education International*. 14(1), pp.5–13.

Horrigan, P.G. (2007). *Epistemology: An Introduction to the Philosophy of Knowledge*. New York: Lincoln Shanghai: iUniverse Inc.

House of Commons Children, Schools and Families Committee (2010). *Training of Teachers: Fourth report of session 2009 – 10*. Volume 2 [Online]. [Accessed 20 July 2010]. Available from:http://books.google.com/books?id=c7aIl38yPtUC&pg=PA178&dq=ofsted+continuing+professional+development+for+teachers+in+schools&hl=en&ei=zvVSTPCNKJSI4gbS9fTgAw&sa=X&oi=book_result&ct=result&resnum=4&ved=0CEIQ6AEwAw#v=onepage&q=ofsted%20continuing%20professio.

Hulleman, C. S., and Cordray, D. S. (2009). Moving from the lab to the field: The role of fidelity and achieved relative Intervention strength. *Journal of Research on Educational Effectiveness*. 2(1),pp. 88–110.

Huston, A.C. (2015). On the role of parents in the ontogeny of achievement-related motivation and behavioral choices. *Monographs of the Society for Research in Child Development*. 80(2), pp.152-157.

Hutchings, W. (2007). *Enquiry-Based Learning: Definitions and Rationale*. Manchester: Centre for Excellence in Enquiry-Based Learning.

Hyde, J.S., Canning, E.A., Rozek, C.S., Clarke, E., Hulleman, C.S. and Harackiewicz, J.M. (2016). The Role of Mothers' Communication in Promoting Motivation for Math and Science Course-Taking in High School. *Journal of Research on Adolescence*. [Online]. [Accessed 12/12/2016]. Available from: doi:10.1111/jora.12253.

Ihamäki, P. (2014). The potential of treasure hunt games to generate positive emotions in learners: experiencing local geography and history using GPS devices. *International Journal of Technology Enhanced Learning*. *6*(1), pp.5-20.

Illeris, K. (2014). *Transformative learning and identity*. London and New York: Routledge.

Ing, M. (2014). Gender differences in the influence of early perceived parental support on student mathematics and science achievement and STEM career attainment. *International Journal of Science and Mathematics Education*. *12*(5), pp.1221-1239.

Ipsos Mori (2011) *Public attitude t science*. BIS. [Online] [Accessed 15/01/15]. Available from:https://www.ipsos-mori.com/Assets/Docs/Polls/sri-pas-2011-main-report.pdf

Ipsos, M.O.R.I. (2012).*The effects of the English Baccalaureate*. London: Ipsos MORI.

Iqbal, J. (2016). *The diverse origins of Britain's Muslims*. UK: BBC. [Online]. [Accessed 02/08/2016]. Available from:http://www.bbc.co.uk/news/uk-33715473

Iuculano, T., Rosenberg-Lee, M., Richardson, J., Tenison, C., Fuchs, L., Supekar, K. and Menon, V. (2015). Cognitive tutoring induces widespread neuroplasticity and remediates brain function in children with mathematical learning disabilities. *Nature communications*.*6*. [Online]. [Accessed 14/01/16]. Available from: doi:10.1038/ncomms9453.

Jackson, P. W. (1986). *The practice of teaching*. New York: Teachers College Press.

Jagoda, P., Gilliam, M., McDonald, P. and Russell, C. (2015). Worlding through play: alternate reality games, large-scale learning, and The Source. *American Journal of Play*. *8*(1), pp.74.

Jarvis, P. (2013) Learning to be a person East and West. *Comparative Education*. [Online]. 49(1), pp. 4-15. [Accessed 20/10/15]. Available from: doi: 10.1080/03050068.2012.740216

Jarvis, P. (2009). *Learning to be a person in society*. London and New York: Routledge.

Jenkins, R. B. (1992). *Pierre Bourdieu*. London: Routledge.

Jensen, E. and Wright, D. (2015) Critical Response to Archer et al. (2015). "Science Capital": A Conceptual, Methodological, and Empirical Argument for Extending Bourdieusian Notions of Capital Beyond the Art. *Science Education*. 99 (6), pp.1143-1146.

Jeynes, W.H. (2010). Parental involvement and encouraging that involvement: Implications for school-based programs. *Teachers College Record*. 112(3), pp. 747–774.

Johnson, A., Brown, J., Carlone, H. and Cuevas, A.K. (2011). Authoring identity amidst the treacherous terrain of science: A multiracial feminist examination of the journeys of three women of color in science. *Journal of Research in Science Teaching*. 48(4), pp.339-366.

Joint Council for Qualifications (JCQ) (2014). [Online]. [Accessed 02/08/2016]. Available from: http://www.jcq.org.uk/examination-results/a-levels/2014

Jones, S.R. and McEwen, M.K. (2000). A conceptual model of multiple dimensions of identity. *Journal of college student development*. 41(4), pp.405-414.

Jungert, T. and Koestner, R. (2015). Science adjustment, parental and teacher autonomy support and the cognitive orientation of science students. *Educational Psychology*. *35*(3), pp.361-376.

Justice, W. Warry, C.L. Cuneo, S. Inglis, S. Miller, J. Rice (2002). A grammar for enquiry: Linking goals and methods in a collaboratively taught social sciences enquiry course. *The Alan Blizzard Award Paper: The Award Winning Papers*.

Kane, J.M. (2012). Young African American children constructing academic and disciplinary identities in an urban science classroom. *Science Education*. *96*(3), pp.457-487.

Ke, F. (2008). A case study of computer gaming for math: Engaged learning from gameplay?. *Computers & Education*. *51*(4), pp.1609-1620.

Kearney, R. (2002). *On Stories*. London: Routledge.

Kegan, R. (2009). What “form” transforms; A constructive developmental approach to transformative learning. In Illeris, K. ed. *Contemporary theories of learning: learning theorists... in their own words*. London and New York: Routledge, p. 35-52.

Kegan, R. (1994). *In Over Our Heads: The Mental Complexity Of Modern Life*. Cambridge MA: Harvard University Press.

Kellner, E., Gullberg, A., Attorps, I., Thorén, I. and Tärneberg, R. (2010). PROSPECTIVE TEACHERS’INITIAL CONCEPTIONS ABOUT PUPILS’DIFFICULTIES IN SCIENCE AND MATHEMATICS: A POTENTIAL RESOURCE IN TEACHER EDUCATION. *International Journal of Science and Mathematics Education*. 9(4), pp.843-866.

Kelman, H.C. (2006). Interests, relationships, identities: Three central issues for individuals and groups in negotiating their social environment. *Annu. Rev. Psychol.*.*57*, pp.1-26.

King, A (2000) Thinking with Bourdieu against Bourdieu: A 'Practical' Critique of the Habitus. *Sociological Theory.* 18(3), pp. 417-433.

Kitsantas, A. and Cleary, T.J. (2016). THE DEVELOPMENT OF SELF-REGULATED LEARNING DURING SECONDARY SCHOOL YEARS. In Wentzel, K.R. AND Miele, D.B. eds. *Handbook of Motivation at School.* New York and London: Routledge, pp.169.

Kuhlthau, C.C., Maniotes, L.K. and Caspari, A.K. (2015). *Guided Enquiry: Learning in the 21st Century: Learning in the 21st Century*. 2nd Ed. USA: ABC-CLIO.

Kvale, S. (1989). *Issues of Validity in qualitative Research. eds.* Lund: Studentlitteratur.

Kvale, S. (1996). *Interviews.* London, UK :Sage

Lapka, M., Aguirre, L., Hill, E., Beni, N., Szillasi, Z., Alexopoulos, T., Hochkeppel, S.M., Petrilli, A., Goldfarb, S. and Bourdarios, C. (2016). ATLAS and CMS Virtual Visits: Bringing Cutting Edge Science into the Classroom and Beyond (No. ATL-OREACH-PROC-2016-003). ATL-COM-OREACH-2016-001. [Online]. [Accessed 31/12/16]. Available from: http://cds.cern.ch/record/2132292?ln=en

Lave, J., and Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, UK: Cambridge University Press.

Lee, Y.-J. (2012). Identity-based research in science education. In B. Fraser, K. Tobin, and C. McRobbie. eds. *Second international handbook of science education*. Dordrecht: Springer, pp. 35–45.

Leitch, C. M., Hill, F. M., and Harrison, R. T. (2010). The philosophy and practice of interpretivist research in entrepreneurship: Quality, validation, and trust. *Organizational Research Methods*. 13(1), pp 67–84.

Lewis, M. (2008). Self-conscious emotions: Embarrassment, pride, shame, and guilt. In M. Lewis, J. M. Haviland-Jones, and L. Feldman Barrett .eds. *Handbook of emotions*. New York, NY: The GuilfordPress, pp. 742–756.

Lieblich, A., Tuval-Mashiach, R., and Zilber, T. (1998). *Narrative research: Reading, analysis and Interpretation*. Thousand Oaks, CA: Sage.

Lin, K.Y., Tsai, F.H., Chien, L.T., (2013) Chang Effects of a science fiction film on the technological creativity of middle school students. *Eurasia Journal of Mathematics, Science and Technology Education*. 9 (2), pp. 191–200.

Lock, R.M. and Hazari, Z. (2016). Discussing underrepresentation as a means to facilitating female students' physics identity development. *Physical Review Physics Education Research*. *12*(2), p.020101.

Lock, R.M., Hazari, Z. and Potvin, G. (2013). Physics career intentions: The effect of physics identity, math identity, and gender. In *2012 Physics education research conference* . 1513(1), pp. 262-265. AIP Publishing.

Loehle, C. (2010). *Becoming a successful scientist. Strategic thinking for scientific discovery*. Cambridge: Cambridge University Press.

Logan, M., and Skamp, K. (2008). Engaging students in science across the primary secondary interface: listening to the students' voice.[Online]. *Research in Science Education*. 38(4), 501–527. Available from: doi:10.1007/11165-007-9063-8.

Ludhra, G. (2015). *A black feminist exploration of the cultural experiences and identities of academically 'successful' British South-Asian girls*. PhD Thesis. London: Brunel University London.

MacDonald, A. (2014). *"Not for people like me?" Under-represented groups in science, technology and engineering. A summary of the evidence: the facts, the fiction and what we should do next.* Women in science, technology and engineering (WI S E). [Online]. [Accesed 10/10/16]. Available from: http://www.equalityanddiversity.net/docs/not_for_people_like_me.pdf

Maltese, A.V. and Tai, R.H. (2011). Pipeline persistence: Examining the association of educational experiences with earned degrees in STEM among US students. *Science Education*, *95*(5), pp.877-907.

Mandler, D., Mamlok-Naaman, R., Blonder, R., Yayon, M. and Hofstein, A. (2012). High-school chemistry teaching through environmentally oriented curricula. *Chemistry Education Research and Practice*. 13(2), pp. 80–92.

Marston, D., Lau, M., Muyskens, P. and Wilson, J. (2016). Data-Based Decision-Making, the Problem-Solving Model, and Response to Intervention in the Minneapolis Public Schools. In Jimerson, S.R., Burns, M.K. and VanDerHeyden, A.M. ed. *Handbook of Response to Intervention*. US: Springer, pp. 677-692.

Merton, R. (1972) Insiders and outsiders; a chapter in the sociology of knowledge. *American Journal of Sociology.* 78 (1), pp. 9–47.

Mezirow, J. (2009). Transformtive learning theory. In Mezirow, J., Taylor, W. and associates. *Transformative learning in practice: Insights from community, workplace, and higher education*. San Francisco, CA:Josey-Bass.

Mezirow, J. (2000). Learning to think like an adult. In J. Mezirow (Ed.), *Learning as transformation: Critical perspectives on a theory in progress*. San Francisco, CA: Jossey Bass, pp. 3–34.

Mezirow, J. (1996). Transformation theory of adult learning. In M. R.Welton. ed. *In defence of the lifeworld*. New York: SUNY Press, pp. 39–70.

Mezirow, J. (1991). *Transformative dimensions of adult learning*. Jossey-Bass, 350 Sansome Street, San Francisco, CA 94104-1310.

Mezirow, J. (1990). How critical reflection triggers transformative learning. Fostering critical reflection in adulthood. 1, p.20. [Online]. [Accessed 10/10/17]. Available from:http://s3.amazonaws.com/academia.edu.documents/30281715/critical-reflection.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1484429283&Signature=PZ7Ofi3jCBXeU2IZJKauMsuWKxc%3D&response-content-disposition=inline%3B%20filename%3DHow_critical_reflection_triggers_transfo.pdf

Mezirow, J. and Marsick, V. (1978). *Education for perspective transformation: Women's re-entry programs in community colleges.* New York: Center for Adult Education, Teachers College, Columbia University.

Midgley, M. (2013). *Science and poetry*. London and New York: Routledge.

Minner, D.D., Levy, A.J. and Century, J. (2010). Enquiry-based science instruction—what is it and does it matter? Results from a research synthesis years 1984 to 2002. *Journal of research in science teaching*. 47(4), pp.474-496.

Moore, T.J., Glancy, A.W., Tank, K.M., Kersten, J.A., Smith, K.A. and Stohlmann, M.S. (2014). A framework for quality K-12 engineering education: Research and development. *Journal of Pre-College Engineering Education Research (J-PEER)*. *4*(1), p.1-13.

Murphy, C. and Beggs, J. (2005). Coteaching as an approach to enhance science learning and teaching in primary schools. *Counterpoints*. 294, pp.207-231.

Nasereddin, M., Clark, T.K. and Konak, A. (2014). Using virtual machines in a K-12 Outreach program to increase interest in information security fields. In *Integrated STEM Education Conference (ISEC). IEEE* , pp. 1-5.

National Audit Office (NAO) (2010). Educating the next generation of scientists. Department for Education. [Online]. [Accessed 10/10/2014]. Available from:www.nao.org.uk/wpcontent/uploads/2010/11/1011492es.pdf

Neuendorf, K.A. (2002). *The content analysis guidebook*. USA, UK and India:Sage.

Newton, D. P. (1988b). *Making science education relevant*. London: Kogan Page.

Nohl, A.M. (2015). Typical Phases of Transformative Learning: A Practice-Based Model. *Adult Education Quarterly*. 65 (1), pp.35-49.

OECD. (2013). *PISA 2015. Draft Science Framework*. [Online]. [Accessed 10/10/14]. [Available from:http://www.oecd.org/pisa/pisaproducts/Draft%20PISA%202015%20Science%20Framework%20.pdf.

Ofsted (2013) *Going in the right direction?* [Online]. [Accessed 10/10/14]. [Available from:https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/413171/Going_in_the_right_direction.pdf

Ofsted (2013) *Subsidary Guidance: Supporting the Inspection of Maintained Schools and Academies*. Reference no. 110166. London: Ofsted.

Ong, K.K.A., Hart, C.E. and Chen, P.K. (2016). Promoting Higher-Order Thinking Through Teacher Questioning: a Case Study of a Singapore Science Classroom. *New Waves*. 19(1), pp.1.

Osborne, J. (2014). Teaching scientific practices: Meeting the challenge of change. *Journal of Science Teacher Education*. *25*(2), pp.177-196.

Osborne, J. F. and Dillon, J. (2008). *Science Education in Europe: Critical Reflections*. London: Nuffield Foundation.

Osborne, J. F., Simon, S., and Collins, S. (2003). Attitudes towards Science: A Review of the Literature and its Implications. *International Journal of Science Education. 25*(9),pp. 1049–1079.

Pedaste, M., Mäeots, M., Siiman, L.A., De Jong, T., Van Riesen, S.A., Kamp, E.T., Manoli, C.C., Zacharia, Z.C. and Tsourlidaki, E. (2015). Phases of enquiry-based learning: Definitions and the enquiry cycle. *Educational research review*. 14, pp.47-61.

Pedrosa, M.H., Lopes, B. and Watts, D.M. (2013). *Striving against invalidity in qualitative research: Discussing a reflective framework*. [Online]. [Accessed 14/01/16]. Available from:http://bura.brunel.ac.uk/handle/2438/11880.

Phillips, T.M. and Pittman, J.F. (2003). Identity processes in poor adolescents: Exploring the linkages between economic disadvantage and the primary task of adolescence. *Identity: An International Journal of Theory and Research*. *3*(2), pp.115-129.

Piersol, L. (2013). Our hearts leap up: Awakeing wonder within classroom. In Egan, K., Cant, A.I. and Judson, G. eds. *Wonder-full education: The centrality of wonder in teaching and learning across the curriculum*. New York and London: Routledge, p. 3-21.

Piggott, A. (2014). In Your View: What Is a Good Science Teacher?. *Education in Science*.257, pp.14-15.

Pike, A. G., and Dunne, M. (2011). Student reflections on choosing to study science post-16. [Online]. *Cultural Studies of Science Education. 6*, 485–500. Available from: doi:10.1007/s11422-010-9273-7.

Powney, J., and Watts, D.M. (1987). *Interviewing in Educational research*. London: Routledge.

Ramirez, G., and Beilock, S. (2011). Writing about testing worries boosts exam performance in the classroom. *Science*. *331*,pp. 211–213.

Ransome,P. (2010). *Social theory for beginners*. UK:Policy Press.

Reay, D., Crozier, G., and Clayton, J. (2010). ‘‘Fitting in’’ or ‘‘standing out’’: Workingclass students in UK higher education. *British Educational Research Journal*. 36(1), 107–124.

Reay, D. (2004) Education and Cultural capital: The implications of changing trends in education policies. *Cultural Trends*, 13(2), pp. 73-86.

Reid, A. and McCallum, F. (2014). ‘Becoming your best’: student perspectives on community in the pursuit of aspirations. *The Australian Educational Researcher*. *41*(2), pp.195-207.

Ritchie, J., Lewis, J., Nicholls, C.M. and Ormston, R. eds (2014) 2nd Ed. *Qualitative research practice: A guide for social science students and researchers*. LA, London, Delhi, Washington DC.: Sage.

Robnett, R.D., Chemers, M.M. and Zurbriggen, E.L. (2015). Longitudinal associations among undergraduates' research experience, self-efficacy, and identity. *Journal of Research in Science Teaching*. *52*(6), pp.847-867.

Robson, C. (2002) *Real World Research*. 2nd Ed. Oxford: Blackwell.

Rodeiro, C.L.V. (2007). A level subject choice in England: Patterns of uptake and factors affecting subject preferences. Financial Times. [Online] [Accessed 17/07/14]. Available from:http://www. cambridgeassessment. org. uk/ca/digitalAssets/114182 Survey Report-Final. Pdf.

Rodogno, R. (2012). Personal Identity Online. *Philosophy and Technology*. 25(3),pp. 309–328.

Rodrigues, S. (2014). Language and communication in the science classroom. In D.M. Watts.ed. *Debates in Science Education*, London: Routledge.

Roffey-Barentsen, J. and Malthouse, R. (2013). *Reflective practice in education and training*. Learning Matters.

Rooney, P. (2005). Researching from the inside--does it compromise validity?-A discussion. *Articles*, pp.1-19. [Online]. [Accessed 28/01/17]. Available from http://arrow.dit.ie/cgi/viewcontent.cgi?article=1004&context=ltcart&sei-redir=1&referer=http%3A%2F%2Fscholar.google.co.uk%2Fscholar%3Fhl%3Den%26q%3DRooney%252C%2BP.%2B%25282005%2529.%2BResearching%2Bfrom%2Bthe%2Binside--does%2Bit%2Bcompromise%2Bvalidity%253F-A%2Bdiscussion.%2BArticles%252C%2Bpp.5.%26btnG%3D%26as_sdt%3D1%252C5%26as_sdtp%3D#search=%22Rooney%2C%20P.%20%282005%29.%20Researching%20from%20inside--does%20compromise%20validity%3F-A%20discussion.%20Articles%2C%20pp.5.%22

Roth, W.-M. (2007). Emotion at work: A contribution to third-generation cultural historical activity theory. *Mind, Culture and Activity*. 14 (1-2), pp. 40-63.

Roth, W., & Middleton, D. (2006). Knowing what you tell, telling what you know: Uncertainty and asymmetries of meaning in interpreting graphical data. *Cultural Studies of Science Education*. 1 (1), pp.11–81.

Ruthven, K., Mercer, N., Taber, K.S., Guardia, P., Hofmann, R., Ilie, S., Luthman, S. and Riga, F. (2016). A research-informed dialogic-teaching approach to early secondary school mathematics and science: the pedagogical design and field trial of the epiSTEMe intervention*. Research Papers in Education*, pp.1-23.

Sadler, P. M., Sonnert, G., Hazari, Z., and Tai, R. (2012). Stability and volatility of STEM career interest in high school: A gender study. *Science Education*. 96(3), pp.411-427.

Salehjee, S. and Watts, D.M. (2015). Science lives: school choices and 'natural tendencies'. *International Journal of Science Education*. 37(4), pp. 727-743.

Savery (2015) Overview of Problem based learning: definitions and distinctions. In Ertmer, P.A., 2015. *Essential Readings in Problem-based Learning*. Purdue: Purdue University Press.

Schank, R. C. (1990). *Tell me a story. Narrative intelligence*. Evanston, IL: North-western University Press.

Schensul, J.J. (2009). Community, culture and sustainability in multilevel dynamic systems intervention science. *American journal of community psychology*.*43*(3-4), pp.241-256.

Schütte, K. and Köller, O. (2015). 'Discover, Understand, Implement, and Transfer': Effectiveness of an intervention programme to motivate students for science. *International Journal of Science Education.* 37(14), pp. 2306-2325.

Seginer, R. (2006). Parents' educational involvement: A developmental ecological perspective. *Parenting: Science and Practice*.6 (1), pp.1–48.

Selvaruby, P. S., O'Sullivan, B., and Watts, D. M. (2008). School-based assessment in Sri Lanka: Ensuring valid processes for assessment-for-learning in physics. In R. K. Coll and N. Taylor.eds. *Education in context: An international perspective of the influence of context on science curriculum development, implementation and the student-experienced curriculum*. London: Sage, pp. 142–151.

Shapiro, E.S. (2016). Evaluating the Impact of Response to Intervention in Reading at the Elementary Level Across the State of Pennsylvania. In Jimerson, S.R., Burns, M.K. and VanDerHeyden, A.M. ed. *Handbook of Response to Intervention*. Springer US ,pp. 661-675.

Sheldrake, R. (2016). Students' intentions towards studying science at upper-secondary school: the differential effects of under-confidence and over-confidence. *International Journal of Science Education*. 38(8), pp.1256-1277.

Shelton, A. (2016). Meaningful Science: A Look at Elementary Science Education Practices. [Online] [Accessed 31/01/17]. Available from: http://commons.emich.edu/cgi/viewcontent.cgi?article=1488&context=honors

Shinn, M.R., Windram, H.S. and Bollman, K.A. (2016). Implementing Response to Intervention in Secondary Schools. In Jimerson, S.R., Burns, M.K. and VanDerHeyden, A.M. ed. *Handbook of Response to Intervention*. Springer US, pp.563-586.

Silverman, D. (2010). *Doing qualitative research*. 3rd Ed. London, England: SAGE.

Sjøberg, S. and Schreiner, C. (2010). T*he ROSE project: An overview and key findings*. Oslo: University of Oslo, pp.1-31. [Online] [Accessed 22/01/16]. Available from: http://www.cemf.ca/%5C/PDFs/SjobergSchreinerOverview2010.pdf

Spector-Mersel, G. (2010). Narrative research: Time for a paradigm. *Narrative Enquiry*. 20(1), pp. 204–224.

Spillane, M. (2000). *Branding yourself: How to look, sound and behave your way to success*. Pan: London: Sidgwick & Jackson.

Stuckey, M., Hofstein, A., Mamlok-Naaman, R. and Eilks, I. (2013). The meaning of 'relevance' in science education and its implications for the science curriculum. *Studies in Science Education*. 49(1), pp. 1-34.

Sullivan, A. (2002). Bourdieu and Education: How Useful is Bourdieu's Theory for Researchers? *The Netherlands Journal of Social Sciences*. 38(2), pp.144- 166.

Surmeli, H. (2012). Examination the effect of science fiction films on science education students' attitudes towards STS course. *Procedia-Social and Behavioral Sciences*. 47, pp.1012-1016.

Tai, R. H., Qi Liu, C., Maltese, A. V., and Fan, X. (2006). Planning early for careers in science. *Science*. 5777(312), pp.1143–1145. Available from: doi: 10.1126/science.1128690.

Tal, T. (2012). Out-of-school: learning experiences, teaching and students' learning. In Fraser, B., K. Tobin,K. and McRobbie, C. eds. *Second international handbook of science education*. Springer Netherlands, pp. 1109-1122.

Tao, V.Y., 2016. Understanding Chinese Students' Achievement Patterns: Perspectives from Social-Oriented Achievement Motivation. In *The Psychology of Asian Learners.* Springer Singapore, (pp. 621-634).

Taylor, C. (2009) *A Good School for Every Child: How to Improve Our Schools*. UK: Routledge. [Online]. [Accessed 10/09/16]. Available from:http://books.google.com/books?id=6ZWRgVl454MC&pg=PA73&dq=science+spec

ialist+teachers&hl=en&ei=rYtSTOCTDIfb4Ab5jN3_Ag&sa=X&oi=book_result&ct=result&resnum=5&ved=0CEMQ6AEwBA#v=onepage&q=walter&f=false

The Fibonacci Project (2012). *Integrating science enquiry across the curriculum*. [Online]. [Accessed 08/08/2016}. Available from:http://www.fondation-lamap.org/sites/default/files/upload/media/4%20-%20integrating_science_enquiry_across_the_curriculum.pdf

The Office for Standards in Education, Children's Services and Skills (Ofsted) (2013). *Maintaining curiosity: science education schools*. [Online]. [Accessed 15/10/15]. Available from:https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/379164/Maintaining_20curiosity_20a_20survey_20into_20science_20education_20in_20schools.pdf

Tissenbaum, M., Lui, M. and Slotta, J.D. (2012). Co-Designing Collaborative Smart Classroom Curriculum for Secondary School Science. *J. UCS.18*(3),pp.327-352.

Topping, K.J., Thurston, A., Tolmie, A., Christie, D., Murray, P. and Karagiannidou, E. (2011). Cooperative learning in science: intervention in the secondary school. *Research in Science & Technological Education.* 29(1), pp. 91-106.

UK Commission for Employment Skills (UKCES) (2013). *The Supply of and demand for high-level STEM skills, Evidence report 77*. Sanctuary Buildings, Great Smith St. Westminster London, November 2013. [Online] [Accessed 31/10/15]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/302973/evidence-report-77-high-level-stem-skills_1_.pdf

vanVondel, S., Steenbeek, H., van Dijk, M. and van Geert, P. (2016). "Looking at" Educational Interventions: Surplus Value of a Complex Dynamic Systems Approach to Study the Effectiveness of a Science and Technology Educational Intervention. In *Complex Dynamical Systems in Education*. Springer International Publishing, pp. 203-232.

Vaquez, *J.* A. (2012). Visual Literacy, the Must-Have Skill for the 21st-Century Learner. *Science and Children.* 50(3), pp.8.

Wang, M.T., Eccles, J.S. and Kenny, S. (2013). Not lack of ability but more choice individual and gender differences in choice of careers in science, technology, engineering, and mathematics. *Psychological Science*. 24(5), pp.770-775.

Winterbotham, M. (2014). *UK Commission's Employer Skills Survey 2013: UK results, January 2014*. [Online]. [Accesed 21/10/2017]. Available from: http://dera.ioe.ac.uk/19271/1/evidence-report-81-ukces-employer-skills-survey-13-full-report.pdf

Walker, J. A. (1996). Learning to be interpretive Hermeneutics and personal texts. *Marriage and Family Review*. 24(3-4), pp. 223-239.

Williams, M. (2012). *Science and social science: An introduction*. London and New York: Routledge.

Wong, B. (2015). Minority ethnic students and science participation: A qualitative mapping of achievement, aspiration, interest and capital. *Research in Science Education*, *46*(1), pp.113-127.

Wood, R. and Ashfield, J. (2008). The use of the interactive whiteboard for creative teaching and learning in literacy and mathematics: a case study. *British journal of educational technology*, *39*(1), pp.84-96.

Watts, M. (2015). Public understanding of plant biology: Voices from the bottom of the garden. *International Journal of Science Education, Part B*. 5(4), pp.339-356.

Watts, M. (1991). *The science of problem solving: A practical guide for science teachers*. London: Heinemann.

Welton, M. R. (1995). *In defence of the lifeworld, critical perspectives on adult learning*. Albany, NY:SUNY Press.

Xin, Y.P., Chen, V. and Kastberg, S.E. (2016). Conceptual Model-based Problem Solving: A Response to Intervention Program in Mathematics Problem Solving (COMPS-RtI). [Online] [Accessed 31/12/16]. Available from: http://docs.lib.purdue.edu/p12nsummit/posters/2016/14/

Yeager, D.S. and Walton, G.M. (2011). Social-psychological interventions in education They’re not magic. *Review of educational Research*. 81(2), pp.267-301.

Yu, K.C., Fan S.C., Tsai, F.H., Chu, Y.H. (2013) Using scientific detective videos to support the design of technology learning activities. *International Journal of Technology and Design Education*. 23 (4), pp. 883–901.

Zald, M. N. (1996). More fragmentation? Unfinished business in linking the social sciences and the humanities. Administrative Science Quarterly. 41, 251–261.

APPENDICES

Appendix 1: Sample consent form - Phase One (scientists and non-scientists)

Brunel UNIVERSITY LONDON

CONSENT FORM

Please tick the appropriate column

	Yes	No
Have you read the Research Participant Information Sheet?	✓	
Have you had an opportunity to ask questions and discuss this study?	✓	
Have you received satisfactory answers to all your questions?	✓	
Do you understand that you will not be referred to by name in any report concerning the study?	✓	
Do you understand that you are free to withdraw from the study: •at any time? •without having to give a reason for withdrawing?	✓	
The research will have no impact on any qualifications.	✓	
I agree to my interview being recorded.	✓	
I agree to the use of non-attributable direct quotes when the study is written up or published.	✓	
Do you agree to take part in this study?	✓	
Do you wish to be informed about the research project result in the form of a brief summary report?	✓	
Signature of Research Participant:	AGreen	
Date:	28/02/2014	
Name in capitals:	A. J. GREEN	
Witness- I am satisfied that the above-named has given informed consent.		
Date:		
Name in capitals:		
Researcher name:	Signature:	
Supervisor name:	Signature:	

Issue date: 06 December 2012 Revised 08 November 2013

1
©Brunel University

Appendix 2: Sample consent form - Phase Three (Secondary school girls)

Brunel
UNIVERSITY
LONDON

CONSENT FORM

Please tick the appropriate column

	Yes	No
Have you read the Research Participant Information Sheet attached below?	✓	
Have you had an opportunity to ask questions and discuss this study?	✓	
Have you received satisfactory answers to all your questions?	✓	
Who have you spoken to?	Saima	Salehjee
Do you understand the name of students and school will not be referred to by name in any report concerning the study?	✓	
Do you understand that school is free to withdraw from the study: **•at any time?** **•without having to give a reason for withdrawing?**	✓	
The research will have no impact on students' qualification.	✓	
I agree to my intervention/ interview being recorded. tape recorder	✓	
I agree to the use of non-attributable direct quotes when the study is written up or published.	✓	
Do you agree to take part in this study?	✓	
Do you wish to be informed about the research project result in the form of a brief summary report?	✓	
Signature of Research Participant:	F.R. Liyawdeen	
Date:	16 . 10 . 14	
Name in capitals:	FATHUMA RIZNIHA LIVAWDEEN	
Witness statement		
I am satisfied that the above-named has given informed consent. SAIMA	S. FATIMA.	
Date:	22/10/14.	
Name in capitals:	SAIMA SALEHJEE	
Researcher name: SAIMA SALEHJEE	**Signature:**	
Supervisor name: MIKE WATTS.	**Signature:**	

Issue date: 06 December 2012 Revised 08 November 2013 1

Appendix 3: Sample participant information sheet from Phase One (scientists and non-scientists) and Phase Three (Secondary school girls)

Version 14.1

Brunel UNIVERSITY LONDON

PARTICIPANT INFORMATION SHEET

Transforming negative attitudes of KS4-KS5 students towards school science: leading to lifelong science learning.

You are invited to take part in a PhD research project conducted by Saima Salehjee, under the supervision of Professor Mike Watts and Dr. Rob Toplis at Brunel University Education department. The aim of the study is to find out the negative and positive attitude of students and professionals towards School, College and University science. The questions will be based on real life stories that triggered the participants to pursue or decline science education in KS5 and beyond.

You have been invited to participate as this project deals with Sixth form/College/University students and teachers. To proceed with the research project you are not required to prepare anything. There is no right or wrong answers; it will truly reflect your opinions.

It is not compulsory to take part in the project. The participant wishes to take part can leave the project at any time and at any stage of the research project. The 40 minutes interview will be recorded on a tape recorder and will be kept anonymous and confidential. To ensure confidentiality the research study is compliant with the Data Protection Act 1998. Therefore the researcher will not in any case expose the name and gender of the participant and name of institution to anyone except the researcher's supervisors. Moreover the tape recorded interview will also be kept confidential.

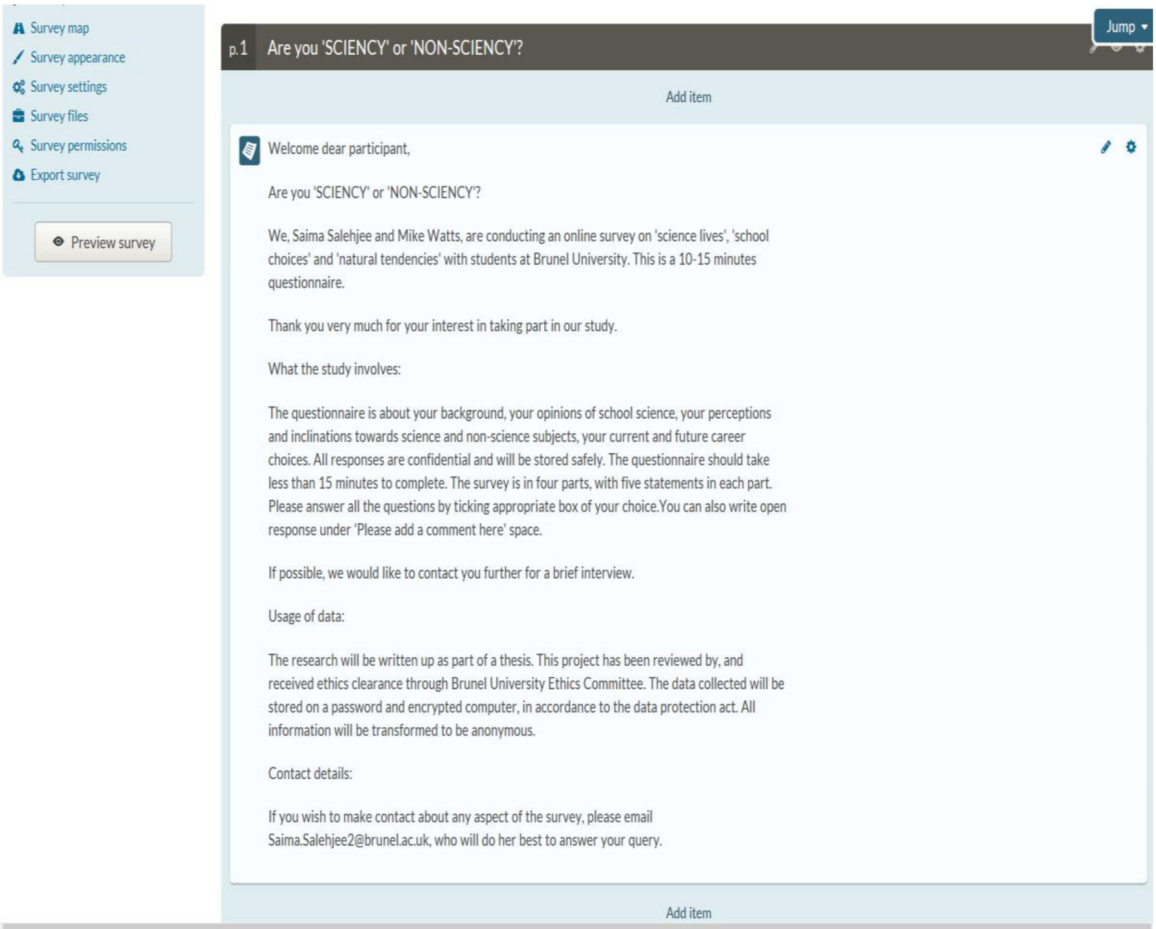
The participants will be informed with the results of the study if they wish. The findings of the research can be published as a research paper, newspaper article, chapter in a book, as a material for specialised internet site for science education. The findings can be useful to college students, teachers, head of sciences and Ofsted to improve the teaching and learning experiences of KS4 and KS5 students.

Please do not hesitate to contact for further information at the below addresses

Saima Salehjee (PhD student) edpgsqs@brunel.ac.uk

Mike Watts (Supervisor) Mike.Watts@brunel.ac.uk

Appendix 4: Sample participant information sheet and an invite for a follow-up interview - Phase Two (university students)



Survey map
Survey appearance
Survey settings
Survey files
Survey permissions
Export survey
Preview survey

Jump

p.1 Are you 'SCIENCY' or 'NON-SCIENCY'?

Add item

Welcome dear participant,

Are you 'SCIENCY' or 'NON-SCIENCY'?

We, Saima Salehjee and Mike Watts, are conducting an online survey on 'science lives', 'school choices' and 'natural tendencies' with students at Brunel University. This is a 10-15 minutes questionnaire.

Thank you very much for your interest in taking part in our study.

What the study involves:

The questionnaire is about your background, your opinions of school science, your perceptions and inclinations towards science and non-science subjects, your current and future career choices. All responses are confidential and will be stored safely. The questionnaire should take less than 15 minutes to complete. The survey is in four parts, with five statements in each part. Please answer all the questions by ticking appropriate box of your choice.You can also write open response under 'Please add a comment here' space.

If possible, we would like to contact you further for a brief interview.

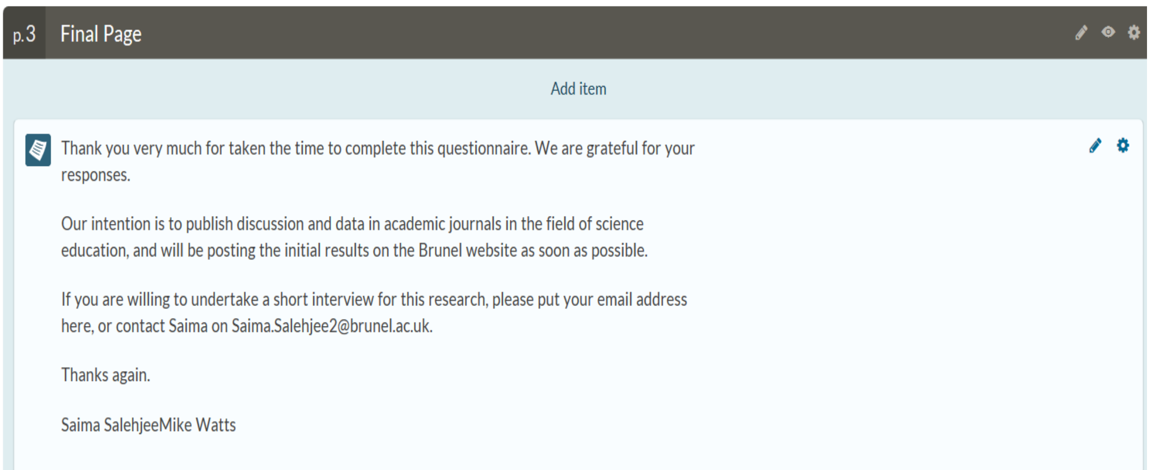
Usage of data:

The research will be written up as part of a thesis. This project has been reviewed by, and received ethics clearance through Brunel University Ethics Committee. The data collected will be stored on a password and encrypted computer, in accordance to the data protection act. All information will be transformed to be anonymous.

Contact details:

If you wish to make contact about any aspect of the survey, please email Saima.Salehjee2@brunel.ac.uk, who will do her best to answer your query.

Add item



p.3 Final Page

Add item

Thank you very much for taken the time to complete this questionnaire. We are grateful for your responses.

Our intention is to publish discussion and data in academic journals in the field of science education, and will be posting the initial results on the Brunel website as soon as possible.

If you are willing to undertake a short interview for this research, please put your email address here, or contact Saima on Saima.Salehjee2@brunel.ac.uk.

Thanks again.

Saima SalehjeeMike Watts

Appendix 5: Dennis interview transcript

First, some biographical details

SC1- Dennis

1. What is your job title?

SC1: I am senior lecturer at electronic and computer engineering.

2. What are your main qualifications?

SC1: My undergrad is in Masters in Physics from University of Kent and then I did a PhD in university of leister. If you go that far in A-levels I did Physics, Biology, Geography and French.

3. For how many years have you been working in your subject field?

SC1: So it will be 10 years since I came to Brunel

4. When did you start teaching?

SC1: About 6 years ago. So when I first came here I was a research student and then I got a lectureship in 2006, so it's since 7-8 years

Second, questions about starting out.

5. At what stage(s) of life did you ask yourself 'Am I able (or not able) to do science?'

SC1: I am not sure I have ever asked that. **The typical male response is that I always thought that I could do whatever I want to do there was nothing particularly implied that I couldn't**. It was always something that I am interested in and there wasn't anything stopping me from taking that path.

6. What were your reasons at 16 for wanting to take up science (or not) at A-level?

SC1: Probably a few reasons I wanted to do Physics rather than Biology. I did Biology as well but Chemistry was too hard. I didn't particularly like that element. But Physics and sciencey things I have always being interested in space flights and astronomy and that sort of thing and that was sort of a gateway to doing that. And the other reason of doing it is that I always seem to do quite well at science with perhaps not as much effort as some people needed so it was something that **I was seemingly naturally quite good at** and also it was quite interesting or could become quite interesting which is why I persuaded through to University as well.

7. Did you make up your mind about studying science fast or slow: Was there a particular 'trigger moment' that decided your 'science future' one way or the other?

SC1 In terms of the school I was at a Grammar school and I was in the top group for the Physics that I was doing at A-levels. But I don't know as whether I was taught at a faster than the other set but the reasons for doing Physics was partly because I could do it and found it interesting are the first two reasons but also the Physics teacher I had she was the same teacher I had already for GCSE Physics and she also taught at A-levels so it was four years with the same teacher who was really good and also she was my form tutor. So she was a very important person in being a continuous link through the whole process. Whereas other subjects like Maths I did do and Chemistry as well. There was a different person in different years. And if you don't get on with one them there is, perhaps a hindrance to pursuing that path but she was always great as a teacher.

In terms of science interest space flights, rockets and astronomy was always my thing and if you ask my mum, I don't remember it myself but she always talk about when, **Haley's comet 1986 and me being obsessed** with collecting articles from newspaper and stuff about that so whether **that was a hinge point** and I have always read comic books and science fiction and all that sort of thing that has geared me down that science path.

8a. How influential were teachers in your decision making

SC1: Yeah so two comments about that one the Physics teacher was great and I knew her four years in my time at that school and she was a consistent person and she was really good at teaching of what she was telling us and the converse effect is the Maths that I did, so every year of those four years I had a different maths teacher for different modules because it was a modular A-level and a different person for GCSE. And I was never that great in Maths element and the influence is sort of the other way around from the Maths teacher that I was told several times that you will not do very well in Maths and they had a problem with me messing about and not particularly be great in Maths. So it was constantly being told off and told that I am not going to get anywhere. From that **particular teacher at A-level Maths** and I always said that was the moment that speared me on so I had one teacher who was great in Physics and I really enjoyed that and I had another teacher that I didn't like at all**, I didn't get along with but then made me annoyed at me, made me do better- just to rub their nose and prove the point.** So works both ways.

How influential were peers in your decision-making?

SC1: I suppose they were little bit. The school I was at had a Sixth form at the same school. So there was an element of knowing who is going to stay in school A-levels and who is going to a different school. And I wanted to be around still with certain people so some of my friends left but majority of the close friends during GCSEs stayed. I think all of us were doing Maths and Biology and about quarter of them were doing Geography and then about half of my friends were doing Physics so there were certainly my close friends who were doing similar subjects to me and helping me keeping interested.

9a. In few words, how did school science or awareness of science in daily life affect your interest?

SC1 Again so like I don't suppose I have read that many newspapers at that time and there was not any internet. But certainly at TV, TV programmes **like Horizon and things to do with space with the news were always that I was quite interested in, I wanted to find more about, so I used to get astronomy books for Christmas and things like to keep me interested**. So I was aware of these science things outside but was really not really until sixth form when I found out that I am quite good at it so I want to look at what universities sort of doing in this area. Start looking at University prospectuses to figure out what you can do. Because I didn't knew what I can do with an interest in astronomy and space. So I think was aware of some things on the news in the media about space and it was always quite interesting.

Third, staying in (or out) of science.

9b. What are the main factors that have kept your interest alive in science (or in your chosen field)?

SC1: Ahhhh just Shear, Sheven and Dever and things like that I was always been launching rockets involving so many people from so many countries and locations. Having done a PhD in space and commendation and subsequently worked with people from so many different countries to make stuff. I have worked on the project that worked on a project that worked in the moon and built things that designed to work in space and that sort of thing was very interesting. The fact that there is a space sector to work in where and when you can find research to find something in that area is good. It’s a big push in UK for with the UK space agency with the last few years. And our first British astronaut and that sort kept me in that area. But I am thinking in parallel to that there is the reason I became an academics so teaching as well as the research side is that I always felt that I want to make other people enthused about these things. So it was about telling other people what’s out there and trying to get them interested.

10. What is it you most like about your chosen field at the moment?

Sc1: I like enthusing students and I like it when they want to talk to you about what you do and find out more about the stuff that you are teaching them. And try and inspire them. There is nothing better than student writing and telling you that your lecture was very fun and can you tell me more about so and so. And then also just being involved with publishing research and doing laboratory work and computer work that ends up going in science papers and being read by hopefully by lots of people, its good you felt that you are contributing to things on an international scale and hopefully doing things that are useful to other people in the future.

11. What kinds of occurrences in life might make you change completely (into or completely away from science)?

Sc1: I don’t know if anything can happen that can completely move away. Having my entire education and everything else is conditioned me to think in that way. So there might be issues like there is no more fundings for science there are things that could have happen. But I don’t think it would ever stop me thinking that way and wanted to be involved with science and understanding that how things behave and how to make things for different science applications.

12. To what extent does your knowledge (or ignorance) of science impact on your everyday life?

Sc1: My scientific background has certainly impact on everyday life because you are always looking into things with that precision. So trying to do things in most sufficient way I can. Evaluating things in quite a lot detail before I buy anything. Yeah that way of thinking is applied to everything else that I work outside work that I do as well.

Appendix 6: Philip interview transcript

NC5: Philip

First, some biographical details

1. What is your job title?

NSc5: Professor of Music, head of music research.

2. What are your main qualifications?

NSc5: PhD in composing.

3. For how many years have you been working in your subject field?

NSc5: 40 years

4. When did you start teaching?

NS5: 40 years.

Second, questions about starting out.

5. At what stage(s) of life did you ask yourself 'Am I able (or not able) to do science?'

NS5: (Laugh) Ahmm I was just it was just assumed to do science I did science, so the question is not able or not able it was more of just continuous nervousness. So I did science O-level A-level and we had career talks from the age of 13 or 14 so at that time I was not confident about science but to the extent I opted for science subjects I failed them.

It is a very interesting story because I started A-levels doing Physics, Maths and Chemistry and I had no formal training for Music a part from piano lessons and I just, Music was just pushing me its way out, so I spent every free period in the ground playing a piano because it was such a beautiful piano and at the end of A-levels we had mock exams end of first year. And I failed I was not finding any of them easy Maths Chemistry Physics. But I failed Chemistry and the deputy principal came and said

What is it Weigold to much music? And

I said Yes and

He said right you can do music this year. **Brilliant he saved my life** (Laugh)

And then I did music A-level in a year I failed Physics and **unbelievably, I got a B in maths and B in music, even after studying only one year of Music.** So I **escaped the sciences** in the last moment. Except that I did Maths for first year of University as well.

8. How influential were parents in your decision making

NSC5: Quite influential not to the extent you must do this but definitely a sense to my father that you will get a better job that way and strangely my mother who is very artistic and always say do what you like but I think about it strange lack of pressure from my mother to follow what she knew was my talent which was music. That's quite interesting I'll ask her this Sunday Why didn't you pressure me more. (Laugh).

How influential were peers in your decision-making?

NSC5: (From above) When we had everyone in Music in second year senior school and at one time I was getting 9/10 10/10 in the every test and everyone else was getting 2 or 3 and then the choice came up do I do Music or Sport. I chose sport and so a lot of it is social pressure as well as much as intellectual clarity isn't, there was kind of trend in my school to do sport nobody did Music and I wanted to be with trendy people probably so I did Sport, whereas again I would have thought hang on I got 10/10 in Music why don't I do Music so there was a slow pressure to both internally and from home and the staff and the peer group from the other students towards certain subjects that were more cool or more.

9. In few words, how did school science or awareness of science in daily life affect your interest?

NSC5: **We had a very frightening Physics teacher, there were days where we could throw things at you, so he throw chalk if he see someone talking he throw chalk from 20 yards and hit you here (pointed mid forehead)** so actually he was really frightening and so I think some of the question is that the teachers were frightening and you know and **certainly made the whole situation more tense and**

more anxious about what was perceived to be difficult thing you know he would be angry if you do something wrong and it was not a question of talent here and nurturing it. It was quite an old fashioned environment.

Third, staying in (or out) of science.

9. What are the main factors that have kept your interest alive in science (or in your chosen field)?

NSC5: I think there is kind of overlapping that how I am very interested in culture and how things work so I did a talk the other day about how music changed around the beginning of last century when it moved to a modern world and exact parallels between that and reactivity by Einstein and Quantum Physics and equally there is a very interesting comparison between Newton and the piano embark and that whole clockwork Universe time So science in 18th century science in 19th century and contemporary science as a whole is interesting. I did a talk the other night in the science museum with a nuclear Physicist, literary critic and a psychologist all talking about order and disorder in science music and psychology and I am very interested in what Quantum Physics order and disorder. So I have a kind of general interest particularly as representing culture because it is extra-ordinary that Einstein reactivity or Darwin theory bit earlier or sometime parallel to society changes when structure and society become relativeness so in that case very very interested in science and then just totally absorbed in Music. I do find other theories like string theory and other that I understand certainly relativity. Some of it is fascinating if it's a science article about how cars go faster and what gravity is its very interesting but especially interested in its relation to its (tales?) and to cultural things. I am also a Buddhist and a lot of Buddhism is to say it's quite scientific like how energy moves how energy transfers so there are so many things in it that links to science and nature.

10. What is it you most like about your chosen field at the moment?

NS5: (Pause 2sec.) What I most like is stand up on the stage and play it and the other thing is that I like all my life is around my own work it's about who I am and expressing that so that's very fortunate.

11. What kinds of occurrences in life might make you change completely (into or completely away from science)?

NSC5: Its not very really likely. I might do a project with scientists and so give a half answer so completely absorbed in scientific idea for 6 months so it a collaboration with my artistic things so I could get very involved in understanding and even doing experiments. So I think it is unlikely that I will go back to that physics teacher throwing things on me. (Laugh)

Will do a research work in science? To me (this would be shocking) to me this could be simpler to what I do

12. To what extent does your knowledge (or ignorance) of science impact on your everyday life?

NSC5: Marginally, so if I don't understand software then that's not like understanding something sciences like. Maths logic. So it doesn't really effect as someone repairs my car and someone else designs my software but I come up with things against like understanding software or somebody do my plumbing. So marginally is the answer.

13. What are your impressions of the positive (and negative) features of the school curriculum (teaching/ learning/ assessment)?

NSC5: I will give next week a talk about my ideas about pedagogy and I talk about my own work and after talk about it. So in a slide I would say that the answer to most questions is, **I usually put up a picture of Einstein (he is wondering) and the answer is BOTH.** So one of the stupidest argument is should English be taught through grammar or creativity and I think Both so it would seem to be the same with science particular with Michael go and this kind of stupid and hippi in 1960s now we have to a kind of Victorian notion of learning facts**. I think there is a third way and it must apply to science as well as the arts where you learn both facts and imagination research exploration that would be my comment on current education**. My perception is NO its driven by that reductive number crunching and league tables and it teaches its strange notion of learning information rather than intelligence.

Appendix 7: Helen's questionnaire

bos

Are you SCIENCY or NON-SCIENCY2

Response ID	Completion date
4543-4541-393688	25 Sep 2014, 14:07 (BST)

Demographic details

1	Which Brunel College / research institute do you attend?	Health and Life Sciences
1.a	If you selected Other, please specify:	

2	What is your student status?	PhD full time science student
2.a	If you selected Other, please specify:	

3	Which academic year of study you are in?	1

4	Did you study one or more science subjects at A-levels (College/Sixth form)?	Yes
4.a	Please indicate major science or non-subjects at A-levels (College/Sixth form)	Psychology, Mathematics
4.b	Please add a comment here	

5	Please indicate your gender	Female

Part1: My perception

6	I always had natural inclination towards science	Strongly disagree

6.a	Please add a comment here	-I always thought science was 'too difficult for me'. In school I found it hard to relate to chemistry or understand Physics. I still can't get my head round the big bang? However, I wish they hadn't used the overarching term 'science' to describe biology, chemistry and physics (they are very different subjects!) I had the view 'I'm not good at Science' but realised when I did a Bsc and biology modules on the brain I was both interested and good at this as well as conducting scientific work for my degree and Phd.

7	I always had natural inclination towards arts and humanities	Strongly agree
7.a	Please add a comment here	I've always loved to write and read and never been 'scared' or put off by these subjects.

8	My decision towards choosing/declining science subjects at A-levels (College or Sixth form) is mainly influenced by my parents and peers	Strongly disagree
8.a	Please add a comment here	

9	My decision for opting or declining science subjects at University level is mainly influenced by my parents and peers	Strongly disagree
9.a	Please add a comment here	

10	I am happy with the choice of subjects I have made at Brunel	Strongly agree
10.a	Please add a comment here	

Part 2: School science

11	I think science should be compulsory to all students till A-levels	Disagree
11.a	Please add a comment here	No. People are interested in other things as well. However some of the principles used in science should be taught e.g. how to think logically, how to research on the internet, critical appraisal of sources etc.

12	The things that I learnt in science at school is helpful in my everyday life	Strongly disagree

12.a	Please add a comment here	Only after school did I realise science is for everyone! and it's not as 'difficult' or impossible as I thought in school. I'm reading Bill Bryson's short history of everything and great stuff in there on the big bang etc.

13	My decision for opting or declining science subjects is mainly influenced by my science teacher(s)	Strongly agree
13.a	Please add a comment here	My Psychology teacher encouraged me strongly that I was good at this subject and should pursue it at University. At the same time my teachers for Biology and Chemistry put me off... those subjects 'were not for me'.

14	My decision for opting or declining non-science subjects is mainly influenced by my non-science teacher(s)	Strongly agree
14.a	Please add a comment here	Hmmm this is a two-fold question! I opted for non-science subjects for A-Level and yes that was because of my 'non-science' teachers. At University I went for Psychology because this was my interest, my 'non-science' teachers taught me how to write and I took this into my degree.

15	I think school science curriculum has influenced my interest into sciences	Strongly disagree
15.a	Please add a comment here	If we are talking about 'science' as in physics, chemistry and biology... dusty textbooks, confusing symbols and a lack of 'real-worldness' Psychology curriculum- loved it and definitely influenced my interest in people and the biology/neuroscience of the brain

Part 3: Career opportunities

16	I think doing a degree in science unlocks the opportunities into diverse and exciting jobs	Strongly agree

16.a	Please add a comment here	-YES! but you don't realise this in school! It's one of those subjects you either feel included or excluded in. You can or can't do it. Rather than seeing yourself on a line of continuum.

17	I think doing a degree in arts and humanities unlocks the opportunities into diverse and exciting jobs	Strongly agree
17.a	Please add a comment here	All degrees do!

18	I think doing a degree in science leads to becoming a scientist	Disagree
18.a	Please add a comment here	

19	After my graduation I would like to work in the current field of study	Disagree
19.a	Please add a comment here	After my PhD I'd like to go into the Civil Service as a researcher

20	I think one can gain more employability skills (like communication, team working, self-reliance and generalist skill etc) through studying sciences rather than arts subjects	Agree
20.a	Please add a comment here	A little. There is more opportunities if you do a BSc as you can go into research, engineering, design, physics etc. And a lot of business careers like the 'scientific' way of thinking.

Appendix 8: Saira’s pre-intervention questionnaire

Edit this page

Are you 'SCIENCY' or 'NON-SCIENCY'?

Section 1: Biographical details

1. My secret number is

Saadiya

2. I am in year 7

(select all that apply)

☐ yr9 ☐ yr10

☐ Other *(please specify)*:

Yr 7

3. I am 12 years old

○ 13 ○ 14 ○ 15 ○ 16

○ Other *(please specify)*:

Section 2: School science

4. The things that I learnt in science at school is helpful in my everyday life

(select all that apply)

☐ Strongly agree ☑ Agree ☐ Disagree ☐ Strongly disagree

Please add a comment here *(Optional)*

I just agree.

5. In A-levels I would like to take up more science subjects rather than non-science subjects because of positive influence from my science teacher(s)

(select all that apply)

☑ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

Please add a comment here *(Optional)*

6. In A-levels I would like to take up more non-science subjects rather than science subjects because of positive influence from my non-science teachers

https://www.survey.bris.ac.uk/?manifestid=200116&op=preview 14/10/2014

(select all that apply)

☐ Strongly agree ☑ Agree ☐ Disagree ☐ Strongly disagree

Please add a comment here *(Optional)*

7. The things that I learnt in science at school is helpful in my practical/everyday life

(select all that apply)

☐ Strongly agree ☑ Agree ☐ Disagree ☐ Strongly disagree ☐

Please add a comment here *(Optional)*

Agree

Section 3: Career opportunities

8. I think doing a degree in science unlocks the opportunities into diverse and exciting jobs

(select all that apply)

☑ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

Please add a comment here *(Optional)*

9. I think doing a degree in arts and humanities unlocks the opportunities into diverse and exciting jobs

(select all that apply)

☑ Strongly agree ☐ Agree ☑ Disagree ☐ Strongly disagree

Please add a comment here *(Optional)*

10. I think doing a degree in science leads to becoming a scientist

(select all that apply)

☑ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

Please add a comment here *(Optional)*

Appendix 9: Saira's evaluation questionnaire- Sci-Fiction

SCIENCE FICTION

1. My name is sadiya haidar

2. I am in year 7

3. I am 12 years old

4. I enjoyed science fiction related lessons

- ☑ Strongly agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly disagree

5. What did you like about science fiction linked lessons? Please add a comment here

it's very interesting

6. What you didn't like about science fiction linked lessons? Please add a comment here

Nothing

7. The science fiction lessons made me feel good about science

- ☐ Strongly agree
- ☑ Agree
- ☐ Disagree
- ☐ Strongly disagree

8. Why science fiction lessons made you feel good or bad about science? Please add a comment here

Because I love sience

9. Because of the science fiction related science lessons I will now think differently about my choice of A-level subjects

- ☐ Strongly agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly disagree

10. What changes you have noticed about your choice in A-level subjects? Please add a comment here

english teacher / siencetics / chemist (but not in Pharmacy) geoligist / peadtric

11. The things that I learnt in science at school are helpful in my everyday/ practical life.

- ☐ Strongly agree
- ☑ Agree
- ☐ Disagree
- ☐ Strongly disagree

Please add a comment here

1

Appendix 10: Saira's sections of post sixth and twelfth month questionnaire

1. I am in year 8 2. I am 12 years old

3. Would you like to study one or more science subjects at A-levels (college or sixth form)?

(Yes) No

a) What major subjects you would like to study at A-levels (college or sixth form)?

1. Chemistry
2. biology
3. physics
4. space

4. I always had natural inclination towards science

- ☑ Strongly agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly disagree

Please add a comment here_______________

5. I always had natural inclination towards arts and humanities

- ☐ Strongly agree
- ☐ Agree
- ☐ Disagree
- ☑ Strongly disagree

Please add a comment here_______________

6. My decision towards (choosing)/declining science subjects at A-levels (college or sixth form) and beyond is mainly influenced by my parents and peers

- ☑ Strongly agree
- ☐ Agree
- ☑ Disagree
- ☐ Strongly disagree

Please add a comment here_______________

7. I think school science curriculum has influenced my interest into sciences

- ☐ Strongly agree
- ☐ Agree
- ☑ Disagree
- ☐ Strongly disagree

Please add a comment here I've always liked mixing chemicals

Are you 'SCIENCY' or 'NON-SCIENCY'?

15. I think doing a degree in science leads to becoming a scientist

- ☑ Strongly agree
- ☐ Agree
- ☐ Disagree
- ☐ Strongly disagree

Please add a comment here I want to become a sciencetest

16. I think one can gain more employability skills (like communication, team working, self-reliance and generalist skill etc) through studying sciences rather than arts subjects

- ☐ Strongly agree
- ☑ Agree
- ☐ Disagree
- ☐ Strongly disagree

Please add a comment here_______________

Finish

Powered by BOS

| Copyright

4

Appendix 11: Saira's interview transcript

1. At what stage(s) of life did you ask yourself 'Am I able (or not able) to do science?'

There wasn't really a stage in my life that I would choose if I ~~want to~~ would be able or not because all I know is that I'm willing to do science for my GCSE, A-Levels and finaly to be a pharmicust / scientist

2. What are your reasons at 16 for wanting to take up science (or not) at A-level?

When I'm 16 I would want to do A-Level for science because science is my favourite subject I'm intrested in it and I enjoy learning what i'm really intrested in is Chemistry, Physics.

3. Did you make up your mind about studying science fast or slow: Was there a particular 'trigger moment' that decided your 'science future' one way or the other?

I used to hate science but when I started learning about Chemistry I really enjoyed mixing chemicals together and I love watching chemical reactions its just so amaizing.

4. What are the main factors that have kept your interest alive in science (or in your chosen field)?

- Chemistry 100%
- physics 100%
- biology 50/50

5. What is it you most like about your chosen subject choice at the moment?

Science then english then geograph then Art then but apart from those subjects I don't like any other

6. What kinds of occurrences in life might make you change completely (into or completely away from science)?

~~May~~ Because i've already made future Plans if unexpectedly I move to a different country then my plans would be ruined and I cant follow what i Love / desire (science)

7. Looking back at primary to secondary level, what do you feel you have gained from the subject and how? What do you feel you have not gained from the subject and why?

I think I haven't gained bioligy its not that i don't understand it its just that I don't enjoy learning it. Looking back at my primary levels I used to be on Level 3s and 4s but know I'm level 5A if I achieve my target I would be 6c

8. In your view, what is the single most important factor that would motivate more young people to take up science?

I think young people should go for science. Science is a really enjoyable Subject and its really fun especially Seeing volcanoes errupt or chemical reactions it filled with variety of fun activities.

Appendix 12: Distribution of the thirty girls in accordance to C1-C4 groups

Group - C2							
	Subject choices at A-levels			Year groups			Total
	Before intervention	After 6 months	After 12 months	Year 7	Year 8	Year 9	
1	C2	C1	C1			Sarmin	01
2	C2	C1	C2		Tabu		01
3	C2	C2	C1	Saira	Sitara, , Samray		03
4	C2	C2	C2		Rabi	Hijir,Sana, Zeenat, Zaki	05
5	C2	C2	C4	Anushka			01
Total				02	04	05	11

Group - C3							
	Subject choices at A-levels			Year groups			Total
	Before intervention	After 6 months	After 12 months	Year 7	Year 8	Year 9	
1	C3	C2	C2	Sabah , Zikri	Huma	Humaira, Roshan , Samar, Talat	**07**
2	C3	C4	C4	Bano			**01**
Total				**03**	**01**	**04**	**08**

Group - C4							
	Subject choices at A-levels			Year groups			**Total**
	Pre-intervention	After 6 months	After 12 months	Year 7	Year 8	Year 9	
1	C4	C2	C2	Rukhsana Hajra	Isra, Rakhi, Star	Maha, Mahnoor, Samia	**08**
2	C4	C2	C4			Iqra	**01**
3	C4	C4	C2	Hadi			**01**
4	C4	C4	C4		Mehtab		**01**
Total				**03**	**04**	**04**	**11**