UNIVERSITY OF SOUTHAMPTON

FACULTY OF SOCIAL AND HUMAN SCIENCES

Southampton Education School

Aristotle’s Daughters:

A Biographical Study of Six Women’s Experiences of Physics from Three Families across Two Generations.

By

Ceri Jane Edwards-Hawthorne

Thesis submitted in partial fulfilment for the degree of Doctor of Education.

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ABSTRACT

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Since the First World War, there has been a concern about the dwindling number of physicists and engineers in the United Kingdom and the resultant negative implications for the economy. A' level physics courses attract fewer students than biology or chemistry courses do. Since the Second World War, it has been noted that the recruitment of women into physics has been particularly poor. Whilst women have entered many occupations previously considered to be in the male domain such as medicine or law, very few are entering physics-oriented professions. Numerous initiatives from both the government and other interested institutions appear to have failed in this regard; despite these organisations' investment, boys consistently outnumber girls on A' level physics courses by approximately four to one. This scarcity of female A' level students results in less women having the necessary qualifications to study physics and engineering at a higher level. Those women who

do attain higher qualifications in physics are far more likely than their male colleagues to leave physics-oriented professions, are less likely to attain senior positions in physics or engineering, and are more likely to move from physics research positions to physics support occupations such as administration or teaching (Dainty et al., 2010).

This narrative study has explored how six women, belonging to two generations of three different families, developed a ‘physics literacy’ and ‘identified’ with physics. It has considered how the women’s experiences of physics have changed across the two generations studied. This research was conducted within a radical orthodox paradigm applied to a sociological context. Five of the participants took part in a semi-structured interview. These interviews were then transcribed, interpreted, and analysed using a hermeneutical-phenomenological approach. The women’s stories were then presented using a Bronfenbrennerian ‘Ecology of Human Development' (Bronfenbrenner, 2006) style framework, which was achieved by placing each of their stories in a micro, meso, exo, macro, and chronosystem. Using this framework enabled the study of interactions between the different influences on the participants’ lives.

What this study has revealed, contrary to the findings of many other statistical studies, is that the physics literacy of women is increasing as is their ability to identify with physics. However, there remain many cultural boundaries that continue to discourage women from pursuing a career in physics. Although it could be argued that the United Kingdom is a physics-based culture in that it assumes that the laws of physics underpin its existence, the study of physics is seen as a mysterious remote activity carried out by an elite minority of wealthy, white men. It recommends an approach to physics that will make it more exciting and accessible to a wider range of students, that physics be made less mysterious, and that families, especially those with young children, be encouraged to engage in physics-oriented leisure activities, in similar ways to which families currently engage in literature, music, and sports, to raise the overall physics identity and physics literacy of the population.

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DECLARATION OF AUTHORSHIP

I, Ceri Jane Edwards-Hawthorne

declare that this thesis entitled:

Aristotle's Daughters: a biographical study of six women's experiences of physics from three families across three generations

and the work presented in the thesis are both my own, and have been generated by me as the result of my own original research. I confirm that:

❖ this work was done wholly or mainly while in candidature for a research degree at this university;

❖ where any part of this thesis has previously been submitted for a degree or other qualification at this university or any other institution, this has been clearly stated;

❖ where I have consulted the published work of others, this is always clearly attributed;

❖ where I have quoted from the work of others, the source is always given, with the exception of such quotations, this thesis is entirely my own work;

❖ I have acknowledged all main sources of help;

❖ where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;

❖ none of this work has been published before submission.

Signed:

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Date:

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Thanks are also due to my former science teachers Mr Essex, Mr Reeves, Mr Tullis, Mr Trevor, and Mr Thomas who fostered my early interest in science, and to the physical science and education departments of Trent Polytechnic, Nottingham for allowing me to develop this interest further.

I have my father to thank for inspiring me to follow in his footsteps and study science, and my mother's example for making me question the traditional role of the woman as homemaker.

I am indebted to the participants of this study without whose input this research would not have been possible, but who cannot be named for reasons of confidentiality.

Finally, thanks are due to my long suffering husband Andrew and children Emilia and Rhion whose lives have been put on hold while I carried out this study.

Dedication

This study is dedicated to my mother

Margaret Edwards,

and

Hypatia of Alexandria

Definitions and Abbreviations

A' level	General Certificate of Education – Advanced Level
C.S.E.	Certificate of Secondary Education
G.C.E.	General Certificate of Education
I.C.T.	Information Communication Technology
IOP	Institute of Physics
LEA	Local Education Authority
O' level(s)	General Certificate of Education - Ordinary Level
P.G.C.E.	Post Graduate Certificate of Education
STEM	Science, technology, engineering, and mathematics
WES	The Women's Engineering Society
JCQ	Joint Council for Qualifications

Figures

Chapter 1: Introduction

Every piece of knowledge is produced by subjects in a given historical context. Even if that knowledge aims to be objective, even if its techniques are designed to ensure objectivity, science always displays certain choices, certain exclusions, and these are particularly determined by the sex of the scholars involved (Irigarary 1993, as cited in Mayhew, 2010, p.15).

1.1 Introduction

This is a narrative study that tells the stories of how women from three different families across two generations have experienced and developed a relationship with physics. It reflects upon what might happen in the next generation.

This project began with a pilot study of a woman from a family well known to the researcher. The data gathered from this pilot study proved so rich that it was decided to include it in the main study. The main study began with an observation of mothers and daughters from two different families in their family homes. This established trust and a good working rapport with the participants. The second phase comprised of semi-structured interviews of the mothers observed in phase one. This was followed by similar semi-structured interviews of the mothers' mothers or 'grandmothers'. These interviews were recorded and transcribed by the researcher. The transcriptions were then analysed and compared with findings from literature such as the work of Alison Kelly undertaken in the 1980s when the mothers' generation was at secondary school (Kelly, 1981) and those published by The Institute of Physics (Murphy and Whitelegg, 2006).

This study is of interest because, despite considerable research and investment since the First World War, there appears to have been little change in the proportion of women choosing to either study or pursue careers in physics (Barnard et al., 2010), as the House of Commons Science and Technology Committee, 2014 reports:

… the issue of women engineers and scientist goes back to WWI … there have been almost annual enquiries into aspects of this issue for many years and 'wake-up calls' followed by short term projects every decade since the 1970s … progress has been modest, at best and short term at worst with too much fragmentation of effort and re-invention of the wheels (WES in The House of Commons Committee for Science and Technology Committee, 2014, p. 49).

What this study hopes to add to existing research is an insight into what the statistical data from other studies mean when lived out in the real lives of the participants of this study. It compliments previous findings by providing background detail and verifying data, and looks at the issues from a new perspective. By exploring the experiences of women over two generations, this study was able to cover a span of eighty years—an option often not available to larger scale studies. Whilst this study's data supports the overarching findings with regard to women's relationship with physics, it also points to subtle changes in opportunities, knowledge, and confidence with each successive generation.

This chapter will summarise the current situation regarding women in science, technology, engineering, and mathematics (STEM) based vocations with a particular reference to physics. It will suggest that physics should be regarded as a special case because while there are similar challenges for female graduates in physics, chemistry, and biology, far fewer women choose to study physics than biology or chemistry at A' level; consequently, there are proportionally less female physics graduates than other science graduates. The chapter will then explain the significance of this work's title by linking the current situation of women in science to the thinking of Aristotle, the classical Greek thinker who set the pattern for the study of science in subsequent generations in Western European culture. Section 1.4 will explain why this area of research is of interest to the researcher. The penultimate section will detail the aims of this project. The final section of this chapter will outline the structure of this thesis.

1.2 Women in Physics

The following table, based on figures supplied by the Joint Council for Qualifications (JCQ), shows the ratio of male and female students who appeared for the G.C.E. A' level examination in physics, from 2006 to 2016.

Figure 1.1: A comparison of males and females appearing for G.C.E. A' Level examinations from 2006 to 2016.

Year	% Female Students	% Male Students
2006	22	78
2007	22	78
2008	22	78
2009	22	78
2010	22	78

2011	21	79
2012	21	79
2013	20	80
2014	22	78
2015	22	78
2016	22	78

(JCQ, 2017)

This implies a fairly constant ratio of one female for every four male A' level physics candidates over the last ten years. Indeed, there appears to have been little change over the past 40 years, despite numerous initiatives to recruit more female students (Barnard et al., 2010). By contrast in 2016, 61% of the A' level biology entrants and 50% of the A' level chemistry entrants were female (JCQ, 2017). Physics had the least number of A' level entrants when compared to biology and chemistry, and was ranked the 9th most popular A' level subject when compared to all other A' level entries. Women predominate in subjects that were traditionally seen as feminine, such as the arts and humanities; they also now outnumber men in what were seen as traditionally male subjects such as law and medicine at an undergraduate level (Pinker, 2009).

Post 'A' level, however, both industry and academia appear to have a problem in retaining and recruiting women in all STEM subjects, including physics. The 2014 House of Commons Committee found that only 13% of all STEM based jobs were held by women and that there was a problem in attracting women to leading STEM positions. These figures are despite an increase in the proportion of women in medical-related sciences. The General Medical Council (G.M.C.) reported in 2012 that 55% of all United Kingdom medical students and 61% of doctors under the age of 30 were female as opposed to only one third of the doctors being female in the 50+ age range. From these figures, the G.M.C. implied that the profession is moving from being a male dominant to female dominant one.

'It is astonishing that despite clear imperatives and multiple initiatives to improve diversity in STEM, women still remain underrepresented at senior levels across every discipline' (House of Commons Science and Technology Committee, 2014, p 3).

There are several arguments for accepting this status quo. Browne (2002) and Pinker (2009) suggest that these discrepancies between male and female students opting for physics are a consequence of the natural, biological differences between the sexes. Others, such as Odone (2015), argue that in encouraging girls to study physics, schools are limiting free choice. By valuing masculine subjects like physics over subjects such as languages—which girls have been traditionally good at—schools are subtly undervaluing women and their natural inclinations. Echoes of the belief that 'the woman's place is in the home' and that 'women having careers will have a detrimental effect on family life, especially the nurture and care of children' can be found in Tirana's (2010) research. This study takes a different view; it believes that the study of physics is important for both women and men in order to develop a physics literate population. For the purposes of this study, the term 'physics literate' is taken to mean having a confident knowledge and understanding of physical concepts and processes such as matter, forces, motion, electricity, time, space, and energy, sufficient enough to be able to identify when physics is being used or applied. A person who is '*physics literate*' knows what it is to do physics, has an understanding of the methodologies used when engaging in physics, can use the language of physics fluently, and is initiated in the culture of physics. In this sense, the term ‘physics literacy’ is parallel to the term ‘emotional literacy’ meaning the ability to identify and express feelings. A ‘physics literate’ population would not only provide the industry with an increased number of potential physicists, but would be able to make physics-sound judgements, such as those aimed at energy conservation, in everyday life. Not only would physics based industries be in a stronger, more internationally competitive position, but there would also be a greater supply of enthusiastic physics teachers ensuring that the traditions of physics were passed on to subsequent generations, parents would be able to instil a love of physics in their children, and the population would be able to make informed decisions concerning issues such as transport, sustainable development, and nuclear power. Physics occupies a central place in Western European culture; theories of physics, such as the planetary system, form the foundations on which other knowledge and customs are based. Physics commands respect and authority, which places the uninitiated in a position of lesser importance and power (Wertheim, 1997).

In order to become *‘physics literate’*, a person must develop a positive *‘physics identity’*, which means to have a positive relationship with physics, the person must feel confident in their knowledge of and ability to study physics, enjoy engaging in physics related activities, and be able to converse confidently about topics related to physics.

The 2014 House of Commons Report (House of Commons Science and Technology Committee, 2014) suggested that the following factors discourage women from studying or pursuing careers in STEM:

- gender bias within the scientific community,

- a reluctance to accept (and therefore a resistance to change) the gender bias by some members of the scientific community perhaps because by admitting to such a bias, the scientific community would be admitting to a lack of objectivity which many see as a core value in science,
- a lack of female role models,
- work patterns and structures that make it difficult to combine work with family life, especially at a time when many potential recruits are in their late 20s or early 30s, finishing their doctoral studies and perhaps considering starting a family.

These work structures include:

  - short term contracts for post-doctoral recruits,
  - international collaboration requiring employees to travel extensively,
  - long inflexible hours in order to complete projects,
  - difficulties in taking parental leave, especially at key stages of a project.

The net effect of this is that most STEM jobs are in a predominantly masculine environment which women may find hard to enter. This appears to fit the theories of the French sociologist Bourdieu, which say that the society seeks to reproduce itself by ensuring that knowledge and power remain with the existing ruling classes, which in this case is the class of white, wealthy males. The mechanism for this is cultural capital, which is the body of skills and knowledge that enable or inhibit an individual from gaining a position of power. This knowledge may be conscious and explicit as in the gaining of recognised qualifications, or unconscious and implicit as in being initiated in the etiquette, dialect, and social interaction of the profession into which the individual seeks to gain entry. Thus, physics remains a masculine subject as social forces work to maintain the existing status quo (Bourdieu et al., 1990).

These concerns are echoed by the Institute of Physics (I.O.P.) which has conducted studies in order both to understand what is preventing women from following a career in physics and to find ways of overcoming this. The consequences of a fall in the number of students both male and female has led to a 30 per cent decline in the number of physics departments in universities since 1979 (Whitelegg and Murphy, 2006). The Institute suggests that poor practice in the classroom puts off both males and females from continuing to study physics, but that this has a bigger impact on girls than boys. Conversely, where there is good practice, both boys and girls benefit; not only will a higher percentage of women be recruited, but more men will choose to study physics too (Ibid, 2006).

Both the I.O.P. and the House of Commons Committee note the apparent ineffectiveness of initiatives to date, to increase the recruitment of women to physics-oriented occupations. This problem is exacerbated when considering the collective knowledge of the population at large. Whilst industry and academia are losing female graduate of chemistry and biology to the domestic sphere, it could be argued that this knowledge is not lost to society as a whole; it is, instead, directed from the work place to the nursery. The potential exists for these female chemists and biologists to apply their knowledge to the domestic setting, thus raising the profile of these disciplines within the wider culture, and inspiring the next generation, both male and female. Mothers who are themselves knowledgeable in these fields are more likely to be able to support and nurture the development of a similar temperament in their children. The lack of women qualified in physics when compared to other science disciplines results in the shortage of mothers who are able to foster the knowledge and love of physics in their children, potentially ensuring a shortage of physicists in the subsequent generations (Gerson, 1986). Although there are considerably more men than women studying physics at higher education levels, there is a persistent shortage of physicists of either sex. A further consequence of this is that physics teachers with a qualification in physics are proportionally fewer than those without qualification in physics. Lack of specialist teachers has been shown to have an impact on whether the subject is opted for by the students (The Comptroller and Auditor General, 2010). Physics seems to appeal the most to men of a particular personality profile, i.e. those who are cautious, inhibited, controlled, and lacking in confidence socially (Wilson and Jackson, 1994). Physicists are also most likely to have come from middle to high socio-economic backgrounds—42% of the country's leading scientists have come from independent schools (STEM Equality and Diversity Toolkit, 2010). It is possible that the same barriers preventing women from studying physics might also be restricting access to men of diverse personality types and those from poorer social economic backgrounds; making physics more accessible to women might also make physics more accessible to a larger number of men.

This study has physics as a primary focus. However, there is an inevitable overlap between physics and other STEM subjects. In many schools, physics is not taught as a discrete subject, but rather as an integral part of a general science curriculum. As previously mentioned, the problem of retaining qualified female physicists seems identical to the problem of retaining qualified females from any STEM discipline, and much of the research data has not made the distinction between these areas. For these reasons, it has not been possible to limit this study solely to the study of physics and it has drawn information concerning women and girls in a range of STEM contexts. However, the difficulty of encouraging girls to study the subject at A' level appears to be specific to physics. This study refers to 'physics' where specific physics examples can be found, and to 'science' and 'STEM' where the data does not refer to physics discretely but offers evidence for generic issues concerning science or STEM with the implied inclusion of physics.

1.3 Aristotle's Daughters

The classical Greek scholar Aristotle is considered by many to be the 'father of biology' (Millett, 2011). He used observation and deductions to draw conclusions about the living world. His world was Hellenistic, which relied on a clear distinction between men and women, and the specific division of roles along gendered lines. It is perhaps not surprising that Aristotle deduced from his observations that women were the weaker sex both physically and intellectually. Women of his culture were denied formal education and the chance to develop a political voice, and were expected to have a solely domestic role (Mayhew, 2014). Those such as Sappho (Sappho, 2003) faced ostracisation and exile if they challenged the existing patriarchy. Aristotle's reflections on women were later adopted by the Church as can be seen in the works of the theologian Thomas Aquinas (Aquinas and Fathers of the English Dominican Province, 1981) making their inferior standing relative to men not just an observation but a moral requirement set by divine law. Those who were perceived as challenging this divine law were seen as unnatural or even evil and risked severe punishment, an extreme example being the murder of Egyptian physicist, Hypatia (Alic, 1986). Aristotle's ideas on the nature of men and women became embedded in the narrative of the Western European culture, the norm against which new ideas were tested (Ragland, 2004).

Aristotle is also thought to be the first person to have coined the term 'physics' (Fielding and Aristotle, 1984). His work formed the primary source of reference for physical concepts until it was eventually replaced by the work of scientists such as Galileo and Newton. He laid the foundations of the scientific method using observation and deduction, while the later scholars added experimentation, which has become the method associated with physics today (Mayhew, 2014).

Thus, physics from its birth has been perceived as a masculine subject beyond the capabilities and interests of women, at least in Western European culture. *'Sons'* of Aristotle, such as Galileo, Newton, Faraday, and Einstein have become household names and part of the narrative of Western Europe, inspiring subsequent generations of men to follow in this tradition. *'Aristotle's Daughters'* however remain largely forgotten.

This study will explore the impact of Aristotle's legacy within physics through the lives of two generations of women, from three different families. It will consider how the cultural setting has impacted the development of these women's relationship with physics, and how this might be changing over time with each successive generation. These women could be considered 'daughters of Aristotle' in that they are inheritors of the Western European culture that has its origins in the philosophy of classical Greece. This study explores how the legacy of Aristotle may have influenced their access and attitude to physics.

The twenty-first century world, with its transportation, energy, and ICT issues, is perhaps more dependent on physics that the world of Aristotle. Today's woman is likely to have to operate a range of machinery both at home and work that function according to the principles of physics. If a woman is to be able to carry out day to day maintenance, operate machines efficiently, and make wise purchase choices, then she is required to have a basic working knowledge of physics. If she is to be denied this knowledge, then she will forever be dependent on male colleagues or family members in this area of her life. Many domestic tasks that have traditionally been carried out by women, such as cooking and laundry, rely on elements of physics such as energy transfer. Knowledge of physics helps a person understand the workings of the body. This is particularly important when considering manual handling such as what might be needed when a nurse supports a patient. A working knowledge of physics is a prerequisite for understanding topical issues such as global warming, nuclear power, and sustainable energy solutions. Without an understanding of these, it would be difficult for a woman to come to an informed decision when making lifestyle choices or voting in elections.

1.4 The Significance of this Study to the Researcher

This topic is of interest to me at several levels, both personal and professional. As a teacher, with a specialisation in science, I am interested in finding ways to improve my practice. At a more personal level, I would like to understand my own rather negative experience of studying A' level physics. Both my grandfathers and my father were electrical engineers, and I was encouraged by them to study science subjects. I sensed that my father was keen for me to follow in the family tradition. While I enjoyed my biology and chemistry lessons, I found physics lessons a trial. I felt less able in physics than in other subjects and was very conscious of being one of only two female students in my group. I remember being reluctant to talk about my difficulties with my physics tutor due to a fear of appearing stupid and thus letting down '*female-kind'*. I was keen to drop physics at the higher education level, and instead chose chemistry as the main component of my education degree. I had assumed that my 'failure' in physics was my problem, and so I was interested in discovering how my experiences of physics lessons may not be untypical and that my difficulties with this subject may not have been entirely of my own making. In this study, I hope to have a better understanding of my own relationship with physics, an understanding of how other women in my community relate to physics, and through this have a greater understanding of why, despite considerable investment, it is proving so difficult to recruit women into physics.

I have chosen to take a qualitative approach using biographical narratives in order to have the scope to probe personal and emotional issues in some depth. There is already an abundance of quantitative data which in turn has fed into reports such as those cited earlier, all of which agree that there are difficulties in recruiting women to physics. This study is intended to provide in-depth data about the lived experiences of women and relate the findings of these studies to the lives of women from two generations from three different families. By studying a limited number of participants, it has been possible to gather detailed data which will illustrate and complement the quantitative data, translating the statistics into everyday experiences in the lives of individuals.

1.5 The Aims of this Study

The aim of this study is threefold:

1. to examine the opportunities two generations of women from three families had to become '*physics literate'*,

2. to understand of how a ‘physics’ identity may be developed or inhibited,

3. to examine if any changes to the development of a ‘*physics identity’* occurred over two generations.

1.6 Structure of the Thesis

This thesis has been organised into the following chapters:

Chapter 2: Literature Review

This chapter will provide a background to this study by considering some of the reasons found in the research literature for the shortage of female physics students, physicists, and engineers. It will explore some differing viewpoints including some biological and sociological stances. The chapter goes on to discuss the culture of physics, and how its perceived masculinity may discourage women from studying it. It will then examine the relationship between physics, education, and society over time. Finally, it will consider some factors influencing the physics curriculum.

Chapter 3: Methodology

This chapter will outline the biographical narrative approach adopted for this study. It will describe the processes followed and highlight the ethical factors that were taken into consideration when undertaking this research.

Chapter 4: The Findings

This chapter provides narratives of the participants in order that the reader may gain an insight into the lives of the women included in this study.

Chapter 5: Analysis

This chapter analyses the stories of the participants from chapter 4 and relates their stories to the literature discussed in chapter 2.

Chapter 6: Reflections and Recommendations

This chapter reflects on the findings and relates these back to the aims of the study. It also makes recommendations for practice based on the overall findings of the study.

<u>Chapter 2: Literature Review</u>

'We have all been deeply affected by the mathematical world picture physicists have constructed. Whatever people's private beliefs, it is this picture that is taught in our schools and universities, that is endorsed in encyclopaedias, atlases, science magazines, television programs and newspapers. In short, whatever private world picture individuals may hold, it is physicists' mathematical world picture that is endorsed by the public institution of our society.' (Wertheim, 1997, p. 5)

<u>2.1 Introduction</u>

This study has adopted a Bronfenbrennerian view of the 'Ecology of Human Development' (Bronfenbrenner, 1979) in that it assumes that a human mind is the product of an on-going interaction between an individual and his/her environment. The environment is composed of both physical elements and interactions with fellow human beings at a micro (the setting in which individuals operate), meso (the interactions between different settings), exo (external microsystems that have an influence on the individual's microsystems), and macro (the cultural and social milieu in which the other systems are located) level. These interactions take place within a temporal framework or chronosystem.

Wertheimer's (1997) view places physics at the centre of the macrosystem, colouring all aspects of the environment in which the young human develops. The ensuing relationship between that individual and physics will determine how physics literate he or she will become and how she or he will identify with physics. This will then have an impact on how he or she relates to society as a whole.

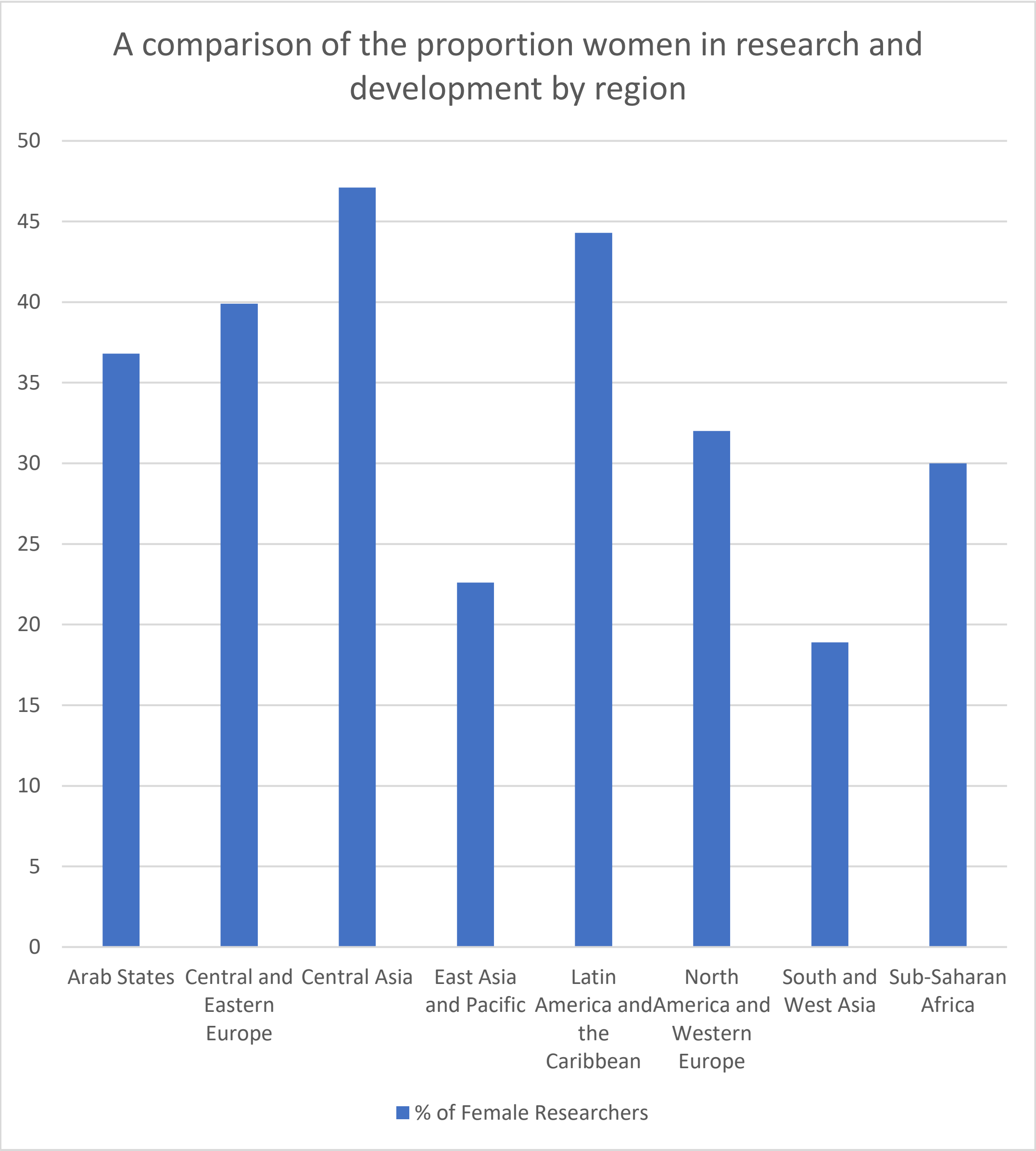
The purpose of this chapter is to collate information from literature in order to construct a picture of the chrono, macro, and exosystems in which the participants of this study have lived and thus provide an explanation for their degree of identification with physics. It has been divided into the following sections: section 2.2 will consider some of the differing beliefs about women and their relationship with physics (macrosystem), section 2.3 will examine the culture of STEM with a particular focus on physics (exosystem) and some of the difficulties women have with this subject as highlighted in chapter one, section 2.4 will look at the historical context (chronosystem) considering how the relationship between women, education, and physics has changed over time, and section 2.5 is a brief exploration of curriculum theory. This chapter will conclude with a summary of the key ideas explored in the chapter.

2.2 Some Beliefs about Women and Science/Physics - Macrosystem

All the participants of this study were British and had lived in the United Kingdom all of their lives. This section will construct a narrative to describe the macrosystem, i.e. the overriding cultural milieu in which these women's stories have evolved.

In its 2017 report, WISE (Wisecampaign.org.uk, 2017) states that women made up only 21.1 percent of core STEM based occupations in 2016 in the UK, and that there had been a fall of 1 percent since 2015. By contrast, women made up 73 percent of the medical STEM workforce in the same year. WISE also reports that only 20 percent of physics A' level students are female, and that this proportion has stayed constant for the past decade. Similarly, the Institute of Physics (2012) in its statistical report found that only one fifth of undergraduates studying physics at either the bachelor's or enhanced bachelor's degree level were female. This pattern is not restricted to the UK; in many societies across the globe, proportionally fewer women are in physics related occupations than men, as is exemplified in the table in figure 2.01.

Figure 2.01: a graph showing the proportion of females working in research and development across the globe.



(Source: United Nations Educational, Scientific and Cultural Organisation, 2015)

It is interesting to note, however, that whilst in most countries fewer women are involved in scientific research than men (with only countries in Central Asia achieving parity), the proportion of women engaged in research and development across the globe varies from 18.9 percent in South and West Asia, to 47.1 percent in Central Asia. Catalyst, an international organisation that aims to improve the inclusion of women in the workplace reported that in 2015, 51.1 percent of Australian natural and physical science undergraduate students were female, and in India, 46.7 percent of science undergraduates were women (Catalyst, 2012).

Wertheim (1997) describes how physics knowledge could be seen as underpinning the belief system of our society. She argues that figures (such as those shown in figure 2.1) are evidence of the underrepresentation of women in physics. The result of this is a society in which fifty percent of its members do not contribute to a significant aspect of its foundation beliefs, are not authorities on some of its founding principles, and have lower status as a consequence. The end-product is a potentially male-dominated belief system onto which women are grafted to have periphery roles, rather than a society which has both men and women at the heart of its ideology.

The views of Wertheim (1997) appear to be part of a complex web of ideologies that together form part of the macrosystem in which people operate. Within this macrosystem, there appears to be confusion and conflict about the place of women in all aspects of science, not just physics, and how society should respond to this. An illustration of this is the Tim Hunt controversy of 2015 as was reported in the media (BBC, 2015; Ratcliffe, 2015; Dearden, 2015; and Sanghani, 2015).

Sir Tim Hunt, a much-respected Nobel Prize winning biologist, made some controversial remarks about women and their place in the science laboratory at The World Conference for Science Journalists in Seoul, June 2015 (Ratcliffe, 2015). The ensuing debate led to his resignation from The Royal Society and University

College, London. Tim Hunt’s story is an example of the complexity of the macrosystem and the strength of the feeling the issue of female representation in science can evoke.

A study of literature reveals that the society has a range of conflicting explanations for the currently perceived underrepresentation of women in physics and other STEM based occupations. If Bronfenbrenner (1979) is correct, then this social uncertainty concerning the place of women in science at a macrosystem level could contribute to the young child growing up in such an environment developing a perception of science as unfeminine, and thereby, not a desirable occupation for a woman. This section will consider some of the many ideological explanations for the position of women in science arising from the literature review. In the interest of simplicity, the ideologies discussed here are presented in a polarised or pure view. In reality, most individuals will hold a complex mixture of often conflicting ideologies depending on the context, and thus mirror the confusion of society at large (Nucci, 2005). The views to be considered are as follows:

- biological/creationist view
- sociological view
- ecology of human development view

2.2.1: A biological/creationist view

Proponents of this view, such as Browne (2002) and Pinker (2009) believe that there are fundamental differences in the biological make up of men and women. These differences are a fixed part of a person’s nature and are determined by his or her genetic make-up. The distinct characteristics of men and women are the result of evolution, with men having evolved those attributes which have best suited them to a ‘defender and provider’ role whereas women have evolved those attributes which have best suited them to a home making and nurturing role. Browne (2002) suggests that women are genetically less capable than men of mastering subjects like physics, as physics has little application in a woman’s role as a nurturer and homemaker. Men, however, with their increased physical strength and greater ability in the areas of spatial awareness and mathematics, are more likely to pursue careers in engineering and physics. This is the natural state of things and trying to work against this state is unlikely to be successful. Furthermore, Browne (2002) argues that trying to redress the balance and ensuring that more women engage in physics results in the injustice of positive discrimination with less able women being given positions in preference to their more able male competitors.

This biological view, in the Western European culture, appears to have been greatly influenced by the beliefs of the Christian church. Theologians such as Thomas Aquinas (Aquinas et al., 1981) believed that women were created from men in order to be a companion to them (Genesis 2). Aquinas, who held much influence on the church’s thinking, was in turn influenced by the Greek philosopher and father of science, Aristotle (McInery and O’Callaghan, 2016). The belief that women were created differently and have very different roles and attributes to men pervades in many church quarters to this day. For example, the US-based Christian Broadcasting Network interprets the first chapters of the Genesis literally and suggests that the first woman was formed from the first man in order to serve as his companion (CBN.com(beta), 2013). Women may not be ordained in the Catholic church (Kirchgaessner, 2016); in the Church of England, the first women were ordained deacon in 1987, priest in 1994, and bishop in with the provision of ‘provisional episcopal visitors’ i.e. bishops who would not ordain women and take over pastoral responsibilities for those parishes that did not recognise the ordination of women

(The Church of England, 2010). Although a decreasing influence on English society, in the 2011 Census 59% of the population identified themselves as Christian (Office for National Statistics, 2012). The Church of England, through its special relationship with the state, links to ruling classes and church schools has had an important role historically in the formation of English society (Graham, 2007). There may be some correlation between religious affiliation and the proportion of women in science; McGrayne (2001) noted proportionally more Jewish and Quaker scientists both male and female when compared to Catholic and non-Quaker Protestant Christians. Figure 2.02 presents a simplified picture of the concentration of religious groups across the world. According to this table, women scientists fare best in Hindu cultures whereas opportunities are varied between different Christian and Muslim societies. Further consideration of this is beyond the scope of this study.

Figure 2.02: A table showing the principle religious affiliation in regions across the globe compared to their percentage of female researchers

Region	Majority Religion	Percentage of female scientists
Central Asia	Hindu	47
Latin America	Christian	44
Central and Eastern Europe	Christian	40
Arab States	Muslim	37
North America and Western Europe	Christian	32
Sub-Saharan Africa	Christian	30
East Asia and the Pacific	Christian and Muslim	23
South and West Asia	Muslim	19

Sources: (UNESCO, 2015) and (Pew Research Center, 2017)

There is great variation within Christian beliefs not only shown by the range of denominations but by the variation within each denomination, and in particular, within the Anglican church (Graham, 2007), by no means are all Christians creationists, and there are feminist movements within Christianity such as the 'Women's Ordination Conference' (womensordination.org, 2017) that advocate women's equality with men. However, the Christian Broadcasting Network is an example of a persistent creationist strand within Christianity. Creationism adds weight to the evolutionary biologist's view in suggesting that the perceived differences between men and women are not merely an evolutionary accident but rather the result of the intervention of a divine being and that to challenge this is sacrilegious (Pennock, 2010).

Browne (2002) cites the cross-cultural similarities of the roles of men and women as evidence of his biological stance. He argues that as different cultures show similar demarcation of masculine and feminine roles, these differences cannot be adequately accounted for by cultural influence and must therefore be the result of a force that transcends culture, i.e. biological make up.

Similarly, Pinker (2009) cites the work of Baron-Cohen (2004) as evidence of genetically determined differences between the sexes. Baron-Cohen's work suggests two distinct brain types. One is labelled the *'empathy'* or *'E'* brain type; persons with this brain are good at empathy and relationships, but not so good at logical processing. The second type is labelled the '*system*' or *'S'* type. The *'S'* type brain is good at working logically and systematically, but not so good at understanding people and relationships. The research suggests that between these extreme brain types is a spectrum: some brains are more *'S'* than '*E'* while others more *'E'* than *'S'*. Those with an *'S'* brain are likely to be better at mathematics and physics, while those with an *'E'* brain are likely to be better at communication. The research findings imply that the *'S'* type brain is much more commonly found in men, whereas the *'E'* type brain is more commonly found in women.

There are however several flaws in the biological/creationist model. The first difficulty is philosophical; in stating that the differences between men and women are the result of biological differences and that therefore men and women should have different roles, Browne is committing a naturalistic fallacy (Sear, 2005). Logically speaking, just because something is—i.e., biological difference in this case—it does not follow that something ought, i.e., therefore, men and women ought to have different roles. Similar difficulties in encouraging girls to engage with physics can be found when trying to engage boys with reading. However, few are prepared to accept the status quo and allow boys to fall behind girls (Boys' Reading Commission, 2012). There have been a number of initiatives to try and promote boys' reading even though similar arguments could be used to state the case that boys are biologically less capable of language-based work than girls. In the view of the researcher, the difference is that the ability to read is seen as an essential life skill that must be mastered irrespective of sex, whereas physics, although highly respected—even revered—as a discipline is not seen as an essential life skill. The statistical evidence that boys achieve less than girls in reading and the underlying assumption by some that the cause of this lies in biology has not led to the view that boys should not be taught to read. Instead, resources have been ploughed into primary schools to raise the level of boys' literacy (Boys' Reading Commission, 2012).

Other scholars question the interpretation that cultural similarities indicate a reason beyond culture, i.e., a universal biological difference for differences in the role between men and women. Researchers such as *Keller (1993) and Kelly (1981)* maintain that the differences in culture are in fact significant and come to the opposite conclusion to Browne. Their view will be discussed in the next section. Figure 2.1 suggests that whilst there is underrepresentation of women in science across the globe, the degree to which they are under-represented varies from 19 to 47 per cent. This data suggests that there is in fact a cultural component to women's identification with science, including physics.

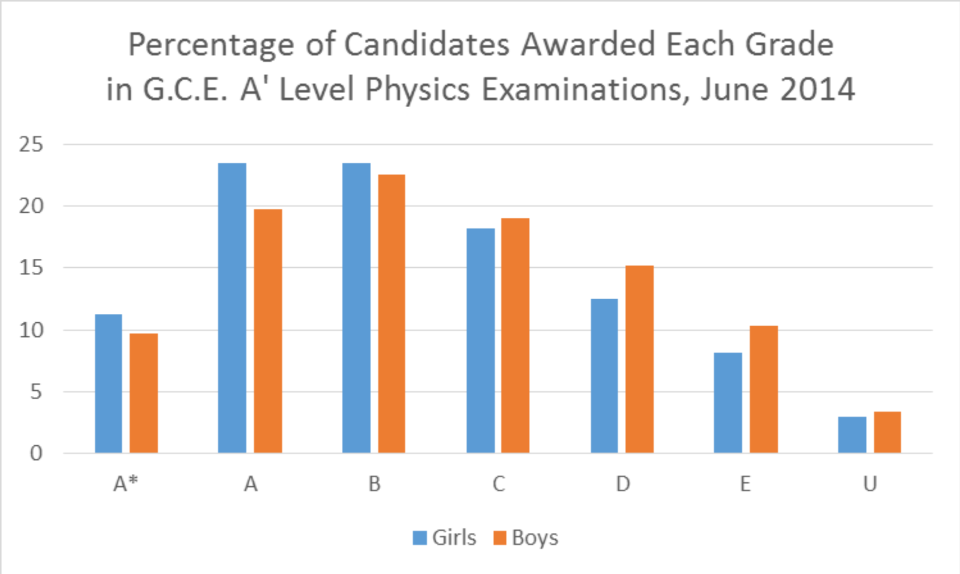
A further issue is the validity of the findings of researchers such as Baron-Cohen (2004). Other studies, such as that of Hyde (2005), contradict the findings of Baron-Cohen. Baron-Cohen found large differences between men and women whereas Hyde's findings suggest that the differences are small to the point of insignificance in many instances. It is difficult to get precise, objective data when investigating the human mind, as it is neither possible nor ethical to control all variables. Human beings vary in genetic make-up, diet, relationships, and exposure to environmental factors, and thus everyone is unique, which makes it difficult to gather objective data with absolute certainty. Furthermore, data will have been collected within a cultural context; the beliefs and values of the researcher will have had an influence on his or her interpretation of the findings (Ritchie, 2014). Baron-Cohen may have collected data that does indeed show a spectrum of *'E'* and *'S'* type brains with the *'E'* type predominating in females and the 'S' type predominating in males, but this does not necessarily mean that these differences are a result of purely genetic differences. Bronfenbrenner's (1979) work suggests that from conception, the human child is bathed in a matrix of culture, relationships, and environmental factors. Given this, it could be argued that it is not possible to isolate biological factors when carrying out research on the make-up of the human mind. It cannot therefore be said with absolute certainty that any differences found between the sexes are a result of genes. Baron-Cohen (2004) himself expressed concern about his research being used to reinforce sexual stereotypes.

Browne (2002) and Pinker (2009) assume that differences between the sexes are biological in nature, and therefore cannot be changed. Dwerk's (2012) '*Growth Mindset'* provides an alternative model. According to this view, learning is about making connections between synapses, and therefore most knowledge can be acquired and skills can be mastered with practice. If this is hypothesis is correct, then one's ability in any area of the curriculum, including physics, is not fixed, and it is possible for a child to achieve good scores in any subject. George (2012) suggests that achievement is determined by attitude, creativity, and self-belief as well as any innate ability determined by biological make-up.

Browne (2002) also argues that the biological differences are the product of evolution; and here lies a paradox. Evolution is the process by which a species changes over time in response to its environment. The concept of evolution implies continuous change, whereas Browne seems to be arguing that the evolution of men and women is complete, that evolutionary change has stopped. He describes adaptations in both men and women which made them suited to a prehistoric existence of clearly demarcated gendered roles. Arguably, even if such a distinction did exist in prehistoric times, it is difficult to see how such gendered roles continue to be biologically advantageous in a modern electronic age. If biological sex differences between men and women are the result of evolution, as Browne suggests, then rather than seeing a continuing polarisation of differences between men and women, the researcher would like to suggest that there should evolve a new generation of people better able to understand and use the technological advances of their age. The ability to master the basic principles of physics and apply these to daily life, for example being aware of the dangers of using an electrical kitchen appliance with wet hands or knowing how to conserve energy in the home, gives the modern physics literate homemaker an advantage over his or her less physics literate peer. Even in prehistoric times, the physics literate woman who could apply the principles of physics to grinding corn in her hand mill would have had an advantage over her physics illiterate sister.

There are also difficulties with both Browne (2002) and Pinker's (2009) assumption that women are less able in physics when compared to men. Evidence from the G.C.E. A' level examinations do not support this view. Figure 2.03 shows the provisional G.C.E. A' level grades for 2014. In this year, 28958 males sat for the A' level physics examination compared to only 7743 females—a ratio of nearly 4:1 males for every female. As can be seen from the graph, although fewer females sat for the examination than males, a higher proportion of females got higher grades than their male counterparts. A female candidate was more likely to have scored an A* than a male candidate. It could be that only the more confident or able female students chose to study physics and that this has had an impact on the figures, but nevertheless it is clear that some females do have the ability to do well in this subject.

Figure 2.03; A graph comparing performance of boys and girls Advanced Level Physics Examinations in 2014



Source; Joint Council for Qualifications, 2014

There does not seem to be any reliable conclusive evidence that women are less able than men at physics.

2.2.2: A Sociological View

Researchers such as Saragar and Griffiths (1981) argue that the disparity between male and female performance in physics cannot be explained in terms of mere biology but are due, at least in part, to the bias of the social milieu in which women grow and operate.

By its very nature, a sociological view will be more diverse and open to interpretation than a biological view (Ormston et al., 2014), for while a biological view typically involves a close up of a microscopic component, a sociological view attempts to take a broad view of the whole human social system. The biologist looks for measurable right answers whereas the sociologist looks for meanings and values in human cultures. This study therefore looks for '*a*' sociological explanation as opposed to '*the*' sociological explanation, accepting that there may be many interpretations. The nature of sociological research will be considered in more detail in the next chapter.

One sociological explanation for the persistent under-representation of women in science including physics is that of Bourdieu's (Bourdieu and Passeron, 1990) social reproduction. Bourdieu suggests that society reproduces itself in a way that is analogous to biological reproduction, whereby the off-spring are reproductions of their parents. In biological terms, the passing on of DNA leads to children who share the characteristics of their parents, so in sociological terms the passing on of beliefs, values, and social capital ensures the passing on of wealth and social standing from one generation to the next. Bourdieu (Bourdieu and Passeron, 2014) suggests subtle ways in which society is replicated, for example in the courses of study that children are steered towards depending on their position in society. Legally, it may appear that children have a free choice, but in practice, social conditioning programmes individuals to select courses that best reflect the values of the homes from which they come.

In terms of physics, a Bourdieuian view would be that the predominance of wealthy, white, Western European males in the physics laboratory is ensured from one generation to the next through social replication. Archer et al. (2012) applied Bourdieuian principles to their study of how children engage with and identify with science. This project used both qualitative (in the form of transcribed interviews) and quantitative (in the form of numerical statistics compiled from questionnaires) data to gain an in-depth picture of the impact the '*family habitus'* had on the children's development. By '*family habitus*', the researchers meant a complete view of the family unit, which includes interactions, interests, values, cultural capital, and wealth.

Archer et al.'s (2012) provisional findings imply that '*family habitus'* has a more significant impact on children's relationship with science than other factors such as education. However, there were many contributory factors such as gender, race, and income. The findings differ from Bourdieu's view in that there appears to be some element of choice and the outcomes are not completely predetermined. '*Family habitus'* was a powerful influence and could be used to predict the most likely outcome, but some children resisted the '*habitus*' of their families.

Studying a sociological system is highly complex and it is often not possible to cover all aspects of an area of study (Ormston, 2014) so this chapter will look at some of the factors that recur in the literature over the past 40 years i.e. education, vocational and career opportunities, relationships, physics in the home (or *family habitus*), and self-concept.

Archer et al. (2012) found that the school experience was a significant factor in determining whether children identified with science. This was linked closely to parents, in that articulate middle class, pro-science parents would actively choose schools for their children because of their science teaching and facilities. Kelly et al. (1981) found that many school practices were inhibiting girls' development in science. Keller (1993) argues that the very division of the school curriculum has gendered science, thus those aspects of science concerned with life i.e. biology are classed as feminine, whereas those sciences concerned with death and destruction e.g. weapon making such as physics are classified as masculine. Gray (1981), on the other hand, argues that it is not physics itself that is masculine, but the way in which it is presented. Similarly, Ebbutt (1981) suggests that the success criteria of many physics lessons do not value the aspects of physics that many girls are good at: accurate measurement is often seen as more important than neat presentation of work, although meticulous presentation of findings is an important scientific skill. Creativity in physics lessons was also often undervalued. The ‘re-marketing’ of physics lessons and what counts for success might encourage more girls to identify with it.

Examination is another area where discrimination between the sexes is evident. Harding (1981) found that boys performed better with multi-choice questions whereas girls performed better with essay type questions. Stranger-Hall (2012) found that multiple-choice questions inhibited the development of higher level thinking skills in science and increased gender bias in the results. Miyake et al. (2010) found that including a psychological component to first year degree level physics exams reduced the gender gap in performance by raising the attainment of female students. The Joint Council for Qualifications’ results tables for recent years however show female candidates out performing males in physics at G.C.S.E. and A’ level. This may not necessarily reflect an improvement in girls’ performance in physics but may instead be the result of change in exam emphasis.

The curriculum offered in physics can present another problem according to Kelly (1981); she found a bias in physics towards topics such as transport and flight that boys were interested in and had greater exposure to outside of school, thereby giving them an advantage. This continued bias has perhaps given rise to the continued perception detected by Whitelegg and Murphy (2006) that physics is a masculine subject. The following figure (2.05) outlines the topics of the physics component of the A.Q.A. G.C.S.E. core and additional science syllabus, 2010. Murphy and Whitelegg (2006) found that girls were more interested in light and electricity, whereas boys were more interested in forces and flight. Both girls and boys were interested in space. Girls also preferred a topic-based approach and the opportunity to work co-operatively rather than competitively. Phipps (2008) has found that girls are more motivated by topics that can be linked to the common good and are less interested in subjects that lead to capital or material gain, hence the growing interest of girls in biomedical sciences, which can be directly linked to human benefits.

Figure 2.04: a table showing the physics topics of the AQA core and additional science syllabi, 2010.

AQA Core Science Unit 3 Physics	AQA Additional Science Unit 3 Physics 2
Energy Transfer	Forces and their effects
Energy and Efficiency	The kinetic energy of objects speeding up and slowing down
The usefulness of electrical appliances	Currents in electrical circuits
Methods we use to generate electricity	Using mains electricity safely and the power of electrical appliances
The use of waves for communication and to provide evidence that the universe is expanding	What happens when radioactive substances decay, and the uses and dangers of their emissions
	Nuclear fission and nuclear fusion

The pink shading indicates topics that Whitelegg and Murphy (2006) have indicated appeal more to girls and the blue shading indicates the topics that appeal more to boys.

It is difficult to make an accurate judgement based purely on topic headings; a more detailed examination of the course content is needed. It does, however, appear to be the case that attempts are being made to ensure a balance of topics that appeal to boys and girls. However, little use seems to have been made of both boys' and girls' interest in space other than the unit applying waves to the investigation of an expanding universe. This is also the only reference made to light which has been highlighted as a particular area of interest to girls. Links are being made in these syllabi to the applications of physics, but there is no direct reference to physics and people, be it in the use of physics in medical sciences or learning about the lives of the scientists behind the discoveries; Kelly (1981), Phipps (2008), and Whitelegg and Murphy (2006) have all found that girls can find the impersonal nature of physics off-putting.

Thirty years ago, Kelly (1981) noted timetabling issues. Girls often had to choose between physics and more traditional feminine subjects such as art, when making the decision on their choices at the age of 13. Kelly (1981) contrasts this with the position of her Thai friends:

We have been told that getting girls to choose to study the physical science has been a problem in several Western countries, so we removed that option. You cannot do well in a subject you are not studying. (Kelly, 1981, p.80)

Whitelegg and Murphy (2006) do not list timetable clashes as one of the issues inhibiting girls in physics. This is perhaps as a direct result of physics, as an integral component of the science curriculum, being made compulsory following the implementation of the National Curriculum in 1988 (National Curriculum, 1988).

There is a debate concerning the benefits of girls being taught in single sex classes. Ormerod's (1981) and Gillibrand et al.'s (1999) findings suggested that girls perform better in all-girl science classes where they did not have to compete with more confident boys. Dee (2017) reports similar findings in the United States where several schools are experimenting with single sex classes often within co-educational schools. Shapker and Keating (2017) concur with Dee (2017); their research found that girls' attainment and engagement with science lessons was improved after them being taught in all-girl classes whereas boys fared better in a mixed sex class. As Shapker and Keating note, however, the students surveyed were all high performers and so their results may not be transferable to all classes. A similar issue could arise if trying to compare a single sex grammar school to a co-educational comprehensive. Questions also arise about the benefits of teaching girls science in an all-girl group if the aim is for them to eventually work in a physics laboratory which under current circumstances is likely to be male dominated.

Several researchers have noted teacher attitude as being a crucial factor in girls' engagement with science (Whyte, 1981), (Whitelegg and Murphy, 2006), (Archer et al., 2012), (Daniels, 2001). Kelly's (1981) research in the 1970s and 80s saw girls being steered towards what were considered to be more feminine subjects. Galton (1981) found that it was not always overt sexual stereotyping that led to girls feeling isolated from physics (although there were cases of this) but also subtle teaching styles and questioning techniques that the teachers themselves may not have been aware of. Galton (1981) found that teachers tended to respond to the more confident students, who were often boys, and within a short time the less confident students stopped volunteering answers to questions. Even the time a teacher allowed a student to provide a response before moving on to another pupil made a difference.

Another factor was the resources used. In the 1970s and 80s, Kelly's research found that the lack of examples of female scientists in text books further reinforced the stereotype of scientists being male. Whitelegg and Murphy (2006) found a similar bias. Both found that teacher expectations had a significant impact on girls' performance. Girls did not perform as well in science classes when their teachers subscribed to sexual stereotypes.

Archer et al.'s (2012) research suggests that students' career aspirations are affected by their exposure to examples in their community. Girls who encounter female doctors and pharmacists might then be inspired to follow a similar career trajectory; they cannot opt for careers whose existence they are unaware of. The shortage of physicists in general, and female physicists in particular (Whitelegg and Murphy, 2006), results in girls being less likely to meet positive female role models in physics in their everyday lives. Kelly (1981) suggests that there has been little change over the past three decades. Newton (1981) found that the earlier students had to make career choices, the less awareness they had of the range of career possibilities, and thus their options were limited. Now that the study of science has been made compulsory from ages 4 to 16 in state schools, girls do not have the option to drop physics until they are 16. This gives today's students two more years potentially than the students during Newton's days, to find out about physics related careers. Some feminists such as Phipps (2008) criticise careers advice services for not recognising the different factors that motivate girls. The career system, according to Phipps, is part of a capitalist, patriarchal system that assumes motivation by capital gain, increased power, and status. Many women, argues Phipps, are not motivated by these factors but instead want to have vocations where they feel they are contributing to the good of society. If this is the case, then career advisers need to stress the benefits of an individual choosing to study physics to the society.

Archer et al. (2012) also found relationships to be important in determining children's career path. Where parents valued science, especially if they were scientists themselves, children of both sexes were more likely to have a positive image of science and expect to follow a scientific career themselves. Elinor Kelly (1981) found that girls were more likely to follow a science career if their mothers were scientists. Archer’s (2012) work however suggests that fathers seemed to have a particularly important role in encouraging their daughters to pursue science. McGrayne’s (2001) study of high achieving female scientists found that having a supportive spouse was a significant factor in enabling female scientists to continue in their research. Marie Curie’s husband, and on his death her father-in-law, provided childcare for her two daughters, thereby enabling her to continue working after their births. Pierre Curie also turned down a promotion so that he would not have to move and interrupt his wife’s career. This is particularly significant given that the House of Commons Science and Technology Committee report of 2014 cites giving up work to start a family as being an important reason for many young women scientists leaving their careers. The relationship with teachers has been already been mentioned. One reason for girls’ increased attainment in science in all-girl schools could be the increased chances of having a female science teacher to act as a role model (Dee, 2017).

The most important factor in deciding the future science outcomes for a child according to Archer et al. (2012) was the home environment or ‘*family habitus’*. Archer et al. divided their participants into groups ranging from ‘science families’ which were middle class, white, or South Asian families with a strong identification with and knowledge of science, to ‘science as irrelevant’ families where there was little interest in science. In the science families, the children had lots of exposure to science through books, visits to museums, television programmes, parents’ interest in school science, and through day to day interaction with parents, extended family members, and friends who were ‘*science literate’* and used science naturally as part of their daily lives. In these families, engagement and attainment in science was highest, whereas at the other end of the spectrum in the ‘science is irrelevant’ families the children had little exposure to science, never went to museums, or watched science programmes on television, the children showed little engagement with and poor performance in science. However, Archer et al. (2012) are keen to point out there were children who were exceptions and resisted the family model. Much of these findings concur with the earlier research of Kelly et al. (1981).

Kelly was looking at girls in particular, rather than children in general. She found that girls and boy were given different chores around the home that helped to reinforce gender stereotypes. Boys had opportunities to play with toys that helped to promote their mechanical understanding of the world, whereas girls were given toys like dolls that encouraged them to develop social and parenting skills. The theory that the purpose of play is to prepare young animals for adult life was proposed by Carl Groos in the 19th century (Groos and Baldwin, 2005). There has been much debate concerning gendered toys in the press in recent years. The campaign ‘Let Toys be Toys’ was founded in 2012 to dissuade toy retailers from organising toys into gendered categories (Tessa and Winkless, 2016). Fine (2010) is concerned that retailers have increasingly used gender stereotypes when marketing toys so as to persuade parents from mixed sex families to buy new toys rather than pass the toys of older siblings on to younger siblings of the opposite sex. A notably controversial toy has been the American teenage fashion doll ‘Barbie’, and her English counterpart ‘Sindy’. These dolls are thought to reinforce gender stereotypes and restrict girls’ career aspirations, particularly in STEM based careers (Sherman and Zurbriggen, 2014). However, there is a counter argument that suggests that the Barbie doll, in portraying an independent woman with over 150 careers, broadens girls’ outlooks rather than restricting them to the mothering role that playing with a more traditional baby doll might encourage (Alter, 2014).

Another controversial toy has been Lego. Both Joan Freeman (1991) and Harry Kroto (Telegraph, 2001) bemoan the substitution of Meccano with plastic construction kits such as Lego. These eminent scientists attribute part of their later success in science to the opportunity they had to play with Meccano as children. Meccano however, was marketed as a toy for boys; its advertising showed boys or boys playing with their fathers. If it was used by girls, then this appears to have been an afterthought, as the following quote illustrates:

'The story of Meccano is the story of five generations of boys who found enjoyment in a toy that taught the principles of mechanics and enabled them (and a few girls) to make things that really worked.' (Marriott, 2012)

Even Freeman herself was only introduced to Meccano by a boy who lived in her neighbourhood and had to persuade her mother to buy this 'boys' toy for her. Meccano may have been a good vehicle for developing an understanding of physical concepts; however, if it was not made readily available to girls it could have contributed to sexual stereotyping and excluding women from engineering-based careers.

Another aspect of family life that may have a bearing on women's identification with science is that of religion. As mentioned in section 2.2, McGrayne (2001) noted that some religious denominations seemed to produce more scientists of both sexes than others. Judaism, perhaps with its focus on the natural physical world and reverence for matriarchy, has produced a relatively high number of female high-ranking physicists. There is a strong tradition of Christianity in Western European physics, including Galileo and Newton (Poole, 1995); but as Wertheim (1997) suggests, some Christian denominations in holding the idea that sex differences and genderisation are of divine origin, have promoted the continuance of exclusive patriarchies in science.

Another potential barrier to women achieving in science is self-concept. Several researchers including Kelly (1981) and Whitelegg and Murphy (2006) have noted that girls lack confidence in physics/science. Ormerod (1981) found that girls in particular, did not want to be wrong in lessons, and so, found physics and mathematics with their emphasis on right or wrong answers emotionally challenging. Girls were found to be more reluctant to take risks. Whitelegg and Murphy's (2006) research suggests that physics is still perceived as a masculine subject. Kelly (1981) found that girls at the onset of puberty were particularly insecure about their female identity and loathed to engage in a subject that might be seen as undermining their femininity. Elinor Kelly (1981) expressed concern about the impact of advertising aimed at adolescents that promoted certain stereotypes about women; she felt that this was putting pressure on girls to perform to these ideals. Smithers and Collins (1981) studied the type of girls who were willing to study physical sciences: they were typically very able, confident in their academic ability, lacked confidence in her social skills, and saw themselves as being less physically attractive than their peers.

Erikson (2014) saw the 'self' as something that was constantly developing as a result of the interplay between the individual, his/her immediate environment, and the layers of social interaction established through historical and social convention. He identified the following main components that form the 'self': current historical prototype, parental temperament, capacities, social situation, social stage, maturational stage, and temperament. In Erikson's view, the individual's identity evolves as he/she resolves a series of identity crises. These crises usually occur at similar ages as the individual matures.

To reconcile historical and psychological methodologies, we must first learn to deal jointly with the fact that psychologies and psychologists are subject to historical laws and that historians and historical records are subject to those of psychology. (Erikson, 2014, p 403).

Erikson suggests that children use historical prototypes to help them establish an identity; thus, a girl might look to women and stories about women from her culture in order to find role models and direct her own life. Erikson's model provides a mechanism for Bourdieu's (1990) social reproduction.

Erikson believed that during adolescence, relationships between peers became particularly significant and girls needed to group together to assert their femininity and conform to expectations.

For adolescents not only help one another through much discomfort by forming cliques and by stereotyping themselves, their ideals and their enemies; they also perversely test each other's capacity to pledge fidelity. (Erikson, 2014, P. 262)

Kelly suggests:

Feminine adolescent culture does not glamorise academic success and careers; instead it promotes an ideology of romance, marriage, family life, fashion and beauty (Kelly, E, 1981 p.66).

Further evidence that women can achieve in physics is found in the examples of women who have had success in this field, for example, the Australian born physicist Joan Freeman (Freeman, 1991) who managed to gain a university place to read physics having taken evening classes in physics secretly at her local technical college. In order to achieve this, however, she first had to have an awareness of and passion for the subject; she then needed the financial and moral support from her mother and the sympathy of her tutors.

This section has skimmed through a range of factors that may have a bearing on women's identity with physics. It is a huge topic well beyond the scope of this study. What it does suggest is a strong cultural bias to maintain the status quo. Any woman wishing to pursue a career in physics will have to be prepared to break many social taboos.

2.2.3 A Summary of the Macrosystem

In summary, there is a view in the macrosystem that women are less able than men in their ability to understand and practice physics. Holders of this view believe the disparity between the proportions of males and females studying this subject can be justified by predetermined biological sex differences. Traditionally, this view has been supported by some members of the Christian Church who see sex differences as being divinely ordained. Different studies come to different conclusions, some supporting this view, others refuting it. Logically, this view commits a naturalistic fallacy in saying that because women are less capable of physics than men, women should not be encouraged to have parity with men in physics. Even if it could be shown conclusively that women are naturally less capable than men, it does not follow that they should therefore be denied the chance to improve their knowledge; by contrast, perceived weaknesses in boys' literacy skills are not seen as a reason for boys not to be encouraged to become more literate but rather as a need for more investment and better teaching in order that the gap between boys and girls be narrowed and boys become more literate.

Others such as Kelly (1981), Whitelegg and Murphy (2012), and Archer et al. (2012) account for the disparity between men and women's uptake in science, including physics, to sociological factors. Archer et al. (2012) take a Bourdieuian view that society replicates itself through reinforcement of existing social norms and values; for example, parents who are scientifically literate might naturally make reference to science in their day to day interactions with their children and in so doing, give their children an advantage over the children of less scientifically literate parents. Numerous sociological factors such as the lack of female physicists in the community, the lack of representation of female physicists in literature, the gendered division of domestic chores, gendered distribution of toys, an examination system that favours one sex over another can all contribute to reinforcing the existing norm within a culture i.e. that physics is masculine, not a normal career choice for a woman, and that women are not good at physics. Archer et al. (2012) label this as 'habitus' and suggest that children raised within a 'family habitus' are likely to replicate their parents views and aspirations in adult life, thus supporting the Bourdieuian view. However, Archer et al. note that this is by no means predetermined; whilst continuing the parents' 'habitus' may be the most likely outcome, some children do resist their home culture and develop in a different direction. An example of such resistance could be the life of physicist Joan Freeman (1991).

There is a concern that promoting women in physics could put male physicists at a disadvantage. However, supporters of the 'women in physics' view such as Phipps (2008), and Murphy and Whitelegg (2006) are not arguing for role reversals, that is, for women to predominate over men in physics, as this would not eradicate the problem but merely change the sex of those who have to overcome it.

Rather, what is being asked for is equality of opportunity, for the voice of female physicists to be heard alongside their male counterparts, and for a greater take-up of physics by both women and men.

Fausto-Sterling suggests that looking at the issue of male and female differences from a nature versus nurture perspective is an over simplification:

Some scientists and social theorists (myself included) no longer believe in the scientific validity of this framework [nature versus nurture]. Such thinkers reject the search for unique 'root causes', arguing instead for a more complex analysis in which an individual's capacities emerge from a web of interactions between the biological being and the social environment. Within this web connecting threads move in both directions (Fausto-Sterling, 1992, p. 7).

This would seem to fit well with Bronfenbrenner's (2006) model. The following figure (2.04) is the researcher's summary of some of the conflicting perceptions of physics and its relationship with women that form the '*habitus'* of the macrosystem into which a 21st century British woman is born.

Figure 2.05: A diagram summarising some of the differing beliefs about physics within the macrosystem arising from a review of literature.

2.3 The Culture of Physics - Exosystem

Bronfenbrenner defines the exosystem as follows:

Consisting of one or more settings that do not involve the developing person as an active participant but in which events occur that affect or are affected by, what happens in that setting. (Bronfenbrenner, 1979, p. 237)

In chapter 1, several issues were highlighted that suggest that the exosystems of physics—be they industrial or academic—are difficult systems for women to enter into and become an intrinsic part of.

The image of these exosystems that is transmitted via the mesosystems (links between exo and microsystems) such as literature and television is predominantly masculine. This section will begin to explore the culture of physics and why it is that women find it so difficult to break into the system.

Historically, physics has been seen as a masculine discipline that evokes perceived masculine characteristics such as rationality, objectivity, and neutrality (Dainty et al., 2010). Wertheim suggests that the structure of physics mirrors the patriarchal system of the church, making it particularly difficult for women to gain entry.

Yet it is precisely in the re-emergence of this priestly image of this priestly image of the physicist that I believe we can locate a significant factor inhibiting women's entry into the field. (Wertheim, 1997, p.222)

There are different beliefs concerning the direction in which physics should now develop. Some such as Dainty et al. (2010), Howes (2002), and Keller (1993) argue that physics would benefit from embracing more feminine attributes alongside its traditional objectivity. Feminine attributes such as care and compassion, linguistic skills, observation, and presentation of data could further develop this discipline and increase its application and relation to everyday life; physics would still be physics, retain the same rigour and authority, but be all the richer by broadening to include more feminine virtues. In this model, the image of physics as a masculine subject is merely a historical construct; it could be reconstructed along more inclusive or feminine lines. It could be argued that dividing the sciences into physics, chemistry, and biology is in itself a masculine activity; that the masculine brain thinks in dichotomies i.e. physics v not physics, male v female, whereas the female brain thinks in terms of spectra and take a more holistic approach.

Conversely, there are those of a more logical positivist inclination who would see female friendly physics as a dumbing down of the subject (Browne, 2002) (Pinker, 2009), and that feminising physics could actually put men at a disadvantage and thus, rather than making physics more inclusive and equal, feminisation could just change the sex of the victims of inequality.

Both of these positions appear to take the view that qualities such as neutrality and objectivity are fixed and cannot be changed. Some educationalists argue that irrespective of the starting point, the ability to think rationally and objectively, to transcend a position and take a neutral perspective, can be improved with the right teaching approach. Thus, even if many girls do start off less able to reason objectively than their male peers, with targeted teaching this gap could be minimalized (Dwerk, 2012).

A further product of the masculine image of physics is that women who study it can feel that their femininity is compromised, that they have failed as women

(Dainty et al, 2010). Smithers and Collings' (Kelly, 1981) research in the late 1970s implied that girls who chose to study physics saw themselves as less attractive, less popular, and less feminine than those who studied biological sciences. Whether this was as a result of girls who felt less confident in their femininity retreating into physics, or whether the process of studying physics made girls feel less feminine is unclear. Similarly, Pinker (2009) found that physics seemed to appeal to boys with mathematical ability but relatively poor social and emotional skills, as its masculine image enabled some men who find social situations difficult, to find a niche and contribute to society. Feminising physics could potentially exclude this cohort and whereas feminine women have other career options, these men have limited alternatives.

Dainty et al (2010) and the Government Science and Technology Committee Report of 2014 highlight the difficulties faced by women working in a masculine environment. After work social activities and inter-colleague conversations tend to revolve around topics that appeal most to men, such as football and motorbikes, whereas topics that tend to be of interest to women, such as children and childcare, were often dismissed by male colleagues. Joan Freeman (1991) recalls being expected to climb over a fence when out with by male colleagues who had simply forgotten that she was female and too short to be able to manage. This discrimination is not intentional but rather a natural state in a predominantly male environment. It can make women feel left out or encourage them to develop masculine rather than feminine interests (Dainty et al, 2010).

The lack of opportunity to work flexible hours or part-time in physics-based occupations is another key factor identified by Dainty et al. (2010) in discouraging women from working in physics. The Office for National Statistics' 2013 figures suggest that it is still largely women who take primary responsibility for childcare once their children are born, with fathers continuing their careers interrupted. Women wishing to combine caring for their children alongside continuing physics careers are at a particular disadvantage as current structures do not allow for flexible working hours or part-time work. This creates a working environment where there are few mothers, especially in higher managerial positions, and therefore little empathy for women who try to balance child care with a professional physics role. This is cited as a reason why many women leave physics posts on becoming mothers. Conversely, it could be argued that women are choosing to take on a domestic childcare role rather than pursue a career as they find raising children more fulfilling and may be biologically programmed to feel like this (Pinker, 2009).

This argument does not explain why female physicists are more likely to want to stay at home with their children than female nurses, for example. Throughout the last century, successful female physicists seem to have sacrificed family life in order to pursue their careers. Those who combined family life and a career tended to be married to fellow physicists and often acted as their spouses' assistants (McGrayne, 2001).

2.3.1: A Summary of the Exosystem

For most people, the world of professional physics is an exosystem, that is, it is a self-contained unit that interacts with the wider macrosystem through the exchange of people and information. It controls the knowledge it generates through a rigorous methodology and culture which is accessible only to the initiate or *physics literate*. It presents as an exclusive elitist world, revered but yet remote. Traditionally, physics has been a male domain operating an almost monastic structure with a clearly defined hierarchy. It is a domain that women have had difficulty in penetrating due to:

- their own lack of confidence in their ability,
- the difficulties in becoming *physics literate* through the restrictions of the education system,
- mixed messages and doubts in the macrosystem about women's suitability and ability to do physics,
- and through barriers emanating from the world of physics itself.

These barriers include work practices that are:

- incompatible with caring for children or relatives,
- a male dominated social structure that naturally makes it difficult for women to fit in to,
- prejudices from established male colleagues that are difficult to challenge.

The lack of women physicists makes it difficult for women to network and gain support from female colleagues. This can lead to a feeling of isolation and a reluctance to challenge the status quo as women can feel like a lone voice in the laboratory.

The perception of physics then is one that is remote and inaccessible for women, dominated by masculine men.

2.4 A Brief History of Physics, Education and Women from 1930 to the Present - Chronosystem

The purpose of this section is to outline the historical context (i.e. from the 1930s until the present) in which the lives of the participants, whose stories are told in Chapter 4, have been or are being lived. This correlates to Bronfenbrenner's 'chrono' system which he added as an extra dimension to his ideas about ecological development.

Erikson suggests:

To reconcile historical and psychological methodologies, we must learn to deal jointly with the fact that psychologies and psychologists are subject to historical laws and that historians and historical records are subject to those of psychology. (Erikson, 1995, p. 403)

A longitudinal study such as this needs to take into account the historical context and how that context has changed and interacted with the subject over time.

This section will attempt to tell the story of the relationship between women, education, and physics decade by decade. For each decade, key historical events will be highlighted, including significant events for women. The changing role of women at work will then be explored. Following this, the major educational developments will be described with a particular focus on science and physics. This section will conclude with a discussion about curriculum theory.

The story of women, education, and physics up to 1930

We think of the history of science as a history of men. More than that, we think of the history of science as the story of a few men – Aristotle, Copernicus, Newton, Einstein – men who drastically altered our view of the universe. But the history of science is much more than that. It is the story of thousands of people who contributed to the knowledge and theories that constituted the science of their eras and made the 'great leaps' possible. Many of these people were women (Alic, 1986, p.1).

As mentioned in section one, many feminist thinkers such as Keller (1993) and de Beauvoir (2010) believe(d) that the genderisation of roles and the establishment of patriarchy began about the same time as the use of metal tools and the beginnings of agriculture; prior to this, there was less specialisation and greater equality of worth between men and women. It is difficult to prove or disprove this view in the absence of written records. Throughout ancient history, there are examples of women being trained and taking on medical roles, perhaps paving the way for modern women in medicine (Alic, 1986); female medical students now outnumber males in UK universities (G.M.C., 2017). There were also women who contributed to the advancement of scientific ideas such as 1st century 'Maria the Jewess' whose invention of the 'water bath' to maintain reagents at a constant temperature is still used today, and to whom Alic accredits with the foundation of modern chemistry (Alic, 1986). Whilst it may be true that such women were the exception to the norm in what was essentially a patriarchal society, it seems that respect for knowledge and a love of learning enabled society to overcome some of its prejudices against these exceptional women.

In Western Europe, the Christian Church appears to have been a leading influence both on the direction of science and in directing the gendered roles of men and women. First the Catholic Church and then in England, the Anglican Church aimed to control the minds and souls of its membership (Graham, 2007). The Church's battles with astronomer Galileo Galilei (Poole, 1990) are an illustration of how it tried to control knowledge and thus retain its hold over the faithful. A key thinker of the Church, Thomas Aquinas believed that women were by their very nature less able than men; their feeble minds were easily manipulated and therefore their evidence could not be relied upon as truthful. Their inabilities in science actually afforded them greater holiness:

Science and anything else conducive to greatness, is to man an occasion of self-confidence, so that he does not wholly surrender himself to God. The result is that such like things sometimes occasion a hindrance to devotion; while in simple souls and women devotion abounds by repressing pride (Aquinas, and Fathers of the English Dominican Province, 1981).

The murder of mathematician and physicist, Hypatia of Alexandria in 415 AD, is an extreme example of the lengths the Church could go to in order to control women and knowledge. The convents of the mediaeval period, however, did become centres of learning, and women did take on roles as midwives, herbalists, physicians, and alchemists, thus sowing the seeds for women's entry into the medical profession, biomedical sciences, and chemistry in the 20th century (Alic, 1986).

The protestant reformation in the 16th century appears to have been a setback for women scientists in England. The reformation saw the destruction of convents which had been the main source of education and learning for women. Some of the money from the dissolution was used to found secular colleges in places like Oxford and Cambridge, but these colleges only admitted male students (Alic, 1986).

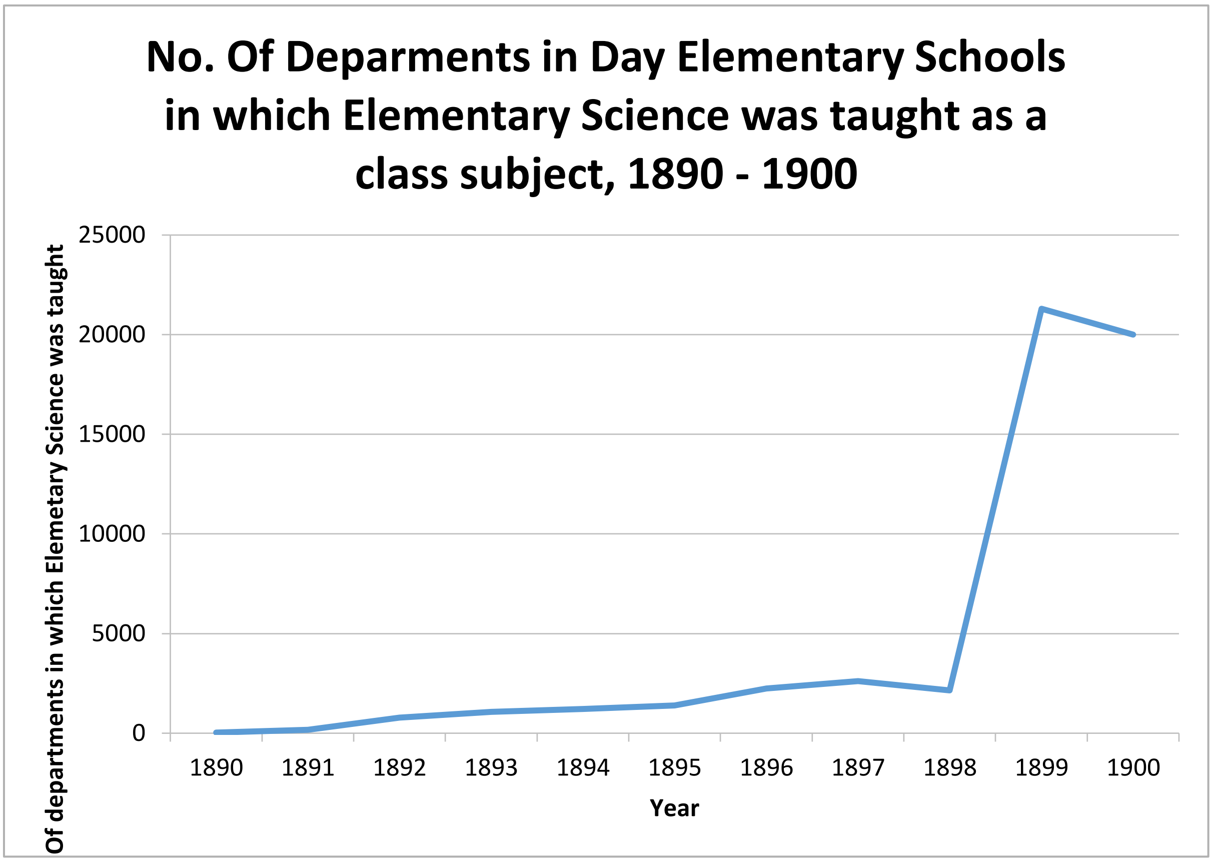
In the 18th century, the works of Newton were used to reinforce Biblical teaching and there seems to have been a symbiotic relationship between physics and the Church. God created the universe and so it was believed that a study of that universe would reveal the mind of God (Werthiem, 1997). Metaphors surrounding science were used to reinforce the authority of both science and the Church, for example, the use of the term 'law' e.g. 'laws of nature', 'laws of mechanics' (Keller, 1993). Few people, male or female received a formal education at this time; science was an amateur pursuit of the very wealthy. It seems that there was a conflict about women and science at this time. There was a school of thought that considered it improper for ladies to indulge in science, and ‘bluestockings’ were ridiculed in some circles. However, many scientific instruments such as pocket telescopes became popular amongst wealthy women and it became fashionable for these women to take an interest in science so long as their knowledge did not become too detailed or challenging (Alic, 1986). Mary Shelley’s *Frankenstein,* written at the beginning of the 19th century, was perhaps inspired by her exposure to popular experiments with electricity, for example.

During the 19th century, men and women were expected to conform to gendered roles with women working in a domestic environment and men usually working outside of the home. Women who went out to work usually had occupations that were linked to domestic life, with the majority being in domestic service. The 1851 census lists domestic service as the most common occupation for women, followed by clothes making or mending, laundering, and then nursing (Steinbach, 2013).

The 19th century saw a great expansion of education. Upper and middleclass girls continued to be taught by their mothers and or governesses with some going to finishing schools in their late teens. The curriculum was concerned with developing accomplishments that would affirm their status as respectable ladies and also the practicalities of running a home. It was the aspiration of middleclass parents that their daughters would not work but would instead marry a man rich enough to support them and enable them to devote themselves to the domestic duties of raising children and running the home (Steinbach, 2013).

More and more working-class girls went to elementary schools run by voluntary organisations such as the church (Steinbach, 2013). The Elementary Education Act of 1870 (Foster Act) required school boards to provide elementary education for both boys and girls in areas where there was not already provision. This was followed by the Elementary Education Act of 1880 which made education compulsory for children aged five to ten. By the end of the century, the school leaving age had been raised to twelve. There was no national curriculum, but in order for schools to gain funding, children were tested by the six standards of Lowe's Code (Gillard, 2011a). This led many schools to restrict themselves to the 'code' subjects known informally as '*The 3 Rs'* (reading, writing and arithmetic). The relaxing of this code seems to have led to an immediate rise in science lessons in elementary schools as can be seen in figure 2.6.

Figure 2.06: A graph showing the increase in elementary science lessons from 1890 to 1900.



(Jenkins, 1979, p. 20)

The Grammar School Act of 1840 (Gillard, 2011) allowed boys who had won scholarships to grammar schools (often ancient schools established from as far back as medieval times to provide education for able boys) to be taught science and literature in addition to or in place of the curriculum of Latin, Greek, and Hebrew. This reflected a growing recognition of the importance of science to trade and industry. No similar provision was made for girls who by and large did not win scholarships for grammar schools. Secondary education for girls was restricted to private seminaries for the wealthy.

The first quarter of the 20th century was a period of dramatic social change with women over 30 getting the vote in 1918 and the foundations being laid for the welfare state. Education expanded as did the range of occupations available to women. Clarke (1995) suggests that the Woman's Hospital Corps formed in July 1915 gave greater credibility to female doctors which increased in number by two thirds in the period after the First World War.

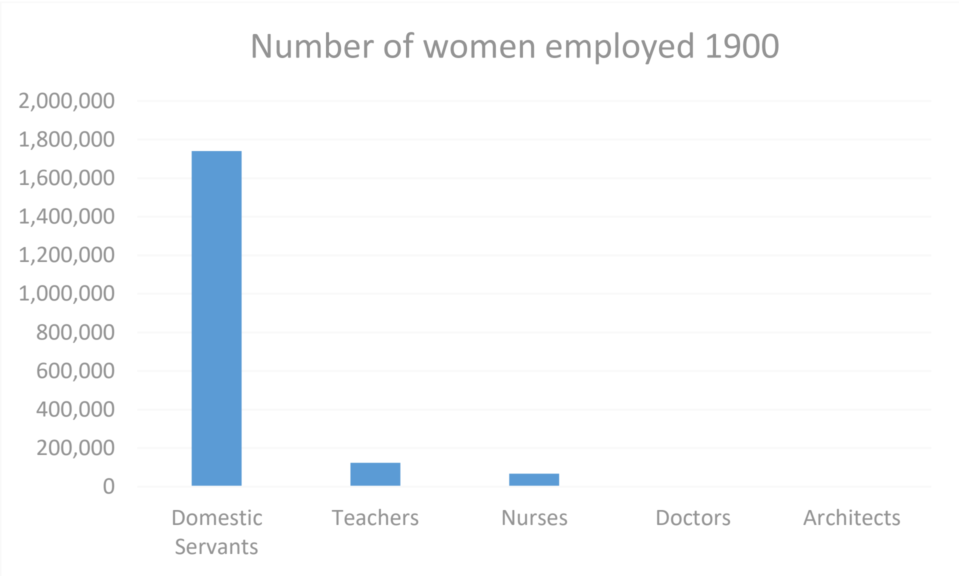
'Women's employment seems to have increased by nearly 1 ½ million during the war. The most significant change came in commercial and clerical posts; the number of women office workers doubled.' (Clarke, 1996 pp 94-5)

Women continued to face barriers to equal pay and to equal access to certain professions, despite the Sex Disqualification Removal Act of 1919.

The 1901 census suggests that around 80% of adult males were in paid employment as opposed to just under one third of adult women. As with the previous century, the majority of employed women were in domestic service. Nearly two million women were employed in domestic service compared to just two female architects. This pattern of work was disrupted by the First World War when many women took up traditionally male occupations to replace men who were serving in the armed forces. This included STEM based jobs such as working as mechanics for the specially formed Women's Royal Air force. At the end of the war, women were expected to return to their pre-war occupations and the Women's Royal Air Force disbanded (Clarke, 1995).

It seems that the role and perhaps even the aspiration of women at the start of the twentieth century was that of a house wife. This role was not considered work, and was not recognised as being an important part of the economy, according however the solution to high infant mortality, high death rates through pregnancy and childbirth related illness, and the labour intensity required to run a home without electronic gadgets was for women to devote themselves to unpaid domestic work upon marriage. Much of the paid work carried out by women prior to their marriages was in occupations related to childcare and homemaking such as domestic service (Clark, 1997).

Figure 2.07: A graph showing employment distribution of women in 1901 with figures based on the 1901 Census.

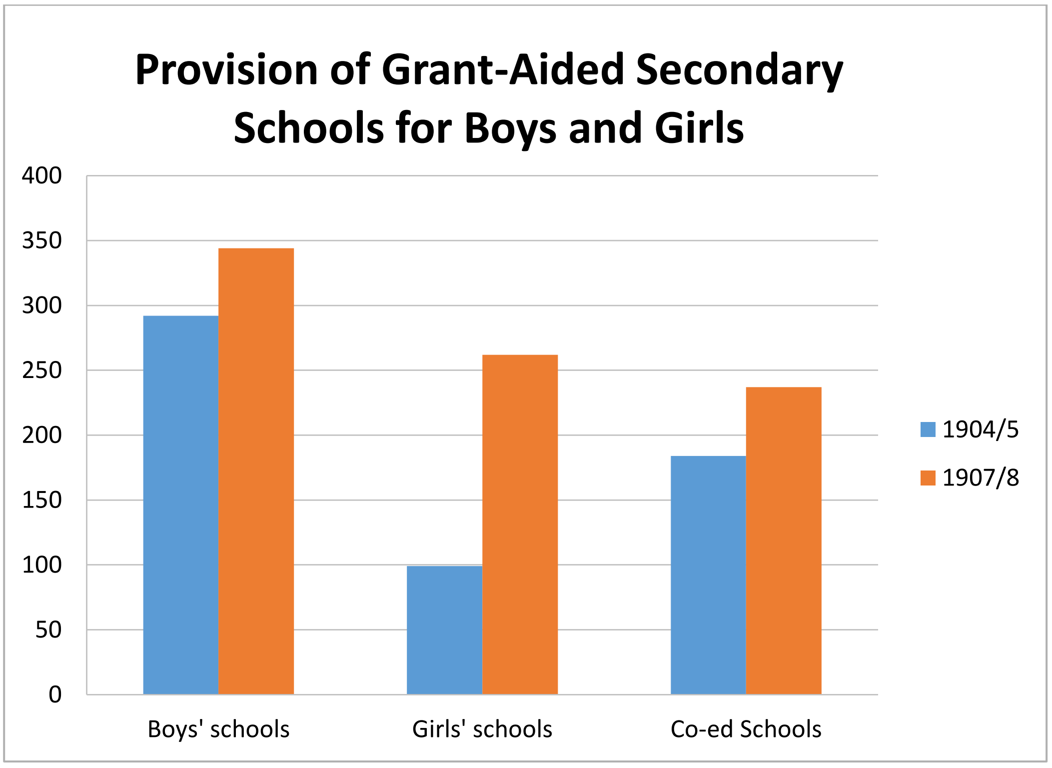


(National Archives, Gov. UK accessed 28th August 2016)

Secondary education expanded; the 1902 Balfour Act brought the responsibility of secondary education for both boys and girls under the control of local education authorities, and provided government grants for able children to attend secondary schools. These secondary school were classified as either ‘A’ or ‘B’ school. The ‘A’ schools received more substantial grants per student from the central government. These schools were obliged to provide a minimum of 13 hours of physics, chemistry, and mathematics each week whereas the ‘B’ schools were only required to spend nine hours a week on science and mathematics in order to qualify for grant aid. In this, the government was attempting to address the issue of the country’s poor performance against its competitors which it perceived to be at least in part due to the lack of science education. The ‘B’ schools followed a more traditional grammar school syllabus. In 1904, the system was revisited as there was a concern about the lack of literature and humanities being taught at secondary level, and schools received the same grants irrespective of the science humanities bias. Science and mathematics had to be taught for a minimum of seven and a half hours per week however to qualify for a grant (Aldrich, 2001). The school certificate was established to recognise achievement in secondary school.

Secondary provision for girls lagged behind boys but was improving as can be seen in the figure below.

Figure 2.08: A graph comparing secondary provision for boys and girls in grant aided schools in the early 20th century.



(Jenkins, 1979 p 172)

These figures show that over a three-year period the number of girls' secondary schools increased by 150%. This may have been in part to redress the balance as there was already a degree of secondary provision for boys.

About two thirds of the secondary school population were in single sex schools which allowed for a different curriculum for each sex. In 1923, the Report of Consultative Committee on Differentiation of the Curriculum for Boys and Girls in Secondary Schools suggested that girls were disadvantaged by the curriculum. Concerns were also expressed that the school certificate disadvantaged girls as traditional girls' subjects such as art and domestic subjects, were not included. However, girls were given the opportunity to sit the same examinations as boys for the first time (Aldrich, 2002).

The school leaving age was raised to 14 with part-time schooling being available for children over 14. The school certificate was introduced thus pupils were able to take public examinations at the age of 16 (Aldrich, 2002).

The 1926 Hadow report suggested that education be structured much as it is today with primary schools until the age of 11 and secondary schools from the age of 11. This report also paved the way for the later system on two tier secondary education with the establishment of 'modern' schools to run alongside grammar schools.

In 1924, Swiss psychologist Jean Piaget published *Language and Thought of the Child*, which eventually revolutionised educational thinking in this country.

The heuristic approach to teaching science, championed by Armstrong (Jenkins, 1979) was widely adopted. In this approach, the teacher places the student in the position of the discoverer or scientific researcher; the student is given a series of observations or measurements to take, and from these, is led to come to the same conclusions as those of established scientists. The science education of girls over the age of 12, if provided at all, seems to have been quite different from that which was provided for boys. Jenkins gives the example of Sara Burstall, headmistress of Manchester High School for Girls, complaining that the curriculum in girls' schools was already becoming unmanageable as girls were expected to study the traditional boys' subjects of mathematics and Latin alongside the girls' subjects. A further problem with the curriculum in girls' schools was that the school day was often shorter, allowing girls time to assist with domestic duties at home. Arthur Smithells believed that girls' science should be linked to practical everyday activities and that girls should study 'applied science of the household' rather than physics and chemistry. His opponents argued that the rigours of science could not be taught in this way. The 1918 Thomson Committee report noted large differences between the provision of science education for girls and boys in secondary schools. It seems that girls' schools were less well equipped for teaching physical sciences than the boys' school. If girls studied science at all then they were likely to study botany. A lack of opportunity for girls to study physics led to a lack of female physics teachers which then led to a shortage of female physicists in the next generation (Jenkins, 1979).

There was a rapid expansion in higher education with some colleges being given full university status and the establishment of new university colleges in Newcastle, Reading, and Southampton. Many of these colleges were established so as to improve the nation's knowledge of science and engineering. However, as their status improved, they moved towards more traditional classical education bias. The University Grants Committee was established allowing access to less wealthy students. Women students at the newer universities were able to receive degrees and in 1919, Oxford University followed suit (Aldrich, 2002). However, the position of women in higher education seems to have fluctuated as feminists and traditionalist battled to make sense of the social changes. Watts (2002) comments:

> *... Female students only gradually integrated into the full life of the university, despite assertions to the contrary. Supervised residence, countless rules and regulations sprang up to defend both the virtue of females and the spaces of male students*. (Watts, 2002 p.143)

The turn of the last century saw a revolution in physics. The birth of quantum theory, Brownian motion, the Bohr-Rutherford model of the atom, and of course, Einstein’s theory of relativity changed the content and practice of physics (Tallack, 2002). Physics was now even more closely aligned to complex mathematics; it was an abstract theoretical subject rather than a ‘hands on’ practical science. Wertheim (1997) notes that the scientists behind these developments were almost exclusively male. Popular images of the ‘mad scientist’, the antithesis of the feminine, appear to be based on Einstein (Wertheim, 1997). There were some women, such as nuclear physicist Lise Meitner (1878 – 1968), mathematician Emmy Noether (1882 – 1935) (McGrayne, 1998), and astronomer Henrietta Swan Leavitt (Tallack, 2002) whose contributions were largely unrecognised. In 1903, for the first time, a Nobel Prize in physics was awarded to a woman, Marie Curie, for her work on radioactivity. Since Curie’s success, radio-physics seems to have attracted a greater proportion of female students than other branches of physics perhaps finding it easier to establish themselves in fields with few established male precedents (M^{c}Grayne, 1998).

Summary

From the end of the 19th century to the beginning of the 20th century, there was much change for education and physics. Education has seen a major expansion, with more boys and girls having access to some form of secondary education. These opportunities came first for boys but by 1930, the places for girls were catching up. Much of secondary education was offered in single sex schools with a curriculum adapted to suit the expected career trajectory for each sex. Thus, boys studied subjects that would lead to work outside the home, perhaps in construction or manufacturing whereas girls were taught subjects that would fit them for a domestic life. Some girls were entering professions but by far the most common paid occupation for women was domestic service. Education was run on largely capitalist lines. The increase in science lessons at both elementary and secondary level was intended to boost industrial output once each cohort left school. Science was principally taught as a boys' subject as girls were not expected to work in industry.

It was an exciting time for physics as the secrets of the atom were revealed. Some of this important work was carried out by female physicists but much of their work went unrecognised and in some cases, was even accredited to their male colleagues.

The story of women, education and physics - 1930-1970

This period of time corresponds to the lives of the first generation of participants (the grandmothers) of this study from birth until they became mothers which happened between 1967 and 1971.

These forty years saw enormous change in the lives of women. Ward suggests that at the start of the 1930s, women who worked outside the home continued to be mostly employed in traditional female occupations such as domestic service or working as a shop assistant or factory hand. It was still expected that middleclass women who had managed to break into the professions would give up work on marrying until around 1960.

Yet on the eve of the Second World War the women's movement seemed to be in decline. Both economic depression and the achievement of equal franchise in 1928 contributed to this development. A revived 'cult of domesticity', associated with mass circulation magazines such as Woman, emerged during the 1930s. Marriage rates rose rapidly. The number of local branches of NUSEC dropped from 220 in 1920 to just 48 in 1935 (National Archives, 2014).

As with the First World War, the Second World War (1939 – 1945) required women to take on roles that were traditionally undertaken by men. It was during this time that part-time work, enabling women with children to work, became widespread. This practice continued after the war so that by 1950 about 20% of women were employed in part time work. Ward argues however that this was a mixed blessing for whilst it allowed women to carry on in paid employment after having children, it also restricted their pay and promotion opportunities. Following the War, the number of women employed in domestic service fell dramatically (Ward, 2008). Women’s entry into the workforce did meet with some resistance with many believing that the woman’s place was in the home. This feeling grew stronger in the 1950s (Clarke, 1997) and (Kynaston, 2010). However, a shortage of labour, particularly in low paid jobs, the birth of the NHS providing locally based work in areas linked to roles that women had traditionally done at home such as cleaning and care of the sick, improved educational opportunities, and the increase in time saving domestic appliances all contributed to the movement of women into the workforce.

Physics and engineering based jobs however remained in the realm of men (Ward, 2008).

Education saw many changes too; a series of Hadow reports recommended that the primary curriculum should be about activity rather than the acquisition of facts, that infant schools be separated from junior schools and that nursery schools be established (Cunningham, 2001). It was also recommended that the school leaving age be raised to 15 but this was postponed, when war broke out, until 1947. Towards the end of the 1950s and continuing into the 1960s, there was a lot building in primary schools:

‘*Classrooms became more flexible, allowing for groupwork and specialized activities such as creative work, scientific investigations and library resources.*’ (Cunningham, 2002, p. 18). There was, however, no requirement that primary schools teach science, and many did not.

The Plowden Report, 1967 had a huge impact on primary and nursery education. It was a comprehensive report; the committee gathered a range of evidence, primary school teachers were interviewed, photographs gathered, visits made to primary schools in Europe, USSR and the USA in order to make comparisons. The report also tried to incorporate the current understanding of child growth and development and was heavily influenced by the work of Jean Piaget. It looked at the inequalities of educational opportunity, how children of parents in low paid unskilled occupations fared less well academically than those of professional parents. It advocated a progressive, child-centred approach to primary education. It recommended the abolition of selective education at the age of 11 on the grounds that it restricted the curriculum and opportunities in primary schools as pupils were prepared to pass the 11+ examination. It also recommended the middle school system with children being in a first school until the age of 8, then a middle school between the ages of 8 and 12 with a largely topic based primary curriculum but augmented by specialist teachers and facilities for some subjects. Secondary school would then cater to the 13+ age group.

The Butler Act of 1944 put much of Hadow's recommendations into action and legalised the tripartite system that had been evolving during the earlier part of the century. Now education was split into primary (rather than elementary), secondary—which began at age 11—and further sections. Children were examined in their final year of primary education and based on their results segregated into grammar, technical, and modern schools. In many areas, the children were also segregated in terms of sex, and girls were then offered a different curriculum to their male counterparts with more emphasis on domestic subjects and the arts as opposed to mathematics and science (McCulloch, 2001).

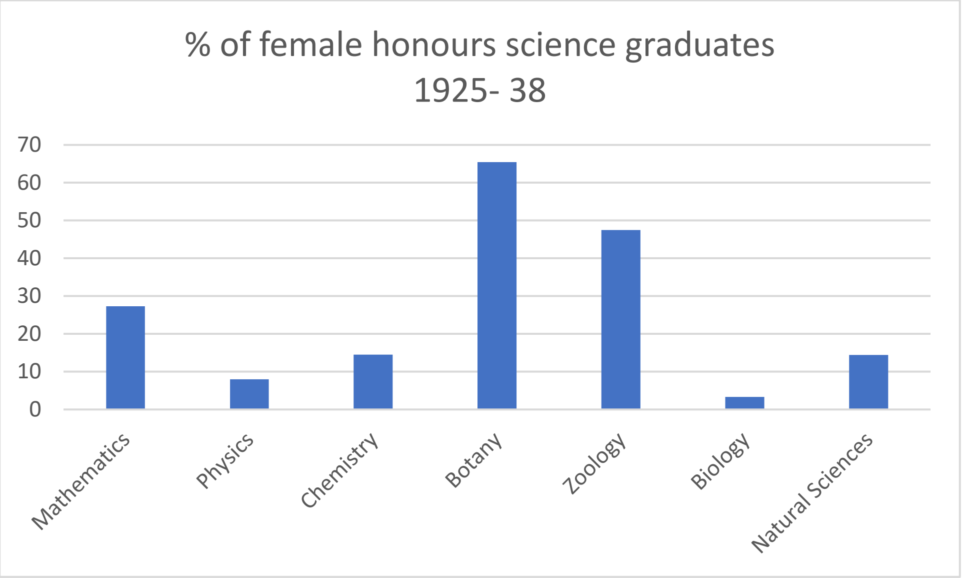
In 1951, the public examination system was overhauled, and the school certificate was replaced by Ordinary Levels to be taken at age 16 and Advanced Levels at age 18. The Certificates of Secondary Education (C.S.E.s) were introduced in 1962 so that those not considered academic enough for O' Levels could still leave secondary school with a qualification. This gave traditionally feminine subjects such as French and Arts the same status as the traditional masculine subjects of the school certificate (Wolf, 2002). Following the Plowden Report of 1967, LEAS were asked to investigate schemes to introduce comprehensive schools. The Crowther Report proposed a 20-year programme with a target of keeping half the population in full time education up to the age of 18. Educational opportunities were thus increased for both boys and girls although the curriculum was still gendered in practical subjects, science, and P.E. Most secondary education continued to be conducted in single sex schools (Gordon, 2002).

Higher education was expanded for both men and women. In 1948, Cambridge University admitted women to do degrees (Aldrich, 2001). In the late 1960s, many colleges were upgraded to university status and 30 polytechnics were formed. It was originally intended that polytechnics would provide a higher level of vocational technical education and enable Britain to compete with its main competitors the U.S.A and U.S.S.R. In practice, their humanities and social science courses proved equally popular. In 1969, the Open University received its charter thus providing even more access to higher education to both men and women and the opportunity to learn part time whilst working or running a home (Lowe, 2002).

In science education, the heuristic approach developed into the Nuffield approach of guided discovery. Students were taught biology, chemistry, and physics as discrete subjects. The underlying assumption, which was never tested, was that learning science was like doing science, and thus science lessons should replicate what happens in the industrial science laboratory (Jenkins, 1979).

Jenkins reports that in many girls' schools, the resources for and teaching of science were causes for concern. Domestic science was often taught in place of the traditional science as this was thought to be of greater relevance and interest to girls. However, concern was expressed by chemists in particular about the low standard achieved through this subject. In many girls' schools, botany had been replaced by biology or general science by the end of the 1930s. Not all girls were offered these subjects and not all were offered the opportunity to study science to school certificate level. At graduate level, few women were studying physics but Jenkins considers this no surprise given the lack of physics teaching to girls in previous decades and the resultant lack of physics teachers in girls' schools leading most girls' schools to offer general science instead.

Figure 2.09: A graph showing the percentage of female science graduates for the period 1925 -38.



(Jenkins, 1979)

This figure shows that few women were studying for physics degrees at this time but many more were studying zoology and botany. Biology was still very much a male subject but it was a very new academic discipline at this time.

The 1946 Barlow Committee on Scientific Manpower's report suggested a ten-year programme to double the number of scientists at universities. In 1964, the ministry of education became the ministry of education and science; this was as the result of a continuing concern about the standard of science education and the resulting perceived poor performance of the British industries (Alrich, 2002).

The war spurred on developments in physics. In 1942, Hahn and Strassmann were able to split an atom using nuclear fission. This led to the making of the atom bomb at the end of World War Two, and to the nuclear power station. Keller sees the making of the atomic bomb as a significant factor in putting women off physics (Keller, 1993). In 1946, the first general purpose programmable computer was made. Carbon radio carbon dating was first used in 1947, and the transistor was invented.

1948 saw the theory of quantum electrodynamics. It seems that the need to stay ‘ahead of the game’ in a military sense sparked off developments in the non-combative world too. Gerty Radnitz Cori won a Nobel Prize in chemistry in 1947.

In physics, there continued to be advances in astronomy. Drake began his project to use radio transmissions to attempt to communicate with possible alien civilizations. Quasars and named and studied and echoes supporting the ‘big bang’ theory were discovered. In 1967, pulsars were discovered although female doctoral student Jocelyn Bell received little credit for her part in this. The Apollo missions of the 1960s resulted in the first moon landings. There were also advances made in our understanding of the subatomic with the discovery of quarks and unified nuclear forces. Maria Goeppert Mayer won the 1963 Noble Prize in physics. A year later, Dorothy Crowfort Hodgekin won the Nobel Prize in chemistry (Tallack, 2002) (McGrayne, 2001).

Summary

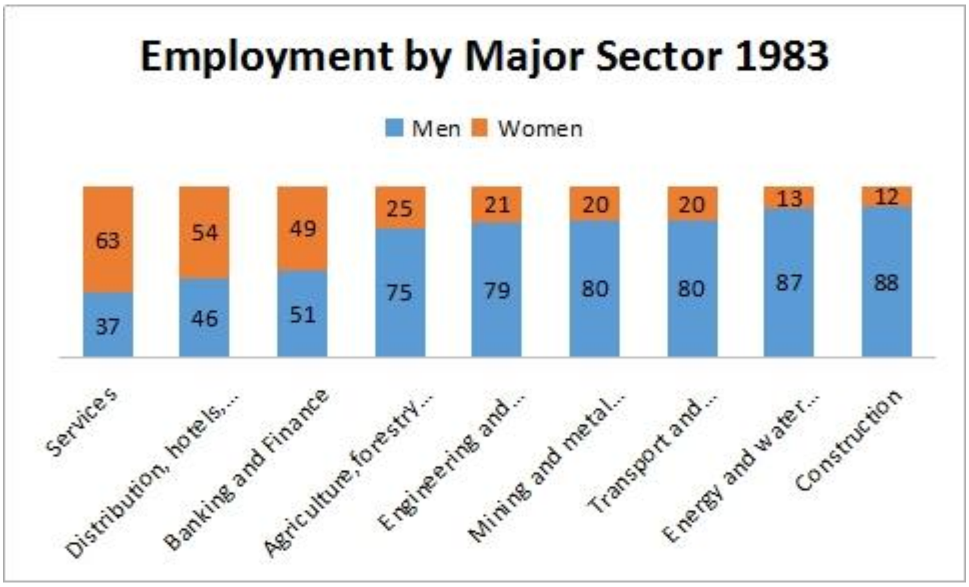
This time period saw many changes for women as they began to work their way into higher education. A change in economics and labour patterns meant that domestic service which had been the biggest area of employment for women had dramatically reduced. Instead, women were working in new areas such as the newly formed NHS and office work. The Butler Act 1944 saw the provision of secondary education for boys and girls up to the age of 15. This was delivered through the tripartite whereby children were sorted, according to ability at the age of 11and put into modern, technical, or grammar schools accordingly. The school certificate had been replaced by O’ Levels allowing for greater flexibility at age 16. The Plowden Report 1967 led to a move to more progressive education in primary schools. In physics, there had been many advances in astronomy culminating in the first moon landings and the ‘space race’.

The story of women, education and physics - 1970-2000

These 30 years roughly correspond to the time from birth to becoming mothers of the second or ‘mothers’ generation of this study.

The role and expectations of women changed throughout this period. In 1975, the Sex Discrimination Act was a further piece of legislation aimed at providing equality to women. Four years later, Britain had its first female prime minister.

Figure 2.10: A graph showing the relative proportions of men and women working in different employment sectors.



(Phipps, 2008)

The figures for the above graph have been taken from Breakwell and Weinberger's survey for the Manpower [sic] Services Commission as cited in Phipps 2008. As can be seen, women made up the bulk of the workforce in the service industry but only 21% of the engineering and vehicle manufacture workforce. All industries with high physics content, such as construction, employed very few women. However, the fact that this survey was commissioned in the first place suggests that the government was concerned about the situation and there were certainly a lot of initiatives in this decade aimed at changing the status quo.

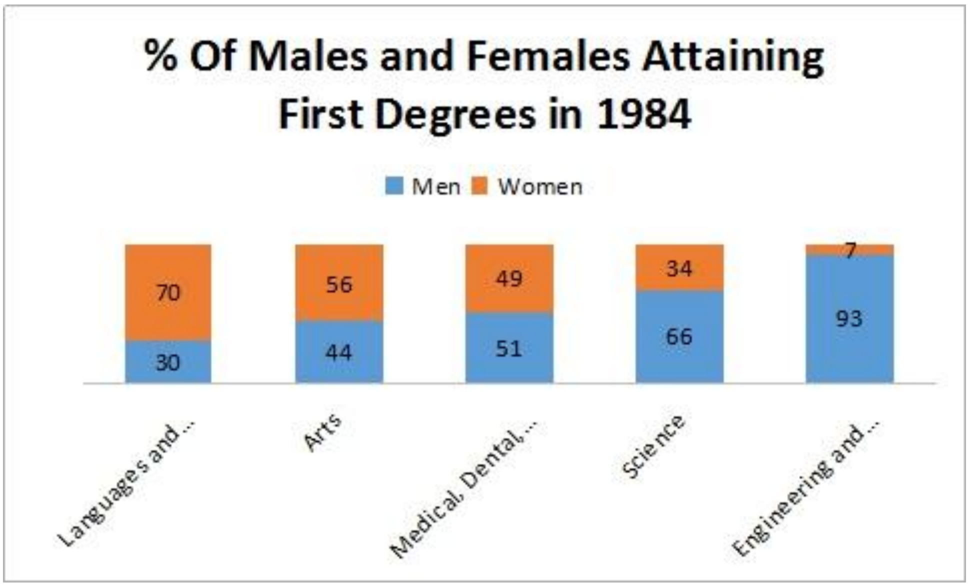
In education, the 70s saw a growth in the comprehensive movement. The tripartite system was abandoned in all but a few authorities. The 1976 education act compelled LEAS to introduce comprehensives. This was overturned by the Conservatives with a counter education act in 1979. James Gallaghan made his famous Ruskin speech in 1976 paving the way for the National Curriculum of 1988 (Aldrich, 2001).

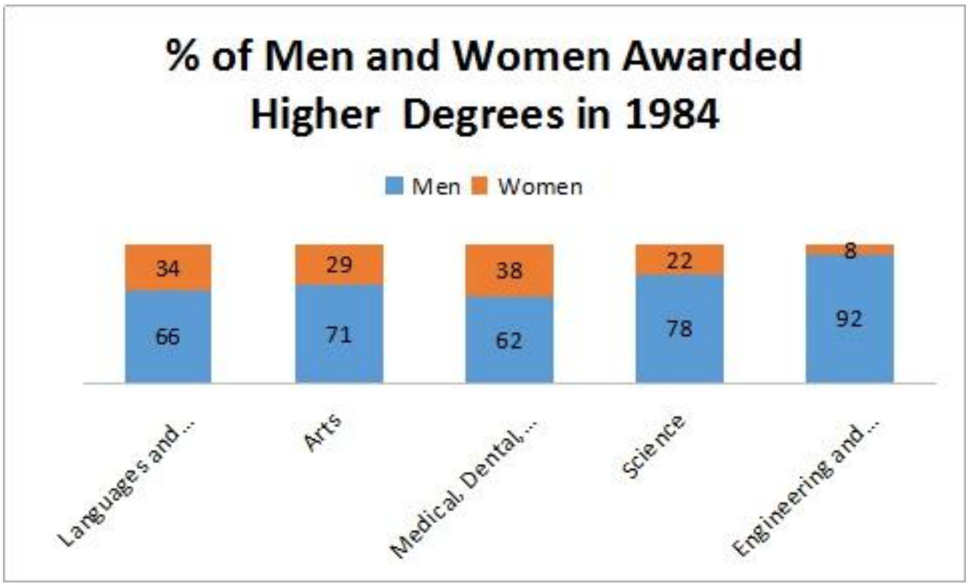
In education, there were lots of political activities. The most dramatic event was the 1988 Act which regulated the curriculum through legislation for the first time in British history. In the past, the government had exerted much influence on the curriculum through its system of grants and inspections but it was only since the 1988 Act that the government controlled the curriculum followed by children from the ages of 5 to 16 by law. There was also much change in the university sector; for example, life tenure for lecturers was abolished.

The equal opportunities act seems to have taken hold in education. The national curriculum made no distinction between boys and girls and the curriculum taught. From the age of 14 boys and girls could choose options and thus the possibility of girls and indeed boys either choosing of their own free will or being encouraged to choose certain subjects still existed but on a much more limited scope. Both boys and girls had to learn science from the ages of 5 to 16 and physics or ‘physical processes’ as it has been called, was an integral part of this.

The following graphs show the situation with regard to both first and higher degrees in 1984. These students were pre National Curriculum and would have completed their secondary and tertiary education in the 1970s.

Figure 2.11: Graphs showing the relative proportion of men and women students attaining first and higher degrees across a range of areas.



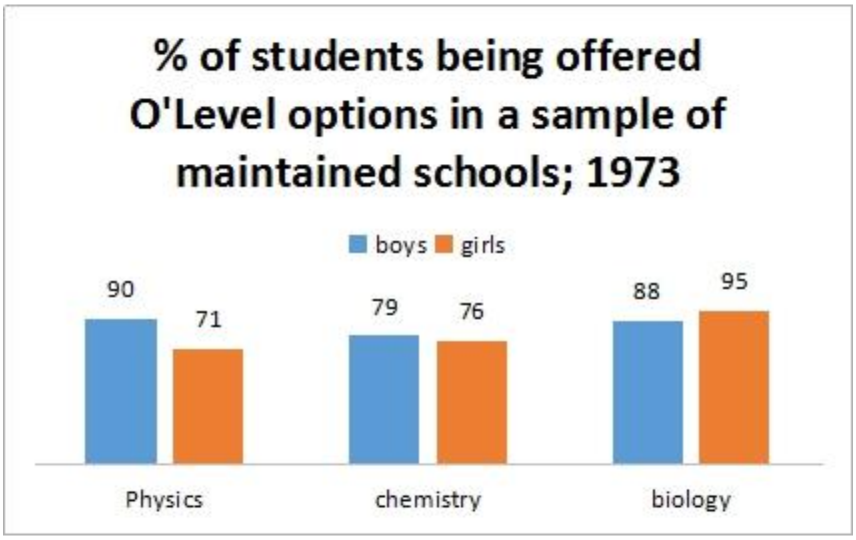


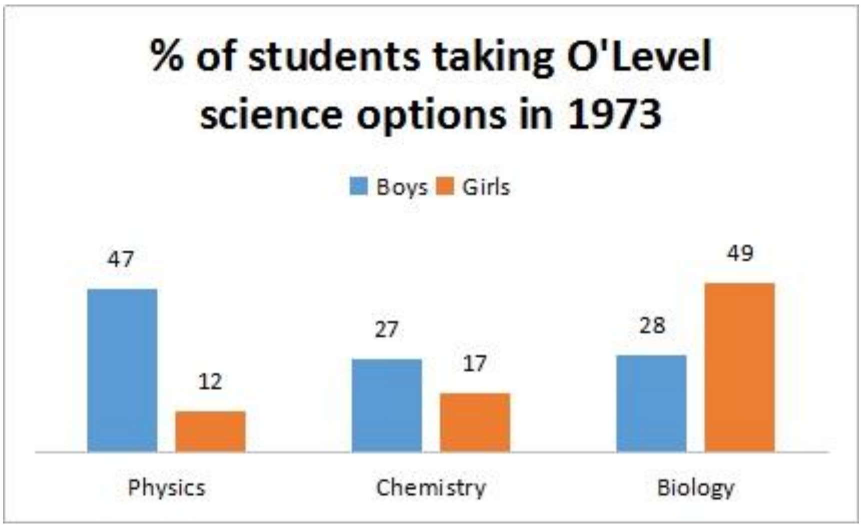
(Whyte, 1986)

At the higher degree level men outnumber women in every area. However, at undergraduate level, women dominate the language and arts courses. There are slightly more women on the health care related degrees than men, but the men outnumber women significantly in the science and engineering categories.

There were a number of developments in science education. The Nuffield system which had worked well with able students in the grammar schools was not so successful when introduced to less able students. Piaget's theories began to be applied to the teaching of science. The Nuffield combined science scheme was introduced for less academically-oriented students. Pioneers like Alison Kelly began to express their concerns about the inequalities in science education. The following tables show the percentage of girls and boys being offered O' Level science options and also the actual % of take up in these subjects. These graphs are taken from the results of a 1973 Department of Education and Science survey of a sample of maintained schools.

Figure 2.12: Graphs showing the differences in boys and girls science options at G.C.E. O' Levels in 1973.





(Kelly, 1981)

As can be seen, the opportunities for girls and boys to study chemistry were more or less equal but more boys had the opportunity to study physics, and more girls biology. Clearly, things had improved for girls in that they were not being fobbed off with domestic studies in place of science lessons, and boys were being given opportunities to study biological sciences but these opportunities were by no means equal. When it came to pupil choices, girls were clearly opting out of physics and boys biology. Overall, the sciences were not proving to be popular options for boys or girls in spite of the education system's attempts to promote science teaching for the masses.

Science education also underwent major revision. The 1988 act made it a core subject alongside English and mathematics. It was to be examined at the end of each key stage. Teacher assessment using prescribed resources was used at the end of key stage 1, but formal written tests or SATs were used at the end of the other key stages. During this decade, there seems to have been a lot of interest in trying to find out how children develop their understanding of science. It had been assumed that children learnt science by being mini scientists and emulating what went on in science laboratories. However, the findings of projects such as the S.P.A.C.E. project challenged this view and some teachers began using a constructivist approach.

Physicists made some more advances in astronomy; NASA explored gamma-ray bursts and Stephen Hawking furthered our understanding of black holes. Rosalind Yalow was awarded a Nobel Prize in psychology or medicine in 1977.

In 1982, the French physicist Alain Aspect was able to gather data that supported quantum mechanics over reality theory. Green and Schwarz developed String Theory. Shelton discovered a supernova in 1987 and the notion of self-organized criticality was also developed in this year. Three women were awarded Nobel prizes in science in this decade; the following were awarded prizes in physiology or medicine: Barbara McClintock in 1983, Rita Levi-Montalcini in 1986, and Gertrude Belle Elion in 1988.

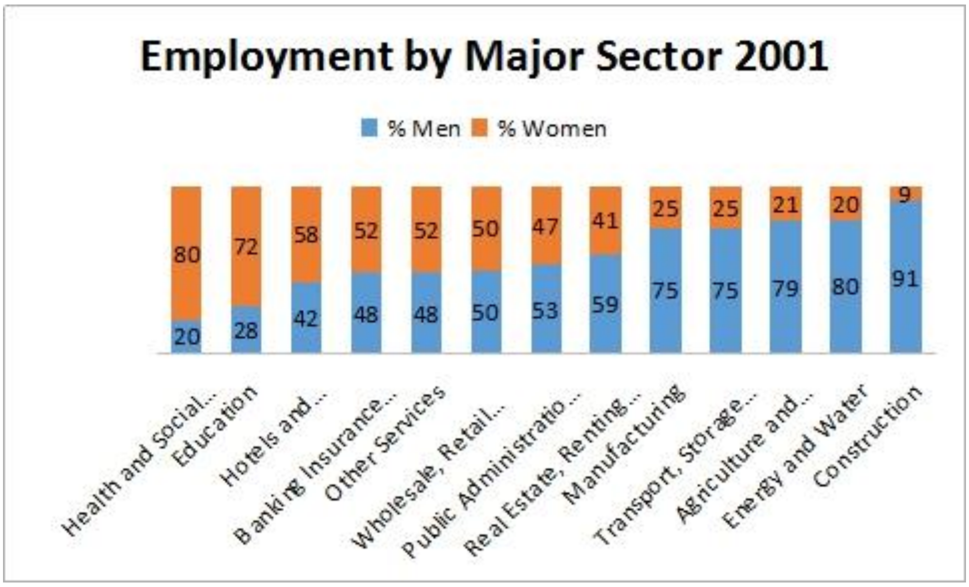
Summary

This period continued to show a polarisation in women's and men's employment. Higher education had expanded but was showing gendered patterns with women predominating in the languages, arts, and humanities, and men predominating in science and engineering at first degree level. For higher degrees, however, men were the majority in all subjects implying perhaps a glass ceiling for women. At secondary level, schools had largely moved away from the tripartite model towards comprehensives and primary schools had embraced much of Plowden's 1967 progressive ideals. However, there had been a backlash to the progressive movement sparked by the Gallaghan speech of 1976. At the end of this time period, there was a movement back from progressive methods; the National Curriculum had been implemented giving central government a much greater degree of control over schools. Science had become a core subject and physics as physical processes was a key component of this. As a result, all children in state schools were taught physics either as a discrete subject or as part of a general science course from the ages of 4 to 16. In physics, there were more advances in astronomy and quantum mechanics.

The story of women, education and physics - 2000 Onwards

This time period corresponds to the births of the participants of the third or 'daughters' generation of this study. The Office for National Statistics shows a continued increase in the number of women employed. Many women are employed in jobs below their qualification level, and many work part-time. Women dominate in 'caring' occupations such as education and healthcare whereas the reverse is true in areas such as construction.

Figure 2.13: A graph showing proportions of men and women in different areas of employment 2001.



(Office for National Statistics, 2013)

The National curriculum has undergone a series of revisions since its birth in 1988. Science is still technically a core subject and all students have to study science including some elements of physics from the ages of 4 to 16 with elements of science featuring in the nursery curriculum. However, science is no longer examined by standardised tests at the age of 11 and anecdotal evidence suggests it now has the same status as a foundation subject in the primary curriculum. It is nevertheless an integral part of the primary school experience whereas at the time the mothers' generation were at school few young children were offered the chance to learn science (Kelly, 1981).

Analysis by WISE shows that although boys are still more likely to take STEM subjects than girls, a higher proportion of girls get the top grades.

- 882, 251 boys chose Science, Statistics, Physics, Maths, Additional Maths, ICT and Design and Technology compared to 830, 853 girls

- A higher proportion of girls got an A* grade in Science, Statistics, Physics, Additional Maths, ICT compared to boys taking these subjects
- More girls took GCSE Physics, Maths, Additional Maths and ICT than in 2012. (WISE)

2.5 Curriculum

This educational story has taken place against a backdrop of rapid social change including universal franchise first for men and then women, an explosion of electronics and ICT and an unprecedented increase in the number of women, including married women earning an income outside the home (Kynaston, 2009). The evolution of the current school curriculum appears to be a complex process that is influenced by many factors as Daniels (2001) writes:

The development of the content, sequence and criteria of evaluation of the curriculum in school may be subject to many influences and pressures. These pressures may serve immediate political purposes and/or reiterate historical tradition. The extent to which cultural artefacts such as the school curriculum are structured with principles of learning and development in mind is open to speculation. (Daniels, 2001, p.121)

Similarly, Carr and Kemmis (1986) offer three different perspectives on curriculum development:

1. <u>Systems View:</u> Education is a commodity produced by the State and 'sold' to an increasing number of clients. Those clients who are more worthy either through their persistence, hard work, or natural ability gain more of this commodity. Their efforts are seen as an investment and are rewarded by higher status, monetary reward, and success than their less worthy peers. This view has echoes of Neo-

Darwinism and eugenics. From this view point, we see that the women of the second generation are given more opportunity than the women of the first, they work hard and their efforts are rewarded with better paid higher status jobs than those of their mothers. They are also better able to provide for their offspring giving them a head start as they engage in the education system. The second generation makes little progress in physics as it has not invested in this subject in the same way that is has invested in others. More investment in physics both by the educational provider and by the student as ‘client’ would have resulted in better results.

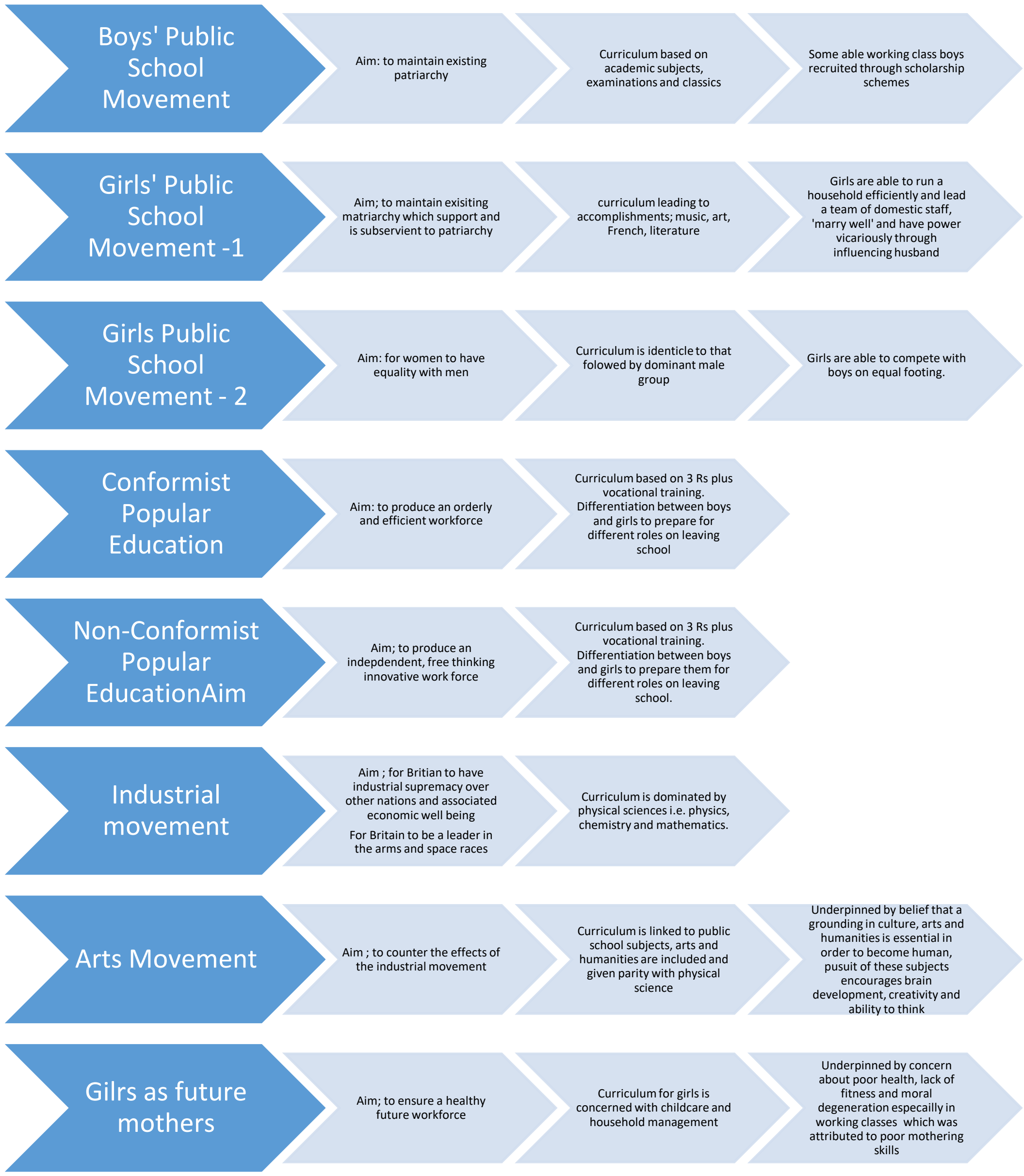
2. Humanist view: This view sees education much more in terms of the individual. It has to do with finding personal fulfilment and developing a high self-esteem. The learner takes ownership for his/her learning. It also has to do with developing human relationships and social structures. It is a view favoured by liberals and progressive educators. From this perspective, the women of the first generation of this study were given little opportunity to develop their own identities especially in the area of physics The curriculum offered to the second generation did not allow them to fit physics into a personal schema or set physics in a wider social context. As a result, they did not find their experience of physics intrinsically motivational and their self-esteem in respect of their ability in this subject appears to have been lowered how the third generation will view their experience of physics is yet to be determined.

3. Social-political view: This appears to be based on the work of Bourdieu. It looks at how the education process replicates the culture and society from one generation to the next. It sees education as the process by which power structures of dominant groups are maintained. From this perspective, it would be difficult for women, with their relatively low status, to break into the world of

physics which is still ‘owned’ by the dominant group of white middle to upper class males. The current school system offers women opportunities to study physics but these may seem tokenistic in light of the subtle and at ties overt forces at play which ensure the perpetuation of a relatively female-free culture of physics. (Carr and Kemmis, 1986).

The story of the 20th century science curriculum in England is an integral part of the on-going conflicts within the English education system(s). The overall trend over the century seemed to be an attempt to amalgamate a range of different systems and ideologies that had grown up largely independent of each other in the previous century and form them into a unified consistent system. Some of these influences have been illustrated in the diagram below, but this list is by no means exclusive. Furthermore, some of the categorisation is arbitrary; they represent extreme or pure positions whereas in reality, most views have elements of a number of these factors. This is a simplification of those influences as the real picture is too complex given the limits of this study.

Figure 2.14: The researcher's summary of key movements in education.



2.6 Summary

At a macro level, there are mixed and often conflicting messages about the relationship between women and physics. Some like Browne (2002) explain that the differences in taking-up of physics between men and women are as a result of biological differences and that this is the reason why the numerous initiatives over the past forty or so years have been unsuccessful in recruiting more women into physics and consequently physics or engineering based careers. Other researchers, such as Baron-Cohen (2004) agree that what may be true for a hypothetical average is not necessarily true for an individual and that therefore it should not be assumed that a woman will be unable to do physics by virtue of her sex. However, the data leading to such conclusions can be interpreted in different ways and may be as much as a result of differences in socialisation as evolution. Sociologists such as Bourdieu (1990) argue that human systems resist change and try to reproduce and maintain the status quo and that it is this rather than biological factors that resist change in power distribution thus keeping physics as a largely all male, white middle class preserve. Archer et al. (2012) largely support Bourdieu’s view but have found incidents of individuals resisting the cultural norm. Fausto-Stirling (1992) argues for a complex combination of biological factors interacting with sociological factors and it is the resulting combination that determines the outcome in the individual. All of these positions and a range of positions between exist within the culture of the macrosystem in which girls live and grow. In the view of Bronfenbrenner, all of these elements will influence the growing child to varying degrees and determine his or her identification with physics.

The exosystem of British Physics remains a predominantly male domain with many barriers making it difficult for women to break in. These barriers include reduced educational opportunities leading to restricted access, working practices that conflict with childcare responsibilities and a male culture that can leave women feeling excluded or isolated. There are examples throughout history of women, such as Joan Freeman (1991) who have succeeded in physics in spite of many obstacles and prejudices but in many case, this seems to have been at the expense of family life. If physics is to attract women, it seems it must change its identity, its working conditions need to become more female and family friendly, it needs to review its emphasis on cold objectivity and allow that good scientists may become passionate about their projects, it should exploit its relationship with humanity by stressing its contribution as a discipline to areas that are widely valued such as healthcare, energy conservation, and the environment. In schools, the curriculum should be further revised to place greater emphasis on topics that both girls and boys enjoy such as space, electricity, and radioactivity rather than an over reliance on forces and mechanics especially when presented in a vehicular context.

The chronosystem of the last century saw much change in terms of the role of women, the nature of physics and the education system. There are many different perspectives and value judgements concerning these topics within society and some of these are contradictory. It is then up to each individual woman to decide her role, her identity, and what her relationship with physics shall be.

Chapter 3; Methodology

1.1 Introduction and aims of this study

The first chapter gave a brief summary of the current situation concerning the underrepresentation of women in physics. Chapter Two explored some of the explanations given for this in related literature. This chapter will detail the methodology used in this study.

As outlined in previous chapters, this study's aims were:

1. to examine the opportunities two generations of women from three families had to become '*physics literate'*,
2. to understand of how a 'physics' identity may be developed or inhibited, and
3. to examine if any changes to the development of a '*physics identity'* occurred over the two generations studied and consider what further changes might occur in the next generation.

This chapter will continue with a reflection on the nature of sociological research in order to set the context for this study in section 3.2. It will then detail the particular methods chosen for this study in section 3.3 including a consideration of the ethical parameters of this study. Section 3.4 will reflect on the researcher's position within this study. The penultimate section, 3.5, will outline the structure of the specific study undertaken. This chapter will conclude with a summary of the main points discussed.

3.2 A Reflection on the Theoretical Basis for Sociological, Narrative, Biographical Research

This research is a sociological study of women's experience of physics which places it under the discipline of social science.

The word ‘science’, derived from the Latin ‘*scientia’* meaning knowledge (Glare and Stray, 2012*)*, has come to mean the systematic study of the physical world typically comprising physics, chemistry, and biology with their associated derivatives (Forsyth, 2014). As was discussed in Chapter 2, science has developed a particular methodology involving: deduction, observation, control of variables, and neutrality of observer or as physicist Marie Curie termed ‘*disinterestedness’* (Quinn, 1996). The word ‘scientist’ in common usage refers to a person who studies or works within these fields (Glare and Stray, 2012).

In the eighteenth century, thinkers such as Comte (Ormston et al, 2014) began to apply qualities and strategies developed in scientific research for the study of the material world, such as objectivity, neutrality, observation, and deduction, to the study of the social world, thus giving birth to the ‘*social sciences*'. As social science developed, however, it became apparent that the methods developed in physical science were not always appropriate when applied to investigating non-material concepts such as communities, societies, values, emotions, or culture (Ormston et al., 2014). There is some debate about the actual practice of science and whether indeed those engaged in physical science always follow the prescribed method as was discussed in Chapter 2, but in social science, there is a yet wider range of strategies, techniques, and practices. This can present a challenge for the social science researcher when ensuring the credibility, validity, and authority of his/her work (Ritchie, 2014).

One major difference between the study of physics and the study of sociology is that in physics, the physicist controls the environment in order to isolate the one variable to be studied whereas the sociologist attempts to study all the variables within a system in their natural setting, and places particular emphasis on the resulting interconnections (Ritchie, 2014). In most studies, were the sociologist to isolate and control variables in the same fashion as in a typical physics investigation, the very system to be studied would be destroyed. The challenge for the social scientist has been to devise a methodology that would enable the study of social, cultural, and human systems in a rigorous, truthful and meaningful way (Ritchie, 2014). As Ormston et al. (2014) illustrate, this challenge is on-going as it requires the simultaneous study of a wide range of complex factors including less tangible and concrete elements such as beliefs and values.

It follows from this that, unlike scientific research, sociological research will not necessarily give rise to universally accepted, value free, falsifiable laws. Unlike science, sociological studies do not always follow a prescriptive method but rather employ a range of investigative strategies tailored to suit the nature of the study (Ritchie, 2014). This poses a problem for sociological researchers: how can truth be established without adhesion to an agreed method of investigation? This problem is overcome by the researcher: having a clear understanding of his or her own philosophical position at the time of the study, operating consistently within this paradigm throughout the duration of the study, having a clear idea about the aims of the study, justifying the selection of research strategies used in relation to the purpose of the research and the presiding paradigm, and establishing his or her relationship to the research (Markula and Silk, 2011), (Creswell and Miller, 2010), and (Ormston et al., 2014).

At the time of this study, many social scientists, such as Creswell and Miller (2010) make sense of the range of sociological tools through a system of classification. Traditionally, sociological research was divided into quantitative and qualitative categories. Quantitative research typically follows a deductive process involving the collection of numerical or statistical data which is then analysed in support of a theory. In simple terms, qualitative research was any research that was not quantitative and encompassed the new methods developed by sociologists to study human aspects such as values that could not be investigated numerically. Silverman surmises, '*unless we use the negative criterion of being non-quantitative there is no agreed doctrine underlying qualitative research'* (Silverman, 2011, p.23). The qualitative investigation was primarily inductive process involving the collection of word or image data from which a theory could be constructed (Creswell and Miller 2010). Pearce (2012) notes historic tension between quantitative and qualitative research with qualitative researchers feeling required to justify their research according to quantitative criteria. As the social sciences began by applying agreed science methodology to the study of the social world hence the term social science, it is perhaps understandable why there has been some resistance to the adoption of new methodologies that fall outside the realm of conventional science. This concern can perhaps be countered by adopting a '*Wittgensteinian'* approach (Wittgenstein and Anscombe, 1973) to research. Wittgenstein's theory of 'Language Games' likens the study within different disciplines to a game with each discipline or 'game' having its own rules and language. If a person is engaged in one game, what he or she is doing may make little sense to a person playing another; applying the rules of netball to a game of chess would make little sense, for example. Following from this, the researcher must be clear what 'game' he or she is playing then use the language and play by the rules of that particular game. If a different researcher is playing a different game using different rules, this does not negate the work of the first researcher; what both researchers must do however is know which game they are playing and apply the rules of that game consistently. Using this analogy, qualitative research asks different questions to quantitative researchers. Therefore, qualitative researchers use different tools and language to their quantitative colleagues. Creswell and Miller (2011) liken this to looking at the world through different lenses. However, when carrying out sociological research it may be necessary to play more than one ‘game’ or develop an entirely ‘new game’ in order to gain a meaningful understanding of what might be happening. Any ‘new game’ still has value and credibility if it has rules and a language structure that are consistently and fairly applied.

Over the past thirty years, social science researchers have found that the complexities of studying human society and culture do not always lend themselves to observation through one method be it qualitative or quantitative (Bryman, 2006). Creswell (2009) suggests much can be gained by the use of mixed-methods. This involves combining numerical and word data from both quantitative and qualitative research. The justification for this is that it is thought to give a fuller picture of the phenomena or systems under study. It also gives researchers the opportunity to compare and combine results and thus validate findings. Creswell (2009) advocates the use of strategies such as triangulation, correspondence, and cohesion to combine and validate qualitative and quantitative data.

Although a self-confessed mixed-methods researcher himself, Bryman (2006) has some reservations about some of the recent research carried out using mixed methods as advocated by researchers such as Creswell (2009). His analysis suggests that many researchers find it difficult to distinguish between qualitative and quantitative methods and often assign their work to the wrong category. He also suggests that some types of data are incompatible with others or come from different and often contradictory paradigms and therefore cannot be combined in this way.

Ormston et al. (2014) question whether sociological research, with its relationship to changing cultures and beliefs, can be restricted to the neat categories as defined by Creswell (2009). They suggest that each study is unique and has to be specifically designed for its purpose rather like literary genre, students of literature can offer criteria for classifying texts into specific genre but often a particular text does not fit neatly into one genre but contains a mixture of several different types.

This study gathers only qualitative data, however, as the analysis shows, it does complement findings from more quantitative studies such as that of Murphy and Whitelegg (2002) and Kelly (1989). It is an independent qualitative study in its own right but a further test of its validity is the extent to which it supports existing research form other paradigms. It is interpreted and presented through the medium of biographical narratives. These terms will now be examined.

Put simply, a narrative is a story; it is an account of events real, imagined, or a mixture of the two arranged within a time framework to give meaning (Stanley, 2013), (Andrews, 2000), and (Denzin, 2014). It has to do with people/person, places/place, and time (Hamilton et al, 2008). There has been a growing interest in the use of narratives by social scientists as they can provide a point of access for aspects of human experience that do not lend themselves to empirical study such as perceptions, feelings, emotions, needs, and desires (Hamilton et al, 2008). There is a wide range of narrative genre such as myth, ballad, and legend; these are found in all human cultures, and yet the telling or writing of stories appears unique to the human experience and is not found in other animals (Stanley, 2013). It seems that the creation of narratives is something human beings have always done in order to make sense of their lives. Ricoeur (Ricoeur and McLaughlin, 2009) and Erben (1998) explain narrative as a human strategy for making sense of events time. Narrative has a beginning, middle, and an end. Through narrative, events are organised, sequenced, and linked together. In order to do this, a narrative has to be created or constructed from the interpretation of events. A narrative is not a neutral, unbiased regurgitation of facts as Andrews et al. (2000) explain, in narrative it is not the events themselves that are important but how these events are put together and interpreted to make meaning.

Biography then is creating a story or narrative about a person's life. The use of biography in social science is an example of how social science methods and preferences change over time. Erben (1993) states that the use of biography, as used by Wilhelm Dilthey is underused in social science; however, he notes that there is a growing interest following the work of Paul Ricoeur's work on time and narrative. Goodley (2004) and Merrill and West (2009) all note the rise of the biography both in popular and academic culture. Merrill and West (2009) suggest that this may be due in part to a sense of disconnection felt by many in a post-modern fractured culture; by creating biographies, people have a means of rediscovering what it is to be human.

In Merrill and West's (2009) view, biography can be used to fulfil a number of functions:

- it can give insights into a person's life over a period of time; by contrast, many quantitative studies, for example, gather data over a very short time period,
- it can give life meaning; e.g. take the analogy of children's clothes. Clothing manufacturers gather data and create sized clothing. Based on average figures, there may not actually be a child who fits these proportions perfectly. Manufactured clothes are bought for children according to best fit and may need

pleats and tucks in order to fit properly. In this way, a real child could be said to give meaning to the hypothetical averagely proportioned child generated by statistical studies,

- it can give voice to people who are marginalised or ‘lost’ by statistics
- it can give value to a specific human life

This study makes use of biography to tell a story about women’s experience of physics over a span of 80 years. It has involved the study of real women, giving them voice and value. Biography was chosen in order to complement the work of studies such as those of Kelly (1981), Murphy and Whitelegg (2006), and Phipps (2008).

As a form of narrative, a biography is a created arrangement and interpretation of events (Denzin, 2014) that tells a story which makes sense of a person’s life. Human life, however, is complex, and open to a possibly infinite number of interpretations, so as Denzin (2014) writes:

There is no single life story or self-autobiography that grasps or covers all that a life is for a person. (Denzin, 2014, p.55)

The question of how to find truth in biography has been one that has challenged biographical researchers. In his earlier work, Denzin (1989) described biographies as fictional accounts:

Ethnographies, biographies, and autobiographies rest on stories which are fictional, narrative accounts of how something happened (Denzin, 1989, p.41)

However, his more recent work clarifies this stance by explaining some of the different ways in which something can be true even though it may also have been created. A biography, according to Denzin (2014), is not a ‘real’ person: it is a creation based on the interpretation of how the writer has perceived that ‘real’ person. The only thing that can truly be the ‘real’ person is the actual ‘real’ person. Anything else pertaining to that person, be it a text, photograph, film, conversation, or painting, for example, cannot be the truth of that person, but it can point to or approach the truth of that person. Biography has several layers of interpretation: there is the first interpretation be it the observation of the biographer, the person’s own words—perhaps in an interview scenario or documents and artefacts concerning the person—then there is the second interpretation which is the biographer’s attempt to put the first interpretation or interpretations into words, and finally there is the interpretation of the reader who reads the written biography. Thus, in Denzin’s (2014) view, the reader is three steps away from the real person. Although a biography can never be the complete truth about a person, it can take the reader nearer to the truth and help him or her to make sense of the subject’s life in as much as it is able to reveal.

Denzin (2014) goes on to explain how a person’s life story will be made up of events that actually happened, these may be historical truths or facts that might be verified by documentation, facticities which Denzin describes as how the person experiences those facts, and fictions which are an imagined construction used to complete the narrative by which a person makes sense of his or her life. These fictions, however, are part of that life as it is experienced and or interpreted, and so in this sense become a truth of that person’s life.

Goodley et al. (2004) highlight some of the different approaches writers of biography might adopt. They describe emancipatory approaches where the voice is given to the participant or subject of the biography, ethnographic approaches where the biographer is the voice, participatory approaches where the participants have some input into the writing, and non-participatory where the actions of the participants are observed without any direct input. As with other aspects of qualitative work, these approaches may be combined and merged to create an even broader number of possibilities, thus making it possible to tailor the approach to suit the purpose. They argue, for example, that research aimed at improving the position of minorities is perhaps most effective when using an emancipatory, participatory approach, and that ethnographic work is more about giving the researcher a better insight into his or her own culture, and so is better carried out within the researchers own ethnic group.

It seems that sociological research is of a dynamic, organic nature thus allowing it to adapt to the beliefs and questions of the times and cultures from which it arises. Wertz et al. (2011) explain that qualitative research in particular, is a field of study that is continuing to emerge. Human society is complex and so its research needs to be tailored and designed to suit each project (Ormston et al, 2014). Sociological researchers do not have agreed prescribed methods that they can pull off the shelf and use for their studies in the way that a physicist may, but rather they have to design each research project individually. This means that the research methodology needs to be finely worked out in detail in order that it may be credible, validated, and held up for public scrutiny. Although each project may have its own method, there do appear to be generic criteria that can be applied to any project. Markula and Silk (2011) suggest that a good study should possess the following elements: a well formulated research question, be set within a paradigmatic logic, an explanation of sampling and sampling techniques used, a clear explanation of the methodological practices used, have the ethical issues identified and explained, a clear explanation of the analysis and interpretation of the resulting data, and an account of the researcher’s self-reflexibility. In addition, Creswell (2009) stresses the importance of knowing the lens through which the research is viewed. The lens may be that of the participants, the researcher, or the reader. These three groups also have a role to play in validating the research.

The next section will explain how this research meets Markula and Silk’s (2011) criteria.

3.3 Approaches Adopted for this Research

The aims of this study have been developed and refined as the study has progressed. From the onset, this study had the purpose of increasing the understanding of why, after years of investment, there had been little change in the number of women studying or working within physics. The specific research questions of physics literacy, physics identity, and changes in these across generations grew out of the analysis of the material gathered from the investigation as a result of interaction between the researcher, the participants, and the resultant transcripts as they were reflected upon and analysed. This places the research somewhere between an objective, deductive study where the questions or hypothesis are set at the start of a project and data is then collected to either prove or disprove the position and a subjective, inductive study where the aims emerge from interaction with the participants.

The Research Paradigm

Despite their different positions and range of research approaches adopted, there does seem to be some agreement about what constitutes social science research. Many social science researchers such as Creswell (2009), Ormston et al. (2014), and Markula and Silk (2011) agree that it is important for the researcher to identify his or her own philosophical position or the paradigm under which he or she operates as this will underpin the research undertaken from the forming of aims, ethical considerations, methods used, analysis and interpretation and outcomes.

This research is clearly of a social science rather than science nature as it is concerned with human perceptions and values rather than direct observation and measurement of material or physical phenomena (Ormston et al., 2014). It does not fit neatly into one paradigm, as is often the case with sociological research, as human systems are complex and do not always fit into discrete categories (Ritchie, 2014). The researcher comes from a tradition of radical orthodoxy (Wineland, 2005), a position which attempts to reconcile the certainties offered by logical positivism with a constructivist or interpretive approach. As with hermeneutics (Bauman, 2010), radical orthodoxy has its roots in theology but as a system for understanding beliefs and values it can easily be applied to other studies of human experience (Opderbeck, 2013). The radical orthodox thinker, like the logical positivist, believes that there is an external reality. However, unlike the logical positivist, the radical orthodox thinker believes that this reality is beyond the reach of human understanding. Instead, all that the individual human has access to are a few disjointed glimpses of this reality; rather like having a few pieces of a large puzzle. The thinker then uses his or her imagination to fill in the gaps and construct a picture of reality, where possible linking those pieces to pieces owned by other thinkers. The result is a reality constructed from fragments rather like a palaeontologist constructing a model of a whole dinosaur from a few fossilised fragments or an archaeologist constructing an ancient pot from a few broken shards. The result may not bear much resemblance to the external truth or reality and may be constantly refined as new pieces are uncovered or new ways of connecting the existing pieces are found. What is created is a reality that works and is meaningful within the context of place and time and approximates to the external truth but it is also temporary. This is the paradigm under which this study has been conducted. In this case, the fragments of reality are the participants' accounts of their experiences as revealed through interviews with the researcher, the interpretation put on these encounters by the researcher and the interpretation drawn from the literature review also by the researcher. From this, a reality has been constructed that is meaningful to the researcher. This ideology closely matches Denzin's (2014) understanding of biographical research.

Sampling

There are a number of recognised ways of selecting the participants or population sample that contribute to a research project. Different researchers ascribe their own labels to these sampling methods. Merrill and West (2009) identify criterion, theoretical, purposeful, and opportunistic sampling strategies.

For this study, opportunistic sampling best describes the sampling method adopted i.e. participants were selected by their willingness to participate in the study. However, there was an element of criterion sampling in that participation was restricted to women where two generations of the family were living in an area close to the researcher. Merrill and West (2009) cite this as a positive sampling strategy as the participants are likely to be enthusiastic and engage with the study thus offering up rich data. Conversely, Ritchie et al. (2014) who label this method convenience sampling argue that such sampling methods rarely produce reliable data. In this case, the data appears reliable in that it is believable and fits the historical context as described in the literature review. Through being opportunistic while restricted to women living within a certain location, the sampling naturally brought forth participants who were from a similar ethnic background and class making an ethnographic approach more reliable (Goodley, 2004).

Initially, it was planned to study three generations of women from three families in addition to a pilot study. This would have involved collecting data from nine women or girls for the main study. Three generations were chosen so as to cover the maximum timespan and opportunity to observe change over time. It was intended to gather data pertaining to the experiences of women from two previous school generations and then to compare them to the experiences of a generation experiencing school today. The study was to be limited to three families due to time constraints.

In practice, due to time constraints and the difficulty of finding willing participants the main study was limited to just two families. Data from the pilot study was then included in the main study so as to provide a broader perspective. Similarly, once the data was analysed it became clear that the data gathered from the third generation was of limited value. The participants from this generation were children who were too young to have made life choices concerning physics and it became apparent that the activities designed by the researcher did not give reliable information pertaining to the projects aims. The observations undertaken of the third generation interacting with the researcher and their mothers did however serve a useful purpose in introducing the researcher and participants.

Ethical Considerations

Bio/autoethnographers such as Denzin (2014), Ricoeur (2009), Merrill and West (2009) and Erben (2000) take the Aristotelian view that every human life is of value. It can be argued therefore that the very engagement in biographical studies is intrinsically ethical as it ascribes worth and value to the life under study. That being said it is important that the life or lives under scrutiny are not harmed physically, emotionally or by reputation (Silverman, 2011).

Ensuring the wellbeing of the participants and the communities they represent can be more complex than it initially appears; Silverman (2011) raises concerns about how research findings have the potential to reinforce racial stereotypes for example, interview questions may have a negative cultural bias and the responses of the interviewees may be deemed racist. In the latter case the researcher is faced with the dilemma of fairly representing the views of the interviewees against promoting an unethical and potentially harmful opinion. The possible difficulty with this particular project is its potential to reinforce sexual stereotypes particularly around the issue of women in science. This is something the researcher is aware of and has tried to counter throughout this study whilst at the same time not avoiding challenging or uncomfortable evidence.

Merrill and West (2009) warn of the potential for exploitation especially where there is a power imbalance such as adults researching children. They stress the need for equality between the researcher and the participants and ensuring that the participants' voices are heard. In this research the children's parents were present at all times when children were involved and were able to speak on their behalf. The researcher led the interviews but other than in the case of the pilot study did not know the participants and so the participant had control of any knowledge that was shared. In all but one incident, the interactions between researcher and researched took place within the homes of the participants i.e. a place where the participant felt comfortable and had control. All of the adult participants were articulate and all bar one gave the appearance of confidence. One participant lacked confidence at first but appeared to relax into the interview as it progressed. The participants were given the opportunity to read through and correct the interview transcripts before they were analysed and so had a measure of control about what material was used. These factors served to make a more equal relationship between the researcher and the participants.

All of the participants were given anonymity by selecting pseudonyms for themselves. The texts were further made anonymous by removing specific place names. Confidentiality could not be provided as this work will become the property of Southampton University, will be seen by assessors, and could potentially be viewed by other students. This was made clear to the participants at the outset. However by anonymising this text, the identities of the participants have been protected. The negative aspect of this is that the participants who have contributed so much to this work have not been acknowledged by name or received any credit for their contribution other than the thanks of the researcher.

Throughout the research the researcher has aimed to be transparent with the participants. At the start of the project the adult participants were given a written outline of the project, its aims and potential audience (see Appendix 2). This information and accompanying discussion enabled the participants to make an informed choice regarding their consent to participate in the project. To confirm this, the participants signed a consent form. The right to withdraw from the project was also emphasised.

The researcher came from the same ethnic background, class, and gender as the participants. This enabled her to make a connection and establish trust. This trust is evident in the detailed responses given by the participants, which the mothers' generation were happy to invite their mothers to participate following their own interviews and in the way that the most anxious of the participants became more relaxed as the interview progressed. Crucial to establishing this trust was the observation phase of this investigation. This had been included to gather data concerning the children's generation. In this, it was unsuccessful and the material was not used however the observation did allow for the researcher and participants to introduce each other and to feel comfortable in each other's space.

Before carrying out this research, approval was sought and granted by the University's Ethics Committee (see Appendix 1).

Data gathering - Observation

As mentioned in the discussion about ethical concerns, the data gathering began with a videoed observation of the mothers and their children in their family home setting. This had initially been intended as a data gathering exercise with particular emphasis on the children's and mother's relationship with physics. In this, it was unsuccessful. What it did achieve, however, was establishing a trusting relationship between the mothers and the researcher. Interacting with the children in the home setting was a natural activity for the mothers and led to general discussion about the research project in a relaxed way. This set the scene for the next step in the cycle i.e. the interviews with the mothers.

Data Gathering – Semi-Structured Interview

Erben suggests: *the collection of contemporary data through interview is one that is especially useful to educational and other social science researchers* (Erben, 1989, p.5)

Interviews were chosen as the data collection method as it was felt that this would be the most effective way of gathering detailed information about the women's lives, how they perceived their lives and how they felt about their relationship with physics. It was felt that other strategies such as using a questionnaire would not have given the in-depth information required for this study. The interview, in allowing for interaction between the interviewer and participant, provided an opportunity for a degree of shared understanding to be reached. By being a face to face encounter in a home setting, it enabled a rapport to be established between the interviewer and interviewee which improved the richness of the data as Benney and Hughes suggest:

… but in the research interview at least ... the assumption is general that the information is the more valid the more freely it is given (Ibid,1970 p.194)

Interviews can be classified into three main categories i.e. unstructured, semi-structured or structured. An unstructured interview, as is often favoured by grounded theory researchers has the advantage of being led by the participant. The disadvantage is that the participant may not know what to talk about and give short answers restricted answers. The lack of direction from the researcher in this situation can make the encounter uncertain and stressful for the participant. The structured interview directs the participant enabling specific data to be elicited. The disadvantage of this is very much controlled by the interviewer and does not allow for the participant to give information freely. The semi-structured interview was chosen for this exercise as it provided pointers for the conversation ensuring that certain topics were discussed in some depth whilst still allowing the participant freedom to take the conversation in their own direction.

Data Analysis

The data was first audio recorded in situ. It was then transcribed. Once transcribed it had become a text and as such it could be interpreted and analysed (Lindseth and Norberg, 2004). The analysis of this text became a compromise between a grounded theory and a phenomenological hermeneutical approach, the grounded theory element being an attempt to let the text lead the research rather than the research lead the text and the hermeneutical phenomenological approach being an attempt to discover meaning within the text.

The first phase of the analysis was constructing a concept map for each script in order to identify the key concepts revealed and the relationship between these concepts. This involved reading the texts, identifying key words or concepts, writing these on a diagram or map and then drawing links between the words. These words and their links were then further connected by adding a colour code to recurrent themes.

The second phase of the analysis was to return to the transcribed interview scripts and add the colour coding from the concept map. This highlighted the frequency that themes were recurring and presented a visual image of the pattern of themes within the text.

The next step was to decide which themes were the most crucial in illuminating the research aims. These themes were selected as the themes to be explored further. The other concepts were then reorganised and fitted into the major themes selected. This information was then tabulated. An example of how this was done can be found in the next chapter.

Validity

Creswell and Miller (2010) suggest the following strategies for establishing validity: member checking, triangulation, thick description, peer reviews, and external audits. However, Ormston et al. (2014) recommend that a qualitative research project be validated by its trustworthiness and authenticity. They identify credibility, transferability, dependability and conformability as indicators of trustworthiness and fairness, enlargement of personal construction, improved understanding of the constructions of others, stimulation of action and empowered action as indicators of authenticity. Ritchie et al. (2014), Merrill and West (2009), Denzin (2014), and Erben (2000) share the view that the product of qualitative research must be meaningful.

This study meets several of these validity tests which will now be outlined.

The stories of the participants are meaningful in that they can be understood and interpreted by others. The analysis of their stories is also meaningful in that it fits into a wider picture of physics experiences such as those highlighted in the literature review. The stories and analysis have been examined in a Bronfenbrenian medium which gives them additional contextual meaning.

The transcripts of the participants were checked by the participants and minor alterations made thus these scripts were reliable constructions when viewed through the lenses of those participants. The transcripts are a verbatim account of the interviews undertaken. They illustrated a detailed and in depth conversation allowing the participants to describe their experiences at length giving them further confidence. Readers of this work will have their own perception as to the extent to which these accounts ring true and are meaningful. Thus, the readers present a further validity test.

With more time, better use could have been made of triangulation, perhaps supporting the participants' stories with documentary evidence such as school reports and text books from their school days, photographs, and anecdotes from friends and relatives. The stories have been set in a time frame and links have been made to reported historical events and this adds further validity to the findings.

The trustworthiness of the data can be demonstrated by its credibility. The stories of the women's lives are believable and conform to the historical contexts in which they have been set whilst retaining individual experiences and perceptions that confirm their reality. The transferability is evident when comparing the women's stories with those of the other participants from their generation. Much of the women's narrative can be confirmed with reference to the historical account in the literature review.

As will be demonstrated in chapter 6, the researcher's personal construction has been enlarged by undertaking this project, similarly light has been shed on the constructions of the participants although this is an on-going process that can never be completed. A concerted effort has been made to present the stories of the women involved fairly particularly in terms of their opportunity to check the scripts and their right to withdraw. There is not much evidence of empowerment although chance conversations with two of the participants since have indicated that they have reviewed their life and future direction as a result of the interviews; the women involved were all busy devoting their lives to families and work, the interview provided each with a chance to reflect on her own life and actually take some time to consider her own needs and aspirations. The voices of the participants have been interpreted and presented from the researcher's perspective, rather than from their own. In hindsight, the researcher could have involved the participants more in the interpretation, editing, and presentation of their stories. However, the fact that the stories were listened to and interpreted gives them value and in this the research, can be said to be authentic.

The rigour of this study comes in the construction of the women's stories. This construction is based along Vygotskian lines. Each participant brought her interpretation of her life to the project. The researcher has reinterpreted these alongside sharing something of her interpretation of her own life. These interpretations have then been added to the body of knowledge acquired through the literary review and used to construct a new interpretation of these women's relationship with physics.

3.4 The Researcher's place in study

In contrast to quantitative research, where as far as possible researchers attempt not influence or interact with objectively gathered data, qualitative research relies on the interaction between researcher and participant, the personal and subjective and intersubjective interpretations of those interactions and subsequent constructions (Merrill and West, 2009). In order to do this effectively the researcher must reflect on his or her practice and role in the research, she/he must identify his/her perspective, the lens through which the research is being viewed and interpreted (Gilgun, 2010). The '*Curiean* disinterestedness' which some consider important in scientific research is not always achievable or desirable when working within social science according to Bourdieu:

'If the sociologist manages to produce any truth, he [sic] does so not despite the interest he has in producing the truth but because he has an interest in doing so - which is the exact opposite of the usual somewhat fatuous discourse about neutrality.' (Bourdieu, 1993 p.11)

To this end, I will now attempt to place myself, the researcher, into this study.

I am a 48-year-old female, white, British, and the mother of two children. I am also an experienced primary school teacher who has recently changed the direction of her career and currently teaches young adults with severe learning difficulties. I am of primarily Anglo-Saxon origin, but with some French and Scandinavian ancestry.

My age and background are very similar to that of the second or 'mothers' generation of participants in this study and has also enabled me to relate to the first or grandmothers' generation as someone similar to their daughters and to the third or daughters' generation of participants as 'friend' of their mothers or as a teacher like their teacher. This strong identification with the participants led to relaxed and productive interviews as there was a strong sense of us understanding each other and speaking the same language. One potential drawback of this is the tendency to over identify and assume that the participants will have identical experiences, interpretations, and constructions to myself. Throughout this research, I have attempted to compensate for this by rigorous reading of the data, checking that any claims I have made can be traced directly back from the utterances the participants rather than my interpretation of the same and by allowing the participants to read the research and make amendments.

As a former primary school teacher, I was a science subject leader, and came from a science background of science A' levels and a bachelor of education degree with chemistry as the main focus. My interest in science began as a young child and I believe was heavily influenced by my family background: both of my grandfathers, my father and two maternal uncles were electrical engineers my father and paternal grandfather specialising in telecommunication. My main reason for choosing to study science at ‘O’ and then ‘A’ level was my ambition to become a medical doctor. My experience of physics at secondary level was largely positive although I did not enjoy the subject as much as chemistry and biology. On leaving secondary school, my grade in physics was equal to my grade in most other subjects; I achieved a higher grade in history and a lower grade in music and English literature but in all other subjects my grade was the same. This would indicate that, at this phase of my education, my ability to study physics was on a par with my ability to study other disciplines. At A’ level however I struggled with physics finding it much harder than chemistry or biology. I felt uncomfortable in a predominantly male class, there being only one other girl alongside me continuing into the second year of study. I left tertiary education with an E grade in physics and D grades in biology and chemistry. Although there was only one grade difference between my performance in physics and the other subjects my perception was that I was much less able in physics. Instead of going to university to study medicine as I had planned I went to a polytechnic to train to be a teacher. The sense of failure I felt has a result of this has stayed with me all of my adult life; I remain uncomfortable when I have to declare my A level grades on job application forms. One motivation for undertaking postgraduate study has been the desire to compensate for my perceived poor academic performance at aged 18 and to prove to myself and others that I can succeed academically. Realising that my experiences of physics may not be unique and that there may have been other factors besides lack of natural ability that contributed to my performance has given me a very personal interest in this topic and I am conscious that my need to find explanations other than lack of ability is a strong bias in this study.

Coming from a biological and physical science background most of my learning to date has come from a logical positivist, objective, quantitative stance. I have had little experience of social sciences and no first-hand experience of using qualitative methods prior to this study. Learning how to collect and interpret qualitative data and thus narrowing a large gap in my knowledge and understanding has given an additional purpose to this study. Conversely, I am conscious that my lack of background and experience in this method of study has resulted in a less polished and sophisticated result that that which could have been produced by a trained and experienced qualitative social science researcher. At times my need to learn and master new skills has been to the detriment of the quality of this research.

3.5 The Structure of the Study

This study consisted of the following phases:

1. selection of participants,
2. a video recorded observation of each of the mothers with their children,
3. an audio recorded semi-structured interview with each mother,
4. an audio recorded semi-structured interview with each grandmother,
5. transcription of the interviews and observations, and
6. analysis of the resulting texts using concept mapping, colour coding into themes.

These phases were followed in three cycles: the first cycle being the pilot study involving a family identified as the Lloyd-Boots, the second cycle being the first family of the main study who have been given the pseudonym ‘Walker’, and the third cycle with the second family of the main study who for the purposes of this study will be known as the Disneys.

The video recordings of the interactions between the researcher and a parent with children took place in each of the family's home setting. The audio recorded semi-structured interview between the researcher and each of the mothers took place in each of the mother's homes. The audio recorded semi-structured interview between the researcher and the first grandmother took place in her daughter's i.e. the mother's home and interview between the researcher and the second grandmother took place in the researcher's home at the grandmother's request.

3.5.1 The Pilot Study - Cycle One: the Lloyd-Boot Family

The pilot study began with an observation of a family well known to the researcher. The purpose of the observation was to ascertain the family members' current identity with physics. This family was selected as it was willing to help the researcher but it was felt that the family was too close to the researcher for reliable data to be collected for the main survey. The family consisted of the father, Melvin aged 44, his daughter Jane aged 13 and his son Ben aged 5. A video recording device was set up in the family's dining room. It was intended that this observation would take an hour it actually took an hour and a half with one activity being cut short in order to complete the tasks within this time. The family was video recorded taking part in the following activities under the direction of the researcher: drawing pictures of a physicist named Alex, sorting photographs of faces into occupations, creating a concept map.

A sample of the materials used for this has been included in Appendix 3.

The first task was to draw a physicist called Alex. This fictional physicist was based on the real physicist, Dr. Joan Freeman (Freeman, 1991). The pseudonym 'Alex' was used so as not to ascribe a particular sex to the physicist. At the time this study was undertaken the name Alex was commonly given to both girls and boys and the family knew Alexes of both sexes. The task was, after a brief introduction, to draw Alex and then write or draw the toys that Alex might have played with as a child. This led on to a discussion about the toys the children of the family played with and whether or not toys were gendered.

For the second task, the family was presented with a selection of face photographs that had been downloaded from the Internet. They were also given a table with different occupational headings. The participants were then invited to assign each face to a job from the table and stick them in place.

The final task was to construct a concept map about science with the researcher.

Melvin, who was very well known to the researcher, was clearly uncomfortable with the tasks set and his results could not be relied upon. The children responded positively to the tasks set and seemed to enjoy doing them. The biggest problem with this activity was the time it took. The playing element had to be cut short as the tasks had taken well over an hour. The concept mapping activity was unfamiliar to the group and so it was very much lead by the researcher. As a result it was felt that it did not give a true reflection of what the family felt. The photo sorting activity did show some interesting results in that the children did not seem to show a strong gender bias. They tended to use examples of relatives when ascribing faces to professions thus as their mother is a teacher women were selected as teachers, as their father was the principle carer and homemaker they chose men for this role. Some of the professions they had no idea about, and so the results were quite random. On balance it was decided that the children were probably using other factors in addition to sex when ascribing the faces to a role. It was considered whether to repeat the exercise using male and female symbols, but in the end, this idea was abandoned purely because it was felt that for ethical reasons it would be unfair to observe participants for more than an hour. From this observation it was decided that for the study the tasks should be limited to the ‘Alex’ exercise and a toy sorting and playing activity. It was hoped that this activity would also serve as an introduction to the family and give the researcher an opportunity to build a relationship with the mother who would then be the interviewee in the second phase.

The second step of the pilot study was a semi-structured interview with Lynne, the aunt of the children who participated in the pilot study. At the time of the interview, Lynne was a pharmacist in her forties who was well known to the researcher. Lynne was approached directly by the researcher and invited to take part in the pilot study. She was very willing and enthusiastic in her participation and has continued to show an interest in this project. Following the pilot observation with the family well known to the researcher, the researcher was concerned that similar difficulties might be encountered in this interview with both the participant and the interviewer finding it hard to put their relationship aside and take on these different roles. In practice, the interview went very smoothly with no apparent awkwardness on either side.

The interview took place in the living room of Lynne's family home. It was recorded on a digital audio recorder. The interview lasted 53 minutes. The questions for this interview can be found in Appendix 4. Before the interview began the purpose of the research and its audience was discussed with Lynne as were the steps taken to ensure anonymity. Lynne chose her pseudonym appeared to understand the purpose and nature of the research. She was happy to sign the consent form. Lynne adopted a relaxed pose on her sofa while the researcher sat on the floor opposite her, resting her interview questions and digital audio recorder on the coffee table between them. After the interview the conversation between Lynne and the researcher was transcribed by the researcher and sent to Lynne. Lynne made some minor corrections and then the script was ready for analysis.

As the interview went well and produced rich data, it was decided not to modify it but use the same questions and order for the mothers and a slightly modified version for the grandmothers of the main study. No pilot was used for the grandmother's interviews.

3.5.2 The Main Study - Selection of Participants

The participants for the main study were found through opportunistic sampling. The participants were unknown to the researcher prior to commencing this study. A chance conversation with acquaintance led to that acquaintance approaching three women who were friends of that acquaintance, had a daughter in Year 1 and a mother living locally, on the researcher's behalf. Telephone numbers were then exchanged through the mutual acquaintance, and two of the women, following this telephone contact, were willing to take part in this project. Their motivation for agreeing to participate in this project was not articulated but both had an interest in education and a desire to be helpful. One participant, Meryl had herself undertaken postgraduate research and so perhaps had an empathy with the teacher's position; Jasmine was herself a teacher who had considered post graduate study and so could perhaps also relate to the position of the researcher.

3.5.3 The Main Study – Cycle One: the Walker Family

Following a telephone conversation, Meryl agreed to participate in this project and acquired provisional consent from her mother Julie that she would also be prepared to take part at a later stage. Meryl invited the researcher to her home for the observation activity on a Saturday morning when the whole family would be at home.

Introductions were made: the family comprised of Meryl, her husband Pierce, and their two daughters Sophie aged 6 and Charlotte aged 3. The sheet explaining the purpose of the study, its potential audience and the right to withdraw was exchanged, read, and discussed. Meryl appeared to understand its content and the researcher is confident that the subsequent signing of the consent was informed.

The researcher set up the video recorder in the dining area just off the family kitchen. It was decided to use this space by Meryl as the table provided a surface for drawing and writing activities. The researcher also had a notebook and pen to make notes as a back-up to the video recorder. Meryl and her daughters worked through the activities with the researcher while Pierce laundry tasks in the adjoining kitchen area and made occasional contributions to the discussion. The researcher was with the family for about an hour and a half with the activities taking 56 minutes.

The first activity undertaken was to draw a picture of a physicist called 'Alex' and then write or draw the toys Alex may have played with (see Appendix 3). This led to a discussion about boys, girls, and physics. The activity was taken from the pilot study.

The second activity was to sort a selection of toys into they thought might belong to a boy, those they thought might belong to a girl and those they thought might belong to either. The toys used included a wooden train set, a set of glove puppets including a dragon, princess and a knight, a plastic Meccano set, and a baby doll. The children had the chance to play with the toys. With prompting from Meryl they then fetched some of their own favourite toys to show the researcher. The video recorder stopped working before the end of this activity so the researcher had to rely on her notes for the latter part of this activity.

At the end of the interview, Pierce joined the group and the family chose pseudonyms based on the film *Mamma Mia*. The whole family was given the name 'Walker' by the researcher at a later date in order to distinguish them from the other participating families. A date was set for the interview with Meryl, to take place a fortnight later, also on a Saturday morning in Meryl's family home.

The setting for the semi-structured interview with Meryl was identical to the setting for the activity observation. Meryl sat opposite the researcher at her dining table; Pierce, her husband continued with household task in the kitchen whilst keeping an eye on their two daughters Sophie and Charlotte who alternated between playing in the back garden and in the living. On two occasions, 3 year old Charlotte came to ask her mother a question, but other than this the interview proceeded uninterrupted for forty minutes.

At the end of this interview, Meryl arranged another Saturday for the researcher to interview her mother, Julie. Meryl had already consulted her mother and agreed that they would prefer the interview to take place at Meryl's house. Meryl's house was a familiar and comfortable setting for Julie as she was a frequent visitor there, often taking care of the children while their parents went to work.

The researcher had not found a grandmother to take part in the pilot study and so used a slightly adapted version of the mothers' interview questions with Julie. After greeting her grandchildren, Julie sat with the researcher in the family's living room whilst the family occupied themselves in other parts of the house. The interview lasted 39 minutes and was recorded on a digital audio recorder. Pierce and the children occupied themselves in other parts of the house and garden. At first, Julie seemed very nervous but as the conversation developed she appeared more relaxed and like her daughter was able to give a wealth of useful information.

3.5.4 The Main Study – Cycle Two: the Disney Family

It proved more difficult finding a time slot for the second family but in the end an afternoon in the school holidays was found when the researcher could meet the mother with her two daughters aged 6 and 9 while the father was at work. After introductions and formal consent had been given, the family chose to have pseudonyms based on Disney princesses. The daughters were Belle aged 9 and Rapunzel aged 6; they chose Jasmine for their mother, and her husband is referred to as Aladdin. The observation activities concerning drawing and discussing the physicist 'Alex' followed by the toy sorting exercise were followed as with the Walker family. This activity was video recorded. As with the Walker family, the Disney family chose to do this exercise seated around their dining table. The activity lasted an hour and ten minutes. An evening was then arranged when the mother could be interviewed.

The interview with Jasmine took place one evening a couple of weeks after the observation activity on a day when the children had been to school but Jasmine had not had to work. The children were ready for bed when the researcher arrived but had waited up to say hello. After they had gone to bed Jasmine invited the researcher into her living room where the interview took place. During the course of the interview Jasmine's husband returned home from work and introduced himself before going to check on the girls. Other than this the interview proceeded without interruption. This interview also seemed to go well with Jasmine able to talk freely about her childhood memories and frankly about her career trajectory. She appeared to be enjoying the experience of sharing her life story and was interested in hearing about the researcher’s similar experiences. As with Meryl, the interview had the feel of a natural conversation rather than a formal interview. At the end of the interview, Meryl agreed to get in contact with her mother. The interview lasted one hour fifteen minutes.

Having gained consent, Jasmine forwarded her mother’s contact details to the researcher. Following this, Jasmine’s mother agreed to meet in the researcher’s house. The interview took place in the researcher’s lounge, an environment that was totally new to Jasmine’s mother. The grandmothers’ interview schedule as used for Julie Walker was used again here and as with the previous interviews an audio recording was made. The participant chose the name Tinkerbelle so as to be in keeping with the Disney princess theme of her daughter and granddaughters. She was able to give a lot of information about her education, home–life, and career. Again, the participant appeared to enjoy the experience and had lots to say about her life. She became very involved in telling her story and the interview over-ran, lasting 1 hour 45 minutes.

3.5.5 The Main Study – Including Elements of the Pilot Study

The researcher was unsuccessful in finding a third family to take part in the main study. However the material gathered from the pilot interview with Lynne proved very rich and had a lot of data that would be pertinent to the project. The interview with Lynne had gone without difficulty and the researcher was confident about the veracity of its content. The same script had been used for the other mothers in the survey as no modifications had had to be made. The researcher also felt that whereas the other participants were to have their stories told albeit anonymously, there was no platform for Lynne’s voice to be heard even though her contribution had been crucial to the project. For these reasons it was decided to include Lynne’s story in the analysis. Permission was sought from and granted by Lynne to do this. There were three problems with this decision however:

1. Lynne's mother was dead, and so could not lend her voice to the project.

2. As a different family had been used for the pilot observation task there was no data concerning Lynne's children.

3. Although each of the families had a six year old child at the time of this study, Lynne's six year old was a son rather than a daughter, her daughter being 12 years old at the time. This put her out of step with the other families.

After a telephone discussion with Lynne and her father Raymond, it was decided to include Lynne's mother Doreen's story. It was acknowledged that this story being based on Lynne's interpretation rather than Doreen's would be one further step removed from Doreen's voice and therefore arguably less credible than the other stories. It was felt by all concerned however that Doreen would have wanted her story to be told and that telling her story, albeit from a more distant perspective, would give context to Lynne's story.

An attempt was made to carry out the observation activity with Lynne and her children. This attempt was aborted however as, as with the children of the original pilot study, the children were known to the researcher and found it difficult to engage with her in a different role. The children were clearly uncomfortable and resented their play being interrupted.

As the data was analysed it became clear that the data gained from the observations was of limited value especially when compared to the richness of the data from the interviews. It was decided to modify the project to examine two rather than three generations. The disparity in ages between Lynne's and the other participants' daughters was then deemed to be irrelevant.

3.6 Summary

This is a qualitative, biographical, narrative study that has been conducted from a radical orthodox perspective. The inexperience of the researcher has led to flaws that a more experienced researcher is unlikely to have made. However, the naivety of the researcher allowed for an equal, trusting, and natural relationship developing between the researcher and the participants, which in turn, has enabled the collection of thick descriptions in the participants' narratives. The researcher's own learning has been significantly enhanced by this experience.

The semi-structured interview was the primary tool used for collecting data. Phenomenological hermeneutical techniques were applied to produce the data analysis. The results of this analysis are explored in chapter five. The next chapter will share the researcher's interpretation of the participants' life stories.

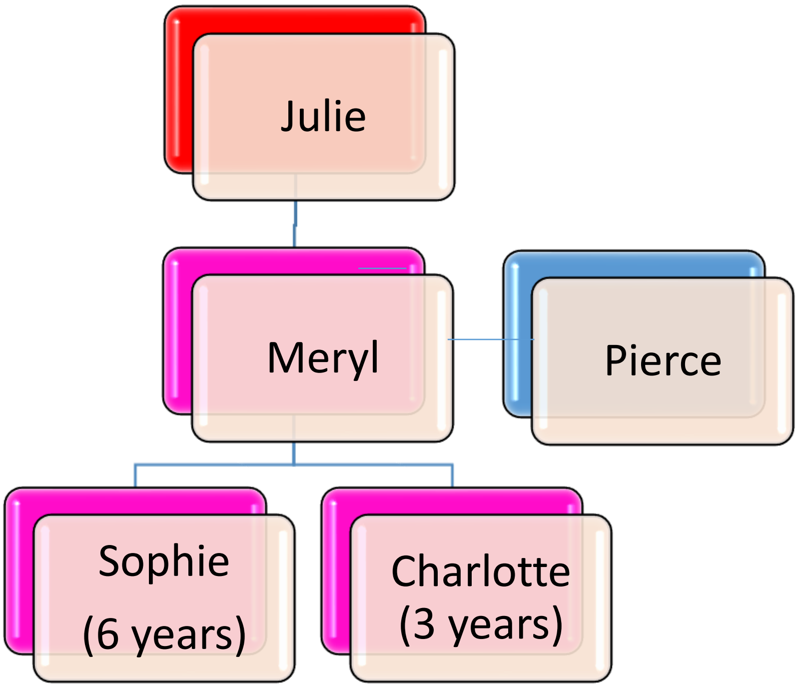
Chapter 4: The Families and Their Stories

4.1: Introduction

This chapter will provide a story of each participant using a Bronfenbrennerian (Bronfenbrenner, 2006) style analysis. It will not be possible to tell a complete story for no person can have a complete view of all the factors influencing his or her life (Denzin, 2014). This represents the researcher's interpretation of the participant's lives. An explanation of how the narratives were constructed has been included in Appendix 8.

4.2.1: The Walker Family

Figure 4.2.1.1: The Walker family tree at time of interview.



I was introduced to Meryl through a mutual acquaintance. Following a telephone conversation, Meryl agreed to take part in this study. Meryl then recruited her mother, Julie, to join the project. I met Meryl in her family home on three occasions, the first to video record Meryl with her two daughters, the second to interview Meryl on her own and the third to be introduced to, and to interview Meryl's mother, Julie, on her own.

The family chose their pseudonyms which are based on actors from the film *Mama Mia*.

<u>4.2.1.1: Julie Walker - Grandmother</u>

Figure 4.2.1.2: A Table summarising some key facts concerning Julie's life at the time of the interview.

Pseudonym	*Julie Walker*
Age	*80*
Year of Birth	*1931*
Parents and their occupations	*Mother – WRAF, hospitality, homemaker* *Father - hospitality*
Siblings	*Older brother* *Younger brother* *Maternal uncle who lived in family home as an older sibling*
Occupation	*Home maker*
Age on leaving fulltime education	*14*
Education Level	*Left secondary school 1945 aged 14*
Qualifications at time of leaving fulltime education	*No formal qualifications*
Marital Status	*Widow of Stellan Walker – Stellan had died 13 years prior to this interview*
Child(ren)	*Meryl (born 1970)*
Grandchildren	*Sophie aged 6* *Charlotte aged 3*
Location of interview	*Living room of daughter Meryl's house*
Duration of interview	*39 minutes*
Time of interview	*Saturday morning, June 2012*

Julie's preschool years: 1931-1935

Julie did not have specific memories of her preschool years but she was able to create a description of what her home dynamics were like.

It was hard work; my father was working to provide for us. Mum was at home looking after us. We'd already got her brother living with us, then my grandfather had got nowhere to go so my mother said he could live with us. ... but it was very very busy for her. She was always on the go, always doing. She had no washing machine or hoover or anything and it was all home cooked our food.

My mother had a good education. Two years before it came to deciding to go to university my mother had to give up to look after her mother who had a stroke. She joined the R.A.F. When she came out she got a job in the hotel. She met my father, married and went to live in my father's home town.

The microsystem that Julie describes with its polarisation of labour corroborates Clarke's (1996) description of family life from this period. Julie seems to have identified much more closely with her mother than her male relatives. Her father appears a remote figure who worked away from the home. Julie's reminiscences of her mother fit de Beauvoir's (2010) observation that women often see their home as an extension of themselves. There is evidence that Julie's mother held some authority within the home in that it was her decision to take in her invalid father against her husband's wishes.

Julie describes a life that was fairly self-contained; there is not much evidence of other settings or of interactions between these settings at a mesosystem level. The only exosystem mentioned was Julie's father's work. This seems to have been kept quite separate from the family's home-life.

There were a number of changes in the macrosystem around this time that may have had an influence on Julie's life. Julie's birth was just three years after the general election of 1928 in which women were allowed to vote for the first time. The franchise however was not universal, in order to vote women had to be over thirty and own property (Clarke, 1996). National Archive records (National Archives, 2014) suggest there were some changes in the opportunities for women following the First World War, for example the 1921 census showed a threefold increase in the number of female medical doctors, and the 1920 Sexual Discrimination Removal Act allowed women to enter the legal and accounting professions for the first time. However, it could also be argued that for most women the opportunities had changed very little and may even have declined following the First World War (Clarke1996).

Julie's mother then seems typical of the period; she worked for the '*R.A.F',* possibly as a member of the Women's Royal Navy Service, the Women's Army Auxillary Corps or from the 1st April 1918 the Women's Royal Air Force (*R.A.F. Museum*, 2016). Julie's mother and may have had a STEM based role during the war, but if so she reverted to a traditional female role once the war had ended.

In the days before the National Health Service it was quite usual for the women of the family to care for elderly relatives (Clarke, 1996). They were less likely than their male relatives to be employed and if they were employed they were likely to have a lower income than their male counterparts furthermore the education they had received had prepared them to expect a domesticated life (Watts, 2002).

It is unclear what was meant by Julie's mother not gaining a place at university. Few women had access to university education at this time (Watts, 2002). Women had been able to gain degrees at Oxford University since 1919 but were still unable to graduate from Cambridge. Even in the London and civic universities, which were more inclusive, women only made up 29% of the student population (Lowe, 2002). Perhaps Julie was thinking of a place at a local grammar school rather than an opportunity for higher education as there was some expansion of secondary education (McCullock, 2002). Julie's mother's life fits Bourdieu's model of social reproduction, her education provided little cultural capital and so her life choices were very restricted (Bourdieu and Passeron, 1990).

Around the time of Julie's birth there was much debate about education. The Hadow Reports of 1926, 1931 and 1933 were paving the way for a complete overhaul of state education (McCulloch, 2002). They recommended specialist phases at nursery, primary and secondary levels with a division of secondary education between 'grammar' for the academically more able and 'modern' schools for those who were destined for a more practical or vocational occupation.

At this stage of Julie's life, there does not appear to be any conscious interaction with physics, she did not encounter anyone with a physics background and if her mother had had experience of physics during her time in the air force this was not apparent in the way she parented Julie.

Figure 4.2.1.3: The micro, meso, exo, and macrosystems of Julie's early years set within the chronosystem 1931-1935.

<u>Macrosystem</u>

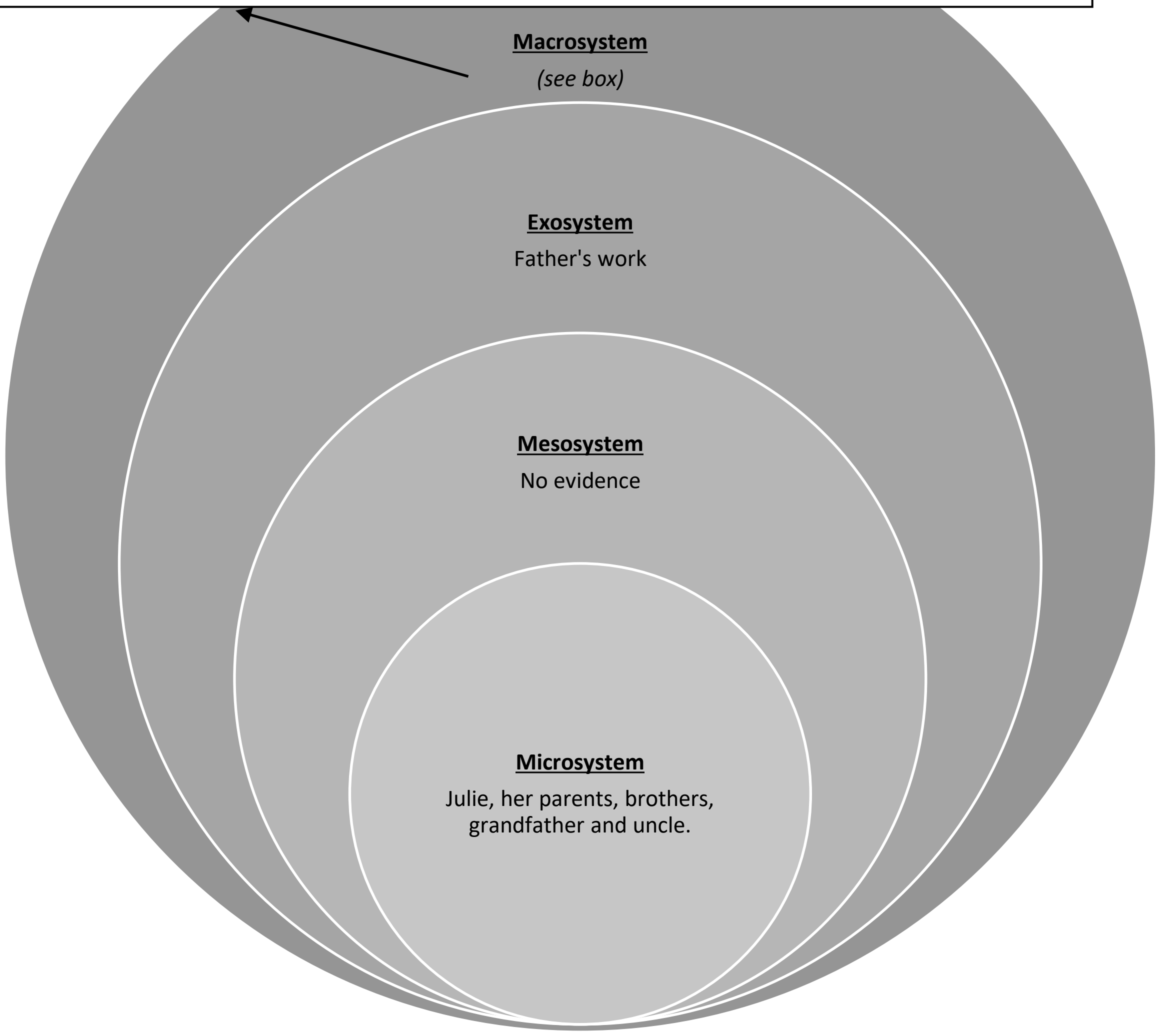
Polarisation of gendered roles for men and women.

Universal suffrage – for women over 30

Pensions for the elderly

Compulsory, free at source, education for 5 – 14 year olds

Hadow Reports: 1926, 1931 and 1933 recommend restructuring of educational system i.e. nursery, primary and secondary (modern and grammar schools)



Julie's School Years 1935 – 1945

Julie was able to recall several memories from her school years.

I wouldn't change my mum and dad but I wish they had been more concerned with education. I was always quite happy to go to school. The first school I went to was mixed. The second school was a girls' school. We did just the ordinary lessons:- arithmetic, reading, cookery, hockey and netball. I don't remember any science.

School enlarged Julie's micro-system and was influential in preparing her for a future domestic role; she went to a girls' school to follow a curriculum designed for future women. (Watts, 2002).

Out of school, Julie's pastime fit a typically female stereotype (Freeman, 2007).

I played with dolls mostly and colouring books. I used to read quite a lot of story books.

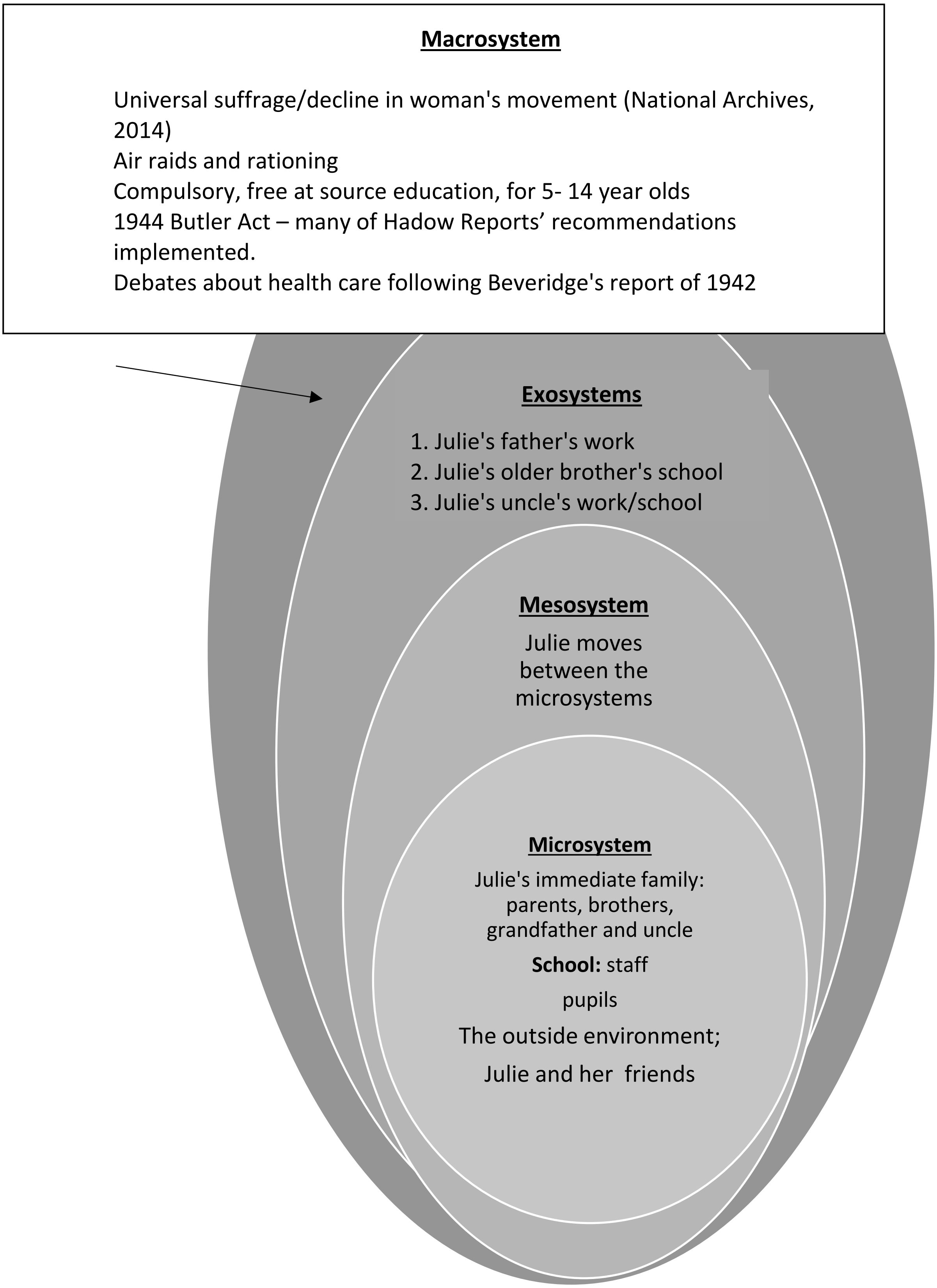
Although Julie lived in a physical world surrounded by physics concepts, physics never seems to have entered her consciousness. Her exposure to physical phenomena was never put into a formal conceptual framework either at home or at school. Much of her time was spent in female company and it is likely that these females would have had a similarly limited science education and therefore would not have been able to develop Julie's understanding of physics following a Vygotskian model (Daniels, 2001).

At the mesosystem level, it seems that there was little interaction between the home and school. Julie remembers her mother talking of her own disappointment in being bright but not being able to take her education further. Perhaps this frustration persuaded her to take little interest in her daughter's education.

At the macrosystem level her school years were largely dominated by the Second World War. It is likely she would have witnessed the changing role of women with female teachers who had left the profession in order to marry returning to the classroom. But as Summerfield (2013) suggests the changing roles of women during this time were not linear or uniform. Whilst there were moves to use women to plug the labour shortage there was also a strong movement to counter this; much propaganda material emphasised women's femininity. Thus, alongside seeing women step into traditional male roles, Julie may also have been influenced by the counter movement and it is possible that the absence of physics from her life was a part of that.

It was also a time of educational reform. Julie left school at about the time of the 1944 Education Reform Act and so would not have experienced the tripartite system. There were opportunities for students to win scholarships grammar and technical schools prior to the 1944 Act but provision was not universal and what was provided depended heavily on the location (McCulloch, 2002).

Figure 4.2.1.4: The micro, meso, exo, and macrosystems of Julie's school years set within the chronosystem 1935-1945.



Julie's After School Years, 1945 onwards

Julie completed her formal education in 1945 and started work at the age of 14.

Julie received no careers advice; when asked about how she decided what work to do Julie said:

In my day you just left school and decided where to go. I ended up in this little shop. I didn't know what else to do, that job was available and so I took it. It was a privately owned stationery shop. I did my apprenticeship in the stationary and leather department.

Julie began her working life while still living with her family in the tightly knit microsystem of the home however the school microsystem was replaced with that of the shop. Being at work connected Julie to a range of other micro, meso and exo systems. She formed new friendships; it was through a work colleague that Julie developed her love of nature and walking that continues to this day:

I worked for a lady and she would go on about the flowers and the trees. And I thought, "You know I've never looked at them" and after that I've kept looking.

Julie's life as a paid employee, ended in her late twenties:

I came off my scooter and fractured my skull. I went back to work but then I was pregnant. It was ectopic. I retired then because it didn't seem fair with the fractured skull and then to go back and find someone to fill my spot. I think I was about 28 and I didn't have Meryl until I was 39.

Julie's acceptance of a domestic life without a career is in keeping with Watt's (2002) findings; there seems to have been an expectation that women would have a domestic role and a belief that girls could not attain in traditionally male domains such as maths and science.

At a macrosystem level, Julie's work and home-life pattern seems to fit into the wider context of what was happening within the culture. Women's work at this time was often part-time, low paid and women had significantly less opportunities for promotion than men (Kynaston, 2008). Women were increasingly working outside the domestic setting but it was men who were still considered the bread winners for their families. Blossfeld and Drobnic (2004) note a gradual increase in women's contribution to the family income over the course of the last century, for married women to have a job outside the home was becoming increasingly normal. By the time Julie married there had been a revolution in household appliances, the NHS relieved many women from the need to care for relatives alongside providing many women with employment opportunities. Housing costs however had risen which meant that any additional income was very welcome Clarke (1996).

Although physics played an important part in the development of household appliances, there is no evidence of Julie thinking about physics. The appliances were bought and operated without any consideration of how they might work.

Julie devoted herself to motherhood and was particularly keen for Meryl to have a better education than she had done.

Julie reminisces about her parenting years fondly:

I don't know what I would have done without Meryl. Whenever you saw her; she was always skipping. We used to go out and about walking. I think that's where she got her love of walking.

She focussed on ensuring Meryl had a better education than she had received:

Well I was concerned about Meryl getting the best out education that she could because my husband was extremely bright. How we two got together is unknown. I'm very pleased with what Meryl has achieved.

Physics did not feature in Julie's consciousness after becoming a mother. She continued to use the products of physics but had no conceptual framework on which to fit these. This also meant that she would not have been able to develop physics literacy in her daughter.

Figure 4.2.1.5: A table summarising the factors that enabled Julie to or inhibited Julie from becoming physics literate and identifying with physics linked to the themes arising from the analysis in chapter 5.

Julie		
Theme	**Development of physics literacy**	**Development of a physics identity**
schooling	No physics education at school so no opportunity to develop physics literacy. Macrosystem – physics not considered a suitable subject for girls.	Physics was not offered in her girls' school, message given that physics was not for girls.
Physics at home	Exposure to physics concepts such as heat transfer but no conceptual framework to help make sense of these experiences.	No expectation that Julie would develop an interest in physics
Relationships	Mother may have had some STEM knowledge but this was not made use of. No opportunity to develop an understanding of physics from social interactions	Close to mother and female friends, went to a girls' school. Relationships reinforced her femininity.

Self-concept		Identified herself as a girl/woman. May have been influenced by movements to promote femininity as a reaction against women taking on male roles during the Second World War.

4.2.1.2: Meryl Walker – Mother

Figure 4.2.1.6: A table summarising some key facts concerning Meryl's life at the time of the interview.

Pseudonym	*Meryl Walker*
Age	*42*
Year of Birth	*1970*
Parents	*Julie – shop assistant then home maker* *Stellan – commerce*
Siblings	*None – only child*
Occupation	*Environmental biologist (part-time)*
Age on leaving fulltime education	*21*
Education Level	*Post graduate*
Qualifications at time of leaving fulltime education	*B.Sc., then MSc after a short gap in education*
Marital Status	*Married to Pierce Walker*
Child(ren)	*Sophie aged 6 (born 2006)* *Charlotte aged 3 (born 2009)*
Grandchildren	*None*
Location of interview	*Meryl's kitchen/dining room*
Duration of interview	*40 minutes*
Time of interview	*Saturday morning, May 2012*

At the time of this study, Meryl a married woman with two young daughters, was working part-time as an environmental biologist, dividing her time between pursuing a career and caring for her children. Her husband Pierce worked full-time but also made a significant contribution towards childcare and household chores. The demographics of Meryl’s life at the time of interview are summarised in the table above (Figure 4.2.1.6).

<u>Meryl’s Pre-school Years 1970 – 1975</u>

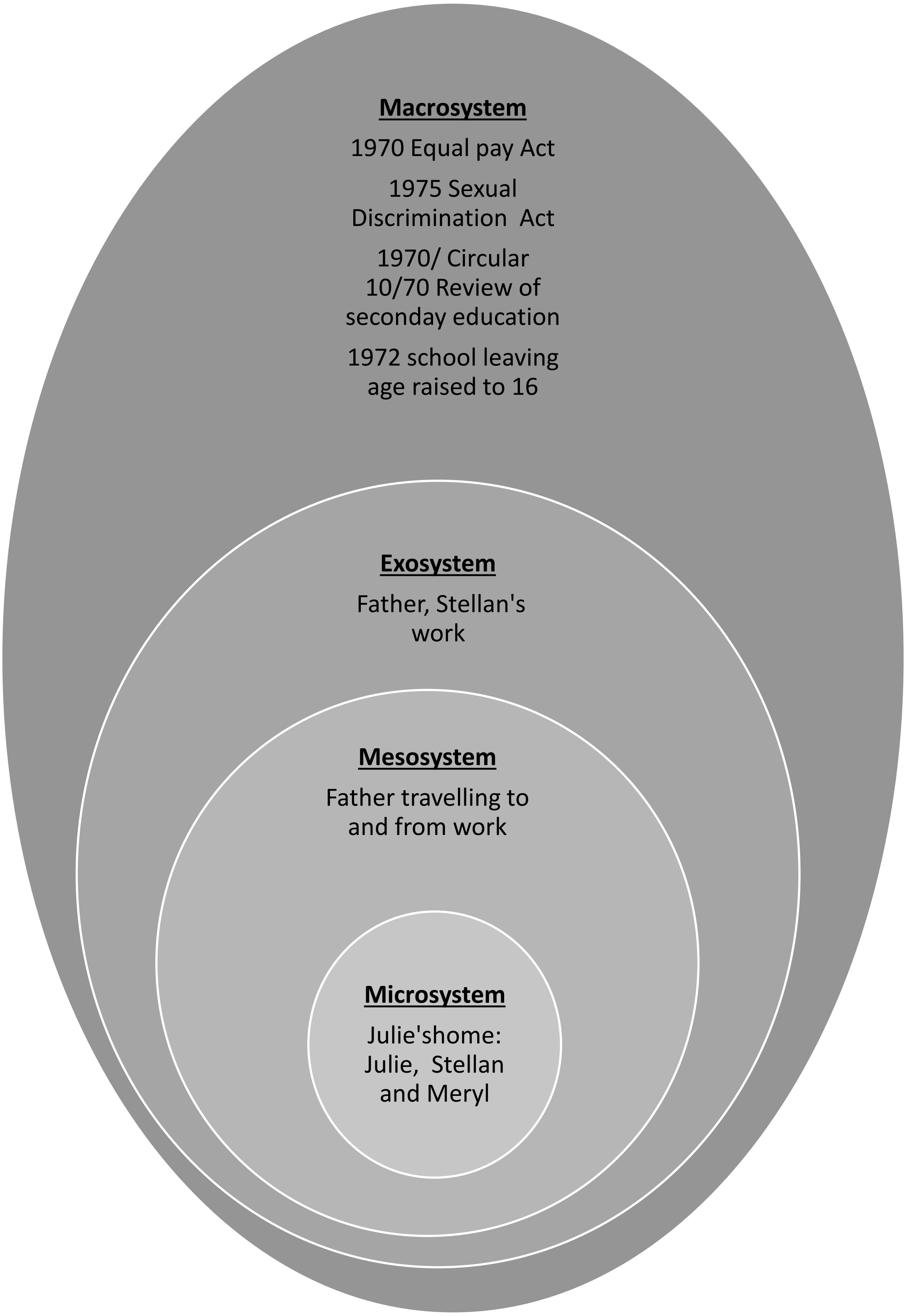
During the course of her interview recollections of Meryl’s preschool years were not discussed specifically. She spent the first few years of her life almost exclusively in Julie’s company. They seem to have operated within one microsystem with Julie and Meryl at home during the day and Stellan joining them in the evenings and at weekends. There were echoes of Julie’s childhood in Meryl’s; Julie continued her domestic role never considering work outside the home as an option

Stellan’s work provided an exosystem. In one sense it had a huge impact on family life, providing the income to sustain it, determining where they lived and dictating the pattern of Stellan’s relationship within the microsystem. In another sense it was a silent partner, not interacting openly with Meryl or Julie. There was little interaction with the outside world for mother and daughter and the family operated as a largely self-sufficient unit.

In the macrosystem beyond the home there was much change; secondary education was under review as questions were raised about the fairness of the tripartite system and the school leaving age was raised to 16 (McCulloch, 2002). The feminist movement was undergoing a revival with the 1970 Equal Pay and 1975 Sex Discrimination Acts (Clarke, 1996) and (Banyard, 2010).

Physics seems to have been very much in the shadows of Meryl’s early childhood. The family were using the products of physics but its contribution to their lives was not recognised or articulated. Meryl was introduced to literature and Julie shared her love of nature with her but there was no mention of physics.

Figure 4.2.1.7: The micro, meso, exo, and macrosystems of Meryl's preschool years set within the chronosystem 1970 – 1975



Meryl's School Years: 1975 – 1989

Meryl was able to give a detailed account of her time at school:

I loved school all the way through. At primary school I used to get told off a lot; the headmistress would often call my parents in.

I went to middle school for four years, then high school. I was only there for two years because we moved house. I went from a very good school to a girls' secondary modern. All the previous schools had been mixed.

Had I stayed at high school I would have had about eight choices for additional subjects whereas when I went to the secondary modern I only had five. I don't know why our system allows that to happen; it just doesn't seem right. I chose commerce which meant I had to do typing. That took up two options so I had to drop physics which was a real shame because I really wanted to do physics.

I got to 16, I had a place at the art college to do foundation art and I had a place at college to become a chef but all of that felt like I was trying too early to decide what I wanted to do. So I then decided to do A' Levels at the girls' grammar school. I just chose the subjects I enjoyed which were geography, biology and art. That is what led me to what I am doing now.

Meryl could also remember quite a lot about her physics lessons:

Now I think of physics as more of a male subject but I had a female physics teacher so I didn't think of physics as a male subject at the time. I didn't see sex as a barrier whereas chemistry was always male teachers. I found chemistry hard to get my head round which was funny because chemistry is more important to what I do now. It was always biology and physics that I enjoyed.

My physics teacher at the high school was quite formidable but brilliant. I loved physics.Probably the two years of physics that I did were very practical. We were in a lab type set-up. The teacher would do quite a lot of experiments. We'd come in for the first part of the lesson and Mrs D. would talk about the subject matter. Then we'd get on with an experiment. Then you'd spend your homework writing it up in detail.

This description suggests an interactive practical approach that fits the structure recommended by the 'Girl Friendly' physics movement as supported by the Institute of Physics (Whitelegg and Murphy, 2010).

Meryl believes that the quality of teaching has had an impact on the direction of her learning and that it was the subjects that had the most inspiring teachers that she chose to pursue.

Out of school, Meryl did apply her knowledge of physics.

My first job was in a lighting department and I had to learn how to change lights and wire up things. People would come in if they had a light that was faulty and you'd try to fix it.

Meryl also had memories of what she did in her free time:

I was just given toys by my parents. I liked dolls, I don't know if that was a gender thing? I had a sink in my room, underneath I used to pretend it was a play house and I had my dolls in there. I used to dress my dolls up in boys' and girls' clothing. I didn't have a 'Ken' or 'Barbie' I had 'Sindies' and I do remember playing with those quite a lot. I liked Lego. I was quite outdoorsy as I liked being out a lot on my bike. I also enjoyed drawing.

I don't think my mum and was at all scientific. My dad had a very good general knowledge. We would watch 'The Cosmos' together because you would *watch what my dad wanted to watch on television. You weren't given a choice because of course we only had one television. I thought it was tedious at the time, but now I'd watch them all. He was interested in education but in terms of science … I don't ever remember getting things like chemistry sets for presents.*

I remember going to the Natural History and Science Museums on school trips. Family trips were more walking based and nature and countryside and that sort of thing but we did go to the Planetarium. A lot of my activities focussed on what my parents were doing which was often gardening. Sometimes I would be happy to play on my own. Later on in life I'd be out on my bike with my friends.

My dad used to do homework with me but my mum was my main focus. I definitely spent more time with my mum. Offering guidance later on in life was more my dad's rôle. Mum did all the cooking, cleaning and shopping. My dad did all the stereo typical washing of cars and cutting the grass. I do remember having a lovely childhood.

Throughout her childhood, Meryl's microsystems increased. She spent much time out of doors and enjoyed going to clubs like Brownies when she was old enough. Many of her activities were along traditional female lines although she had some gender neutral toys such as Lego. At this microsystem level physics appears marginalised. There is some cultural awareness through her father's watching the Cosmos and family visits to the planetarium but the products of physics appear to have been used without much reference to the physical principals governing them. The exception to this being Meryl's Saturday job in her late teens in a lighting department.

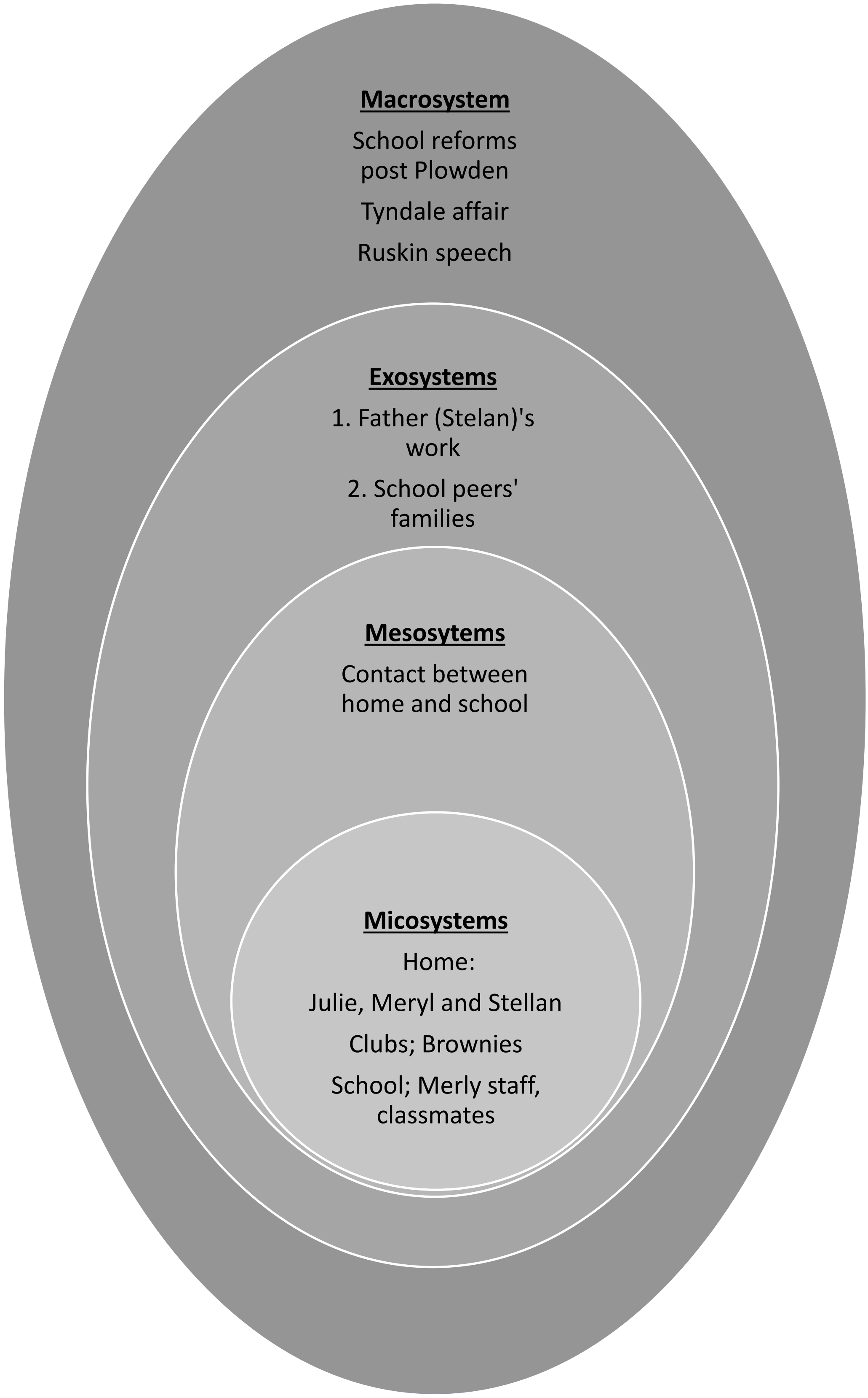
Meryl enjoyed school and she remembers there being a lot of interaction at the mesosytem level. Not only was Meryl moving physically between her principal microsystems but her parents were interacting with the school setting in person too. As Meryl grew older her relationship with her father, Stellan, became increasingly important. He was seen as the authority for matters outside the home such as school and careers advice, providing a bridge between Meryl's microsystems and the macrosystems in which they operated.

Meryl's story reflects many of the changes happening at a macrosystem level. The 1967 Plowden Report recommended a topic based approach in primary schools, greater parental involvement and the middle school system (Cunningham, 2002). Middle schools were usually larger than their infant feeder schools but not as large as a typical secondary school (Aldrich, 2002).

Meryl's experience seems to encapsulate the conflicts within education at the time. Meryl received a post Plowden style progressive, co-educational middle school education until moving to a new region where she was taught in a girls' secondary modern followed by a girls' grammar school (Aldrich, 2002). In contrast to her mother Julie, Meryl was in compulsory education until the age of 16 as a result of the school leaving age being raised in 1972 (McCulloch, 2002). Her decision to remain in education post 16 was a possible as a consequence of the Crowther Report of 1959 which set the target of having fifty percent of children remained in education up to the age of 18 (Bailey, 2002). Meryl was not viewed as an academic at the secondary stage of her schooling but there was an expectation from both home and school that she gained formal qualifications. This follows the replacement of the School Certificate with G.C.E. O' Levels in 1951 and then the introduction of the C.S.E. in 1962. Wolf (2002) suggests that the formation of the C.S.E. was as a result of public demand and changing ways in recruiting employees. The informal recruitment such as had been experienced by Julie where people found jobs through local networking had given way to more formal applications from an increasingly mobile population.

Unlike Julie, Meryl was taught some physics at school. At a government level there was continued concern for the need to promote science further hence the replacing of the Ministry of Education with The Department of Education and Science in 1964 (Aldrich, 2002). A by-product of the comprehensive system of co-education resulted in Meryl studying subjects that had been traditionally seen as masculine, such as physics alongside her male peers (Watts, 2002). When it came to choosing options however, Meryl chose subjects that were more traditionally seen as female (Ormerod, 1981). Ebbutt (1981) suggested that the physics option was often pitched against a subject generally seen as more feminine or popular with girls thus subtly channelling girls into maintaining the status quo. This seems to have been the case with Meryl having to choose between physics, perceived as a masculine subject and typing which was perceived as feminine.

Figure 4. 2.1.8: The micro, meso, exo and macrosytems of Meryl's school years set within the chronosystem 1975 – 1989



Meryl’s Post School Years 1990 onwards

Having completed her A’ Levels, Meryl became the first in her family to enter higher education:

And then I got to finish my A’ Levels and I still didn’t know what I wanted to do so I just kept doing the things that I enjoyed. So I did environmental biology and geography for my first degree.

After a short time working in a polytechnic Meryl met up with a friend who had become and environmental consultant. Meryl decided that this was what she would like to do. She took a master’s degree and has been working as an environmental consultant ever since.

Meryl’s life reflects some of the many changes happening at a macrosystem level. From just before her birth there had been a massive expansion in higher education making it more accessible for middle and working class families including women (Lowe, 2002). This enabled Meryl not only to stay in education until the age of 21, gaining a Bachelor’s degree, but also for her to find a job in one of the newly created polytechnics and from here go on to study for a master’s degree. This seems quite a contrast to her mother leaving school at 14 with no formal qualifications.

Meryl now sees her primary role as being a mother. She is keen for her daughters to become independent and be more self-sufficient than she was when she left home aged 18. Her job enables her to have a family life. She finds the current education system a bit bewildering and is unsure how best to support her daughters:

It’s a complete mystery for me how the next few years for Sophie are going to unfold. To me it’s important that she is at a good school that gives opportunities. I’d like her to be at a school like the county high that I was at and not be frustrated by a lack of choice.

When asked if physics featured in her work Meryl explained:

It comes into it but not directly. I'm sure people like the engineers I work with have a background in physics. I take designing batteries and things like that for granted; you just buy a new bit of technology because it does something well. I see physics as another world and until somebody brings it to the market place and advertises the benefits of it I'm not really aware of it. I was just flicking through a magazine. I found an article which talked about people who invented certain things like the light bulb and apparently there's a folding plug. Now I would not have known that had I not read that magazine. Most of my reading is related to my work, with limited time sadly I don't get much time to read much other stuff.

When asked what the word 'physics' meant to her Meryl said

It conjures up my physics lessons at school, doing really interesting things with the magnets and the poles. I found it interesting. And the frustration as well as I would have definitely gone on to do it at O' Level. And respect; I think of physicists as super intelligent beings who have contributed a lot to society. It's the kind of thing that goes on in the background, that you don't understand or are aware of but if you did think about how things work you'd probably discover that a physicists would have been involved somewhere. I don't know to what age I would have been able to carry on physics at school but I think I'd have had a better appreciation of things if I'd been able to do it for longer.

The opportunity for Meryl to continue working in environmental biology alongside being a mother may be due to a number of factors such as: her high level of education and specialist skills give her a high cultural capital (Bourdieu, 1990), the support of her husband and mother with domestic duties (McGrayne, 2001) and a combined income sufficient to purchase support such as nursery education (Clarke, 1996). Meryl's work pattern is consistent with the findings of the Office for National

Statistics of 2013 which shows an increase in women's employment from 53% in 1971 to 67% in 2010, 42% of these working part-time (Office for National Statistics, 2013)

It is hard to read her account of her physics education without sharing her frustration. Clearly, Meryl is someone who enjoyed physics at school, who wanted to study it further and who retains an interest in physics to this day. Subtle barriers in the form of timetabling clashes and lack of careers advice resulted in her being prevented from studying physics beyond the age of 14. Once her physics journey had been interrupted she was not able to study physics further. She sees physics and physicists as belonging to another world to which she does not have entry.

Her daughters will be studying physics between the ages of 5 and 16 as part of the National Curriculum (Department of Education, 2014) and will stay in education or training up until the age of 18. Meryl has a working knowledge of physics, a respect and an enthusiasm for the subject. Given this, she is in a much stronger position than her mother to impart knowledge and encourage an interest in physics in her daughters.

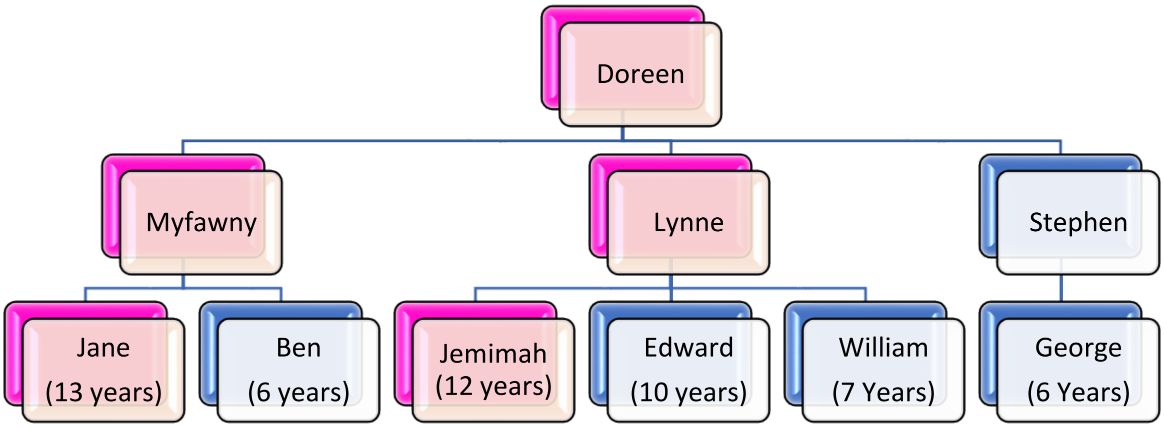
Figure 4.2.1.9: A table summarising the factors that enabled Meryl to or inhibited Meryl from becoming physics literate and identifying with physics linked to the themes arising from the analysis in chapter 5.

Meryl		
Theme	**Development of physics literacy**	**Development of a physics identity**
schooling	Positive physics education in middle school. Well-structured lessons.	Positive school experience – physics was an enjoyable subject that Meryl could do.

	School trips to museums. Further development prevented by restricted option package at age 14.	
Physics at home	Television – watched ‘The Cosmos’ with father Occasional visits to science museums and planetaria. Parents not physics literate and so did not consciously promote physics.	Neither encouraged nor inhibited – did not feature as part of home setting. ‘Cosmos’ programme on television with father A visit to the Planetarium
Relationships	Mother encouraged interest in nature. Father encouraged interest in commerce. Inspirational teacher encouraged interest in physics but this was not sustained.	Positive relationship with inspirational teacher encouraged positive physics identity but this was not sustained once Meryl had moved to a different school.
Self-concept		Meryl believes that she was capable of learning physics but circumstances prevented her from taking this further.

The Lloyd-Boot Family

Figure 4.2.2.1: The Lloyd-Boot Family Tree



This family was initially involved with the pilot study however the as the data provided by Lynne was rich and the project had difficulty recruiting a third family it was decided to include Lynne in the study. Lynne gave her consent for the material to be used in this way. Lynne's interview took place on a Saturday afternoon in April 2012. Once it had been decided to include Lynne's interview in the study and attempt was made to observe Lynne with her children however it soon became clear that the children did not want to participate and so this attempt was abandoned.

This family has been named 'Lloyd-Boot' after two pharmaceutical companies as pharmacy has been an important theme in this family. The first name pseudonyms have been chosen by the family members themselves.

The Lloyd-Boots were known to the researcher prior to the start of this study. Doreen had died prior to the commencement of this study and so was unable to take part however her family were happy for her story to be included. She was also known personally to the researcher and the researcher is confident that if she were still alive she would like her story to be told. Her story has been constructed from informal anecdotes shared by the family and from the researchers' own recollections. It is included so as to provide a background for Lynne's story rather than as a story in its own right.

<u>Doreen Lloyd-Boot – Grandmother</u>

Figure 4.2.2.2: A table summarising some key facts concerning Doreen's life at the time of her daughter Lynne's interview.

Pseudonym	*Doreen Lloyd-Boot*
Age	*Died aged 66 years*
Year of Birth	*1942*
Parents	*Sian – tailor then home maker* *Charles – soldier then electrical engineer (Civil Service)*
Siblings	*2 older brothers – both electrical engineers working in telecommunications* *1 older sister – secretary then homemaker*
Occupation	*Secretary* *Home maker* *Office temp* *Typist* *Clerical officer (Civil Service)*
Age on leaving fulltime education	*16*
Education Level	*G.C.E. O' Level*
Qualifications at time of leaving fulltime education	*4 O' Levels – English language, geography, history and 1 other* *City and Guilds shorthand* *City and Guilds typing*
Marital Status	*Married to Raymond*
Child(ren)	*Myfawny (born 1967)* *Lynne (born 1969)* *Stephen (born 1972)*
Grandchildren	*Jane aged 13 (born 1998)*

	Jemimah aged 12 (born 2000) *Edward aged 10 (born 2002)* *William aged 7 (born 2005)* *George aged 6 (born 2005)* *Ben aged 6 (born 2005)*
Location of interview	*N.A. – data supplied by Lynne and confirmed by Raymond*
Duration of interview	*N.A. see above*
Time of interview	*N.A. see above*

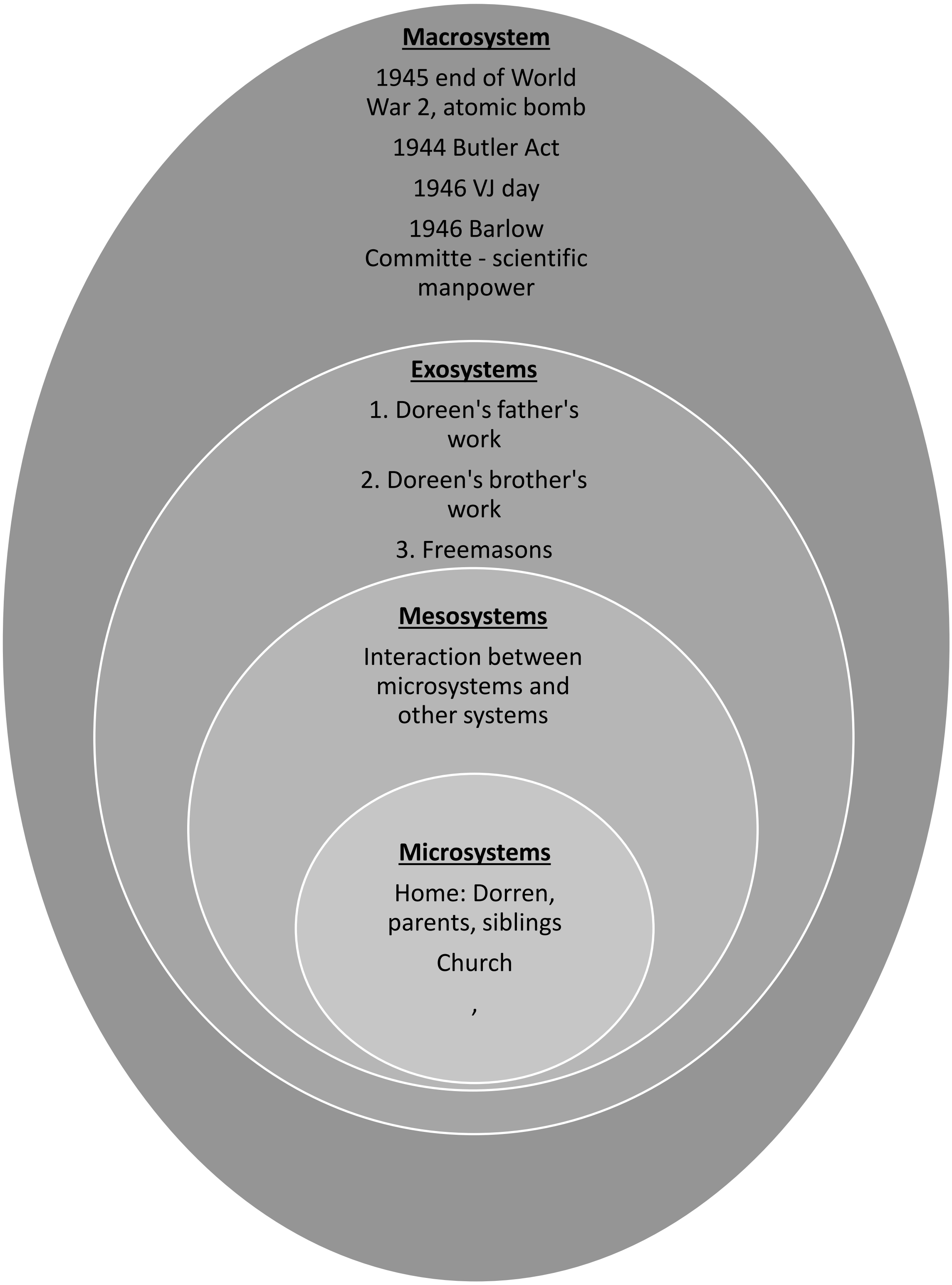
Doreen's Pre-School Years: 1942-1947

Doreen was born in 1942 in the middle of the Second World War. She was 13 years younger than her nearest sibling and all of her siblings had been evacuated at the time of her birth. Her oldest brother was at grammar school and so was able to stay on at school until the age of 18. Her second brother who did not achieve a grammar school place left school at 14. Doreen's sister also went to grammar school. Doreen described her childhood as being quite lonely and remembered spending a lot of her time in adult company. She had a close relationship with her siblings all her life and yet in many ways she saw them as being more like parents than siblings.

She spent a lot of her early childhood close to her mother who taught her a range of domestic skills including cookery and needlecraft which were hobbies she enjoyed all her life. She played with dolls, her dolls pram and a much loved teddy that is now the property of her daughter Lynne. Reading was also an important pastime and as a child she enjoyed books by Enid Blyton.

Doreen's early childhood happened at a particularly turbulent time. The war came to an end, rationing continued and education underwent major reforms. Doreen's father worked as an engineer for the Ministry of defence and was a member of the Freemasons. There is a longstanding connection between freemasonry and engineering (Carpenter, 2011) however Freemasonry, which to this day does not admit women, has promoted patriarchal structures and the maintenance of traditional polarised gendered roles (Harland-Jacobs, 2013). Doreen's mother, who had been a tailor until her marriage when she became a full-time housewife and mother, helped the war effort by joining the Women's Voluntary Service. The whole family was very involved with the parish church and this was the centre of its social life. Home, the Freemasons and church may have influenced Doreen towards a traditional, non-physics based gendered role.

Figure 4.2.2.3: The micro, meso, exo and macrosystems of Doreen's pre-school Years 1942 – 1947



Doreen's School Years 1946 – 1958

Lynne said:

As far as I know my mother had virtually no science education. I know her biological understanding was quite poor. I can't imagine that she did physics or chemistry and I don't think she saw herself as particularly enjoying maths.

Doreen's microsystem was in a state of flux. Her older siblings returned from evacuation but her oldest brother then went to do two years National Service, serving his time in India. Her second brother got a job as a telegraph boy and worked delivering telegrams. He later got a job in the civil service and trained in house to become a telecommunications engineer. Her sister left school and went into office work. Her sister was expected to help out with the care of Doreen, taking her to clinics and sharing a room with her. The two brothers were not expected to help out in this way but Doreen did enjoy spending time playing with her second brother.

Doreen attended her local primary school. Having started school after the 1944 Act (McCulloch, 2002) she sat the 11+ examination in her final year of primary school. She did not gain a grammar school place and this appears to have been a disappointment that she carried for the rest of her life. She spent the next two years of her education at a local girls' modern school which she referred to as '*The Old Dump'*. At the age of 13 she sat the 13+ and as a result won a place at the local girls' technical school. Here she learnt English (language and literature), history, geography, needlecraft, cookery, and French. She was not taught mathematics as there was no mathematics specialist in the school and so she was taught book keeping instead.

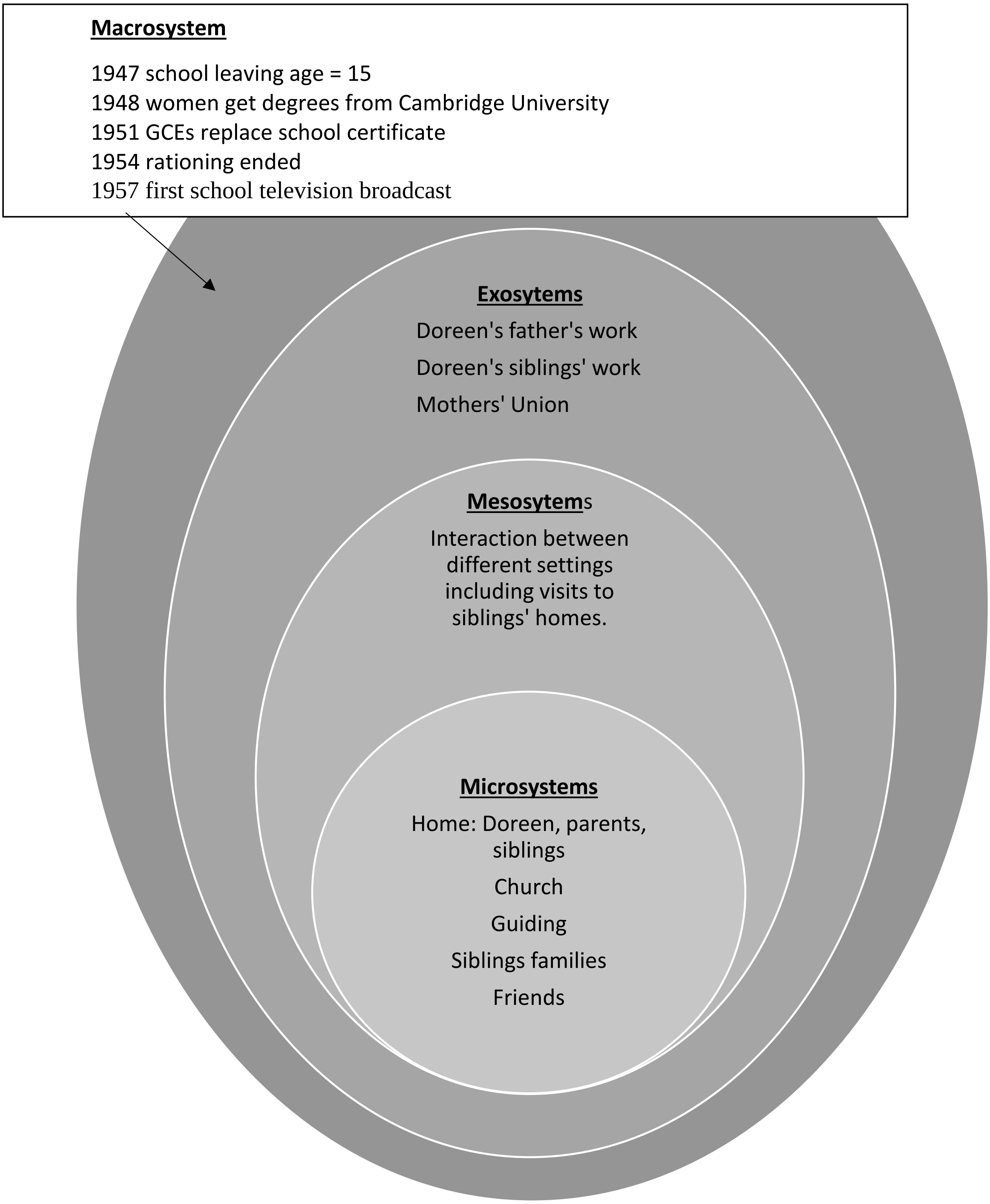
When it came to choosing her options she opted for the same subjects that her friends were doing. When she told her mother what subjects she had chosen and her mother replied by saying ‘I think your father would have preferred you to have taken the ‘O’ Level rather than the business course’, but Doreen never remembered having any careers advice from her parents.

Doreen left school at the age of 16 with four ‘O’ levels. She also gained qualifications equivalent to O’ level in both shorthand and typing.

Being the much younger sibling, Doreen was exposed to several exosystems in her childhood. Her father’s work provided the income for the family. In this respect, Doreen’s family resembles Julie’s in that the father went out to work and provided an income and there appears to have been little interaction between home-life and work life. Doreen, her sister and her mother’s lives by contrast were centred on the home. Both of her brothers left home at 18 to do National Service. As her oldest brother was posted to India there would have been little interaction other than by post. A big impact on Doreen’s life was the marriage of her siblings. They set up homes with their spouses locally and Doreen enjoyed visiting them and playing with her nieces as they arrived. She was closer in age to her nieces than her siblings.

Doreen’s story illustrates some of the changes that had happened in the macrosystem in the ten years between herself and Julie. Doreen stayed on at school for two years longer (McCulloch, 2002), one year being an optional extra in order to be prepared to sit examinations. Doreen was prepared for public examinations following the introduction of the General Certificate of Education (Wolf, 2002). Her education was a mixture of subjects that would fit her for a future domestic role i.e. needlework and cookery and subjects that would provide her with skills in the world of work i.e. shorthand and typing (Watts, 2002). The advent of the typewriter in the 1880s led to a huge expansion in office work. This created a need for typists which was fulfilled largely by women. By the time Doreen left school, office work was a predominantly female occupation (Ward, 2008). Like Julie however she had had little opportunity to learn science and no opportunity to learn physics.

Figure 4.2.2.4: The micro, meso, exo, and macrosystems of Doreen's school years set within the chronosystem 1946 – 1958



Doreen's After School Years, 1958 onwards.

On leaving school, Doreen first got a secretarial post at a shipping company, and then she worked for a broadcasting company. She met, married and moved to be with an electrical engineer specialising in telecommunications, Ray. She was able to find a secretarial post at a local university. A by-product of the expansion of universities at this time was the increase not only in teaching and academic posts but also in the supporting roles such as administration (Lowe, 2002). Doreen had transferable, nationally recognised secretarial qualifications along with several years' experience and so was able to find work in a new location (Wolf, 2002). It was perhaps this exposure to academia that led Doreen to aspire for a university education for her children.

In 1967 Doreen's husband got a promotion and moved to the South East of England. This coincided with Doreen's first pregnancy. Doreen gave up work and moved with her husband. When she became a mother it was her intention to give up work permanently in order to devote herself to raising a family. She saw this very much as her duty as a woman and was highly critical of women who tried to combine motherhood with pursuing a career. Perhaps her views were to some extent the result of the patriarchal influences of her youth i.e. the Church and Freemasonry. Doreen went on to have two more children; her second child Lynne participated in the pilot study, and is the primary source of the information about Doreen's life.

Like Julie, Doreen was keen to promote her children's education but had no knowledge of physics. Instead, like Julie she concentrated on teaching her children to read. Doreen's career choices follow patterns of female labour. Secretarial work had been long established as an acceptable occupation for a woman. The expansion of universities led to a gap in the labour market which could most easily be filled by women like Doreen in need of an increased income in order to purchase the increasing number of available appliances (Clarke, 1996).

The lack of physics in her life seems not to have concerned Doreen in spite of the number of male relatives with a physics background.

Figure 4.2.2.5: A table summarising the factors that enabled Doreen to or inhibited Doreen from becoming physics literate and identifying with physics linked to the themes arising from the analysis in chapter 5.

Doreen		
Theme	**Development of physics literacy**	**Development of a physics identity**
schooling	Little/no opportunity to learn physics at school	Reinforced female stereotypes – segregated schooling from the age of 11 A curriculum concerned with developing good wives and mothers.
Physics at home	No awareness of physics	No awareness of physics
Relationships	Surrounded by male relatives with a physics background but no evidence of any interaction about or development of physics	Patriarchal structure may have inhibited any interest in or identification with physics
Self-concept		Doreen saw herself as a female, females were intended to be wives and mothers not paid workers. She was not an able student – did not get a grammar school place.

4.2.2.2; Lynne Lloyd-Boot – Mother

Figure 4.2.2.6: A table summarising some key facts concerning Lynne's life at the time of her interview.

Pseudonym	*Lynne Lloyd-Boot*
Age	*42*
Year of Birth	*1969*
Parents	*Doreen – secretary then homemaker* *Raymond – electrical engineer specialising in telecommunications for the M.O.D.*
Siblings	*1 older sister, Myfawny – teacher* *1 younger, Stephen – surveyor*
Occupation	*Community Pharmacist (part-time at time of interview)* *Home-maker*
Age on leaving fulltime education	*22*
Education Level	*Bachelor's degree*
Qualifications at time of leaving full-time education	*G.C.E. O' Levels* *G.C.E. A' Levels in Mathematics, Further Mathematics, Physics and Chemistry* *Degree in Pharmacy*
Marital Status	*Married to Nicholas (since 1995)*
Child(ren)	*Jemimah (born 2000)* *Edward (born 2002)* *William (born 2005)*
Grandchildren	*None*
Location of interview	*Lynne's living room in her family home*

Duration of interview	***53 minutes***
Time of interview	***Saturday afternoon, April 2012***

Lynne’s interview took place in her living room on a Saturday afternoon. Lynne is married to Nicholas, a chemical engineer, and worked part-time as a community pharmacist alongside raising her three children.

Lynne's Pre-School Years 1969 – 1974

Lynne described her childhood as part of a traditional family, polarised into gendered roles along similar lines to the Walkers:

My family was very traditional. My father was an engineer with science A' levels. He didn't do anything about the house other than decorating or mending things. My mother was a housewife and then, as financial pressure built up, she gradually returned to work. When I was preschool, she didn't work. My siblings and I were expected to help with various jobs like washing up.

When I was very young I remember playing with stickle bricks. I can't remember being that interested in dolls. Sindies were bought by my parents when I was about four.

I had an older sister and a younger brother. We did a bit of role play. I think having to include my brother in play made quite a difference. We had to adapt our games so he could join in. A lot of our role play games were set in war time because my brother had a lot of soldiers.

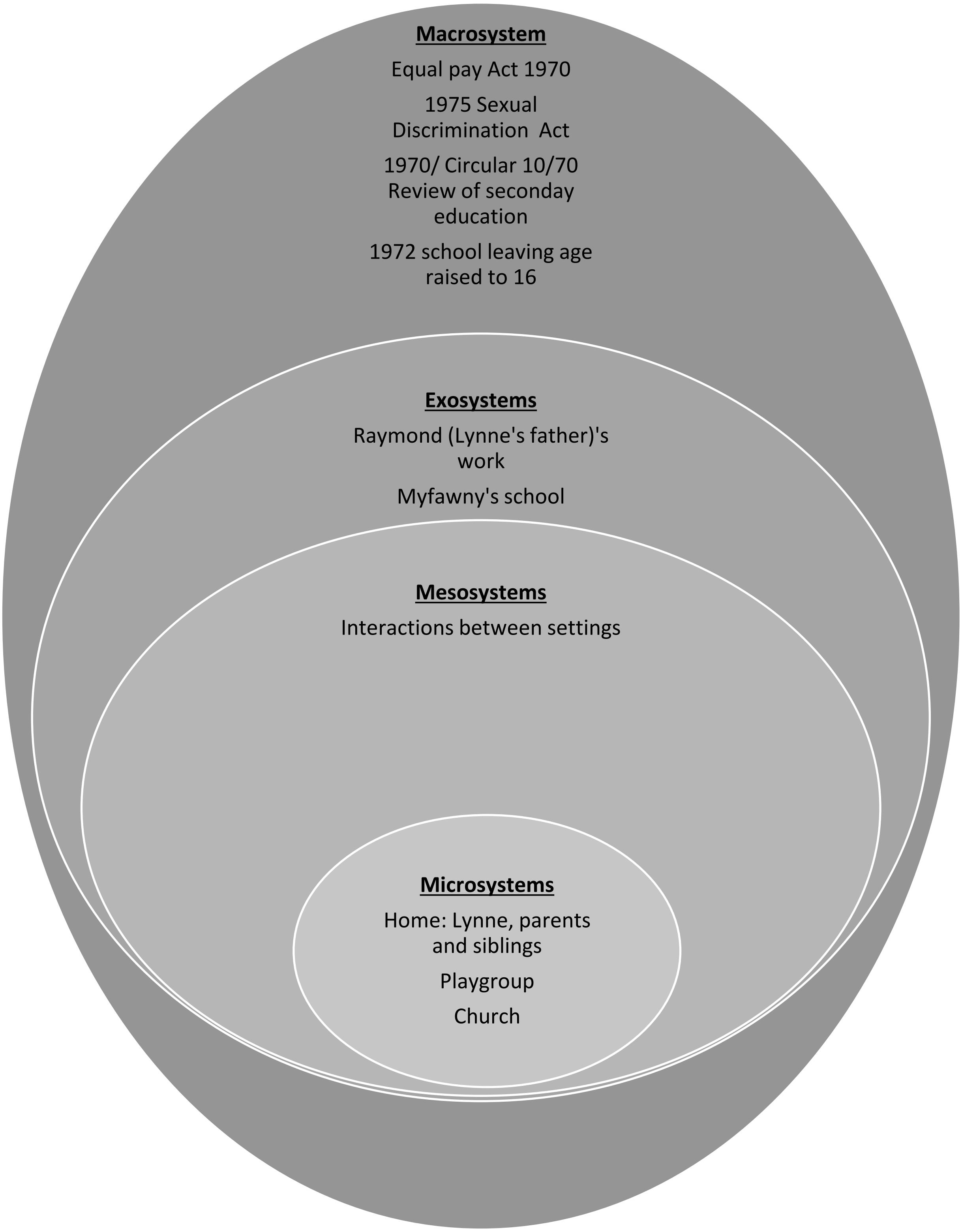
The microsystems of Lynne's early life seem to closely mirror Meryl's. Having siblings and close connections with her extended family seems to have led to more interaction with children her own age and perhaps less interaction with her parents than Meryl. Lynne was expected to be involved with household tasks.

There seem to be different elements to Lynne's early childhood, on the one hand she was presented with traditional gendered role models by her parents but on the other she appears free to be able to explore her own interests including playing with toys that might have been considered more masculine.

At an exosystem level, Lynne was very aware that her father was an engineer and came from a scientific background. This gave Lynne an early exposure to the world of science and engineering. Archer et al.'s (2012) and Kelly's (1981) research suggests that having a parent who is scientifically literate can have an influence on a child's engagement and achievement in science. From a young age Lynne would have been aware of science as a possible career choice; her exosystem suggested that doing science was a very normal activity.

At a macrosystem level, Lynne's world was very different from the world of her mother's early years. The country was at peace, there were no evacuated siblings, economic and technological advances especially in the field of plastics led to a larger number and wider range of toys (Clarke, 1996). The feminist movement of the early 1970s (Watts, 2002) seems to have had little impact on her life as her parents continued in their traditional roles.

Figure 4.2.2.7: The micro, meso, exo, and macrosystems of Lynne's pre-school years set within the chronosystem 1970 – 1974



Lynne's Primary School Years 1974 – 1981

Lynne started primary school in the autumn of 1974. She described a topic based approach to education, similar to that experienced by Meryl.

I can't remember science before secondary school at all. Everything was sort of themed and you are not actually as aware you are doing subjects apart from maths which is obvious, everything else just gets mixed into whatever topic you are doing.

Out of school, Lynne continued to enjoy playing games with her siblings.

I liked playing with my dolls' house probably best. I had a little bit of Lego but I don't remember playing with it that much. It was used to furnish my dolls' house. I liked my farm. I always remember a game where we created a school for dolls and teddies where I was the maths teacher. I think I played a lot until my sister went to secondary school and had homework. Then I didn't have someone to play with. Playing was a social activity so as siblings became less available I would read more. I don't think the books I read were particularly scientific. I read a few girls' classics but the book I really enjoyed was Little Women where Jo was actually rebelling against being the 'stay at home girl' She was one of my childhood heroines and probably a lot of girls had her as a heroine. On television, I remember watching dramatizations of a classic children's novels.

As a family, Lynne remembers days out with a science theme.

Family days out were to do with science; I'm thinking 'S.S. Great Britain' and 'Iron Bridge Gorge'. We were taken to art galleries as well but there was a bigger emphasis on industrial heritage than art because my father was interested in *science. Looking back my paternal grandfather was an electrical engineer. His brother had a science background too. My paternal grandmother was a book keeper. When I was little I thought this meant she was a librarian it was only when I got older I realised that she might have an interest in maths. One of my mother's brothers was an electrical engineer. I have a cousin who is a pharmacist so there were scientists on both sides.*

I think my interest in science is down to environment rather than nature. Although I wonder whether the maths is genetic or not. I've always had a love of maths even when I was very little. I don't know whether that was something encouraged by parents or was it the way I was born?

Doreen's return to work had quite an impact on Lynne's life.

My mother went back to work when I was about 9. After this we had to give half a day to help clean the house. My brother thought that was unfair because that was a girl's job so he was allowed to chop wood and I remember thinking it was unfair because my sister and I hadn't been given the choice.

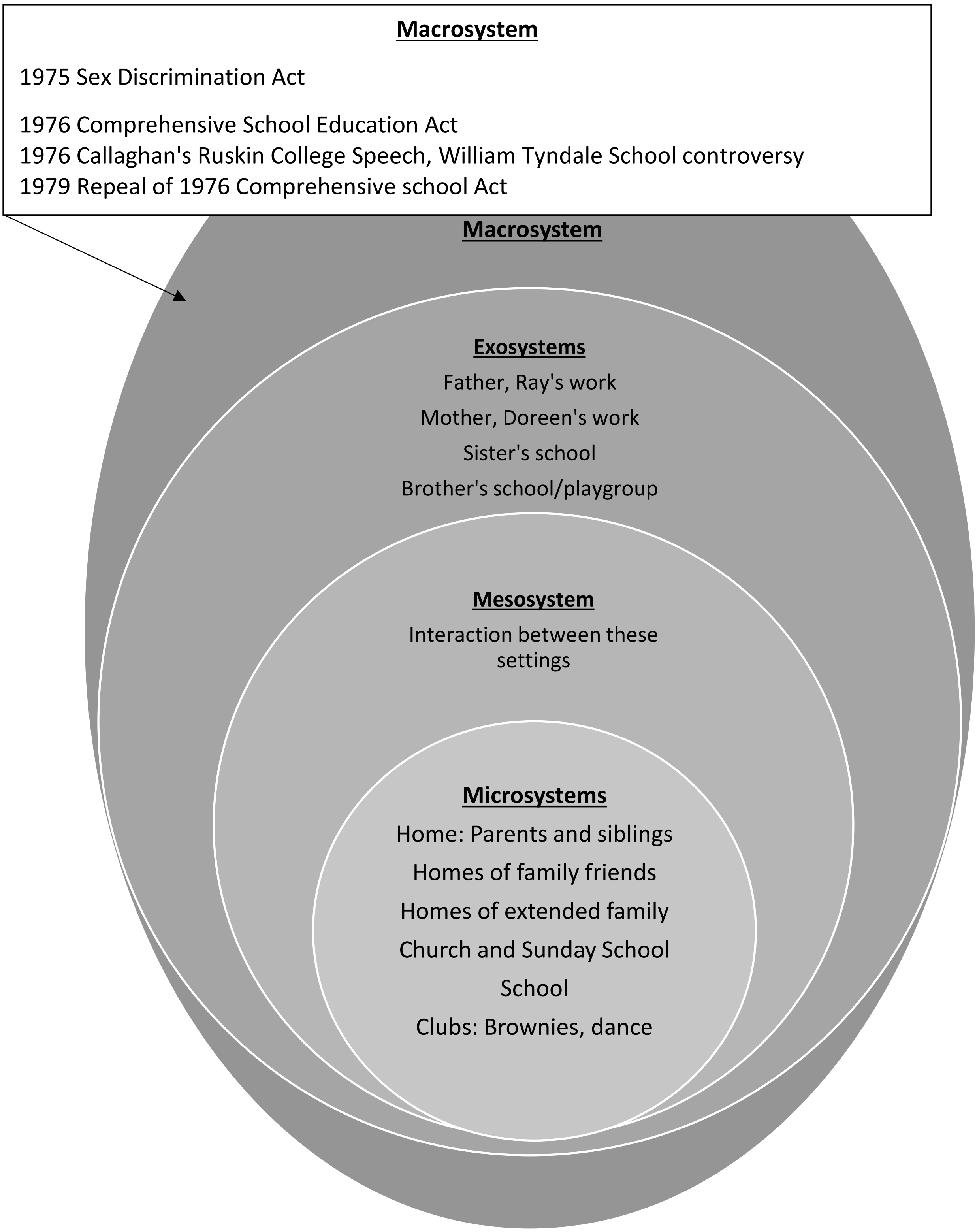
At first, the home microsystem seems to have continued in much the same way as it had done before Lynne started school then her mother returned to work and Lynne and her siblings had to help out more at home as a consequence. The school microsystem broadened Lynne's horizons and increased her social interactions but it seems to have done little to develop a science literacy or identity, this remained very much something that was done at home. Again, Lynne's story seems to corroborate Archer et al.'s (2012) findings; she came from a home where science was valued and seems to have picked up a knowledge and love of science through an almost osmotic process.

Lynne's mother's return to work and Lynne's encounter with female teachers seems to have given Lynne the message that women can work outside the home. However, within the home Lynne's was being given the message that there were distinctive male and female roles and even though to a degree she rebelled against this notion, she still saw herself as a future mother/child carer.

Her exosystems were expanding, for not only did she have her father's work, she now had her mother's work and eventually her sister's secondary school. What is not known is what mesosystems existed between these exosystems. Books provided Lynne with a further exosystem, linking Lynne to a range of different times and cultures. Her interest in classic fiction seems to have broadened her horizons and encouraged her to question the status quo with particular respect to her role as a woman.

At the macrosystem level there is evidence of the influence of the 1967 Plowden Report (Cunningham, 2002). Lynne remembers a topic based approach with little distinction being made between the subjects. There appears to have been little emphasis on science which is in keeping with Kelly's (1981) findings.

Figure 4.2.2.8: The micro, exo, and macrosystems of Lynne's primary school years set within the chronosystem 1975 – 1981



Lynne's Secondary School Years 1981 – 1986

Lynne's recollections of science including physics at secondary school are largely positive.

When you went to secondary school you had a timetable and it said you have science at this time and so you know then that what you are learning is science. I don't think it was differentiated into physics, chemistry and biology until the third year. In my year nine equivalent I had a term of biology, a term of physics and a term of chemistry which helped you decide which one you were going to do. There wasn't the option of doing all three sciences because the timetable didn't allow for that. So I guess it would have been in Year 9 that I was first aware of learning physics.

At the end of her third year of secondary school, Lynne chose her options for the final two years.

I chose physics and chemistry as there were more career options than if I did biology. I wouldn't say I had a love of physics but I did quite enjoy physics at 'O' level. If I hadn't enjoyed it I wouldn't have considered doing it for 'A' Level There weren't that many girls in the 'O' Level physics group but I'd been with that group for five years. I was doing other subjects with the same group so I was familiar with the people I was working with. I achieved really well at 'O' Level so I must have had ability as well. I guess there was an element of maths in 'O' Level physics which complimented my interest in maths.

When asked if her parents wanted her to have a career in science, she replied:

I think my father definitely did. I think my mother just wanted me to go to university; I don't know whether she was bothered about it being science.

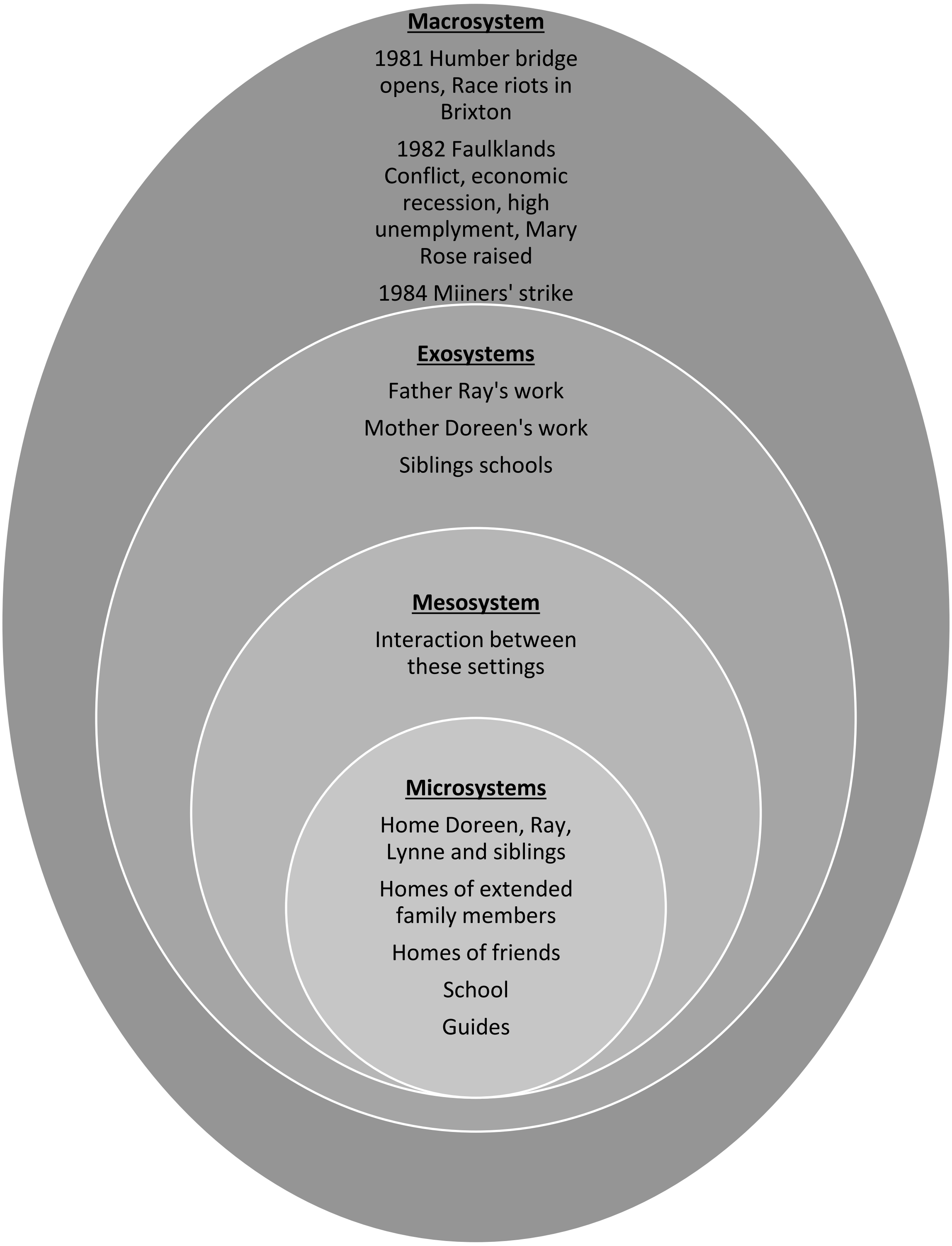
It was at secondary school that the interest Lynne had in physics fostered at home was built on in school. At a microsystem level, it was important that Lynne learnt physics alongside peers she felt comfortable with.

Lynne's parents continued interest in her education was perhaps a consequence of the Plowden Report (Cunningham, 2002). Kelly (1981) found that parental aspiration was a significant factor in the academic performance of students.

Like Meryl, Lynne's subject choices were limited at the end of her third year of secondary education (Ebbutt, 1981). In choosing chemistry and physics rather than biology, Lynne was going very much against the trend. She did fit some aspects of the profile identified by Smithers and Collings (1981) of a female science student in that she was academically able and her social life seems to have revolved around her family circle. However, she differed from their findings in having a definite career purpose and in wanting to work with people.

Politically, this was quite a testing time with economic recession, racial tension and conflict in the Falklands. Having a female prime minister, herself a chemistry graduate, seemed to have little impact on the opportunities and aspirations of women (Clarke, 1996). However, it does mean that Lynne grew up knowing that a woman could have a senior position in government and this may have had an influence on her realising that she could have a career. There were a number of high profile engineering projects during this period i.e. the opening of the Humber Bridge (Brownjohn et al., 2010) and the raising of the Mary Rose (Dobbs, 2017). Lynne makes no direct reference to either of these events but they were both covered in the media and may have influenced her interest in engineering and impressed upon her its importance to society.

Figure 4.2.2.9: The micro, exo, and macrosystems of Lynne's secondary school years set within the chronosystem 1981 – 1986



Lynne's Tertiary Education Years 1986 – 1988

At the time Lynne started sixth form she was considering a career in engineering.

Initially I considered becoming an engineer but as it got to the point of actually thinking about how my life would progress, particularly as a woman, working on a building site with lots of builders, and living in a caravan, didn't have a lot of appeal. Most builders I imagined would be male and I was just thinking actually is that a how I want to live my life? Although the projects would have been interesting I'm not sure if living on a building site is my idea of domestic bliss. So there was a part about following a science career, but also, should I marry and have children what kind of science career would be compatible with the traditional view of a woman? There was also wanting to do something that had a positive influence on people's lives; knowing I could use science and work with people too.

Around the age of 16 Lynne gained some careers advice.

I remember going to a careers fair in my final year of 'O' Levels and talking to a pharmacist which sowed the idea in my mind. I talked to my cousin who is a pharmacist, and then I had my work experience in a pharmacy. They offered me a job working on Saturdays.

I also went to a 'girls in engineering' workshop. I got a sponsorship from a lift manufacturing company for my first year of A' levels. I had to work in the holidays for that company. I was interested in hydraulics but they didn't have a definite structure of what I was going to do so I was given office jobs; it was just filing. I felt that I didn't get a lot of experience of engineering so that didn't really inspire me. I enjoyed working in the pharmacy more and that probably helped me decide.

Lynne went to a tertiary college to study for A' levels in mathematics, and further studies in mathematics, chemistry, and physics.

With me I knew I wanted the outcome then I had to work backwards to achieve it.

Lynne seems to be matching the Smithers and Collings (1981) profile of a female physics student i.e. academically confident but less confident socially.

Lynne's parents continued to be an influence on her choices at this stage of her education.

My mum saw 'A' Levels as a precursor to university, to be specific training for a specific job. I suppose there was an influence there that whatever I was doing for 'A' Level would lead to a specific degree that would lead to a specific job and with pharmacy or engineering it's very clear where your career pathway is going whereas if you are following an arts degree it's less obvious what job you are going to do the end of it..

Lynne's memories of studying for A' Level physics at college are not very positive.

I hated it at 'A' level because the physics lecturer didn't acknowledge I was in the class. We used to hand in our homework and then it would come back marked all except mine. I didn't feel valued. Within my physics group there were two girls and ten boys. The other girl was very, very able and I was struggling. I didn't feel that I could ask questions; probably felt intimidated by the mainly male environment. I would say it was oppressive, particularly at the time when you are growing up and feel self-conscious. You are developing particularly as a woman and surrounded by boys and you don't want to feel that you are thick or making a fool of yourself. I *think if I had carried on with the same group of people I'd been with at school my experience would have been quite different. I would have done better. I suppose I might have carried on doing physics. I think there was a big jump between O' and A' Level physics.*

The syllabus was very taught so there was little opportunity for expression. My feeling was, when it got to 'A' Level it became more abstract and therefore more difficult. We must have done circuits and things like that at 'O' level which was easy to see and relate to. 'A' Level physics was more obscure. I loved nuclear physics; it was like chemistry. I remember doing traffic lights NOR and AND gates which I quite enjoyed, but maybe that's because I have an interest in engineering. It just seemed to make sense at 'O' Level. I don't know what it was at 'A' level? Suddenly I just didn't get it. But I think it was possibly the syllabus that we followed because talking to other people later on, their syllabi didn't seem as abstract as mine. I remember being taken in by the Head of Physics; he wanted to know why I wasn't achieving as I had an A in my 'O' level. He said there was no excuse why I wasn't achieving better. He wasn't very supportive or encouraging. There was the personality of the teacher, there was the syllabus and then there was the group dynamic so I guess it was a mixture of all three.

The macrosystems of Lynne's life were similar to those of her secondary school years the big differences being her sister going away to college and Lynne moving from her secondary school to a tertiary college.

Physics-wise, the move to a tertiary college was negative: Lynne went from being an able, enthusiastic, and confident physics student to someone who hated the subject and lost all confidence in her ability to do it. Her experience appears to have been anti-educative rather than educative. Whitelegg and Murphy (2006) note that the quality of teaching is a key factor in encouraging girls to study physics and this includes having a positive relationship between student and teacher. According to their research, girls seem to find it particularly difficult to study under teachers who they dislike (Cornelius-White, 2007). In keeping with Kelly's (1981) findings, Lynne found that studying physics challenged her identity as a woman. The nature of the physics syllabus being abstract, unrelated to everyday experiences and prescriptive was a further factor in Lynne's disillusionment. Whitelegg and Murphy (2006) found that girls in particular needed to see a purpose to their studies. Lynne clearly wanted physics to help her solve engineering problems and meet a human need. This does not appear to have been a feature of her A' Level syllabus.

At a macrosystem level, Lynne's story also provides a possible insight as to why so much of what has been invested in promoting women in science and engineering has been ineffective in bringing about change. There were several moves around this time to promote physics and engineering for women for example: 'Women in Science and Engineering' (WISE) and 'Girls into Science and Technology' (GIST). Whyte (2017) reports some success with these projects which involved a comprehensive action research study, reorganising option choices and involving female role models from industry. Clearly some initial work and investment had gone in to setting up a science careers fair career. Having recruited Lynne however her placement collapsed due to a lack of planning on the part of the sponsoring company and a breakdown in communication. Those supervising Lynne did not appear to understand the aims of the sponsorship programme hence Lynne being given filing. Instead of inspiring a career in engineering by giving Lynne the chance to gain hands on experience of practical engineering projects the company reinforced stereotypes and prejudices by placing Lynne in a traditionally female environment. Lynne was also put off by her perception of a civil engineering working environment. She wanted the opportunity to have a family, have female colleagues and a comfortable home-life. All of these factors have been identified as potential barriers to women's entry into engineering by Dainty et al. (2010).

Lynne's After-School Years: 1988 Onwards

Lynne left tertiary college and went on to study for a degree in pharmacy at a polytechnic. On completing her degree, she began her career as a pharmacist working full time until she became a mother in 2000. She has continued her pharmacy career on a part-time basis.

The legislation at a macrosystem level ensuring the expansion of higher education, including the formation of polytechnics in 1966 (Lowe, 2002) gave Lynne the opportunity to enter higher education. In opting for pharmacy rather than civil engineering, Lynne appears to be following a trend as highlighted by Bottero (1992).

When asked about how she felt about physics, Lynne said:

I don't actually have bad feelings about physics; it isn't something I would discourage my children from doing. I suppose I wouldn't be doing what I am doing now, if I hadn't studied physics. I think it's a hard science so when people say they are doing physics I feel admiration because they've chosen a hard option. If someone is doing 'A' level physics well I think that person's quite clever. I still think that a science 'A' level is of a higher level, is harder and reflects more ability than quite a lot of arts 'A' levels. I suppose that's a knock on from my parents

Lynne also commented on how she tries to develop science in her children.

I'm just trying to think what I do with my children to influence or encourage them with science. I do want to encourage my children in science but I try not to influence them as much as I think my parents influenced me. We do take them to science museums and things but probably not that many of our activities that we do at home with the children are science based.

It seems that there remains some conflict within Lynne. On the one hand, she clearly values science and sees achievement in science as being somehow superior to achievement in the arts. On the other hand, she recognises this view as having probably come from her father and is anxious to ensure that her children are true to themselves and follow careers and subjects that interest them rather than choosing subjects to please her.

Lynne’s background in physical science has given her a degree of physics literacy sufficient to enable her to feel confident in supporting her children’s science education. This again fits the findings of Archer et al. (2012). Conversely, Lynne is less confident in supporting her children in non-science subjects.

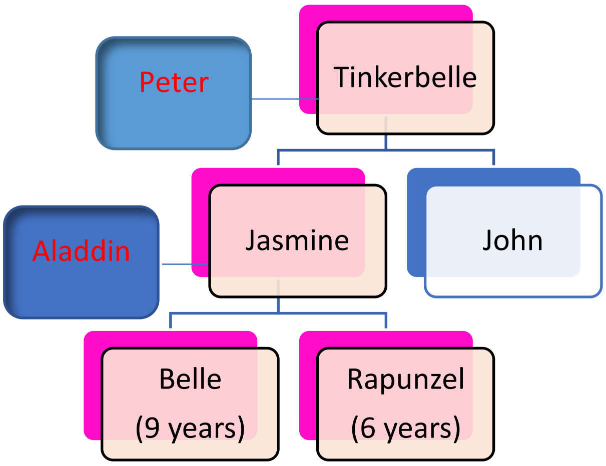
Figure 4.2.2.9.1: A table summarising the factors that enabled Lynne to or inhibited Lynne from becoming physics literate and identifying with physics linked to the themes arising from the analysis in chapter 5.

Lynne		
Theme	**Development of physics literacy**	**Development of a physics identity**
Schooling	Physics lessons at school. Physics options for O’ and A’ Level	School and work experience tended to reinforce gender stereotypes – physics not for girls
Physics at home	Family days out with a physics theme. Construction toys Physics literate father, grandfather and uncles	Physics seen as important by father
Relationships	Parents provided traditional role models Playing with brother gave access to ‘boys’ toys. Had own construction kit	Most male relatives were engineers Found masculine atmosphere of physics classroom intimidating Negative relationship with A’ level physics teacher – felt marginalised
Self-concept		Sees herself as able.

		Physics is a demanding subject. Lynne does not feel as able in physics as in other subjects but this may be due to poor teaching. Physics is something Lynne feels she could have done. Physics conflicted with emerging femininity in teenage years.

4.2.3: The Disney Family

Figure 4.2.3.1: The Disney Family Tree



I was introduced to Jasmine through the same mutual acquaintance who introduced me to the Walker family. The first contact was made via telephone. The video-recorded observation of Jasmine with her two daughters and the audio-recording of Jasmine's interview took place in their family living room. Tinkerbelle chose to come to the researcher's house for her interview.

Tinkerbelle, an administrator, was the youngest of the grandmothers interviewed. Her daughter Jasmine, a part-time geography teacher, was a similar age to the other mothers in this study, Lynne and Meryl. The two granddaughters, Belle and Rapunzel were aged 9 and 6 respectively when the observation and interviews took place. Like Julie, Tinkerbelle helped out with childcare enabling Jasmine to go back to work.

The Disney family chose their pseudonyms based on their favourite Disney characters.

<u>Tinkerbelle Disney – Grandmother</u>

Figure 4.2.3.1: A table summarising some key facts concerning Tinkerbelle's life at the time of her interview.

Pseudonym	*Tinkerbelle Disney*
Age	*60*
Year of Birth	*1952*
Parents	*Father – decorator for telephone exchange* *Mother – dressmaker, working from home*
Siblings	*6 siblings including a twin brother* *Tinkerbelle was the oldest girl but had older brother(s)*
Occupation	*Administrator working in Human Resources* *Home-maker*
Age on leaving fulltime education	*14*
Education Level	*Equivalent of level 2*
Qualifications at time of leaving full-time education	*Shorthand and typing qualifications (City and Guilds?)*
Marital Status	*Married to Peter (an accountant)*
Child(ren)	*Jasmine (born 1971)* *John (born 1973)*
Grandchildren	*Belle (born 2002)* *Rapunzel (born 2005)*
Location of interview	*Researcher's living room in her family home*
Duration of interview	*1 hour 46 minutes*
Time of interview	*Weekday evening, September 2012*

Tinkerbelle's interview took place on a weekday evening in the September of 2012. The interview was arranged through her daughter Jasmine.

Tinkerbelle's Pre-School years 1952 – 1956

Tinkerbelle introduced her family and her preschool years.

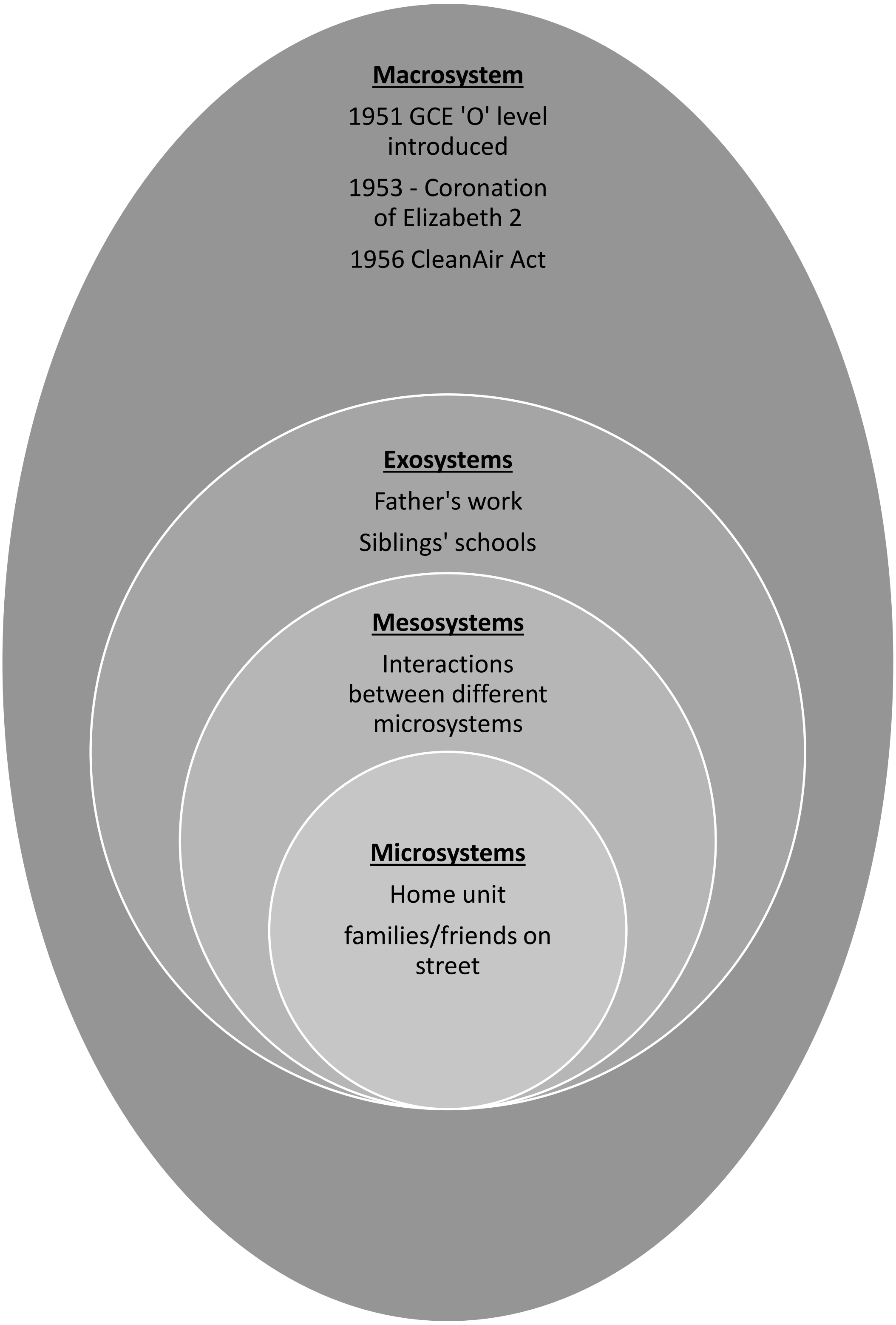
My mum had seven children and worked from home as a dress maker. She had been in the WAAFs. My dad worked at a telephone exchange decorating and that type of stuff. He was a clever man and was very all -round educated. Maths he could just work out straight away in his head. He was always reading papers. I don't know where he got it from. He was one of thirteen children and his mother died when he was really young. It certainly wasn't a privileged life but somehow he picked up a good education. He left school and didn't go onto higher education. He fought in the Second World War. He was a musician as well: clarinet, piano, saxophone. He got us all playing, my older brother and I played the piano, my other brothers played the trumpet and trombone, and we actually played in the orchestra. Dad was always hands on. I think probably for that street for that time it was a bit unusual. We had a washing machine, we were well posh we were. Well with seven kids you needed it. But I can remember we had a mangle. I can remember my dad doing that.

Tinkerbelle's early microsystem seems quite different from Julie and Doreen's. She came from a much bigger family, her mother worked for money and her father helped with domestic chores. In spite of this Tinkerbelle still felt that she, as a girl was expected to do more about the home than her brothers.

Again, there was evidence in educational change at a macrosystem level with the advent of the O' and A' level examination system (McCullock, 2002).

As with the other grandmothers there is no evidence of any consciousness of physics in the childhood home.

Figure 4.2.3.2: The micro, exo, and macrosystems of Tinkerbelle's pre-school years set within the chronosystem 1952 – 1956



Tinkerbelle's School Years 1956 – 1967

As with the other participants, Tinkebelle moved into an additional microsystem once she started school. Overall, the experience seems to have been positive.

I liked school; I liked the camaraderie all my mates but I didn't like some of the lessons. The infants and juniors was mixed. It was quite structured, quite traditional and we were always doing times tables. I went to a Catholic girls' secondary school. The first thing I even knew about science was when I got to senior school and they had the long benches and Bunsen burners. It was general science because I didn't even know what physics was when I left school. I think of science as one subject. Whatever I learnt I don't think it sunk in very much. You see maths was always my worst subject. And I think you always associate science with maths, if you are good at maths you're going to be good at science aren't you. Whereas I was always a bit more arty. I would have thought science was more for boys because in that era it was still very much the woman stays at home and the man goes out to work.We did do domestic science. We also did English, history, geography needlework and art. We had a brilliant art department. I remember Mr X. He was an inspirational teacher, he had a real passion for the subject. We didn't do woodwork and I don't think my brothers were offered cookery, it's terrible isn't it really?

Making children stay at school is probably one of the best things that the government did because I would probably got a more in depth education instead of just leaving; who knows what I would have done. A few of my friends who were more academic than me did do well, they got GCSE O' levels. I should have done. But when you are 14 you don't really know what to choose.

I didn't have half as good an education as Dad did. I don't know whether I *didn't have opportunities or it's just that educationally he was very clever.*

Out of school, Tinkerbelle spent a lot of time in the street playing with her friends. She particularly remembers playing with roller skates. She also spent a lot of time reading both the encyclopaedia she had at home and novels from the local library. Her interest in reading set her a little apart from her neighbours.

You know in that era to have books in the house, that was posh that was; nobody had books in the house. I went to the library and read story books; no science though, I wish I did.

Science does not appear to have been a feature of her home life. With the example of her mother working and her father helping with domestic chores there seems to have been less polarization of domestic chores than in either Julie or Doreen's childhoods. However, there were occasions when Tinkerbelle remembers being discriminated against.

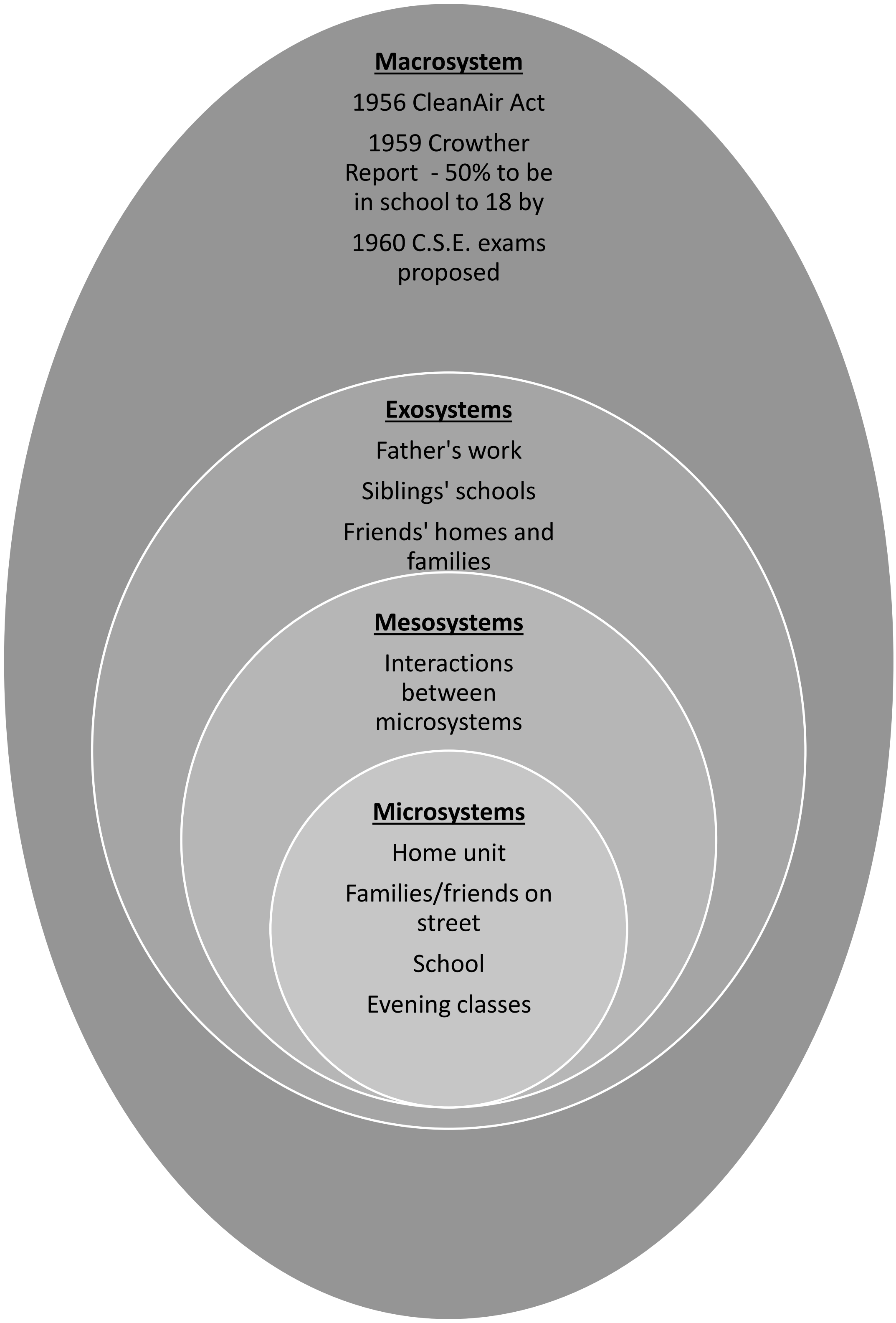
I remember this, you know the film, The Alamo? My parents took the boys to see it not me. I felt why can't I do that, that's not fair? Because of being the oldest girl I did do a lot of household chores, more than the boys. So there was sexism which I didn't like. I mean why should I do blooming ironing while the boys catch up with stuff? I had to look after the youngsters, they didn't.

As with Julie's story, there seems little evidence of a mesosystem between Julie's home and school.

I think I encouraged Jasmine and her brother to do well at school. Whereas with my mum and dad, I won't say they didn't bother but they were more laid back about it. They didn't put much importance on it really.

At a macrosystem level, much was going on. The school leaving age was raised to 15 in 1947, the 1959 Crowther Report aimed to have half of all young people in education up to the age of 18 (Aldrich, 2002). Tinkerbelle however was not encouraged to stay on at school as, coming from a large family, she was expected to earn and contribute to the household's income. Tinkerbelle was taught both science and domestic science although Jenkins' (1979) findings suggest that at this time the quality of science education in girls' schools was of a much lower standard and there was much criticism of domestic science in that it was seen to be unable to deliver the content expected of a scientifically rigorous course. Changes in the exam system (Watts, 2002) also had little impact on Tinkerbelle as she left school at 15 before she could sit for an exam.

Figure 4.2.3.3: The micro, exo, and macrosystems of Tinkerbelle's school years set within the chronosystem 1956 – 1967



Tinkerbelle's After School Years 1967 Onwards

Like Doreen, Tinkerbelle went into office work on leaving school.

I didn't think of my work as a career it was just to get a bit of money. The reason I went into office work is stupid; my parents wouldn't let me go out with all my friends so the only way I could see them was if I went to evening classes. So I went to short hand and typing classes. So consequently by the time I was 14 I had skills so I could do a proper job.

Tinkerbelle continued working until morning sickness with her first pregnancy prevented her. On the arrival of her children Tinkerbelle devoted herself to being a mother, doing a series of unskilled part time jobs at evenings and weekends until her children were in their late teens and she was able to resume her career in administration. Tinkerbelle became more aware of the possibility of women doing physics as she met some female engineers through work but physics didn't come into her life directly.

Besides helping to care for her granddaughters, Tinkerbelle works part-time in the Humans Resources department of a local housing charity. Physics is not something that Tinkerbelle is very conscious of in her day to day life but she does regret never having been taught about it.

Because if you're in a quiz or something and it's a physic question and people say oh well I did that at school but I didn't and I think that was wrong. My husband learnt it but mind you he went to grammar school. But I still think oh no we didn't do physics. It's definitely not my fault but it does make me feel a little bit thick. I just don't know anything about it. Sometimes my husband will say it's a basic rule of physics or something and I'll say is it?

She went on to say that she would have found it interesting to have learnt about the lives of scientists such as Marie Curie.

Around the home Tinkerbelle is the practical member of her family but her lack of physics holds her back.

I've tried to wire a plug in the past but I just couldn't. I spent ages with a screw driver and that and I don't know and brown goes there and blue and I didn't know what was live.

Tinkerbelle’s reflections are evidence of the need for everyone to have a basic knowledge of physics. Although her job is not physics based she finds her day to day life and leisure activities are restricted as a result of this gap in her education.

Figure 4.2.3.4: A table summarising the factors that enabled Tinkerbelle to or inhibited Tinkerbelle from becoming physics literate and identifying with physics linked to the themes arising from the analysis in chapter 5.

Tinkerbelle		
Theme	**Development of physics literacy**	**Development of a physics identity**
Schooling	Some science at school that may have included physics	No opportunity to develop
Physics at home	Not a physics literate family so opportunities through play were not built on.	No opportunity to develop
Relationships	No contact with physics literate people	No opportunity to develop.
Self-concept		Tinkerbelle sees herself as practical but not academic. She is very lacking in confidence with mathematics. She plays down her English skills believing everyone can do English.

<u>Jasmine Disney – Mother</u>

Figure 4.2.3.5: A table summarising some key facts concerning Jasmine's life at the time of the interview.

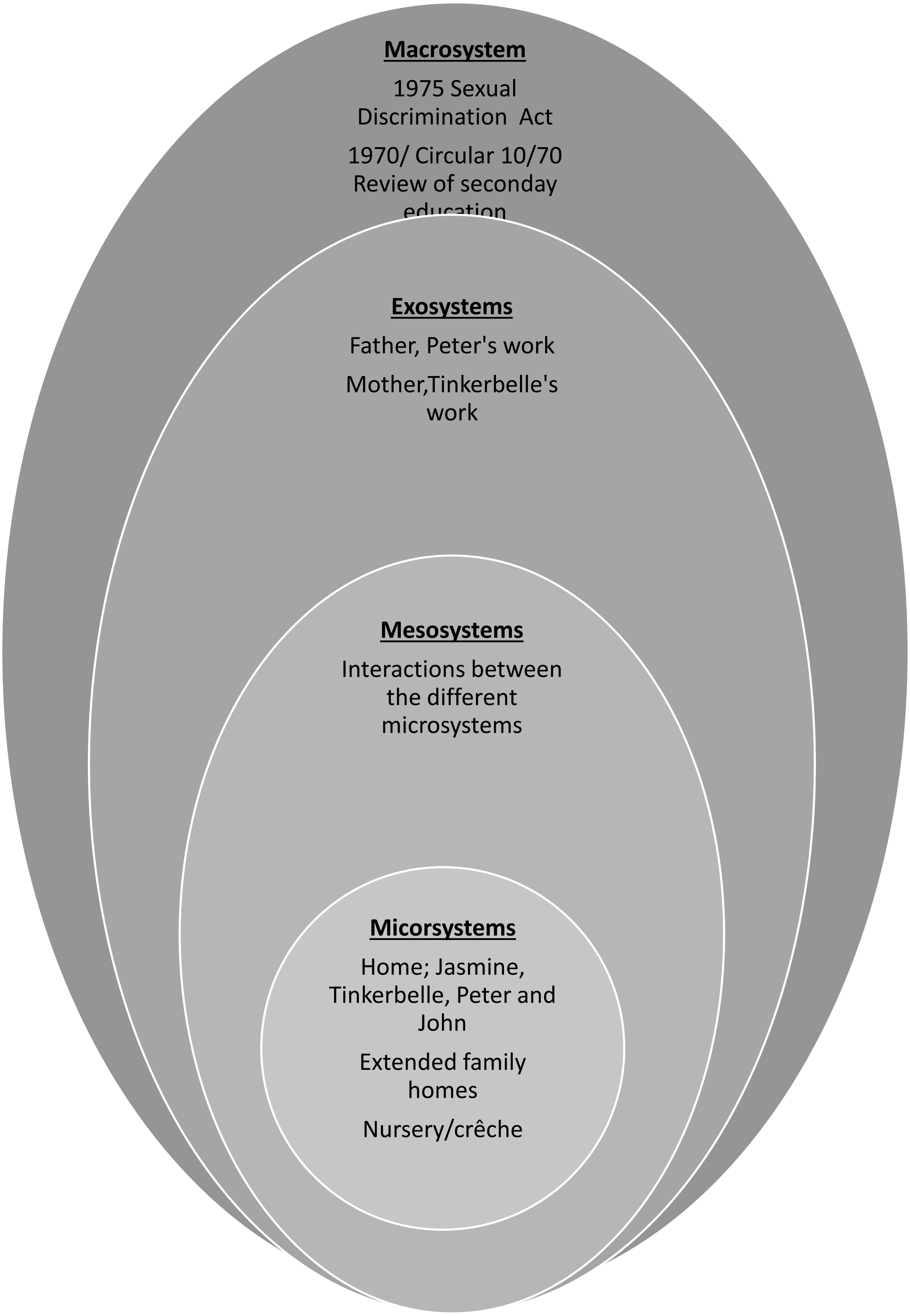
Pseudonym	*Jasmine Disney*
Age	*41*
Year of Birth	*1971*
Parents	*Father – Peter, an accountant* *Mother – Tinkerbelle, administrator working in human resources part-time*
Siblings	*Brother, John, 39*
Occupation	*Geography teacher, head of department, 3 days a week* *Home-maker*
Age on leaving fulltime education	*21*
Education Level	*Bachelor of Arts and Post Graduate Certificate of Education (P.G.C.E.)*
Qualifications at time of leaving full-time education	*G.C.E. O' Levels including a C in physics, (other O' levels @ A or B grade)* *G.C.E. A' Levels in economics, English and geography* *Bachelor's Degree – Geography*
Marital Status	*Married to Aladdin a police officer*
Child(ren)	*Belle (born 2002)* *Rapunzel (born 2005)*
Grandchildren	*None*
Location of interview	*Jasmine's living room in her family home*
Duration of interview	*1 hour 15 minutes*
Time of interview	*Weekday evening, September 2012*

Jasmine was observed with her daughters in her family home in the summer of 2012. She had been introduced to the researcher through a mutual friend. Her interview then took place about a fortnight later also in her family home. At the time of this interview, Jasmine was a part time teacher and head of geography at a secondary school.

Jasmine's Pre-School Years 1971 – 1975

Jasmine operated within a similar microsystem to her contemporaries Meryl and Lynne. She did not have many memories of her preschool years other than playing role play games with her teddies. Her mother Tinkerbelle's job, a direct result of the expansion of universities following the Robbins Report of 1963 (Lowe, 2002) enabled Jasmine to go to the university crèche thus exposing her to the possibility of higher education from a preschool age.

Figure 4.2.3.6: The micro, exo, and macrosystems of Jasmine's pre-school years set within the chronosystem 1971 – 1975



Jasmine's Primary Education 1975 – 1981

Jasmine has happy memories of her childhood, like Meryl and Lynne Lego was a much favoured toy:

Most of the time I played with Lego with my brother. We used to make spaceships and ice-cream vans with the furniture in our bedrooms. We did lots of role play really. We used to play in the garden a lot and in the street with friends. We'd make things like potions. I used to build the Lego and my brother used to be the one that played with the characters. I loved following the instructions and making what was there. I also loved Sindies and playing with my brother's farm.

The family moved home several times within the same locality and at one point lived with one of Jasmine's grandfathers. Jasmine had several changes of school. All of her schools were co-educational. She had few memories of her primary school years:

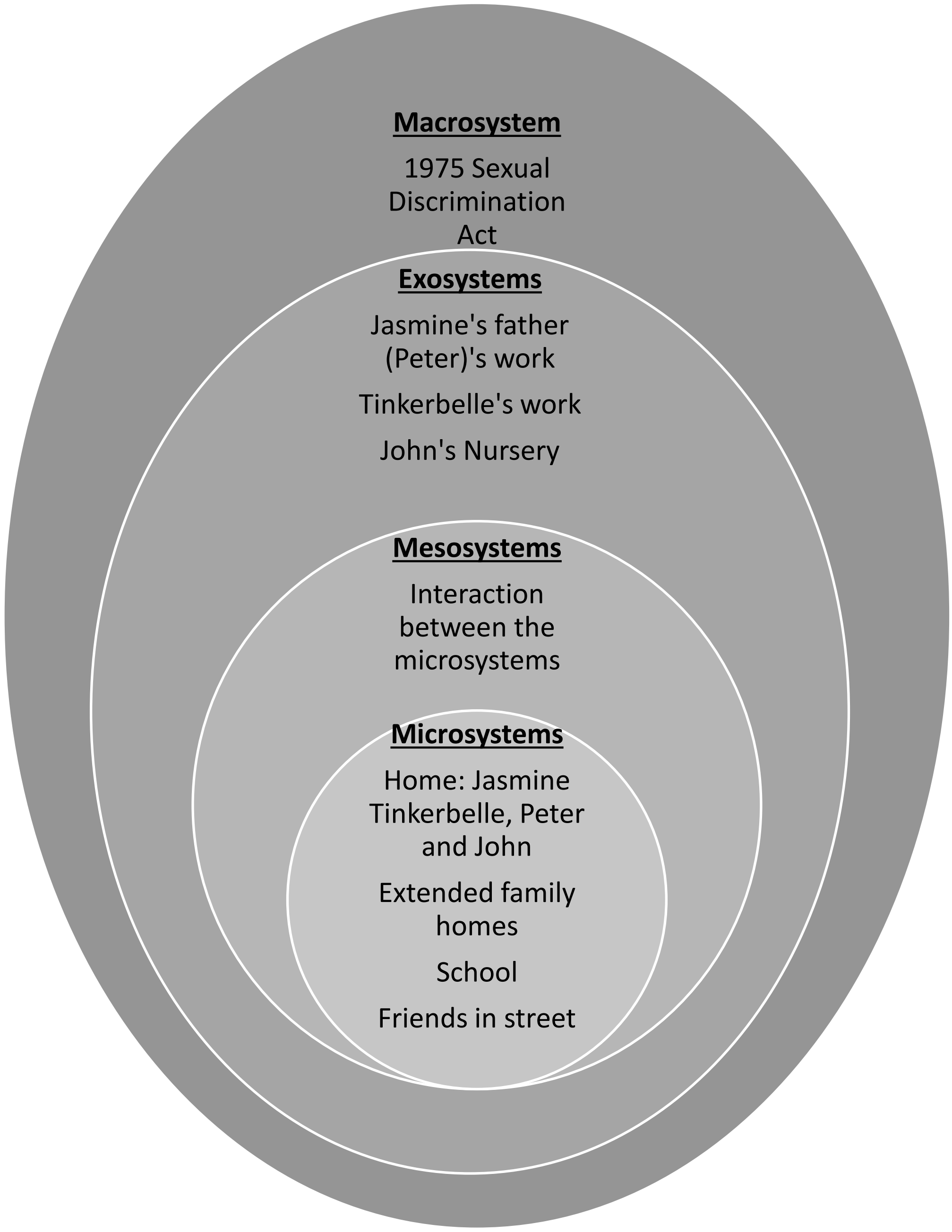
When I was in the equivalent of year one. I remember my teacher; I was completely in love with her. We did lots of projects, one was dinosaurs.

As a family, the Disneys were keen readers. They enjoyed sporting activities such as swimming and also visited places of interest. These places of interest were usually either of environmental such as woods, beaches or historical such as castles. Few of their family activities involved science although Jasmine does remember being taken to the Natural History Museum by an aunt.

Jasmine appears to have operated between several different microsystems including school and her extended family. There is evidence of an extended mesosystem with Jasmine going to her mother's place of work to overcome childcare issues, having days out with extended family members, living with her grandfather and her parents' frequent contact with her schools. Other than a visit to the planetarium, science does not feature consciously in the micro, exo or meso systems of Jasmine's primary school years.

At a macrosystem level, as with Meryl there is evidence of post Plowden influence in that it involved topics and parental participation (Cunningham, 2002). The 1975 Sex Discrimination Act (Aldrich, 2002) had no obvious impact on Jasmine's primary education.

Figure 4.2.3.7: The micro, exo, and macrosystems of Jasmine's primary school years set within the chronosystem 1975 – 1981


Macrosystem
1975 Sexual Discrimination Act
Exosystems
Jasmine's father (Peter)'s work
Tinkerbelle's work
John's Nursery
Mesosystems
Interaction between the microsystems
Microsystems
Home: Jasmine Tinkerbelle, Peter and John
Extended family homes
School
Friends in street

Jasmine's Secondary and Tertiary Education 1981 – 1990

Jasmine's entry to secondary education proved problematic. Her parents wanted her to go to grammar school.

Mum and Dad wanted me to go to the grammar school so I took the exam. I didn't get in. Well my mum and dad fought tooth and nail, I remember my dad being very cross about 'the system' and I hadn't got in because of the system not because I wasn't bright enough. My dad's motto is 'you've got to maximise your potential'. They've been behind me all the way; not pushy, not ever putting too much pressure on me because I'm very internally driven to do well but they're always just there you know if I did just slacken off.

However in spite of her parents' reservations, Jasmine's experience of secondary education seems to have been largely positive.

It was very exciting because we had science labs and everything but I don't remember any particular lessons. In my third year the teacher gave everyone in the class C3. So my mum and dad got my report home and it's all As and Bs apart from C3 for science. Mum and dad had no hesitation in 'going up that school.' Basically they were outraged. He said well they're an average class and she doesn't really stand out from anyone else in the class. I don't know what happened but he was obviously told what for. I can't remember my parents putting any extra emphasis on science. They weren't fussed with art and music just the academic subjects. Just trying my hardest was what they wanted me to do. They knew I was bright; they assumed that I would be getting As all the time.

And then it came to the options. I could choose two sciences out of physics, chemistry and biology. I chose physics and chemistry at O' Level because I wanted to be an astronomer. I joined the British Astronomical Society and I always had my *head in a book about planets and various leaflets and planets and all the rest of it. I borrowed a telescope. I set it up in the back garden and I used to look out of the window every night and identify constellations. I used to make up my own names for them so the Great Bear, was the shopping trolley. I noticed how it would move and that was like a discovery. It made me really think about the fact about that the Earth is spinning round and that they're over there and we're over here. It gave me a sense of awe.*

I was never really hugely interested in biology. Interestingly that was very female. All the girls did biology and it was mostly boys doing physics and chemistry. Was I the only girl in my physics class? I think I might have been and there were only two girls in the chemistry class. There were only two of us doing chemistry O' level. Everyone else was doing C.S.E. and there were classes for just the two of us, special classes.

In physics I remember ticker tape and momentum. But that was the one subject that I really I didn't quite get. I got a C in my physics O' level and I got As and Bs in all the rest. I wasn't hugely surprised; I did find it difficult. Quite I often I remember the feeling of doing physics. I remember the classroom in colours. It was blues and greys. I felt very much on my own; the boys all seemed to know exactly what was going on and they seemed to have more of a passion or an interest whereas I just couldn't get excited about mechanical things. I remember being hugely interested in chemistry, the concept of the atom, the electrons, the neutrons and taking that and thinking about how atoms were arranged. I was fascinated about radioactivity. Physics just hasn't lived with me whereas comments that my history and English teachers made have lived with me. I can remember the terminology of physics but it didn't inspire me enough to stick with it. After that I went to study A'

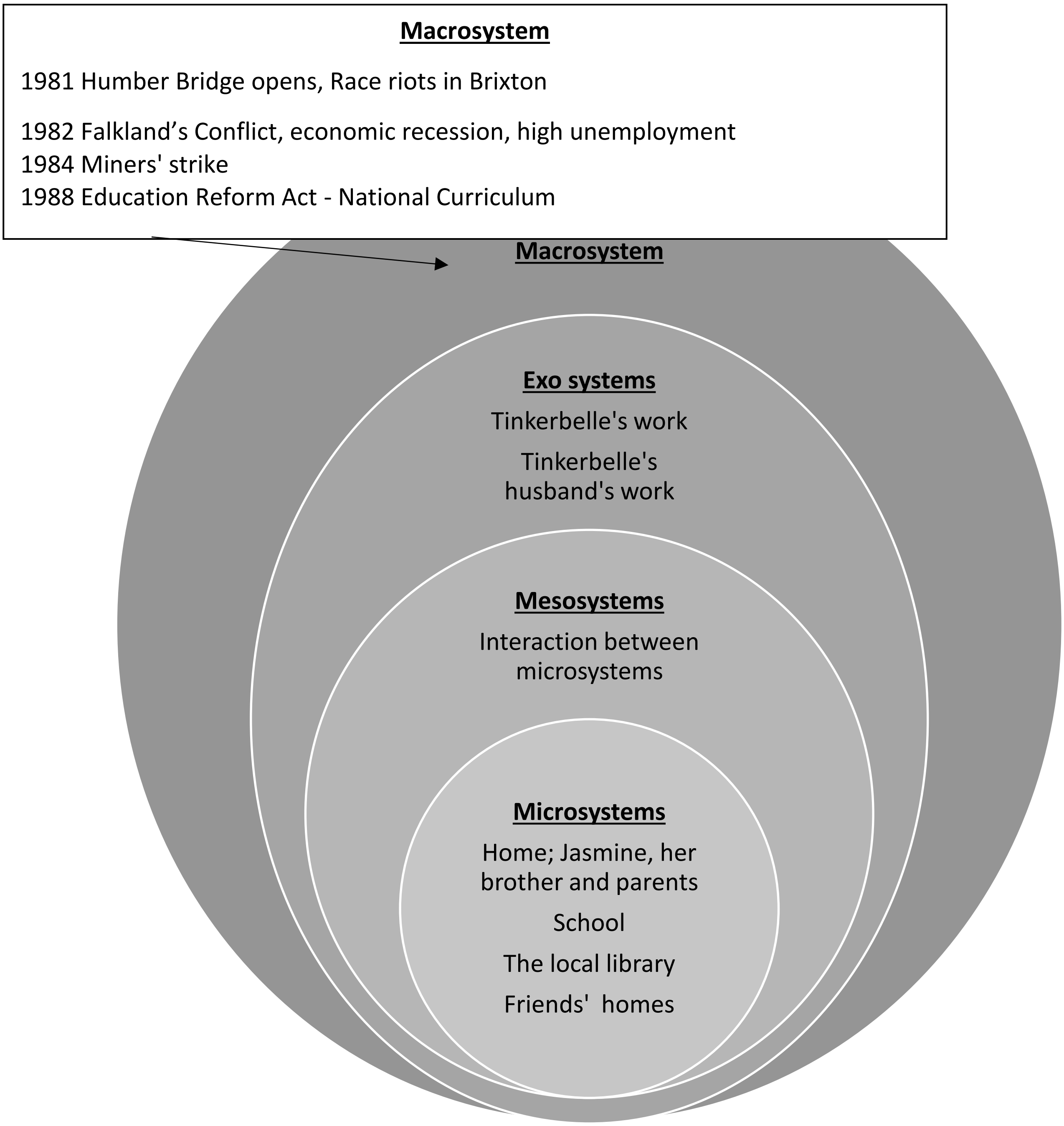
Levels in geography, economics, and English, so I went from almost off the kind of science track at that point.

Jasmine's story has many parallels to Lynne's. Unlike Lynne, Jasmine did not come from a physics literate family but her family did encourage her in all academic subjects. When Jasmine developed an interest in astronomy this was supported by her family and she had access to books and a telescope. Physics in school by contrast appears to have been a very dry, dull subject that did not build on Jasmine's interest in the subject.

A very similar pattern emerges here to that of the previous two families: while Tinkerbelle's parents took little interest in Tinkerbelle's schooling and wanted her to leave school and get a job at the earliest opportunity, Tinkerbelle and her husband were determined that Jasmine would do well academically, and there seems to have been much interaction at a mesosystem level between Jasmine's parents and her school. At times, there seems to have been tension between the microsystems of the school and home, Jasmine's parents believing that the school did not have high enough expectations for Jasmine and were holding her back.

Like Lynne, Jasmine had to decide which subjects to continue after the third year. In her school, the timetable allowed for students to study two out of the three sciences. There does not seem to have been the same timetable conflicts as were faced by Meryl. Jasmine's choice of chemistry and biology mirrors Lynne's choice of these subjects for future career options, in Jasmine's case the desire to become an astronomer. Her comments suggest that her relationship with the teacher, the presentation and context of the lesson and the syllabus weighting, all contributed to her deciding to drop physics. Similar issues have been raised by Kelly (1981) and thirty years later, by Whitelegg and Murphy (2010). Had Jasmine's teachers been more inspiring, the syllabus more interesting and had she been able to develop her interest in astronomy perhaps she would have been happy to continue in physics.

Figure 4.2.3.8: The micro, exo, and macrosystems of Jasmine's Secondary and Tertiary Education set within the chronosystem 1981 – 1990



Jasmine's After School Years 1990 Onwards

Jasmine's story provides further evidence of the expansion of higher education in the macrosystem (Lowe, 2002).

From a very early age my dad said university was where I was going. I'm the first person in my family to go to university. Dad didn't go, mum didn't go and you know it was very much a completely different culture if you like. I remember my auntie saying 'what's the point you're only going to get married and have babies.' Of course her children did eventually go on.

Jasmine studied for a degree in geography at a leading UK University. On leaving university Jasmine did a series of temporary jobs until deciding to do a post graduate certificate of education and becoming a geography teacher. She worked full time and became a head of department. There is little evidence of any conscious engagement in science at this phase of Jasmine's life.

Jasmine gave up her full-time teaching on becoming a mother and has since done a series of temporary part-time teaching posts which have little promotion prospects and at times Jasmine has found this frustrating.

Jasmine feels that being a woman has never been a barrier to her but at times being a mother has:

There was never any gender thing at all as I say the only time when I've experienced any frustration is being a mother. I've never felt like I must succeed in a man's world; it's my I've never felt that I couldn't do anything because I was female.

Her husband has offered to give up his post in order to look after the children and allow Jasmine to return to full time teaching but Jasmine has decided she doesn't want to relinquish her primary care of the children. She does at find it difficult to balance being a mother with being a teacher:

It's all in the balance at the moment I'm in a real flux. It's actually … I'm finding it very hard to be the mum I want to be and the teacher I want to be. I'm finding it very hard to compromise on either; it's difficult.

In many ways, Rapunzel and Belle have a similar home life to that of Jasmine as a child. They have more toys than Jasmine remembers having but they like to play with similar toys to those Jasmine played with i.e. dolls and Lego. Role play is an important part of their play. Sharing books with their parents and grandparents is also a favourite family pastime.

The family enjoy days out; these days out are primarily of either and environmental or historical nature. They enjoy an occasional visit to a local interactive science museum. Jasmine is keen for her daughters to have a broad and balanced experience.

Science is not something that often enters Jasmine's consciousness but it does feature in the background of her life.

I think the biggest thing in terms of science is the technology that we all use and actually rely on that helps us and frustrates us in equal measure it seems and actually crowds us out a bit. If I think of science I immediately think of technology. It's interesting, when the girls have been doing something at school and they bring it home it makes you think at a more basic level about science but unless they were bringing it home to talk about I don't really think I would give it a huge amount of thought. We do look at the stars all of us. We get the binoculars out. We've downloaded an app that's got a kind of GPS on in it and you hold it up to a constellation and it'll work it out for you. Aladdin did get me a telescope for

Christmas one year but it is actually in the loft and I keep saying we must get it out. I've not got it out since the girls were born. We must get it out I'd love to show them

Like the other children in this study, Rapunzel and Belle will be taught science from the ages of 4 to 16 and physics will occupy about a quarter of the curriculum time. The observation revealed that Rapunzel as yet had little idea of what science was and so had no stereotypes to comply with. Belle on the other hand, in spite of her mother's interest in astronomy, saw 'telescopes and stars' as a thing that would appeal to boys not girls because girls were more into creating things than observing them.

Figure 4.2.3.9: A table summarising the factors that enabled Jasmine to or inhibited Jasmine from to becoming physics literate and identifying with physics linked to the themes arising from the analysis in chapter 5.

Tinkerbelle		
Theme	**Development of physics literacy**	**Development of a physics identity**
schooling	Physics lessons in secondary school.	Physics taught in very masculine environment – off-putting. Physics dull and uninspiring
Physics at home	Allowed to follow own interests – had a telescope. Access to range of books including physics topics. Television Lego	Reading Leaflets Astronomical Society Television Museum visits Telescope
Relationships	Spent a lot of time playing	Teacher was not engaging

	with her brother so had access to his toys. Encouragement from parents to do well in all subjects.	Parents encouraged all learning – considered her bright
Self-concept		Jasmine feels less able in physics than other areas. Able student Wants to be a mother first

4.3: Summary

All of the participants were able to give detailed accounts of their experiences of physics. Their stories suggest an overall increase in the opportunities both to become physics literate and to identify with physics. This increase is not uniform.

The grandmothers' generation were not taught physics at school and were left with very little idea about what physics is. The schools of the mothers' generation did not appear to build on the knowledge and interests of their pupils. They provided an introduction to physics but either through a limited range of options discouraged further study as in the case of Meryl or presented physics as a difficult, dull unfeminine subject as in the cases of Lynne and Jasmine.

The home environment had an important part to play in the development of physics concepts and a physics identity. Again the grandmothers of this study had no access to physics based games or activities. By contrast their daughters were taken to science museums, had access to science programmes on television, read books related to science and played with construction kits. One reason for this may have been the greater involvement of fathers in their daughters' education and family life.

The relationships between family members and also physics teachers also seem to have had quite an impact on the level of physics literacy attained by the participants. Relationships were also important in providing role models and establishing a self-concept.

There continues to be a level of conflict between the participants' identity with physics and their identity as women. Those who chose to study physics further had to do so in a predominantly male environment. The women of this study saw physics as a challenging subject and believed that physicists had to be bright. All of the grandmothers saw themselves as less able. This perceived lack of ability may have made them feel more feminine. The women of the mothers' generation saw themselves as bright but in the case of Jasmine and Lynne less bright in physics than in other subjects.

The next chapter will analyse what their stories reveal about the acquisition of physics literacy and the development of a physics identity through the following themes: schooling, physics in the home, relationships, and self-concept. These themes arose from an analysis of the participants' interviews scripts.

Chapter 5: Analysis

5.0: Introduction

The aim of this study was threefold:-

1. to examine the opportunities two generations of women from three families had to become '*physics literate'*,
2. to understand of how a 'physics' identity may be developed or inhibited,
3. to examine if any changes to the development of a '*physics identity'* occurred over two generations.

The previous chapter described the lives of the participants and set them in a social and historical context using a Bronfenbrennerian style approach. From this data it was possible to extract a range of themes for analysis and discussion. The limits of this project did not allow for an examination of all these themes so they have been grouped under four main headings: '*schooling*', '*physics in the home'*, 'relationships' and '*self-concept'*. These themes are solely the interpretation of the researcher's analysis and are therefore as much about opening a discussion of possibilities as finding definitive conclusions.

5.1: A description of how the data was analysed

Following the interviews, the audio recordings were transcribed then checked by the participants. This then provided a text for a phenomenological hermeneutical analysis. The scripts were reread and as they were read a concept map was constructed. An example of one such concept map can be found in Appendix 6. The concept maps were created by writing the key words from phrases or sentence in the participants' responses on blank paper. Once a link could be made between a pair of key words this was shown with a line. As the process continued, clusters of linked key words were formed. These clusters were then assigned a colour and became the subthemes of this study. In order to make the findings more manageable, these subthemes were then grouped together into main themes or headings.

The table in Figure 5.1 lists the themes and major subthemes extracted from the data. The subthemes and consequent main themes did not emerge from the data as in a grounded theory approach instead they were as a result of the steering of the questions from the semi-structured interviews and the researcher's interpretation and application of the literature review to the findings. This resultant interpretation was the result of a dynamic interaction between the experiences and preconceptions of the researcher, the responses of the participants, and the researcher's interpretation of the literature. From a radical orthodox viewpoint, the literature, the participants' stories and the researcher's experiences all hint at reality. The researcher has taken these 'hints' and fitted them together to create a picture that is informed by but not a definitive description of that reality.

Figure 5.1: A summary of the main subthemes and themes extracted from an analysis of the data from the interviews

Main Theme	Subtheme	Bronfenbrennerian System
Schooling	Era	Macro, chrono
	Curriculum	Micro, meso, exo
	Careers advice and training	Micro, meso, exo, macro, chrono
	Options	Micro
	Place	Micro, macro, chrono
	Parental Involvement	Macro, chrono
	Qualifications	Micro, meso, exo, chrono
	Type of Schooling	Macro, chrono
	Duration of schooling	Micro, chrono
Physics in the home	Toys: social, mechanical, physical and creative	Micro, meso, exo, macro, chrono
	Books; fiction and non-fiction	Micro, meso, exo, macro, chrono
	Relationships - Carers and companions	Micro, macro
Relationships	Mother	Micro, exo, macro, chrono
	Father	Micro, exo, macro, chrono
	Siblings	Micro, exo, macro, chrono
	Teachers	Micro, exo, macro, chrono
	Peers, friends, work colleagues	Micro, exo, macro, chrono
	Gender	Micro, exo, macro, chrono
Self-concept	As a woman	Micro
	Puberty	Micro, macro
	Ability, aspirations and expectations	Micro, macro, chrono
	Personality and temperament	Micro, macro, chrono
	Motivation and values	Micro, macro
	Gender and role	Micro, macro

	Social norms	Macro

Once the clusters and their colours had been established, it was possible to return to the scripts and apply the colour coding. An example of this colour coded script can be seen in Appendix 7. This colour coding made the link between the questions asked in the interviews and the resultant data more apparent. It also highlighted any sections of text that had been overlooked enabling these to be assigned to themes. It also illustrated how often one concept fitted into more than one theme.

The main themes constructed from this data were:

1. **Schooling:** this included formal education at primary, secondary and where appropriate tertiary and higher levels, it also encompassed other forms of organised learning such as, in-service training and evening classes, this section was initially labelled education but was changed so as to distinguish it from the education that took place in the home and was therefore covered by the 'physics in the home' theme.

2. **Physics in the home:** this enveloped a wide range of home experiences including toys and games, leisure pursuits, reading, and domestic chores. Some of these subthemes were conscious efforts to promote learning such as visits to a planetarium, others were experience that had subtle links to physics such as watching a mother carry out a laundry task. This theme had many overlaps with relationships.

3. **Relationships:** this theme involved a range of relationships including parents, siblings, friends, colleagues and teachers. It also included the roles that these different relationships fulfilled. Relationships had an important function in the

development of the final theme, self-concept.

4. **Self-concept:** by this the researcher meant those factors which gave the individual a sense of self. Subthemes in this section included gender, puberty, aspirations and role.

These themes will be considered in the next sections of this chapter. Greater emphasis will be given to '*schooling'* and '*physics in the home'* in section 5.2, the development of physics literacy, and '*relationships'* and '*self-concept'* in section 5.3 as these were the areas in which they had the most influence.

5.2 The Development of Physics Literacy

From the analysis of the data two of the main themes i.e. ‘schooling’ and ‘physics at home’ seemed to be the main contributory factors in developing a physics literacy in the participants. This section begins with a brief description of each participant’s level of physics literacy. It will then consider how this developed with reference to the main themes derived from the data analysis.

Julie and, from what was revealed through Lynne’s interview, Doreen did not develop a physics literacy. Neither of these women was taught any physics at school and although they were surrounded by physics concepts at home as they saw their mothers use a range of mechanical appliances for example, the physics behind this was never made explicit to them. Doreen came from a physics literate family with her father and both of her brothers being involved in telecommunications, she married a telecommunication engineer; Julie’s mother may have had a STEM role when working for the Air Force during the First World War but in spite of these connections neither woman became physics literate. Their stories are not consistent with the findings of Archer et al (2012) and Julie would argue that she did not become physics literate because she lacked the ability which supports Browne’s (2002) view (refer to chapter 2, p. 21)

Tinkerbelle also considered herself physics illiterate; she asked if physics was to do with origami. She associated physics with mathematics. Unlike Doreen and Julie, she had had some science education at secondary school but this was not differentiated into different science subjects and so she was unable to isolate any physics elements. Like Julie and Doreen, Tinkerbelle had no physics input from home. Tinkerbelle's lack of physics literacy is a now cause of frustration to her, she cites the feeling of inadequacy when taking part in quizzes. Her story supports Archer et al.'s (2012) findings in that her family were not physics literate and were therefore unable to promote the development of her physics literacy.

Meryl did have a level of physics literacy; she knew what was to do physics, had a basic understanding of physical concepts and occasionally read about physics in her leisure time. She worked alongside colleagues with a background in physics. In spite of this, Meryl felt a sense of frustration with her level of physics literacy. She felt that she could have taken physics further but was prevented from doing this by the limits of her schooling. Meryl's physics literacy came primarily from her middle school. She was taught physics in a co-educational class by an inspirational physics teacher. Her physics education was curtailed when she moved area and went to a girls' secondary modern school with restricted option choices.

Her home environment also had a bearing on her level of physics literacy. Her father's influence seems to have pushed her towards commerce rather than physics although ultimately it was her mother's love of the environment that appears to have had the most influence on her future career choices. This further supports Archer et al.'s (2012) findings. Her childhood reading, although extensive, did not appear to include a physics element, neither did her play. Television, via her father's control and choices did have some influence as she remembers watching '*The Sky at Night'* at his instigation. Meryl does do some science activities with her children but these are primarily of a biological or environmental nature following both Meryl's and her mother Julie's interests in living things and the environment.

Jasmine also has a level of physics literacy as is acknowledged in her O' Level physics qualification. Her grade in physics was her lowest O' level grade however and Jasmine considers herself to be less literate in physics than in other subjects. Her level of physics literacy seems to have been the result of a combination of schooling and her home environment. Although coming from a physics illiterate family and not specifically encouraged to develop an interest in physics at home, Jasmine’s extensive reading and her family’s commitment to expanding her knowledge in all areas allowed an early interest in astronomy to flourish. She has maintained this interest in astronomy since her teens but it has been pushed to the periphery of her life in recent years by work and family commitments. She encouraged a general level of science awareness in her daughters through supporting their schooling, occasional visits to science based venues such as an interactive science museum and through television. Physics was not given any particular emphasis but was seen as part of a comprehensive education.

Of all the participants, Lynne was the most physics literate, studying the subject to A' level. Like Jasmine and Meryl, Lynne studied physics at secondary school, first as part of a general science programme and then as a discrete subject. There were some elements of physics on her pharmacy course which she studied in higher education but there was a greater emphasis on biology and chemistry.

Lynne’s home background was very important in establishing her level of physics literacy. She came from a physics literate family with most of her male relatives having a connection with physics. She had access to some construction toys from a young age and although these did not appear to have the significance of her dolls’ house, she remembers enjoying playing with them. Her visits to sites of industrial heritage do seem to have been significant in emphasising the usefulness of physics and making a connection between physics and human society. Lynne, more than all the other participants, saw physics as a subject that had a purpose, and could make human life better. Lynne is now in a position to pass on her knowledge of physics to her children. She has continued in her family tradition, taking her children to places linked to industrial heritage and encouraging toys with a scientific bias alongside a wide variety of play activities.

5.2.1: Schooling

Schooling appears to have been a key factor in the development or otherwise of a physics literacy. This section will now consider this in more detail by focussing on the subthemes clustered under the schooling heading namely: curriculum, careers advice and training, options, place, parental involvement, qualifications, type of schooling and duration of schooling.

When Julie and Doreen started school, physics had been established as a male subject and it was often not offered to these girls in their girls' schools (Jenkins, 1979, see chapter 2 p.65). There is no evidence to suggest that any of the participants had any awareness of being restricted by the curriculum; rather there seems to have been an acceptance of the status quo. As will be mentioned in the next section, their curriculum seems to have focussed on teaching them how to be women, as physics was not considered a woman's subject then it did not feature in their education. It is easy to see how views such as those of Browne (2002) and Pinker (2009) could emerge from a society whose education is about ensuring its members adopt the gendered characteristics of their sex.

By contrast, all three participants from the mothers' generation remember physics lessons from their secondary schools and have an understanding of what it is to do physics. However science did not appear to feature in their primary education. Kelly's (1981) research suggest that this lack of science in primary schools was typical for this period and that this could be an issue in that most students form an opinion about their subjects before reaching secondary age (see chapter 2, p.76). The lack of primary school physics, however, did not appear to deter the women of this generation and their first encounters with physics at school appear to have been positive. The difficulty with the physics curriculum for this generation seems to have come once the women had chosen their examination options. The syllabus presented to Lynne and Jasmine was dull and did not build on their existing knowledge and interests.

The daughters' generation will have another contrasting experience: they will be taught physics as part of the science component of the National Curriculum from the ages of 5 to 16 years. The curriculum they follow will be identical for both boys and girls irrespective of whether they are in a single sex or co-educational school (see chapter 2, p. 34).

However, the physics curriculum that the daughters' generation will encounter still appears to be driven by industrial concerns with a view to finding the next generation of physics elite who will be able to drive engineering and the economy forward. There seems little interest in making the nation more 'physics literate' or giving physics a more central role in culture and society. In contrast to literacy where the aim is for all students to be literate irrespective of whether or not their future careers will be literacy based, physics education is about producing professional physicists which inevitable makes the subject seem irrelevant to the majority of its students.

Lynne was the only participant who remembers being given clear careers advice and the opportunity to have work experience. The other participants appear to have drifted into their current roles through a combination of what subjects interested them and what job opportunities were available at the time they made their choices. The usefulness of physics to a career was one of the factors that encouraged Lynne to choose to study physics both at O' and A' level. Knowing how she might use qualifications in physics overrode any preference Lynne may have had for other subjects. Similarly, Jasmine chose to study physics in order that she might become an astronomer. Neither participant chose physics for the love of the subject or for material gain. This fits Whitelegg and Murphy's (2006), Phipps (2008), and Kelly's (1981) findings that girls need to see a worthwhile purpose to their studies (refer to chapter 2 p. 35). It would seem that women are more likely to become physics literate if they can see some extrinsic value in doing so, they are unlikely to study physics just for the joy of learning it.

The option package seems to have been a barrier to learning for the women of the mothers' generation. Like the students of Ebbutt's (1981) study, Meryl had to choose between physics and the more accepted feminine subjects of commerce and typing.

Both Jasmine and Lynne opted to study physics. In order to do this however they had to drop biology a science popular with girls. This placed these women in a female minority in their O' and A' level physics classes. In both cases their choices seem to have been driven by their preferred career paths at that time. This complements Whitelegg and Murphy's (2006) findings that girls tended to plan ahead and choose subjects that would be relevant to their futures rather than just choosing subjects because they enjoyed them. Similarly Pinker (2009) argues that women are more motivated by a sense of purpose than status or money when choosing subjects (see chapter 2 p.35)

According to Kelly's (1981) analysis of government statistics, in the academic year 1975/6 only 12% of girls studied physics in the fourth and fifth form compared with 47% of boys whereas 49% of girls studied biology compared with 28% of boys. This places Lynne and Jasmine in a minority.

Kelly (1981) expressed concern about the age at which children are asked to choose options claiming that puberty, when girls are most insecure about their femininity, was not the right time for girls to be making such crucial judgements effecting the rest of their lives (refer. chapter 2, p. 39). Unlike the grandmothers, the mothers did have a *de jure* opportunity to study physics to degree level and beyond. *De facto* these opportunities may not have been as available as they first appear. Bourdieu (Bourdieu and Passeron, 1990) maintains that the educational systems of a state aim to replicate the existing society and culture (ref. chapter 2, p. 42). Thus even though sections of government may have wanted to encourage girls into STEM based careers, for a variety of reasons, merely offering these educational opportunities do not appear to be enough to ensure the uptake of studying physics by girls (Dainty et al, 2010). Both the culture of physics and the wider cultural norms of society may have conspired to counter the intentions of curriculum changes.

For the daughters' generation, the opportunities to become physics literate have further increased. Starting formal education past the 1988 Education Act has ensured a science curriculum that is 33% physical processes (physics) from the age of 5 to 16. Two of Kelly's (1981) concerns have been addressed i.e. science is now taught in primary schools thus enabling them to have experience of the discipline before forming an opinion about it and children have to study either physics or a general science course including physics up to the end of their secondary education. This next generation will not then have to make choices concerning physics during the first throws of puberty. In spite of these improvements however it seems that this generation of women is statistically no more likely to study physics at a further or higher education level than their mothers.

Place seems have had a big influence educational provision for the participants as at the time of their schooling there was no National Curriculum and the type of education and curriculum offered depended on where you lived. Meryl's story goes against the findings of Shapker and Keating (2017) (refer chapter 2, p. 34) as going to a girls' school limited her options thus preventing her from studying physics. Her school did not provide any careers advice and Meryl had no sense of purpose or direction when choosing her options, she instead went for subjects that she enjoyed.

Archer et al. (2012) and Kelly (1981) have argued that parental involvement is a highly significant factor in developing an interest in science including physics (refer to. chapter 2 p. 36). The stories of the participants comply with their arguments for the participant who became the most physics literate was Lynne who came from a physics literate family and whose father took an active interest in her physics education. Conversely, the least physics literate participants, Julie, Doreen, and Tinkerbelle's parents showed little interest in their daughters' acquisition of physics. Meryl and Jasmine's parents took a general interest in their daughters' education but did not put any specific emphasis on physics.

Tinkerbelle contrasts her expectations for her children's education with what she calls her parents' attitude to schooling. Her parents just accepted what was offered whereas she was prepared to fight to ensure that her children had the opportunities she did not. Lynne tells a similar story of her parents. What is unclear is what led to this shift in parental expectations and why these women who were prepared to accept their own lot were so determined that their daughters, should have better opportunities. The Plowden Report of 1967 encouraged greater parental involvement. Wider use of media such as the television may have led to parents being more aware of the issues and possibilities. Both Doreen and Tinkerbelle had worked for universities themselves and so had perhaps had their eyes opened as to what could be available for their own children. The expansion of higher education in the 1960s meant that more university places were available but it seems surprising that it was Tinkerbelle, a woman who had left school at 15 that was pushing for a university place for her daughter and her daughter's teachers who seemed to be putting up barriers to this.

One measure of the level of physics literacy is the qualifications gained. None of the participants from the grandmothers' generation gained a qualification in physics. Two of the mothers gained an O' Level in physics and one of these also got an A' Level in this subject. Working for a qualification directed the syllabus and determined the content and nature of the physics literacy gained. Gaining qualifications appears to have become increasingly important with each successive generation perhaps reflecting the centralisation of education and society in general (Wolf, 2002 refer to Chapter 2, p. 64)

Julie gained no formal qualifications, but both Doreen and Tinkerbelle acquired level 2 qualifications, from school and evening classes, respectively.

There have been marked changes in the length of time spent in education. Julie left school at 14. Doreen could have left at 15 but chose to stay on an extra year in order to complete her 'O' level course. Tinkerbelle left at the age of 15 but did do evening classes.

By contrast, the expansion of 6th form, further and higher education led to all three women from the mothers' generation studying to graduate and in Meryl's case post graduate level (refer chapter 2 p. 64). However none of these women chose to study physics beyond the age of 18, giving up physics at 14, 16 and 18 years respectively. They did not continue to develop their physics literacy after completing their physics education at school.

The next generation will be in compulsory education or training until the end of the academic year when they are 18 and like their mothers they will have the opportunity to go on to higher education dependent on acquiring the relevant qualifications.

These changes are perhaps a reflection of the cultural and social changes highlighted in chapter 2 such as: the country's economic stability allowing people to spend longer in education, the increasing expectation for women to study and gain similar qualifications to their male counterparts, the expansion of higher education and the belief that a more qualified workforce will make the nation more competitive in world trade.

In terms of physics literacy, as expected the longer the women were in education the greater the opportunity for them to study physics. However, all three participants from the mothers generation chose not to study physics in favour of other subjects at some point in their education.

Physics in the Home

Play is widely recognised as an important part of child development although psychologists debate the true function of play. As mentioned in chapter 2, Karl Groos' work, '*The Play of Animals'* (1898) has been highly influential in Western

European psychology and there seems to be wide though not universal acceptance of the idea that play provides the foundation for future learning.

Kelly expressed concern that girls were not having access to toys that would aid their understanding of physics and were therefore disadvantaged when compared to their male peers.

Looking at the toys cited by the participants, it does seem that there was little chance to develop an understanding of physics in the grandmothers' generation however there does seem to have been a slight movement towards less gender specific toys in the daughter's and granddaughter's generation. These women had access to construction kits. There is some controversy over the benefits of plastic construction kits (refer to chapter 2, section 2.2b). However, the women of the grandmothers generation had no access to any type of construction toy and so in this sense this represents an improvement.

All of the participants enjoyed reading and had done so from their early childhood. Most of their reading was fiction and unrelated to physics however Jasmine's reading of books about space as a child kindled and interest in astronomy that ultimately led to her choosing to take an O' level in physics. Meryl's recreational reading of magazines occasionally makes her aware of developments in physics. It was Freeman's (1991) reading of encyclopaedia that fostered began her journey into becoming physics literate. It would seem that the absence of physics from much of the participants' reading material is a missed opportunity, for when they do have the opportunity to read physics as in the case of Jasmine and Meryl, it seems that their interest is sparked.

Relationships

Who the participants spent their childhood with appears to have had an impact on their opportunity to develop physics literacy. Julie spent her childhood largely playing outside with girls her own age. These girls are likely not to have had any more knowledge of physics than Julie. There appears to have been little parental input or supervision, Julie appears to have been encouraged out of the house so as not to be under her mother's feet whilst she completed her domestic chores. Tinkerbelle seems to have had a similar experience and for similar reasons however she did play with both boys and girls in her early years, limiting her company to girls as she got older. Unlike Julie, many of Tinkerbelle's toys were related to sport such as roller skates which could have developed physics literacy but without any input from physics literate person this opportunity appears to have been missed.

The mothers' generation spent much more time at home under the direct supervision of their parents, especially their mothers. None of these mothers (i.e. the grandmothers of this study) were physics literate and so they were unable to pass the knowledge of physics on to their daughters. Instead the grandmothers' generation did pass on a love of reading to the mothers' generation. In Lynne and Jasmine's case playing with siblings seems to have been more important than playing with peers. As previously mentioned playing with brothers came them access to toys that were more traditionally given to boys. In both cases however it seems that rather than being influenced by their brothers' play these participants influenced their brothers' developing their social and communication skills through role play games. Both Jasmine and Lynne were older than their brothers and seem to have been in charge of the games played. The situation may have been different had they had older brothers.

Lynne, as the only participant from a physics literate family, was actively encouraged to become physics literate by her father. There was also a background influence from her grandfathers and uncles, all of whom had a background in telecommunications. Of all the participants Lynne studied physics to the highest level and was the most physics literate. It would seem from this that having close relatives who are themselves physics literate encourages the development of physics literacy. This is supported by the findings of Archer et al (2012) (refer. chapter 2 p.30). If parents are not physics literate themselves then it would seem more difficult for them to encourage the development of physics literacy in their children. In chapter 1 (refer to chapter 1 p.) the shortage of physicists was highlighted. If there is a shortage of both physicists and physics teachers then there is likely to also be a shortage of physics knowledge in the population at large including a shortage of parents who are physics literate and able to promote the development of physics literacy in their children.

Self-Concept

Self-concept was more significant in developing the participants' physics identities. The women who had the most positive physics identity i.e. Jasmine and Lynne were those who developed the greatest physics literacy. Those who had no physics identity i.e. Julie, Doreen and Tinkerbelle were the least physics literate. As Jasmine and Lynne matured, their physics identity lessened and they ceased developing a physics identity. The development of a physics identity will now be discussed.

Figure 5.2: A table showing what impact changes in the macro and chronosystem may have had on the opportunities the participants had to become physics literate.

<table>
<tr><th colspan="5">Grandmothers' Generation</th></tr>
<tr><th rowspan="2">Year(s)</th><th rowspan="2">Change</th><th colspan="3">Impact change had on participant</th></tr>
<tr><th>Julie Walker</th><th>Doreen Lloyd-Boot</th><th>Tinkerbelle Disney</th></tr>
<tr><td>1926 - 1933</td><td>Series of Hadow reports recommending raising of school leaving age and reorganisation of schools into primary and secondary.</td><td rowspan="5">Went to girls' secondary school.
Followed curriculum for girls
No opportunity to become physics literate or develop physics identity.
Left school at 14 years.</td><td rowspan="5">Girls' secondary modern school, followed by girls technical school – no physics offered
Belief that she was less able than grammar school peers</td><td rowspan="5">Girls' secondary modern school.
Belief that she was less able than peers.
Some science offered as part of curriculum but not specific physics lessons.</td></tr>
<tr><td>1936</td><td>Education Act following Hadow recommendations</td></tr>
<tr><td>1938</td><td>Spens Report
Recommends tripartite system</td></tr>
<tr><td>1943</td><td>Norwood Report
Supports tripartite system</td></tr>
<tr><td>1944</td><td>Butler Act; primary, secondary and further education. Raising of school leaving age</td></tr>
<tr><td>1946</td><td>Barlow Committee on Scientific Manpower – aim to double number of scientists in universities</td><td>Had left school by this date so no impact on her education.</td><td>No impact detected.</td><td>Some general science offered at secondary school level – possibly as a result of increasing emphasis on science in education</td></tr>
<tr><td>1947</td><td>School leaving age raised to 15</td><td>Left school before this date therefore no further opportunity to study physics</td><td>Able to stay at school until age of 16</td><td>Stayed at school until age of 15</td></tr>
<tr><td>1951</td><td>G.C.E. O' and A' Levels introduced</td><td>Left school before this date</td><td>Sat O' Level examinations but not in physics</td><td>Left school at 15 having gained office City and Guilds qualifications at evening classes but no O' levels or any qualification in</td></tr>
</table>

				physics.
1963	Robbins Report – recommends expansion of higher education		Worked in administrative role in higher education	Worked in a catering role/support services role in higher education

Mothers' Generation				
Year(s)	**Change**	**Impact change had on participant**		
		Meryl Walker	**Lynne Lloyd-Boot**	**Jasmine Disney**
1959	Crowther Report; by 1980, 50% should be in education up to age of 18.	Joined grammar school 6th form but couldn't study physics as had not opted for this at 14.	A' level physics course at 6th form college	Stayed on at 6th form but chose not to study physics
1962	Certificate of Secondary Education (C.S.E.) introduced.	Remembers doing 16+ exams - possibly another name for C.S.E. - however didn't choose to do physics	Physics O' Level instead	Physics O' Level instead
1965	Circular 10/65 – selection at age 11 to stop.		Comprehensive school	Comprehensive school
1963	Robbins Report – recommends expansion of higher education	Went to university – B.Sc. then M.Sc.in environmental biology,	Went to polytechnic – B.Sc. in pharmacy	Went to university – B.A. in geography then P.G.C.E.
1966	White Paper on Polytechnics – 30 polytechnics formed			

<table>
<tr><td>1967</td><td>Plowden Report

Progressive education

Middle school system

Home school liaison</td><td>Middle school system

Parent – school liaison.

Topic based approach in first school – no physics.

Good physics experience in middle school</td><td>Parent – school liaison.

No physics in primary school</td><td>Parent – school liaison.

Topic based approach in primary school – no physics.</td></tr>
<tr><td>1969</td><td>Open University (O.U.) awarded charter</td><td></td><td>Father graduated from O.U. in science subjects.

Lynne went to ceremony this may have influenced her decision to go to higher education</td><td></td></tr>
<tr><td>1970</td><td>Circular 10/70; further move towards comprehensive education</td><td>Change of location – tripartite system from age of 14.</td><td colspan="2">Went to co-educational comprehensive schools, followed same curriculum as male peers including physics in mixed classes of boys and girls</td></tr>
<tr><td rowspan="2">1972</td><td rowspan="2">School leaving age raised to 16</td><td colspan="3">Opportunity to study physics to O' Level while in compulsory education</td></tr>
<tr><td>Didn't choose physics</td><td colspan="2">Chose physics, majority of peers choosing this option were male. Conscious of being in a female minority.</td></tr>
<tr><td>1975</td><td>Sex Discrimination Act</td><td colspan="3">Impact not explicit but may have influenced decision to continue in education and have a career outside the home, including possibility of STEM based career – suggests a shift in culture and</td></tr>
</table>

<table>
<tr><td></td><td></td><td colspan="3">expectations for women in macrosystem</td></tr>
<tr><td>1976</td><td>Education Act; comprehensive education favoured</td><td rowspan="2">Single sex girls' secondary modern. Limited subject options physics pitched against more desirable option.

6th form in girls' grammar school</td><td rowspan="2">Co-educational comprehensive school.

Opportunity to study physics alongside boys</td><td rowspan="2">Co-educational comprehensive school.

Opportunity to study physics alongside boys</td></tr>
<tr><td>1979</td><td>Education Act; repealed 1976 Act</td></tr>
<tr><td>1986</td><td>G.C.S.E. replaces C.S.E. and O' level examinations</td><td colspan="3">Had left secondary education by this date therefore no impact on them but this is the examination their children will sit.</td></tr>
<tr><td>1988</td><td>Education Reform Act; National Curriculum</td><td colspan="3">Had left secondary education by this date however means that their children will study physics as part of compulsory science curriculum from ages of 5 to 16.</td></tr>
<tr><td>1992</td><td>Further and Higher education Act, Polytechnics granted university status</td><td colspan="3">No immediate impact as reaching end of higher education by this stage. No longer studying physics.</td></tr>
</table>

5.3: A consideration of how the participants' physics identity was developed or inhibited

As explained in Chapter 1, for the purposes of this study an identity with physics is taken to mean how a person relates to physics, whether it is seen as a subject they can engage with, that they consider relevant to their lives.

Julie and Doreen did not identify with physics at all. Tinkerbelle's identity was changing, whilst at school she saw it as a distant subject for boys who were good at maths. As an adult part of her retains this view but another part of her resents that she has been denied the opportunity to learn physics. She is aware of women who have been successful in physics through meeting them as work colleagues and through her extensive reading.

Meryl saw physics as a challenging and important subject. While she was learning physics as a child she didn't see it as a particularly masculine subject although now she does. In the drawing exercise during the preliminary observation she drew 'Alex' as a man. It was a subject she enjoyed and would have liked to have taken further. She feels a sense of frustration at being denied the opportunity to study physics post 14 and believed her physics potential had not been realised. She acknowledges the importance of physics to her daily life but confessed she rarely reflected on the products of physics and tended to take them for granted.

Physics had become a largely separate world for Jasmine, she acknowledged that physics had an influence on her day to day living through the appliances she used but it was not something she consciously thought about or was aware of. As previously mentioned she retains an interest in astronomy by using a sky map app on her telephone she has a telescope but at the time of the interview this had been put away in her loft as she hadn't found time to go star gazing since having her children. During the interview she did reflect that perhaps her children were old enough to go out with her at night and learn how to use a telescope and that astronomy could become a family activity.

Lynne expressed admiration for those who studied physics. She believed it to be a more difficult A' Level than an arts subject, one which only the most able students could study. As a child she had seen herself as a potential physicist or engineer but was put off by her ‘girls into science and technology experience’, A’ Level physics lesson experience and her perception of engineering not being a family friendly career. She has continued the family tradition of taking her own children to industrial heritage sites and had encouraged them to play with physics related toys such as construction kits alongside their other toys however she feels that they have not done much science as a family. She believes that her relationship with physics was damaged by the content and presentation of her A’ level course, and that if she had had a less abstract syllabus, she may have fared better.

In contrast to the previous section, this section will focus more fully on the relationship and self-concept than the schooling and physics in the home themes emerging from the analysis of the scripts.

Schooling

The role of schooling in developing these women’s identity with physics has been contradictory. The grandmothers’ schools appeared to have the aim of giving their students a strong female identity and this seemed more important than the subject content. Physics did not feature as it was not considered a feminine trait. All of these women seem to have a low opinion of their ability, seeing themselves as less able than their fathers, husbands and children. An interesting further study might be to find out why that is and if it had anything to do with the schooling at that time. Were less able women considered better housewives and mothers making underachievement in women desirable?

Schools had an ambivalent role in establishing a physics identity in the mothers’ generation. In the early years of secondary school the women seem to have been encouraged to identify with physics however once the options were chosen at age 14 the syllabi seem to be reinforcing gender stereotypes and crushing the enthusiasm that both Jasmine and Lynne had for this subject. In some respects Meryl, who studied physics for the least amount of time in this generation had the most positive relationship with physics; she continues to regret not having studied physics further.

Physics in the Home

This theme has been explored in some detail in section 5.2. In terms of identity the 'physics in the home element will be considered in the light of the relationships the participants had with their family members. In each case there seems to have been little explicit exploration of physics in the homes of the participants.

Relationships

The Mother- Daughter Relationship

For all of the women studied, the mother remains the primary care giver for the preschool years. Julie stopped work in anticipation of becoming a mother. Doreen also wanted to be a full time mother but returned to work in a lesser capacity due to financial pressures once her children were all at school. Tinkerbelle was prevented from working by morning sickness during her pregnancy with Jasmine but did do a range of jobs to fit around her childcare role until she felt the children were old enough for her to continue her career in administration. All three grandmothers saw themselves as primary carers for their children; physics did not seem to have any relevance to them in this role. They saw promoting education as an important part of their mothering responsibilities and were particularly keen to develop their children's reading skills. However they did not see helping to develop their children's understanding of the physical world as an integral part of this mission.

In the mother's generation all three women were professionally qualified before they had children and had careers and earning powers of similar magnitude to their husbands. On becoming mothers they each became part-time in their profession in order to become the primary care giver to their children at home. Like the grandmothers, Lynne does not seem to have questioned her mothering role and sees her work as means to provide for her children.

Jasmine, however has questioned her role as principle carer and finds it difficult juggling her roles as a part-time mother and a part-time teacher. She and her husband have discussed swapping their traditional roles allowing him to become the primary carer.

The mothers and grandmothers of this study all appear to enjoy a close relationship which was perhaps formed in early infancy. It appears that each generation is spending more time with their children than traditional stay at home great grandmothers who seem to have sent their children outside to play whilst they did their domestic chores.

The impact on this for physics is twofold. If the mother, as principal child carer, does not have a positive physics identity then she will be unlikely to introduce elementary physics into the play and early education of her child. Physics will then be something that is introduced to the child later when he or she starts school and will be seen as part of the 'other' or outside world rather than something intrinsic to the child. If the mother's experience of physics has been negative then she may pass her feelings of discomfort with the subject on to her children. If it is to be the mother who is to remain the principle child carer/educator, and knowledge of physics is to be an essential part of our education and culture, then girls, as the next generation of mothers need to both to have a degree of physics literacy and a positive experience of physics in order to ensure the next generation has a positive identity with physics.

The Father-Daughter Relationship

In the grandmothers' generation it seems that their fathers were rather remote figures who spent most of their time away from the family home generating an income. In the mothers' generation however it seems that while their mothers were the primary carers, their fathers' role became increasingly important, especially as the girls grew up and needed careers advice. Their mothers were less well placed to offer vocational advice as they had been prepared for a primarily domestic role and any earning they did outside the home was secondary to this.

Physics has always been a component of the secondary education of boys thus in having time with their fathers the women of the mothers' generation may have had the opportunity to interact with someone with a degree of physics literacy. However, it was only Lynne's father, who was an electrical engineer and therefore had a strong identity with physics, and who seems to have actively promoted Lynne's interest in this subject.

The daughters' generation of this study seem to be spending increasing time with their fathers and their fathers seem to be involved in many domestic chores. It is still their mothers that have made adjustments to work and careers and are the primary carers at home.

It would seem from this that a father who identifies strongly with physics can foster a similar identity in his daughters and that this may be an influence strong enough to counter social expectations in the macrosystem as in the case of Lynne studying physics to A' Level. This supports the findings of Archer et al. (2012) (refer to chapter 2, p.31).

The Sibling Relationship

For the women studied, the significance of the sibling to sibling relationship appears to be increasingly important with each generation of the study as successive generations spend more time at home with their families rather than outside having unsupervised play with friends. Julie, the oldest participant, does not remember having much to do with her brothers, Tinkerbelle's brothers provided a catalyst for her forming friendships with other children in her street, Meryl had no siblings. Jasmine and Lynne spent much of their childhood playing with their siblings. In the daughters' generation, playing with sibling seems more important that playing with peers.

There seem to be a number of factors effecting this change. Tinkerbelle remarked on a growing concern for safeguarding children. All of the women noted an increase in the use of domestic appliances and therefore less time spent on housework and less need to get the children out of the house in order that domestic chores might be completed unhindered. Women working away from the home require that their children be either in a nursery or be looked after at home alongside their siblings by either their fathers or grandparents. A woman at home might feel comfortable allowing her children to play outside knowing that they could easily get to her should a problem arise but a woman working away from home is perhaps less likely to feel this. As a result, this study suggests children are spending more time at home with siblings rather than out in the street with same sex peers.

One outcome of this appears to have been the sharing of toys and activities between children of different sexes. This has not only given Jasmine and Lynne access to toys that would have been traditionally seen as boys' but also seems to have made them question gender stereotypes. It would be an interesting further study to see if girls who spend time playing with brothers identify more strongly with physics that girls who are only children or only have sisters.

Grandmother-Granddaughter Relationship

In the stories of these participants, the roles of the grandparents, especially the grandmother, seem to becoming increasingly significant in the lives of their grandchildren. Julie plays an active role in caring for her granddaughters, collecting them from school or nursery and looking after them when their mother Meryl is at work. Tinkerbelle and her husband regularly help to look after their granddaughters thus allowing Jasmine to work.

Many of these changes are possible due to the application of advances in physics. Communication improvements have enabled families to be in better contact either physically or electronically. Although the increased longevity is largely attributed to advances in medical science, physics has had its part to play in treatments such as radiotherapy, and in developing mobility and hearing aids for the elderly. Physics has a profound but silent influence on the relationships and lives of the participants and this is especially true in the case of the grandmother-granddaughter relationship. The grandmothers of this study however had no identity with physics. They were unable to promote a positive physics identity in their grandchildren. The grandmother-granddaughter relationship was an important one for the families studied. The mothers noted that the grandmothers were good at fostering a love of books in their grandchildren. The books read were mostly children's story books with no connection to physics. It seems that the effects of the absence of a physics education in grandmothers' generation have trickled down to the granddaughters' generation.

The Teacher-Pupil Relationship

This seems to have been important in determining which subjects the participants favoured. Tinkerbelle attributes her love of art to an art teacher she had at secondary school. Later in life she decided to pursue this further but was put off by poor teaching. Meryl remembers a number of good teachers including her middle school physics teacher. She was most inspired by her A' Level geography teacher. Similarly, it seems that teachers the students couldn't relate to put these girls off the subjects. The physics teaching she received, was a factor in Jasmine abandoning her dream of becoming an astronomer. Lynne's A' Level physics experience was a factor in her choosing not to study physics further.

Peers, Friends and Work Colleagues Relationships

As previously mentioned, one trend emerging from this study is for children to spend less time with peers and more time at home with their families. For the grandmothers, spending time with female peers seems to have been important. It was Julie's female work colleagues who initiated Julie's love of nature. Time spent with female peers who were equally unaware of physics and promoted ideals of how to be female seems to have further lessened the grandmothers' identification with physics. This need to be with women and conform to feminine standards has been recognised by Erikson (2014) (refer to Chapter 2, p. 40).

In the mothers' generation, both Jasmine and Lynne struggled with having to learn physics in predominantly male classes after the age of 14. Jasmine generally got on well with boys and had more male companions than female ones and yet she still felt disadvantaged being the only girl in her O' Level physics group. Lynne felt intimidated by being part of a female minority in an A' level physics class. Her femininity was challenged by this. Realising that if she pursued physics further she was likely to be working in a predominantly male environment was a factor in her deciding to opt for pharmacy instead of physics.

5.3.3: Self-Concept

This section will consider the participants' concept of self and how these concepts relate to physics developing a physics identity.

As a woman

All of the participants in this study appeared to identify strongly with being female. The grandmothers assumed that as women they were responsible for the house and home, any paid work they were able to do was of secondary importance. Physics was seen as something that was done in an industrial environment rather than the home with no links being made between the day to day application of concepts such as heat transfer when cooking. As such, physics was seen as something that was irrelevant to their lives as women.

Meryl, Lynne, and Jasmine, however, all had an awareness of the applications of physics although they admitted taking this for granted on a day to day basis. There was a little confusion about how their femininity stood with physics. They all saw themselves as capable of learning physics. Lynne articulated a potential conflict between being a physicist and being a mother. Although being a physicist was something that interested her, her desire to be a mother was more important. Both Lynne and Jasmine found it difficult to identify with physics as girls in a predominantly male classroom.

Puberty

One crucial factor influencing a girl's subject choices appears to be her maturity when she is asked to make those choices. Kelly (1981) suggests that girls tend to want to conform to traditional gender expectations around the age of puberty. She suggests it is a time when they are feeling vulnerable about their femininity and therefore want to assert their femaleness. Choosing to study a subject that is perceived as masculine could be difficult at this phase of their lives. Lynne remembers feeling quite uncomfortable in her A' level physics group, not feeling confident as a physicist and as a young woman. Jasmine didn't feel her femininity under threat but did feel at a disadvantage in an all-male group.

Both Jasmine and Lynne appear to have been going through mini identity crises trying to reconcile themselves as young women and as young physicists. In each case, although there was some wavering the need to be a woman seems to have been more important than the need to be a physicist. In spite of this experience however Jasmine does not remember having limits put on her because of her sex. Her crisis of identity seems to have fluctuated depending on the context. She was happy to be a lone female amongst male peers in situations where she felt their equal but not in situations where she felt less confident. She felt confident in many subjects and was prepared to hold her own against the boys but in physics she felt less secure and then became more conscious of being different and female.

Ability, aspirations, and expectations

There is much debate about the origins of ability, whether it be predetermined by our genes (refer to chapter 2, 2.2a), the result of a nurturing and stimulating environment or a combination of these two. There is also discussion as to whether or not ability is a given or whether a person's ability can develop and change over time. There is not scope within this study to discuss these ideas further. What will be considered however is whether or not there is evidence that the participants perception of their abilities contributed to their identity with physics.

The ability of the participants was not tested and so no comparison can be made between the participants and their peers' abilities. All of the participants presented as articulate intelligent women who were able to reflect on their experiences during the course of their interviews.

Doreen and Tinkerbelle, of the grandmothers' generation, did not go to grammar schools, and so were not considered to be in the top third of the ability range when they were eleven. Julie, however, would have entered her secondary schooling prior to the 1944 Act and so may not have been given the opportunity to go to grammar school irrespective of her ability. Both Tinkerbelle and Julie saw themselves as being less able than their fathers, husbands and children. They also saw physics as a challenging subject; the implication being that they believe that they did not have the ability to study physics.

All the participants of the mothers' generation are graduates: Jasmine went to Oxbridge, Meryl has a master's degree, and both Jasmine and Lynne have post graduate qualifications. Thus, all three women have proved themselves capable of study at university level.

Meryl, who of the three chose not to study physics, did not seem to see her academic potential until later in her schooling. She spent her latter secondary education in a secondary modern school, transferring to grammar school when she decided to study for A' levels in the 6th form. It seems that her decision to study A' levels came relatively late and was not part of a long term career plan. Both Jasmine and Lynne however saw themselves as competent students by the time they took their options and this may have given the confidence to go against their peers in choosing physics as an option. Once they had embarked on their courses however they both saw themselves as less able in physics than other areas. Smithers' and Collings' (1981) study of 6th form students found that girls who chose to study science tended to be high attainers. Lynne and Jasmine were academically successful and in this sense fit in to Smithers' and Collings' typical female science student category. What is unclear however is whether physics was more difficult than the other subjects they studied or whether other factors made it appear more challenging? In studying pharmacy Lynne has shown that she is capable of remembering and applying abstract concepts such as molecular structures. Meryl's post graduate study of environmental biology would have required her to be able to understand complex interrelated systems; Jasmine's study of geography would also have necessitated developing an understanding of complex abstractions such as the factors determining economic growth. It would seem likely, therefore, that all three women had the intellectual capacity to study physics.

5.3.2.4: Personality and Temperament

Smithers and Collings (1981) saw temperament as a key factor in determining whether or not a girl chose to study physics.

The personalities and temperaments of the participants of this study were not tested but clues as to these attributes do arise from their interviews.

Julie came across as shy, self-effacing and lacking in confidence. She enjoyed sport as a girl and continue to enjoy physical activity now she is in her eighties. This is perhaps the kind of personality that would fit the Smithers-Collings female scientist model. However Julie also lacks confidence in her intellectual ability and was not given the opportunity to study physics. Tinkerbelle has also enjoyed sport throughout her life but she also has a very creative side and loves the company of other people. She has fitted into a social group and therefore would have no need to seek refuge in science.

Of the mothers' generation, there are also personality and temperament clues. Meryl describes herself as a confident out-going girl who became quiet and withdrawn as she progressed through her schooling. Sport has always been important to her. There are aspects then of the 'science personality' and she did study biological sciences at a post graduate level. Jasmine enjoyed being physically active and seems to have preferred the company of boys to girls as a child. She was confident in her academic ability. She may have perhaps taken refuge in the physical science in her latter secondary years. Her becoming a teacher however suggests a degree of person orientation as does her interest in geography. Lynne seems to have been in the greatest conflict when choosing to study physics and it was Lynne who took her study of physics the furthest. Lynne also remembers feeling isolated from her peers in terms of aspiration and attainment. Sport however does not appear to have been an important aspect of her childhood and she favoured role play games over games with set rules. She remembers wrestling with her desire to be a civil engineer against her desire to be a wife, mother and homemaker. Her chosen career of pharmacy has allowed her to fulfil her maternal ambitions alongside pursuing a career that is both science based and person orientated. It would seem then that perhaps in this generation the desire to work with people either professionally or in running their own households proved stronger than any desire to study physics. None of the women from this generation fit completely into the personality type suggested by Smithers and Collings as being most likely to study science although all three of them did study science to a degree and did have some aspects of the science temperament and personality.

These women's stories suggest a complex mix of conflicting elements contributing to their identity with physics. The lack of opportunity coupled with social and historical expectations seem to have prevented the women of the grandmothers' generation developing an identity with physics and this is perhaps as might have been predicted. When it comes to the mothers' generation the system becomes far more complex. It seems that the social rules and expectations for women were being rewritten and that there was much confusion about the female role. By this, girls were expected to study, do well at school and have an occupation outside the home. Some of the messages they were given suggested that they could do whatever their male counterparts did. These girls however had to do this against the historical background of women having a primarily domestic role. Their need to identify themselves as women seems to have been overlooked by their parents and schools and they were largely left to find their own way through this time of change. Physics lessons were offered to them as they were to their male peers but no thought seems to have been given as to how this might have conflicted with their need to assert their femininity or how they might feel uncomfortable in a predominantly male environment. Physics careers still seemed to have a very male image as is shown by Lynne's concerns about how difficult she might find juggling a career in engineering with raising her future family. These three women's stories suggest that the greater the woman's exposure to physics the greater her perception of it being a male subject. Conversely by making physics lessons more accessible to girls it could be argued that physics was actually made more inaccessible as these lessons seem to have had the effect of making physics appear very masculine.

Motivation and Values

Phipp's (2008) found that women were not motivated by power or money but instead wanted to feel that they were doing something for the benefit of others. Direct links can be made between biomedical sciences and caring for others. Physics has been seen as a cold impersonal subject (refer to chapter 2, p. 35).

The women of the grandmothers' generation did not appear interested in a career; their primary motivator was being a mother. They would undertake paid work in order to provide for their children but this work was a means to an end and had little value in its own right.

Meryl, Jasmine, and Lynne have all chosen to follow careers that have a value and the financial gain appears to be of secondary importance (although Lynne does anticipate increasing her hours in order to support her children through university). Meryl sees her job as a means of caring for the environment, as a teacher Jasmine is concerned with ensuring the best outcomes for her students and Lynne's pharmacy is concerned with curing disease, easing pain and extending life. Doing good through their work seems to be as important to these women as earning money.

There are of course many ways in which physics 'does good' for society. Meryl, Lynne and Jasmine all acknowledged the contribution physics has made to making life easier. In considering a career in civil engineering Lynne was hoping to use the knowledge of physics to solve problems and help others. Physics lessons that could be directly linked to a practical purpose were the lessons that Lynne remembers enjoying most.

It seems, however, that the 'helpfulness' of physics was not much emphasised in the lessons experienced by the mothers' generation. Much of what was taught was dry and abstract. This encouraged the participants to see physics as a remote subject, something not directly related to their everyday experience, and therefore less useful to them.

Social norms

The perception of all the adult participants in this study i.e. those from both the grandmothers' and the mothers' generation is that the historical prototype (Erikson, 2014) (ref chapter 2, p.39) was for the woman or wife to stay at home and manage domestic tasks whilst the man or husband had the responsibility of earning an income out of the home in order to provide for the family's needs. However, during the grandmothers' generation this historical prototype was being superseded by a new generation of women who did paid work out of the home in addition to their traditional domestic duties. Julie describes a traditional home-life with her parents having specific gendered roles. She perpetuated these roles in her own marriage, assuming that this was the only option and only later came to realise that she had other choices. In the mothers' generation, there seems to be an acceptance that the traditional view that their grandmothers accepted had changed. Lynne knew her mother was a housewife but was also aware that her female teachers had careers. From a young age, she seems to have been wrestling with difficulties of following a career whilst taking responsibility for children. She saw herself as having a career alongside traditional domestic responsibilities.

The school curriculum of the grandmothers' generation, as has already been discussed in the previous section, appears to have been designed so as to *reproduce* (Bourdieu and Passeron, 1990) this historical ideal hence the number of single sex secondary schools designed to meet the specific perceived needs of each sex i.e. for boys to be prepared to earn a living outside the home and girls to be prepared as future homemakers.

The historical prototype of the woman being at home while the man earns outside of it appears deep rooted in the narratives of these women. The reality however may not have been as clear cut as the women perceived. Julie's mother joined the WRAF during the First World War and may have had a STEM based job. At the close of the war, the WRAF was disbanded but Julie's mother still worked outside the home in the hotel industry until she married and took on an exclusively domestic role. Tinkerbelle's mother worked from home but earned money as a dressmaker. Tinkerbelle has had some form of paid work albeit part-time outside the home for most of her adult life and Doreen returned to clerical work after having some time out to raise her children.

Historically, an aptitude and interest in physics has been seen as masculine. However, many of the tasks and equipment that have historically been linked to women do have strong links to physics e.g. baking and heat transfer, sewing machines, and mechanics. Tinkerbelle's mother is likely to have used a sewing machine for her dressmaking business. The design and maintenance of this machine is likely to have been done outside the home by a man and yet the operation of this machine was likely to have been done by a woman. Logically, there is no reason why a sewing machine could not be designed by a woman and there might even be advantages in using designs that have been developed by those who are likely to use such machines.

Whatever the reality the story that these women have adopted is that of the traditional view of women having a domestic role and not engaging in physics. This story will have had an impact on their self-perception and their relationship with physics. Those who chose to study physics were breaking with the recognised tradition.

The crisis to be resolved in this instance is the perceived historical place of women combined with the perceived masculinity of physics versus any natural interest these women may have had in physics. The historical perception is a powerful obstacle to overcome as it has an influence on the curriculum offered to women and in the case of the grandmothers' generation was not taught to them as a result.

The social situation of the participants when they made their options is closely intertwined both with their perceived historical expectations and their need to have their femininity affirmed as they went through puberty (Refer Chapter 2 p. 39, Erikson 2014).

5.4: The changes that occurred to the development of a 'physics identity' over two generations studied.

What these women's stories suggest, is that counter to more statistical studies that measure the number of women embarking on careers in physics and thereby indicate that there has been little improvement in women's physics over the past forty years, the relationship between women and physics is gradually changing over the course of time.

In the grandmother's generation none, of the women considered studying physics. It was a subject they had no knowledge or experience of. They had little idea what physics was and just assumed it was something that boys did.

By contrast all of the women of the mother's generation had done some physics, had enjoyed doing physics at first and two of them had considered physics based careers. The main change seems to have been their being taught in co-educational comprehensives where girls and boys learnt the same subjects alongside each other. Once the participants had chosen their options for the final two years of secondary school, the two that opted for physics found themselves in an all-male environment. They began to feel different from their fellow students, felt that they were less knowledgeable and at a disadvantage especially with the curriculum content. While the comprehensive system was truly co-educational and they were taught in classes with equal number of boys and girls the participants seemed to thrive. Once they were effectively a female minority in a class of males and therefore strictly speaking no longer in a co-educational environment their enjoyment of and confidence in physics seems to have diminished. This feeling of isolation and inadequacy seems to have been a major factor in turning them off physics. Out of this environment however the participants retained the knowledge of physics and although they took no steps to further their understanding they have done some physics related activities with their children. All of the participants from this generation have a respect for physics and physicists. There is an echo however of their mothers' sense that physics is a remote and mysterious subject for the very bright rather than something that everyone can enjoy and engage with.

Whereas the grandmothers' generation were not given the chance to develop a physics identity the mothers it seems were all given a good introduction to physics and had an interest that began to take root. As there interest grew however it seems to have been crushed by the subtle beliefs of society that physics was a challenging subject for men and not a practical career option for women, especially if they wanted to have children of their own one day. Lynne's experience of being sponsored by an engineering firm, no doubt with the best of intentions resulted in her being put off physics as a career as the firm reinforced gender stereotypes.

5.5: Summary

Figure 5.3 summarises the participants' experiences of physics. It illustrates how there has been a noticeable increase in the opportunity both to become physics literate and to identify with physics between these two generations.

One significant factor seems to be the level of physics literacy within the family. In the grandmothers' generation, even where there were physics literate fathers it did not seem to occur to them to pass on this knowledge to their daughters. In the mothers' generation, Lynne's physics literate father was keen to pass on his knowledge to her. It seems that attitudes towards women physics are slowly changing however with such as shortage of physics capital in the population, many parents, especially mothers, will not have the physics literacy and positive identity to pass on to their daughters. What is needed perhaps is an early start, an education programme for young children and their parents that would p-lug this kno9wledge gap and encourage parents to learn physics alongside their children.

Figure 5.3: A summary of the findings of this study.

Summary of Findings			
First Generation (grandmothers) Born between 1932 and 1952			
Participant	Julie Walker	Doreen Lloyd-Boot	Tinkerbelle Disney
Development of Physics Literacy	No physics education	Physics may have been a component of general science course at secondary school.	
	No career in STEM No awareness/interest in subject Increasing use of products of STEM based industry in everyday life e.g. domestic appliances, cars		
Identity with physics	None – not sure what physics is	None – not sure what physics is	Physics is something boys do – not sure what physics is
How is this different from previous generation?	Mother spent time in WRAF and may have engaged in STEM based work during WW1 otherwise no difference.	Very similar experience to own mother.	Very similar experience to own mother.
Summary of what this reveals in relation to research questions			
Second Generation (Mothers) Born 1969/1970			
Participant	Meryl Walker	Lynne Lloyd-Boot	Jasmine Disney

Development of Physics Literacy	Studied from 11-14 years old	Studied physics from 11 – 18 years old O’ and A ‘Level WISE engineering sponsorship at 6th form	Studied physics from 11 – 16 years old O’ Level
	Have some awareness of impact of physics and STEM related products such as domestic appliances, energy conservation, ICT and transport but tend to ignore this on a day to day basis		
Identity with physics	Interesting subject Would have liked to have taken it further Physicists are clever	Difficult subject Chose not to study it as it would not have led to a family friendly job	Difficult when compared with other subjects. Astronomy remains an interest but not one that is currently pursued
How is this different from previous generation?	Had opportunity to study. Knew what subject was. Has an awareness that physics impacts on life. Is aware of colleagues with knowledge of physics/STEM background	Studied it Knew what it was Engineering was considered as a possible career	Studied it Knew what it was. Enjoyed aspects of physics as leisure activity
Summary of what this reveals in relation to research questions			
Third Generation (Daughters) born 2000 - 2008			
Participants	Sophie and Charlotte Walker	Beth Lloyd-Boot	Belle and Rapunzel Disney
Development of Physics Literacy	Studied as part of compulsory science curriculum from age 5. Will be compulsory up to age of 16. May study it to further or higher education level. At time of study could not distinguish physics from other sciences as taught as part of general science curriculum		
Identity with physics	Not developed as yet as not sure what physics is	No data	Not sure what physics is but Belle sees physics type activities as masculine.
How is this different from previous generation?	Compulsory 5 – 16 curriculum	Compulsory 5 – 16 curriculum	Compulsory 5 – 16 curriculum Like her grandmother, Belle saw it as a boys’ subject
Summary of what this reveals in relation to research questions			

In the next chapter, some recommendations have been made following from these findings.

Chapter 6; Reflections and Recommendations

6.1 Introduction

Studies such as those of Whitelegg and Murphy (2006), and Dainty et al. (2010) suggest little improvement in the take up of physics by women over the past 40 years and imply that the initiatives to date have been ineffective. This study however suggests that, for the families studied, the overall physics literacy of women has improved. Following the Education Act of 1988 and its legal requirement that all children in state schools, both boys and girls, study physics as part of the compulsory science curriculum from the ages of 5 to 16 years of age and that the mothers of this project showed a much greater degree of physics literacy than the grandmothers; therefore it is anticipated that the level of physics literacy will further increase in the daughters of the participants.

This study also suggests that the successive generations of women are developing a closer identity with physics. Women of the grandmothers' generation did not identify with physics at all as they had no direct experience of it, whilst women of the mothers' generation had a confused identity with physics. On the one hand two of the three mothers had seriously contemplated a career in physics seeing physics as something that women like them could do, on the other hand they also saw physics as a subject for the masculine intellectual elite. This mixed identity perhaps reflects the confused messages of society (ref. Figure 2.05**:** page 55 chapter 2). For the participants of this study, developing a positive identity with physics is proving more difficult to achieve than increasing the level of physics literacy but may still improve with each successive generation.

The improvements in physics literacy and to a lesser extent, the improvements in physics identity have not been recognised in much of the pre-existing research.

One reason for the discrepancy between this study's findings and the findings of other studies might be the criteria used to determine success. Many studies seem to consider the success of women's physics education to be measured in the following terms:

1. the proportion of female students opting to study physics in further and higher education,
2. the proportion of females choosing to work in physics related industries,
3. the retention of women in physics based jobs, and
4. the proportion of women attaining senior physics posts.

If the purpose of teaching physics is solely to increase the number of long serving physicists and engineers then it would seem that the initiatives to date have indeed been failures. As mentioned in Chapter 2, however, not all subjects are viewed in this way; we do not teach English with the expectation that all children will have careers as journalists or novelists but rather because we see English as an important skill that transcends all aspects of life. If the purpose of physics education was to increase knowledge of the physical world then success would be seen as an increase in the level of physics literacy across the population and a similar increase in the population's identification with physics. Thus, women who chose to occupy traditional female roles such as homemakers but were also physics literate (for example could carry out their domestic duties mindful of energy conservation, could repair electrical appliances and introduced physics concepts floating and sinking to their children with confidence) could be considered successful and valued alongside their engineering and physicist sisters. It would seem likely, given Archer et al.'s (2012) research that such a physics literate population would naturally produce more physicists and engineers of both sexes as it concluded that parents with a higher science 'capital' were able to pass this on to their offspring largely along Bourdieuian lines.

In the previous chapter, four themes arose from this research, namely: education and training, physics in the home, relationships and self-concept. The follow sections will summarise this project's findings within each of these themes.

6.2 Education and training:

Education and training opportunities were particularly significant in developing the participants' level of physics literacy as in most cases the participants had little opportunity to become physics literate at home. Neither Julie nor Doreen were given the opportunity to study physics at school. Tinkerbelle may have done some physics as a part of her general science course. In the next generation, all three participants received some physics education in their secondary schools. The level of physics literacy attained depended on whether or not they chose to study physics post 14. None of these women did physics in their primary schools. The daughters' generation will receive a minimum of 11 years physics education if they attend state schools. This may be taught as a discrete subject or as a component of a general science course.

Conversely, however, where a rich physics environment was offered in the home, as was the case with Lynne and to a lesser extent Jasmine, schools did not appear to build on this as they offered an uninspiring syllabus that did not take into account the participants' existing knowledge or interests. Whitelegg and Murphy (2010) and Kelly (1981) have suggested that the physics curriculum offered in schools is often abstract, overly dependent on mathematics, divorced from practical human needs, impersonal and overly concerned with topics such as transport and forces which have little appeal to many girls. The stories of Lynne and Jasmine, the two participants who did gain a qualification in physics corroborate these findings. Lynne's interest in civil engineering as a means of solving practical 'real-life' problems and Jasmine's on-going fascination with astronomy were not catered for in their physics syllabi at school. Instead, there seems to have been an overemphasis on tickertape and forces.

Solutions to this problem are complex. In the past researchers such as Jenkins (1979) found that science syllabi aimed at including girls through linking science to their everyday experiences and aspirations, such as domestic science, were unsuccessful in delivering the content and rigour of a pure science syllabus. Furthermore, Kelly (1981) found such syllabi were often dull and lacking in excitement.

The researcher suggests that one issue is the perceived purpose of the physics curriculum. If it is solely to produce the next generation of physicists and engineers it will only ever be relevant and therefore of interest to the minority of pupils who will eventually join these professions. If, however, it is to raise the level of physics literacy and identification with physics across the whole population then a greater emphasis will need to be placed on physics topics that engage and motivate students, make links between physics and society and demonstrate a human side to physics. The dilemma then is how to make physics more accessible and interesting to a wider range of students both male and female without diminishing the content and rigour of the curriculum. One solution might be to offer parallel physics syllabi from Key Stage 4 onwards. A traditional ‘pure’ physics G.C.S.E. and A’ Level Syllabus could continue to be offered to those students who continue to show an interest and aptitude for the subject as it is currently presented. In addition to this, an ‘applied’ physics or ‘physical world’ syllabus could be offered to those students who either opt to study the core and additional science programme or who wish to develop their knowledge of physics in a more general way. The precedent for this is already set in that both English language and English literature and also mathematics and further mathematics are offered as separate subjects. A student who is particularly interested in becoming a physicist or engineer could perhaps study both courses. This would have the added advantage of bringing softer skills into physics related industry and might over time make it more accessible to everyone including women. Appendix 9 shows a hypothetical example of what a ‘Physical World’ G.C.S.E. syllabus outline might look like. This syllabus places an emphasis on solving problems in order to meet a human need. It would develop generic investigative and communication skills which could be applied to any discipline and would give potential physicists a greater awareness of how physics fits into the wider human experience.

Lynne’s story of her experience of a ‘girls into engineering’ sponsorship scheme illustrates some of the frustration in trying to change cultural norms. An initiative was set up and funded and as a result Lynne was recruited. However there appears to have been no planning behind the sponsorship scheme she was recruited into. Those line managing Lynne had neither the resources nor knowledge to ensure that her experience of engineering was positive. Instead of recruiting a female engineer the scheme had the effect of putting off and turning away a young woman who was actually very interested in engineering. If there is to be investment into recruitment and training of potential female physicists and engineers then clearly there needs to be a properly structured scheme with clear objectives for these women that are closely monitored in order to ensure that they are achieving what they have set out to do i.e. recruit more women into physics and engineering. There appears to have been no follow up in Lynne's case and so no lessons were learned from her experience.

6.3 Physics in the home

As mentioned in the previous section, the grandmothers of this study were not conscious of any physics in the home. They were surrounded by physical elements such as heat and light but their attention was never drawn towards these concepts. They were encouraged to follow traditional female domestic based occupations. There were differences in the mothers' generation. The physics input from home for both Meryl and Jasmine was minimal. They did have occasional visits to science museums or planetaria but most family activities revolved around nature, history or sport. These activities were more local, cheaper and easier to set up. In keeping with Archer et al.'s (2012) research, Lynne's family had a much higher science cultural capital than the others and she had a much greater exposure to physics in the home. She was taken to places linked to industrial heritage and her father actively fostered an interest in science. In keeping with Archer et al.'s (2012) findings, Lynne achieved the highest level of attainment in physics of all the participants and studied physics for the longest time period.

Reading was important to all of the participants in this study. Lynne benefitted from reading books that challenged social norms and expectations such as

‘Little Women’ (Alcott, 1869). This may have been significant in enabling Lynne to go against social expectations and study physics in a predominantly male group. For Jasmine, access to a library and books enabled her to develop her knowledge across a wide field and this included astronomy. Meryl still continues to expand her knowledge of a range of subjects including physics through reading magazines. It would seem that having access to books that promote women having opportunities and as positive role models, such as a biography of Marie Curie and exciting books about physics topics such as space could be very useful in developing a physics identity as well as raising the level of physics literacy.

Jasmine and Meryl both found television helpful both in expanding their own knowledge and in teaching their daughters however it would seem that there are relatively few physics based programmes.

The range of toys available has increased with each successive generation and this has included some construction toys being made available to the participants in the mothers’ and daughters’ generations. Meccano, the construction toy that has been advocated by scientists Joan Freeman (1991) and Harry Kato (The Telegraph, 2001), was not mentioned by any of the participants but Lynne’s daughter Beth did have access to a magnetic construction toy. These toys meant that each successive generation was in a better position to introduce physics through play thereby enhancing their physics literacy. In spite of this it seems that little time is spent engaging in physics based games and activities. Family days out continue to be largely historical or sport based. In the areas where these families lived there were lots of opportunities for the children to visit places of historical interest such as museums, country houses and art galleries, they also had access to environmental phenomena such as beaches and forests. There were a number of theatres, cinemas and sports centres at each family's disposal and there were opportunities for music, dance and sports coaching. There were no equivalent opportunities for the families to enjoy regular physics based activities. When they could, all of the families enjoyed going to interactive science centres but these were few, widely spread and relatively expensive. This suggests that physics is something specialised rather than an enjoyable activity that people can engage with on a day to day basis. If physics is to become a more integral part of our culture then there needs to be an increase in the opportunities to engage with physics through play, reading, television, days out and entertainment. Mary Shelley's *Frankenstein* was inspired in part by the recreational use of electric charge apparatus that was popular at the time. There may be opportunities in developing parent and toddler science clubs along similar lines to parent and toddler music groups as these would promote both the toddler's and the parents' understanding.

The findings of this study imply that while the level of physics literacy is increasing, the home environment subtly implies that physics is a specialist activity rather than something that everyone in the family can enjoy and identify with.

6.4 Relationships

In all of the cases, the mother was the primary carer for the child in her early years. The grandmothers' and mothers' generations spent their early years in the company of someone who was not physics literate and who provided a largely stereotypical gendered role model. What is perhaps striking about the grandmother-mother generation relationship is the determination shown by each grandmother that her daughter would have a better experience and greater opportunities than she had done. Each grandmother accepted her lot for herself with little questioning but did not accept the same for her daughters. The attitude of these grandmothers appears to have been a key factor in ensuring that all three mothers went on to higher education and entered professions. All three mothers however still saw childcare as their primary concern and their professional lives had to fit around their domestic life.

With each successive generation the father took a larger role as the child grew up and needed support with homework and career choices. The voices of the participants' fathers were not heard. What each story revealed however was how important the fathers were to their daughters in introducing them to the world outside the home. Once again in keeping with Archer et al.'s (2012) findings, it was Lynne whose father was an electrical engineer that went furthest with physics.

The relationship with siblings seemed increasingly important with each successive generation as each generation spent less time away from home playing with friends than her parents had done, this corroborates the findings of Waller et al. (2017) that children are spending less time outside. Thus the grandmothers' generation spent much of their childhood playing outside in the street with friends the mothers' generation, with the exception of Meryl who had no siblings, spent more time at home playing with siblings. As both Jasmine and Lynne had brothers, their play gave them access to their brothers' toys. This meant that even if gender-based toys were given to them, the girls still had access to stereotypical boys' toys via their brothers.

In Lynne's case the extended family was also important in providing STEM role models and passing on the family's science cultural capital. Lynne's paternal grandfather was an electrical engineer as were two maternal uncles. In the end Lynne followed a female cousin into pharmacy. It was an aunt who took Jasmine to a science museum. Extended family seems to have been less of an influence in Meryl's story. This study suggests that extended family can have a supporting role in developing a science literacy and identity, albeit that their ability to support the development of an identity with physics is dependent on their own physics identity.

This project suggests that the pupil-teacher relationship is very important in developing both literacy and an identification with their subjects. Tinkerbelle attributes her on-going love of art to an inspirational art teacher, Jasmine's love of literature stems from her English teacher and Meryl's interest in biology, geography and physics can be traced back to good teachers. Conversely where the relationship between pupil and teacher is not positive then the student's identification with and interest in that subject appears to diminish as can be seen in Jasmine and Lynne's physics teachers and Meryl's primary history teachers. This supports the evidence found by Whitelegg and Murphy (2006) that the pupil-teacher relationship is crucial in developing positive attitudes towards physics. In order to inspire, the teacher has to have a passion for the subject, but the shortage of physicists inevitably leads to a shortage of teachers passionate about physics. The 'physics world' syllabus as recommended in section 6.2 of this chapter might provide a good foundation for future physics teachers and foster in them a passion for physics.

One problem that the participants who did study physics found was that it seemed to isolate them from their female peers. Both of the women who did study physics had brothers and so were perhaps able to exist in a male dominated environment but nevertheless both felt uncomfortable in their physics classes. This will be considered more fully in the next section.

6.5 Self-concept

Both Tinkerbelle and Julie saw themselves as academically less able. In this, they appear to adhere to the views of Browne (2002) that ability is a fixed, biological given. Tinkerbelle several times mentioned her lack of ability in mathematics and felt that this inevitably held her back in science. The women of the mothers' generation were much more confident about their ability, although some self-doubt still arose with respect to physics for a variety of reasons. Jasmine saw herself as someone who was bright but less able to do physics than other subjects. Lynne saw herself as an able student and attributed her lack of attainment in A' level physics more to the poor teaching and environment than her lack of ability. Meryl attributes her academic successes and failures to opportunities and the quality of teaching. In the mothers' generation there is less certainty about the origins of ability. The grandmothers belonged to the tripartite era in education that was based on the belief that intelligence was fixed and measureable whereas the mothers belonged to the comprehensive era where environmental factors were also considered as important in determining ability. The perceptions of the participants reflect some of the confusion highlighted in chapter 2. Physics was seen by all the women as an academically demanding subject and therefore it is perhaps not surprising that those who considered themselves to be of lesser ability did not attempt to study it.

This study also supports the view that physics is perceived as being in some way unfeminine. Lynne especially struggled with this when being very much outnumbered by males in her A' level physics class. Her story corroborates Kelly's (1981) findings that girls can feel vulnerable and can have a need to assert their female identity around the age of puberty i.e. around the age that they have to make their G.C.S.E. subject choices. This should be less of a problem now that girls cannot drop physics completely until the age of 16 however they could opt to study core and additional science as opposed to physics chemistry and biology G.C.S.E. which might make following and A' level physics course more challenging.

6.6 The limitations of this study

This study has a number of limitations which have been recognised as detailed below.

Whilst every effort was made to protect the identities of the participants and to tell their stories respectfully and accurately, now that they are written, there can be no guarantee about how this study will be interpreted or how future researchers may use this material (Silverman, 2011). This is true of all narrative research.

A further complication is that of voice. When the researcher began this project, she was ignorant of feminist research methods that empower the participants by giving them voice (Stanley, 1992). This study shares the researcher's interpretation of the stories of the participants; it does not give direct voice to the participants themselves and as such could be seen as a patriarchal representation with the researcher in the role of expert, having authority over the participants' views rather than the researcher and participants being seen as equals (Silverman, 2011). If this study was to be repeated, the researcher would like to explore ways of making this more collaborative, with the participants being seen as equal partners in this project and having a say in the outcomes and final interpretation (Alcoff, 1991). The disadvantage of adopting such a stance would be the time and commitment required from the participants in order to ensure that their voices were heard.

A further limitation of this project is the absence of the male voice. This study aimed to find how women develop physics literacy and identification with physics, and how this might have changed over time and so the observations and interviews were limited to the female members of each family. However, it is clear from these narratives that men played a crucial role in the development of these women's physics literacy and identity. Lynne, Meryl, and Jasmine all looked to their fathers for career advice and help with homework. Jasmine and Lynne remember playing with their brothers in childhood which gave then access to toys and games that might traditionally be seen as masculine. Lynne and Jasmine's physics teachers were male. It would be interesting to investigate this further and find out if there is corroboration between the views of the women participants and the men in their lives.

This study was also limited by time constraints, more time and more interviews would have revealed more about the lives of the participants. However as Denzin (2014) suggests, every story is a limited account. It is not possible to record every aspect of a life from every perspective, all that can ever be recorded is an impression taken from a particular viewpoint. Had more time been available it would have been helpful to have corroborated the stories with other sources such as school reports, letters, diary notes, school books, photographs and reminiscences from other family members, friends, and teachers.

A more knowledgeable and experienced researcher could have managed this project more efficiently, incorporated more of the participants' voices, and drawn deeper insights from their stories. Conversely, the naivety of the researcher did enable a more equal relationship within the interviews, allowing some sense of learning together with the participants and enabling the extraction of authentic natural accounts.

A study of this nature is always dependent on the degree of understanding between the researcher and the participants. All of the participants in this case appeared articulate and able to communicate with researcher and had the opportunity to correct the resultant transcripts but there remains the possibility that the researcher may have misinterpreted their responses.

6.7 Recommended Further Research

This study has indicated that, for the families in question, there has been a marked increase in the level of physics literacy and also a significant change in physics identify over time. Similar studies of different families might confirm whether or these changes can be generalised, whether these changes apply only to similar white middleclass families or whether these changes are universal. As mentioned in the limitations, it would be interesting to gain a male perspective and see if similar changes can be detected in boys and what impact if any changing the relationship between women and physics might have on men. Gaining more women physicists and engineers will be of limited value if this leads to a reduction in the number of male physicists; what is needed is an increase in uptake from both sexes.

This study has focussed on two generations. It would be interesting to extend this to the third generation and to compare the experiences of the granddaughters' generation to those of the grandmothers and mothers. There was a marked difference between the grandmothers' and mothers' generation. It would be interesting to explore if there is Will there be a similarly dramatic change between the mothers' and daughters' generation or just a continuation of the changes already in place.

This study contradicts the findings of Osborn et al (1999) and Shapker and Keating (2017) in that the two participants who took physics furthest were those in co-educational school who learnt physics alongside their male peers. However, both of these women studied post 14 in male dominated classes and experienced a sense of isolation. Further study could be made of the advantages and disadvantages of girls having the opportunity to study physics in all girl groups.

Joan Freeman (1991) and Harry Kato (The Telegraph, 2001) both regret the decline in Meccano as a toy. Kelly (1981) suggests that boys have the advantage over girls in learning physics on account of their early exposure physics related toys. However, there seems to have been little research into the relationship between toys and games and the development of physics literacy and identity. More research is needed to establish whether certain toys do indeed foster a greater understanding of and interest in physics and also how physics might be promoted in the nursery. Is it the actual toys themselves that make a difference or is it more to do with having a choice?

6.8 Reflections

A hidden aim of this research was to promote my own learning by coming to understand a new discipline. As stated in chapter three, I came to this research from a logical positivist science and religious education background, and was completely new to sociological research.

After some initial resistance to placing myself in this study and concern that in becoming involved with the participants I would be contaminating the evidence in some way I began to feel confident that what the participants were telling me through our mutual interaction was inherently truthful and therefore more reliable than had I tried to detach myself from the research in a '*Marie Curian'* disinterested way. My interpretation of the stories correlated with the reading I encountered in compiling the literature review.

My own relationship with physics has been changed through carrying out this research. I find myself wondering if in fact I could have studied it further and even enjoyed a career in physics if the subject had been presented to me in a more passionate and exciting way, if I had been allowed the opportunity to carry out my own investigations and if the topics had been delivered through a more meaningful context and had I studied it in either an all-girl or equally balanced male and female group. I would like the opportunity to study physics again and to develop ways of making physics more accessible and exciting to my students.

6.9 Aristotle's Daughters

This study began with a consideration of the legacy of Aristotle, the father of science and also (perhaps unwillingly) father of many of our perceptions about women. This study suggests that the situation for women and their relationship with physics is improving. The physics literacy of women has expanded across the generations studied in this project. Improving women's identity with physics however is proving more difficult as there appears much cultural resistance to women taking on what is still perceived by many to be a masculine subject. Echoes of Aristotle's weak minded woman have rippled down through the generations and it may take another couple of generations until these waves have flattened.

Appendices

Appendix 1: Ethics Approval

The following application was approved by ERGO via an email sent to me at 6:51 p.m. on 2nd April 2012. This email has since been misplaced.

My study number is 1294.

March 2012

SSEGM ETHICS SUB-COMMITTEE APPLICATION FORM

Please note:

- ***You must not begin your study until ethical approval has been obtained.***
- ***You must complete a risk assessment form prior to commencing your study.***
- ***It is your responsibility to follow the University of Southampton's Ethics Policy and any relevant academic or professional guidelines in the conduct of your study. This includes providing appropriate information sheets and consent forms, and ensuring confidentiality in the storage and use of data.***
- ***It is also your responsibility to provide <u>full and accurate information</u> in completing this form.***

1. **Name(s):** Ceri Edwards-Hawthorne

2. **Current Position:** Student (part-time)

3. **Contact Details:**

Division/School: Education

Email: cjeh1e08@soton.ac.uk

Phone: **(**01202) 269250

4. **Is the proposed study being conducted as part of an education qualification (e.g., PhD)**

Yes ✔☐ **No** ☐

5. **If Yes, state name of supervisor**

Dr Jenny Byrne

6. **Title of Project:**

Aristotle's Daughters: an intergenerational biographical account of women's experience of science and in particular physics education from three different families

7. **What are the proposed start and end dates of the study?**

April 2012 – April 2014

8. **Describe the rationale, study aims and the relevant research questions**

In 1981 Alison Kelly (1981) was concerned about difference between girls' and boys' achievement in physics; the ratio of males to females taking C.S.E. physics was 16.4:1 and males to females achieving a PhD in physics 32:1. Kelly argued that many of the reasons for this were sociological. The 2006 Institute of Physics report; Girls in the Physics Classroom states (p.1);

"... the girls' entry rate [A' Level Physics] is now very low compared with the boys', and compared with the girls' entry rate for chemistry and biology. This decline is significant because it impacts on the future workforce which may lack important skills and knowledge, and this includes future teachers who may not have the qualifications and background needed to enthuse the next generation of potential physical science students. Indeed without qualified teachers the decline may accelerate."

Barnard et al. (c2010: p 362) write

Over the last 40 years, numerous research studies and initiatives have attempted to redress the under-representation of women in science, engineering and technology. ... However the progress and achievements to date do not match the investment in terms of the quantity and quality of research and initiatives in this area.

Thus it seems that there is a persistent problem with the number of women and girls studying physics. There has been much research into how physics may be made more appealing and accessible to female students in the classroom; for example, the Institute of Physics '*Girls into Physics: Action Research Project'* . However, I can find little evidence of studies looking into the influence of the home environment on the uptake of physical science. Proponents of the 'ecology of human development' such as Bronfenbrenner however suggest that human development is the result of an interaction between the growing child and his/her environment. This interaction takes place at several interlocking levels i.e. the micro, meso, exo and macro systems. Looking purely at the influence of schooling on child development including the development of the knowledge and understanding of physical science, neglects the meso, exo and macro factors.

The purpose of this study is to provide a biographical account of how knowledge, understanding and attitudes towards physics have developed in women from three different families over three generations using Bronfenbrenner's model as a theoretical framework.

It will explore the relationship, if any, between developments in the philosophy of science teaching and the development of ideas in the participants. It will also explore any patterns of thinking about science across the generations studied.

9. **Describe the design of the study**

Please see the attached flow chart.

10. **Who are the participants?**

Three mothers of girls currently aged around six, their families including children, parents and partners.

Members of my own family will participate in the pilot study.

11. If you are using secondary data, from where are you obtaining it?

N/A

12. If you are collecting primary data, how will the participants be identified, approached and

recruited to the study?

(please attach a copy of the information sheet if you are using one)

A letter and information sheet about the study will be given to women from a social parent group at a local school inviting them to take part in this study. Please see attached.

13. Will participants be taking part in the study without their knowledge and consent at the

time (e.g. covert observation of people)? If yes, please explain why this is necessary.

No

14. If no to 13., how will you obtain the consent of participants?

(Please attach a copy of the consent form if you are using one)

I will obtain consent by asking participants to complete the attached consent form.

15. Is there any reason to believe participants may not be able to give full informed consent?

If yes, what steps do you propose to take to safeguard their interests?

No

16. If participants are under the responsibility or care of others (such as parents/carers, teachers or medical staff) what plans do you have to obtain permission to approach the participants to take part in the study?

I will only be involving children whose mothers are participating in the project and have given their consent both for themselves and their children. The mothers will be present during all interactions with their children and will be invited to check any information used concerning themselves and their children.

17. Describe what participation in the study will involve for study participants. Please attach copies of any questionnaires and/or interview schedules to be used

1. Completing consent form
2. Taking part in an observation session that will be recorded on video and may include discussing, drawing, writing, sorting and playing
3. Taking part in a semi- structured interview (schedule attached) to find out about their experience of science education and influences on the same. Audio recordings will be made of these interviews which will then be transcribed.
4. Relatives of the original participants will be invited to take part in a semi-structured interview talking both about their own experience of science and the experience of the original participants. Audio recordings and transcriptions will also be made of these interviews
5. Checking through and where necessary correcting any written observations made by the researcher from the above points

18. How will it be made clear to participants that they may withdraw consent to participate at any time without penalty?

This will be stated on the original consent form and reiterated at every stage of the study.

19. Detail any possible distress, discomfort, inconvenience or other adverse effects the participants may experience, including after the study, and how this will be dealt with.

The study will require a time commitment on the part of the participants. It is not anticipated that the investigation will cause any harm to those involved and it is hoped that the participants may find it an interesting and enjoyable experience. There is a risk that talking about childhood memories may bring to mind painful memories for some people. Should this prove the case I will remind the participant concerned of his/her right to withdraw from the project and recommend that s/he speak to a professionally qualified person rather than myself about their experiences. The participant will always be in control of what they choose to share with me. They will be encouraged to read through and check everything that I write concerning them and I will not keep or submit any information that they are no longer happy for me to share. All copies of video material will be given to the participants either at the end of the project or sooner if the participant requests this.

20. How will participant anonymity and confidentiality be maintained?

The participants will choose a pseudonym that will be used throughout the project and all place names will be concealed. The video material and audio recordings will not be used directly in the published thesis.

The information will not be discussed with anyone outside the project. The participants will be told who the information is likely to be shared with i.e. my supervisor and examiners. They will also be told who will have access to the thesis once it is completed.

21. How will data be stored securely during and after the study?

All data will be managed in accordance with University of Southampton policy.

Raw data i.e. drawings and writings produced by the participants, video and audio recordings will be stored in a locked safe. The reports and analysis will be stored on a laptop/computer and on a memory stick. The memory stick will also be stored in the safe. The laptop will be password protected.

If any participant withdraws from the project their drawings and writings (and those of their children in the case of the mothers) will be returned to them, any recordings of them (and their children where applicable) will be erased and transcripts of interviews will be deleted from all stored areas i.e. the laptop and memory stick. The data gathered from these participants will not be used in the published thesis.

The data concerning the participants who agree to remain in the project will be stored securely as described above and erased/shredded/deleted as appropriate after the period of time set by the University of Southampton Policy, currently after a period of ten years.

22. Describe any plans you have for feeding back the findings of the study to participants

The participants will be given copies of any analysis and reports taken from their contributions, they will be encouraged to alter and amended where necessary if they feel I have not represented them or their children accurately. They will be given a summary of the project's findings at the end of the project.

23. What are the main ethical issues raised by your research and how do you intend to manage these?

- Confidentiality – see question 20
- Veracity (speaking for another) – by allowing and encouraging the participants to check and correct all that is written about them
- Maintaining the reputation of the research community – ensuring honest, respectful, polite and considerate conduct
- Informed consent – most of the participants will be adults capable of granting their own consent, the child participants will do so only with the consent of and under the supervision of their mothers

- Data protection – see question 21
- No coercion – the participants will join the project of their own free will, they will have the right to withdraw at any time, there will be no incentives to join or withdraw from the project, the researcher will not invite participants from those over whom she may have some influence e.g. pupils and former pupils
- Anonymisation – to protect the identity of all participants only pseudonyms will be used

24. Please outline any other information you feel may be relevant to this submission.

Appendix 2; pre-interview information for participants and consent form

Aristotle's Daughters

An intergenerational biographical study of women's experience of science, and in particular physics education, from three different families

Dear Emma,

Thank you for considering taking part in this project. This leaflet will explain what the project involves, what will happen to the data gathered and what to do if you have any concerns or worries.

<u>Who am I?</u>

I am Ceri Edwards-Hawthorne, mother of Rhion in year 1, a teacher and a part time Ed.D. student, at the University of Southampton.

<u>Why am I doing this project?</u>

I have been studying for an educational doctorate at the University of Southampton for my own personal interest. In order to complete this course I have to carry out a research project. I have decided to carry out this particular study as my own background is in science and I am concerned with ensuring equal opportunities for both boys and girls.

<u>Who am I looking for?</u>

I am looking for three mothers of daughters in year one who have mothers of their own who are likely to be able and willing to take part in the study. Ideally I would like to involve women who have differing experiences of education, especially science. It would be helpful if other family members such as partners, husbands, and fathers would also be willing to take part in this project.

<u>What will the project involve?</u>

This project has three main phases.

The first phase will involve me visiting you in your own home or at another venue if you prefer. I will ask you to do some activities with your family. I will video record what you do and take notes. I will then go away and write up what happened. I will share what I write with you and give you the opportunity to correct anything you think I have got wrong.

For the second phase I will interview you about your life, childhood and experience of science. I will make an audio recording of this interview. I will also note down what you say, write it up and give my report to you for you to check.

Finally I will interview your mother in a similar way to the way I interviewed you. I will share my report with her and allow her to check what I have written about her.

<u>What will happen to what I write?</u>

When I have gathered data from all of the families studied I will be writing a report or thesis about what I have found out. This thesis will be shared with Dr Jenny Byrne, my supervisor, my examiners and possibly members of their departments. If the thesis is accepted it will be the property of the University of Southampton and kept in the University's library for subsequent students to read.

In order to protect your identity you will be invited to create a pseudonym for you and your children at the start of this project. I will also invite your mother to do the same. I will not be using any real names of people or places other than identifying myself.

I cannot give an absolute guarantee that you will not be recognised in the report but will take all reasonable steps to keep your identify anonymous.

What will happen to the data?

The video and audio recordings that I make will be transcribed and then deleted. The data that I collect from you will be stored on a password protected computer in accordance with the University of Southampton's Data Protection Policy. After a time period set by the University, the data I have about you will be deleted from my files. I am happy for you to have copies of anything I write about you.

I will not be presenting video or audio recordings to a third party. They will be made solely for my own personal use to aid my report writing. I will only be submitting written reports to my supervisor.

What if you change your mind?

You are free to change your mind and pull out of the project at any time. Should you decide to do this just let me know. I will then delete any data I have about you on my files and return any recordings to you.

What if you have worries, concerns or complaints?

If you have any concerns please do not hesitate to contact me as follows:

Cjeh1e08@soton.ac.uk

Or 07747561679

Alternatively you may prefer to contact my supervisor;

Dr Jenny Byrne
Southampton Education School
University of Southampton
Building 32
Southampton
SO17 1BJ
United Kingdom

In the unlikely case of concern or complaint, you can contact; Dr Martina Prude, Head of Research Governance (02380 595058, mad4@soton.ac.uk).

Thank you for reading this leaflet.

Ceri

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Participant Information Sheet (Parents)

Study Title: Aristotle's Daughters: an intergenerational biographical account of women's experience of science and in particular physics education from three different families

Researcher: Ceri Edwards-Hawthorne **Ethics number:** 1294

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

This research forms part of the requirement for an Ed.D. at Southampton University. It is a biographical study that will involve telling the life stories of people who have agreed to take part. The focus of the study will be participants' experiences of physics education throughout their lives.

Why have I been chosen?

Participants have been chosen because they live in the locality, come from a similar ethnic background to the researcher and have family members from three generations who are willing to participate in this study. I am also looking for people who have had contrasting experiences of physics education.

What will happen to me if I take part?

The first stage will involve the researcher visiting you and your immediate family in your own home or at a location that you would prefer at a time that is convenient to you. This visit will take a maximum of one hour. During this visit you will be asked to take part in a number of different activities such as writing, drawing, playing and talking with your family. With your consent this visit will be video recorded, the video will be taken away and analysed. The recording will then be given to you after it has been analysed and transcribed. You will be asked to make comments about the transcription and alter anything that you consider to be an inaccurate portrayal of you and your family.

The second stage will involve the researcher visiting you on your own to talk about your life story and find out about your experience of physics education in some detail. With your consent this session will be audio-recorded and the researcher will take notes. Once this has been analysed and transcribed you will also be given a copy of the transcription and draft analysis. You will be invited to check and amend this analysis and alter anything that you consider to be an inaccurate portrayal of you and your family. It is anticipated that this visit will last about an hour.

Finally the researcher would like to visit your mother and interview her both about her memories of your childhood and also her own experiences of growing up and learning about physics. This interview will also be audio-recorded , with her consent , and notes taken. Once this has been analysed and transcribed your mother will also be given a copy of the transcription and draft analysis. She will be invited to check and amend this analysis and alter

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anything that she considers to be an inaccurate portrayal of her and her family. It is anticipated that this visit will last about one hour.
The researcher may wish to arrange a follow up visit with you and or your mother to check details and that you are happy with what has been written.

Are there any benefits in my taking part?

There may not be any direct benefits to you or your family in taking part in this research although it is hoped that participants will enjoy the chance to share their experiences. It is hoped that this research will help to further the researcher's understanding of physics education and more generally provide insights about girls' education.

Are there any risks involved?

It is hoped that this research will not cause any hurt or harm to the participants or their families. For some people talking about their past may be a sensitive matter. If you feel uncomfortable about this aspect you may wish to reconsider whether you should participate.

Will my participation be confidential?

This research will be undertaken in compliance with the Data protection Act and in accordance with the University of Southampton's Data Protection Policy.
The written data will be stored on a password protected computer and the video recordings will be stored in a locked safe until they are returned to you the participant. The information will be shared with the researcher's supervisor, Dr. Jenny Byrne but it will not be shared with anyone outside the University School of Education without your prior consent.
All reasonable attempts will be made to assure your anonymity, surnames and place names will not be used and you will be invited to choose a pseudonym as will your children and your mother. There is always the possibility that a person could work out your identity from the final report but the researcher will act on the advice of her supervisor to minimise the chances of this happening.

What happens if I change my mind?

You have the right to withdraw from this project at any time and for the data gathered about you to be returned or deleted.

What happens if something goes wrong?

In the unlikely case of concern or complaint, you can contact; Dr Martina Prude, Head of Research Governance (02380 595058, mad4@soton.ac.uk).

Where can I get more information?

Further can be obtained from the researcher and Dr. Jenny Byrne (02380 594665, jb5@soton.ac.uk)

[18-3-2012] [Version 2] [1294]

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Parent's CONSENT FORM (*Version Number 2*)

Study title: Aristotle's Daughters: an intergenerational biographical account of women's experience of science and in particular physics education from three different families
Researcher name: Ceri Edwards-Hawthorne

Study reference: 1294
Ethics reference:
Please initial the box (es) if you agree with the statement(s):

I have read and understood the information sheet (March 2012; Version 1) and have had the opportunity to ask questions about the study. ☐

I agree to take part in this research project and agree for my data, and that of my children, to be used for the purpose of this ☐

I agree to have myself and my children video-recorded during the research activities (where applicable) ☐

I agree to take part in a semi-structured interview that will be audio-recorded ☐

I understand my participation is voluntary and I may withdraw at any time without my legal rights being affected ☐

Data Protection

I understand that information collected about me during my participation in this study will be stored on a password protected computer and that this information will only be used for the purpose of this study. All files containing any personal data will be made anonymous.

Name of participant (print name)..

Signature of participant..

Date...

10-3-2012 Version 1 1294

Appendix 3; observation resource and examples of work produced

Aristole's daughters; Draft Observation Schedule; May 2012

Daughters and Mothers in family context observation schedule

Purpose;

To gain an insight into how the family interact, what the gender roles are within the family and how this relates to each member's attitude to science.

<u>Schedule</u>

1. Introduction
   - I am a science teacher – I want to find out what you think about science
   - What we will be doing today
   - Anonymity – choose a pseudonym
   - Video and what I will do with results
   - Right to withdraw
2. What is a physicist (scientist)
   - Let's pretend I know a physicist (scientist) called Alex
   - What do you think Alex might look like (write or draw)
   - What do you think Alex liked doing/playing with as a child?
   - Alex is an imaginary physicist I have been finding out about a real physicist called Joan Freeman, here is a picture of her. Her favourite toys were a car and a mechano set. How similar is Joan to your idea of Alex? Does any of this surprise you?
3. Favourite toys?
   - Do you have a favourite toy?
   - Can I see it?
   - How do you play with it?
   - What is good about it?
   - What else do you enjoy doing?
   - What do you want to be when you grow up?
   - Do you think that you will do science when you grow up?
4. Toy sort
   - I have brought some toys with me – who do you think they might belong to?
   - Which toy would you like to play with?
   - Can you show me how to play with it?

Thank you for helping me with this research.

Alex

Alex is a physicist who started working on atomic energy in the 1940s.

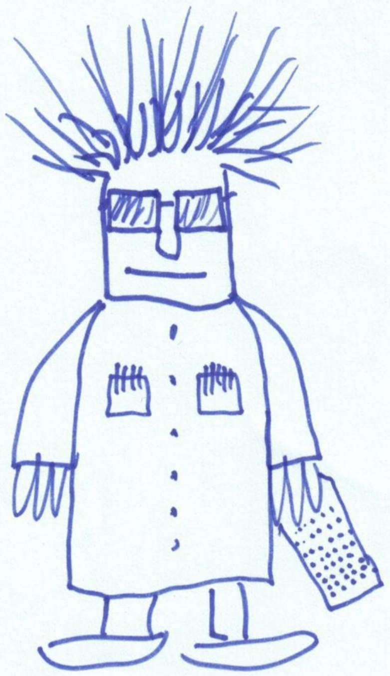
Write or draw what you think Alex might have looked like?

Write or draw what toys you think Alex enjoyed playing with as a child.

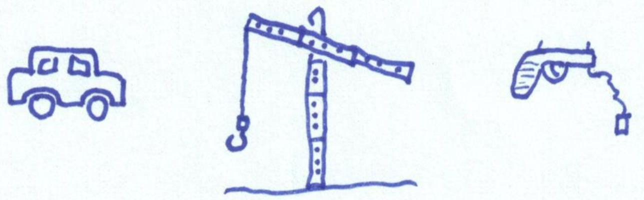
Alex

Alex is a physicist who started working on atomic energy in the 1940s.

Write or draw what you think Alex might have looked like?



Write or draw what toys you think Alex enjoyed playing with as a child.



Alex

Alex is a physicist who started working on atomic energy in the 1940s.

Write or draw what you think Alex might have looked like?

He is cute

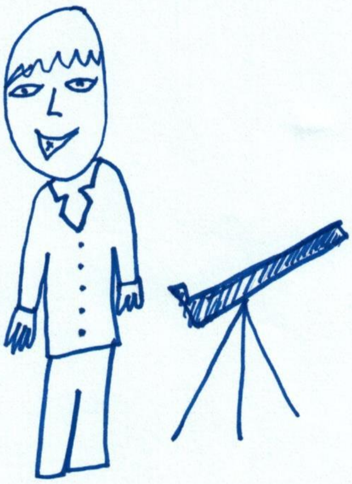
Write or draw what toys you think Alex enjoyed playing with as a child.

He likes trains, football, table tennis and normal tennis

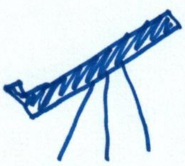
Alex

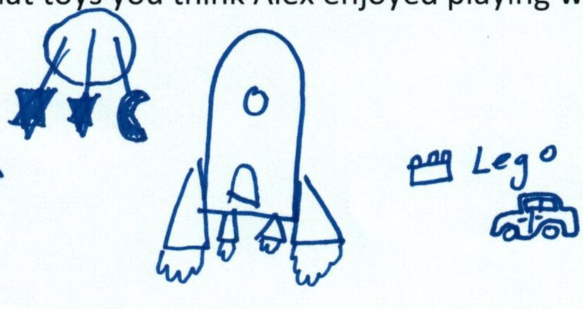
Alex is a physicist who started working on atomic energy in the 1940s.

Write or draw what you think Alex might have looked like?



Write or draw what toys you think Alex enjoyed playing with as a child.





Appendix 4; a sample interview script

Aristole's daughters; Interview Schedule; May 2012

Interview schedule for Mothers

Make concept maps together as we work through schedule.

Questions

1. What do you do and how do you think you got here?
    - Natural ability
    - Personality
    - Convenience/family circumstance
    - Accident
    - Career v family
    - Interests
    - Parental expectation
    - Friends influence
    - Wider cultural influence
    - Mission/ purpose/ethical concerns
    - When did you decide/know this was where you were heading?
    - How do you see your role changing/developing in future?

2. I noticed your child(ren) enjoyed playing with ... ;what toys, games and activities do you remember enjoying as a child?
    - Dolls , cars, construction kits, chemistry sets, paints, books, box modelling/junk ...
    - Who provided the toys
    - Did you have a favourite toy
    - What did you spend most of your leisure time doing?
    - Who did you spend most time with?
    - Who chose them and how

3. Can you tell me what your family life was like as you were growing up?
    - Parents and their roles within the family e.g. homemaker, provider ...
    - Siblings
    - Extended family
    - Home setting
    - Family history/culture

4. Can you tell me anything about your school life?
    - Type of school – single sex, co-ed, selective, state, private
    - Phases of schooling. Primary, infant, junior, first, middle etc
    - Groupings within school e.g. ability, friendship,
    - Gender issues in school – sex of teachers, opportunities for girls and boys
    - Teaching strategies – practical, formal/informal, structure of school day

5. What has been you experience of science and in particular physics education?
    - Primary school

- Secondary
- Tertiary
- Higher
- INSET
- Curriculum type e.g formal, investigative, progressive, content, homework
- Resources including: -equipment, schemes of work, text books, science labs, audio visual, field trips, community links
- Organisation and structure e.g. streaming, grouping, co-ed /single sex, working partners
- Options and how you chose them, careers advice
- Confidence, enjoyment, ability – how did this change and develop?
- Peer relationships, friends attitudes and influence
- Teachers
- Parental support
- Can you describe any significant events in your science education

6. How important was science to your family?
    - General discussions
    - School reports/parents evenings
    - Parents jobs
    - Relatives jobs e.g. aunts, uncles, cousins, grandparents, older siblings

7. How important do you think science, especially physics is to your life today?
    - Work – does it form a part of your working life?
    - Domestic life e.g appliances around the home, cars
    - Leisure e.g. T.V., books, sporting activities
    - Children at home and at school e.g toys, games, books, visits, school curriculum
    - Could you wire a plug, replace a washer in a tap, put a child's toy together?
    - Making informed choices e.g nuclear power, recycling, light pollution

8. As you were growing up, what was your experience of physics out of school?
    - Books
    - TV programmes
    - Visits e.g to science museums
    - Clubs e.g nature, guide badges
    - Play e.g making den

9. What does the word physics conjure up for you/how does it make you feel?
    - Confidence
    - Images

10. This is the last question; is there anything else you would like to tell me?

Appendix 5: an example of a section from an interview transcript

Tinkerbelle Transcript

Tink: Um and games yeah just the normal children's games really.

Ceri: Snakes and ladders and things

Tink: yeah

Ceri: was that similar to what you enjoyed playing with as a child or

Tink: Yeah, pretty much erh I think when I was child we played out more just in the street. There were a lot of children in our street. It was the thing it was a completely different culture I mean when my kids were growing up you wouldn't dare let your children out without knowing where they were but when I was a kid you see you were going everywhere.

Ceri: So it was mostly outside for you.

Tink: it was yeah

05:30

Ceri: was it with children your age or with toys.

Tink: No it was children my age and older because I've got older brother and younger brothers and sisters and in that particular street there were kids all ages and you coukd just go out and play with anyone really ... couple of years younger than me couple of years older than me it was just one of them type of areas.

Ceri: It was close knit and

Tink: You didn't worry abour anyone else and I was always in shorts and always running round the street and that, I had roller skates

Ceri: So very sporty

Tink: Yeah

06:10

Ceri: (indistinct) so any role play things like the girls do ...

Tink: Probably not because I had a twin brother and they're not really into role play and my youngest sister she was four years younger than me.

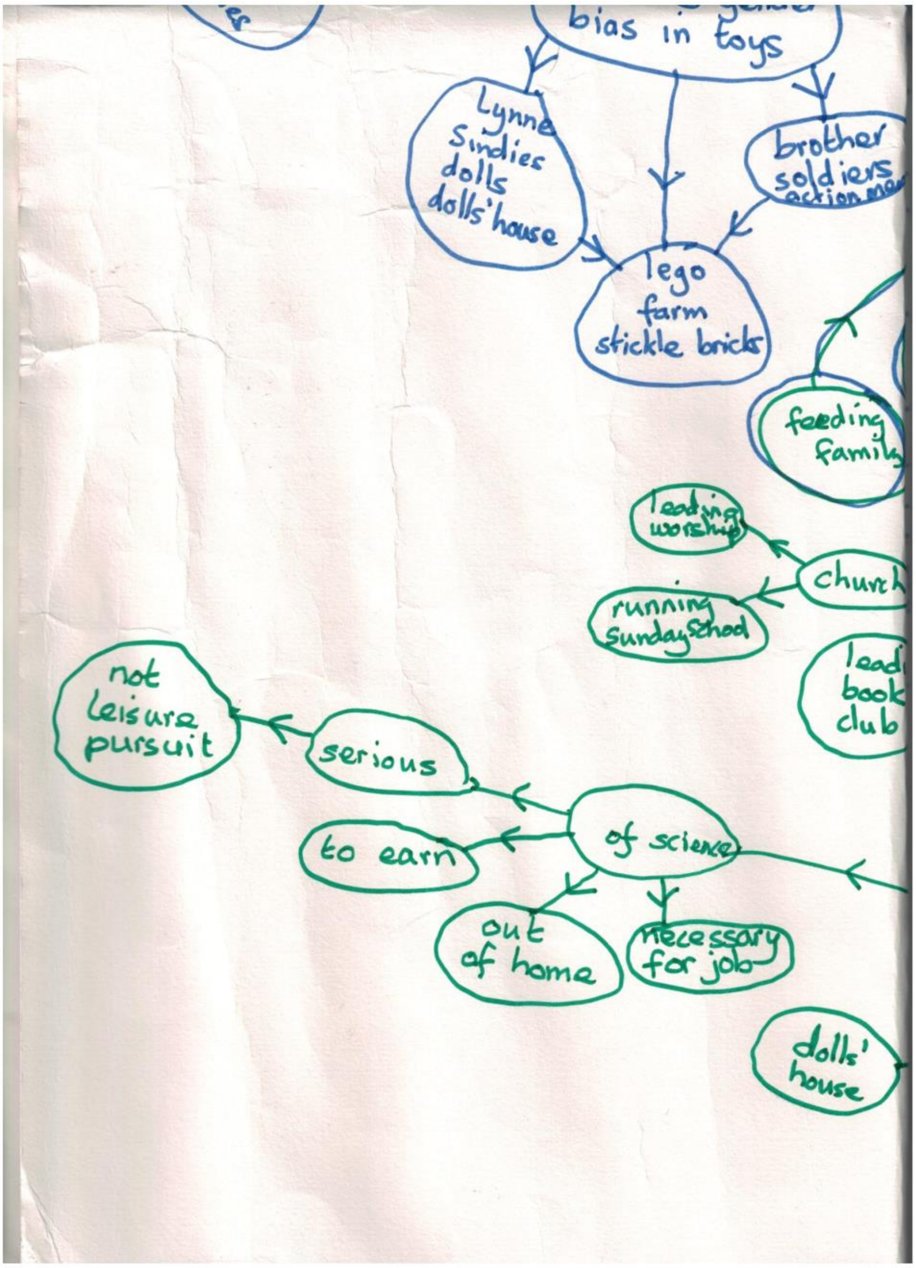
Ceri: So I guess by the time she was into it you'd moved on.

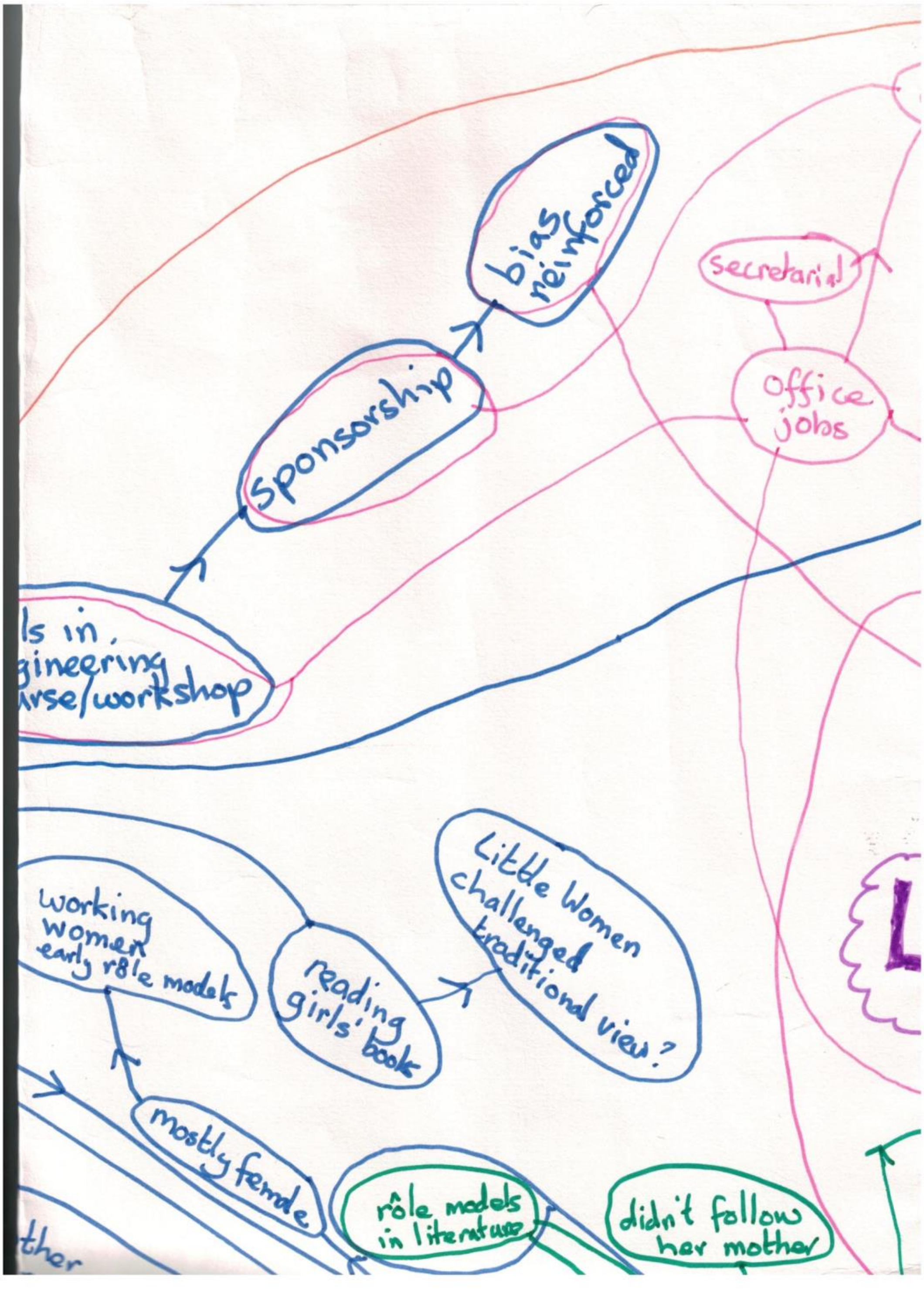
Tink: Cause there were friends in the street my age. But I can't remeber doing role play.

Ceri: So it was very active, roller skates, that type of stuff.

7

Appendix 6: **A colour coded concept map derived from the researcher's interpretation of her interview with Lynne, the mother from the pilot study.**

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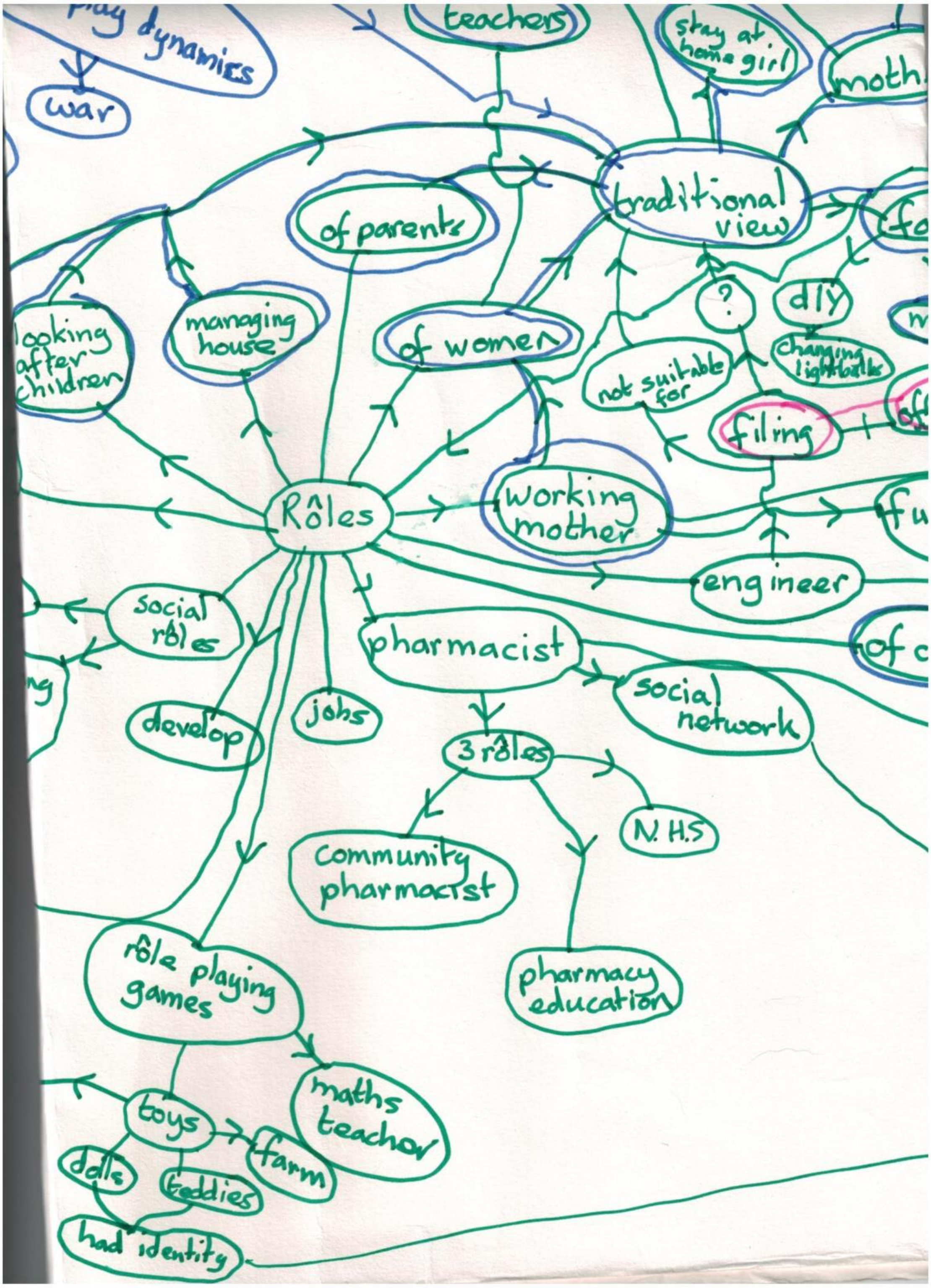
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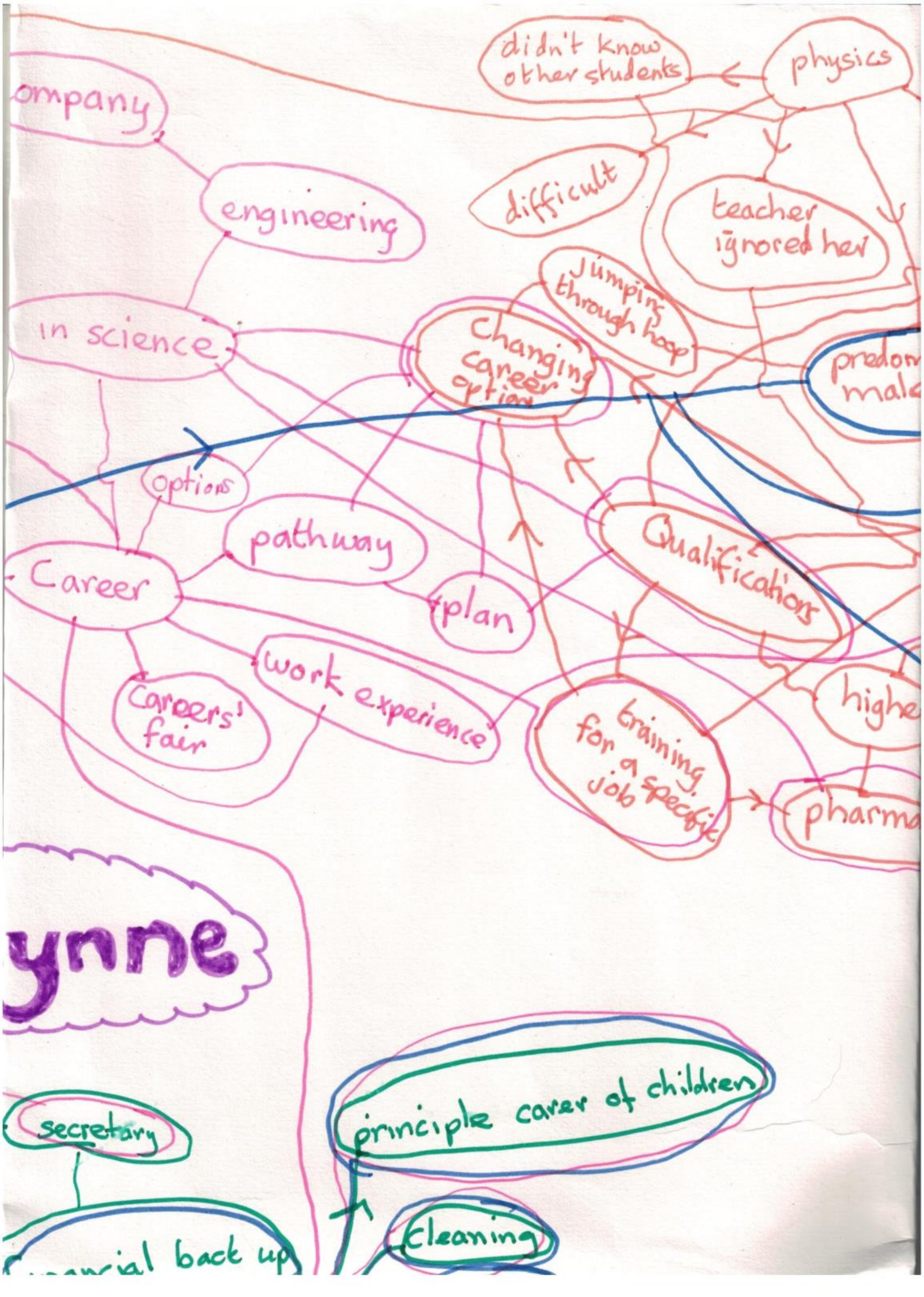
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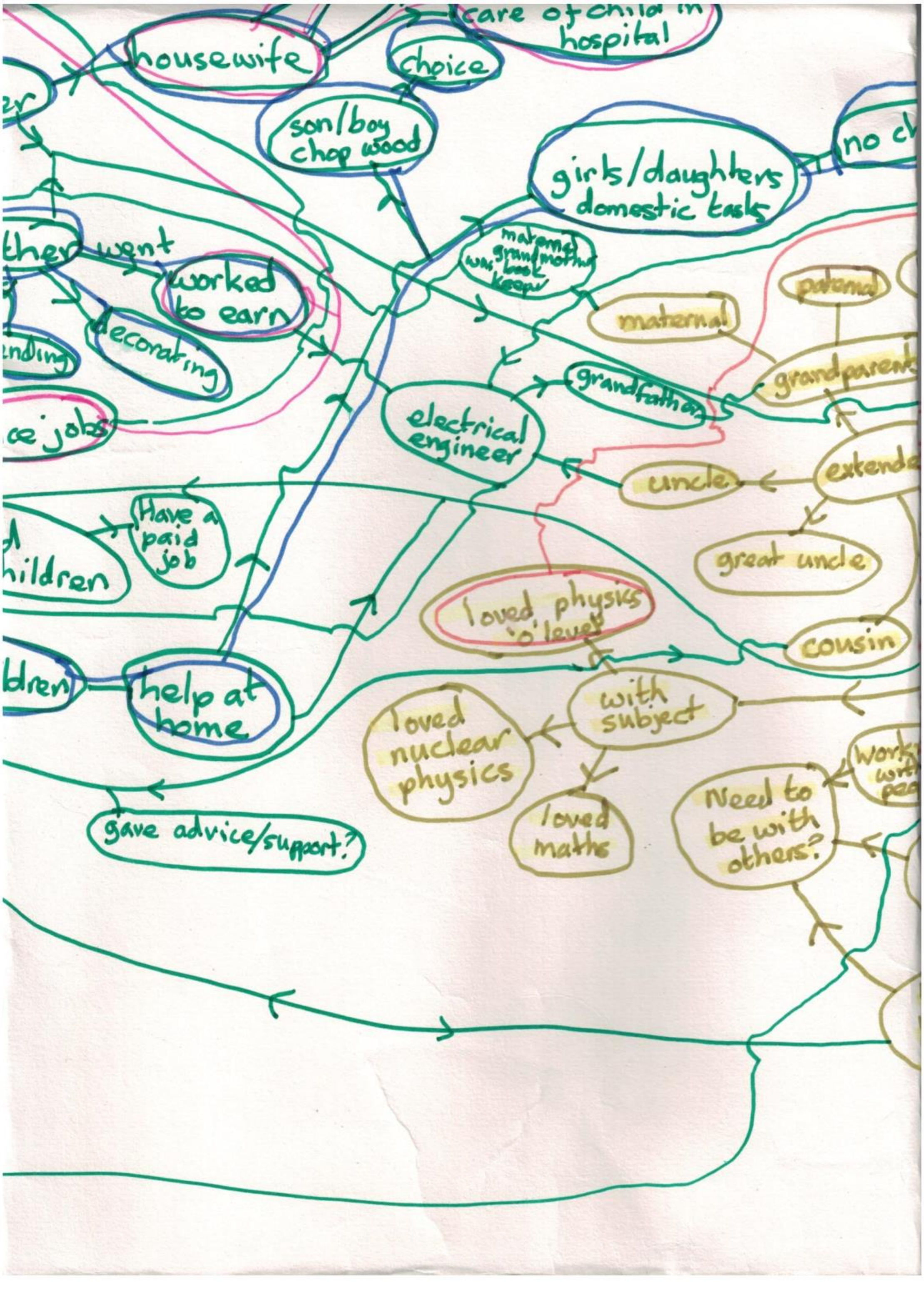
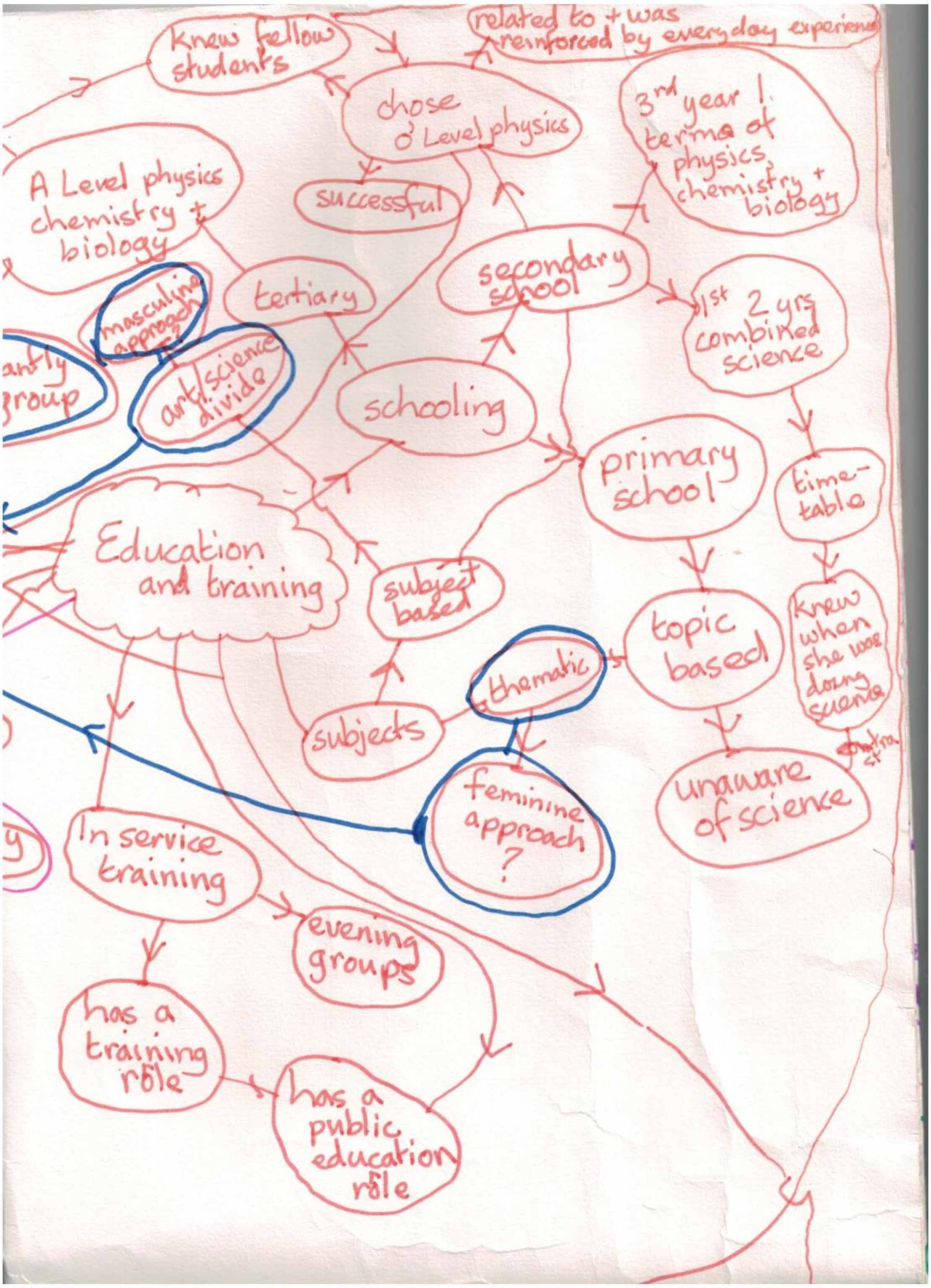
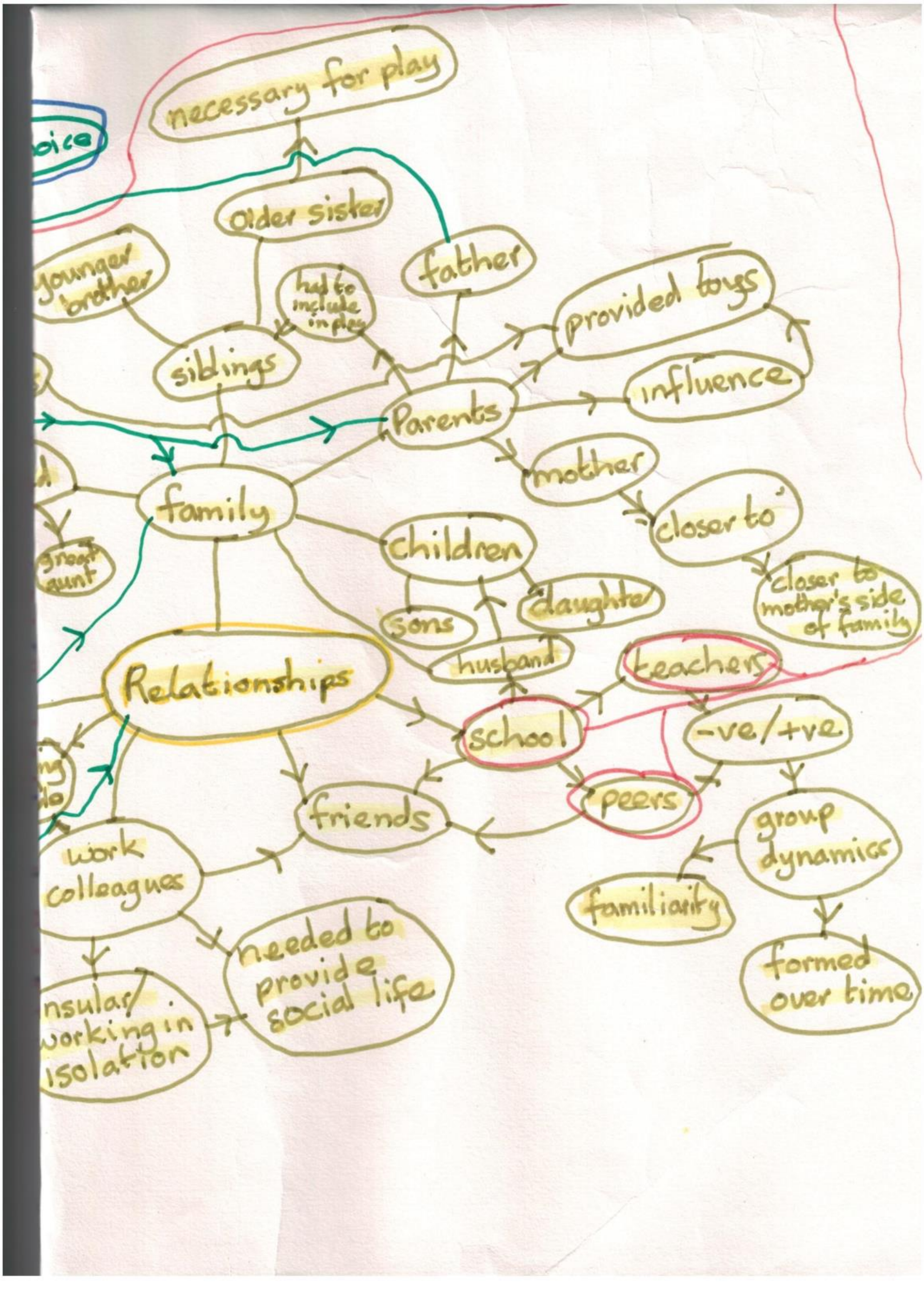
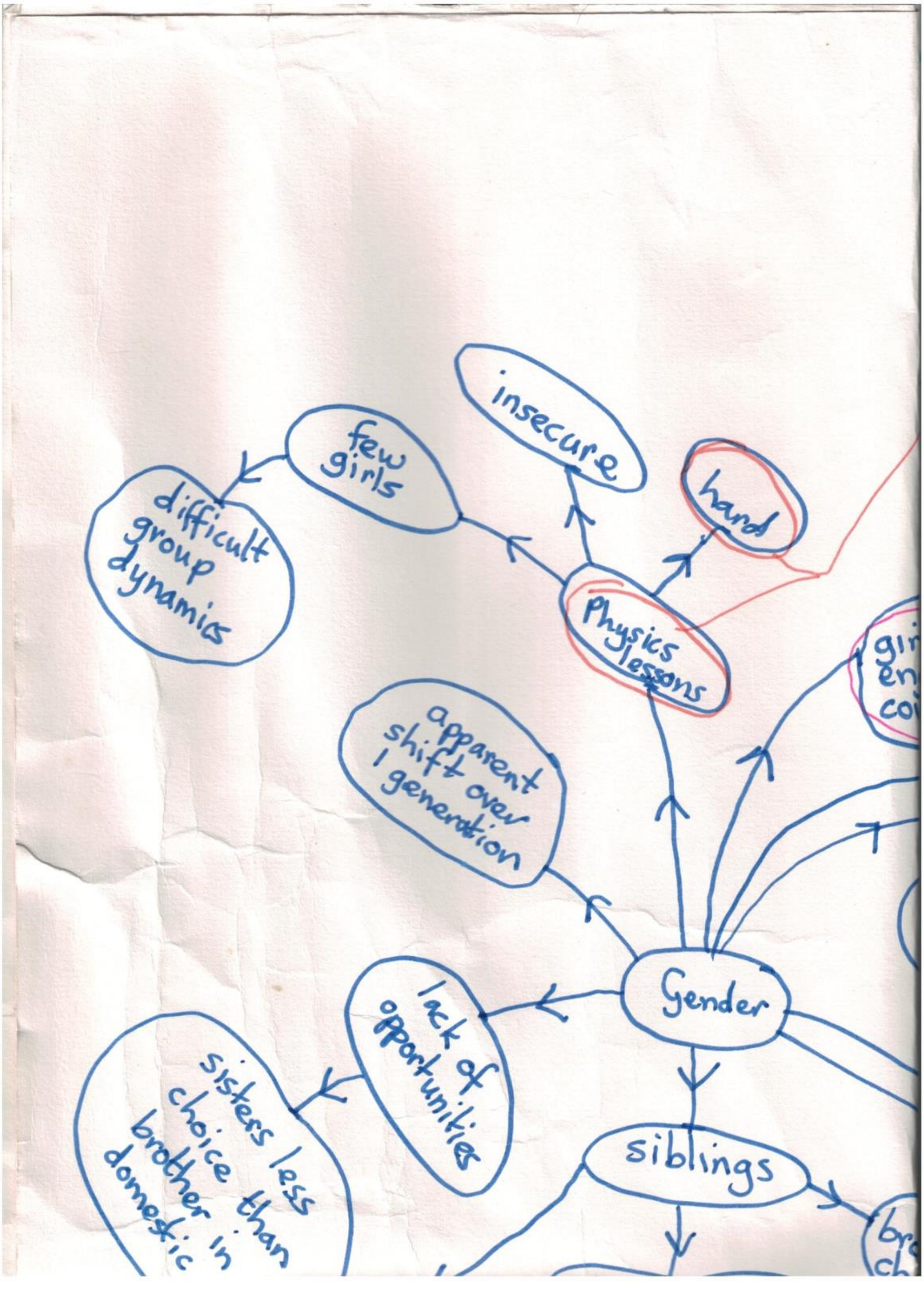
work experience
careers' fair
training for a specific job
pharma
ynne
secretary
principle carer of children
Cleaning
financial back up


housewife
care of child in hospital
choice
son/boy chop wood
girls/daughters domestic tasks
no ch
ther went
worked to earn
decorating
nding
ce jobs
maternal grandmother was book keeper
maternal
paternal
grandparent
grandfather
electrical engineer
uncle
extende
great uncle
Have a paid job
hildren
loved physics 'o' level
cousin
ldren
help at home
with subject
loved nuclear physics
loved maths
Need to be with others?
gave advice/support?


knew fellow students
related to + was reinforced by everyday experience
chose O' Level physics
3rd year 1 term of physics, chemistry + biology
A Level physics chemistry + biology
successful
tertiary
secondary school
1st 2 yrs combined science
masculine approach ?
art/science divide
group
schooling
primary school
time-table
Education and training
subject based
topic based
knew when she was doing science
thematic
subjects
unaware of science
feminine approach ?
In service training
evening groups
has a training rôle
has a public education rôle


necessary for play
oice
Older sister
younger brother
had to include in play
father
provided toys
siblings
influence
Parents
mother
family
closer to
Children
closer to mother's side of family
great aunt
sons
daughter
husband
teachers
Relationships
school
-ve/+ve
peers
friends
group dynamics
work colleagues
familiarity
needed to provide social life
formed over time
nsular/ working in isolation


insecure
few girls
difficult group dynamics
hand
Physics lessons
apparent shift over 1 generation
Gender
lack of opportunities
sisters less choice than brother in domestic
siblings

Appendix 7: A section of colour coded transcript from the interview with Lynne, April 2012

Interview with Lynne Lloyd-Boot (mother)

Ceri: We were just really talking about what your family was like as you were growing up. You've just said about it being traditional; with your dad being at work and your mum being at home and then gradually going back to work.

Lynne: Yeah we were expected to do, to help out. There were various jobs to do like laying the table and washing up. And when mum went back to work we had to give half a day for helping to clean the house. My brother thought that was really unfair because that was a girl's job so he was allowed to chop wood and I remember thinking it was really unfair because we hadn't been given the opportunity to chop logs. I think I just thought we were being normal it's only as you get older you realise being normal probably doesn't exist. Um I remember we used to have stew on Saturdays with rice pudding. We had a roast dinner every Sunday and the cold meat would be used in a salad or something the next day. My mum was organised she was quite systematic about what we ate and when we ate it. So yeah so it was quite structured which you probably don't realise how structured it was. So I guess we did have quite well planned weeks. I guess the house was quite well planned, organised and structured. I guess that at *(some words missing)* a desire for order and quality.

Ceri: And um so we've talked about mum being the principle homemaker and father being the principle

Lynne: Wage earner

Ceri: Earner. And so did he do anything about the house? Or was he...

Lynne: No he didn't do anything about the house. Well he must have done decorating because he did things like decorating or mending things - would have been the father's rôle. Probably changing light bulbs and wiring plugs would have been the father's rôle but I remember when my brother had to go to hospital and I was really concerned that we wouldn't have anything to eat because my mother was going to stay in hospital with my brother and my father wouldn't know how to cook and clean or boil a kettle really anything to do with cooking he wouldn't have known about. And even basic mending like changing a light bulb I would have seen as my father's rôle

Ceri: So you kind of accepted this very traditional role? And so did that make you think - did you expect to follow your mother in the same rôle? When did you come aware there were other options I guess?

Lynne: I don't know. I guess as far as I can remember it always seemed that I would have a job, a career whether that was because initially I guess I thought like most children I would be a teacher because that's something you rôle play at. You get used to that at school and my teachers were female so I must have been aware of women going to work from that perspective - so although there was always the belief that I would be a homemaker as well. Whether I was going to have the two at the same time I don't know.

Ceri: I just find it quite interesting that you are describing a very traditional household with people having very different rôles and yet it sounds like you didn't almost ...tut ... you obviously didn't expect to follow your mother in the same...

Lynne: Um I 'spose I've always expected that I would be the principle carer when, when I had children of my own. And so you were now the main person looking after the home that's something that I do (laughs) but I have a job as well!

Ceri: Ok thank you. And so how important ... in question 1 you said your father wanted you to do science, how important was science to your family as a whole?

Lynne: Again science was seen to be quite important and looking back my grandfather was an electrical engineer.

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Appendix 8: An explanation of how the narratives were constructed.

Constructing the Narratives

The narratives of Julie, Meryl, Lynne, Tinkerbelle, and Jasmine have been derived primarily from a semi-structured interview with each woman. Each interview was audio-recorded in the full knowledge and with the written consent of each participant. These audio recordings were then transcribed by the researcher thus producing the first interpretation of the interview. The following script section shown in Figure 4.21, has been taken from the transcription of an interview with Meryl:

Figure 7.1: A section from the transcript of an interview with Meryl.

A Section from the Transcript of Meryl's Interview	
Researcher	Can you remember what you enjoyed playing with when you were their age?
Meryl	Oh gosh when I was their age? I can probably remember when I was a bit older. I liked dolls, I liked Lego um I liked being out a lot on my bike, quite outdoorsy, but I did enjoy, we used to have um in the days when we used to have a sink in our room and underneath I used to pretend it was a play house. And I had my dolls in there and playing and I do remember playing a lot of Lego, drawing
Researcher	So it sounds like a lot of your interests then ... were quite early on 'cause if you enjoyed the outdoors I suppose that's kind of biology coming in ... So the out-doory things we think primarily your mum and the dolls where do you think that came from?
Meryl	Gosh I don't know. Probably I was just given those. I don't know if that was a gender (chuckles) 'oh we've got a little girl let's give her dolls'. I used to dress my dolls up in boys and girls clothing. I can't remember what awareness that was; boys and girls. I didn't have a 'Ken' or 'Barbie' I had Sindies I think they were in those days, um but

	I do remember playing with those quite a lot.

These transcripts were then printed and given to each participant to check. Some minor corrections were made to some scripts in the light of this.

In order to construct coherent stories from these scripts sections of each narrative were copied and pasted onto a chronological framework .The third level of interpretation involved editing and rearranging the script so as to provide a coherent, readable account of the participants' life as far as possible using the participant's words in order to give the recount authenticity. Thus the above became:

I liked dolls, I don't know if that was a gender thing 'oh we've got a little girl let's give her dolls'. What I really enjoyed, in the days when we used to have a sink in our room, underneath I used to pretend it was a play house and I had my dolls in there. I used to dress my dolls up in boys' and girls' clothing. I didn't have a 'Ken' or 'Barbie' I had 'Sindies' I think they were in those days, but I do remember playing with those quite a lot. I liked Lego. I was quite outdoorsy as I liked being out a lot on my bike. I also enjoyed drawing.

Appendix 9: The researcher's suggested outline for a 'physical world' G.C.S.E. syllabus.

Unit	Investigation	Physics Concepts	Historical/sociological concepts
Physics and medicine	Nurse Brown has recurrent back problems resulting in time off sick and her being unable to do her job. Design hospital equipment and recommend a better working posture.	Levers pulleys Forces Radiography Nuclear physics	Occupational health - lifting heavy loads Working days lost due to back problems Marie Curie Work of radiographers Use of radiation in hospital e.g. xrays
Astronomy	Could the moon landings have been a hoax? How did the universe begin? What really happened to the dinosaurs? Design a telescope.	Light Sound Forces Planet Star Solar system Galaxy satellite	History of space exploration. Explanations for day and night e.g. Phaeton's chariot, Creation mythology
Sustainable Energy	Our energy consumption is increasing, fossil fuels are running out and environmentalists argue that burning these is bad for the planet. Design an energy efficient home. Produce a leaflet to advise people about how to use energy more efficiently within the home.	Energy Energy conservation Heat Insulation Heat Conduction Nuclear power Hydroelectric power Solar power Wind power	Research skills including ICT Environmental campaigns Stories behind the media
Electricity	List all the different uses of electricity you use today. Rig up a lighting system for a festival stage. Design an electrical quiz with a buzzer or	Electricity Conduction Insulation Circuits Current	Historical development of electricity from Greek exploration of amber to current uses. Lives of Volta, Faraday,

	similar electronic game.	voltage	
The physics of communication	How could you convey a message from here to Australia?	Sound Light Electromagnetic radiation photography	Development of cameras television, telephones, computers etc. Morse code

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