Students' attitudes and career expectations in science: a cross-age case study of a specialist science school.

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By

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Thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

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March 2019

Abstract

This cross-age study explores factors impacting students' attitudes and career expectations towards science in a 'specialist science' secondary school for 11 to 18 year olds in the North East of England. It examines these from perspectives of two potential spheres of influence, namely the school and individual.

The study adopted a case study approach using qualitative data collections methods such as semi-structured interviews with science teachers and other staff in the school; group discussions and science lesson observations of students aged 12 to 17 years old. These were supplemented with questionnaire data and document analysis. Data were collected during one academic year, allowing changes in students' attitudes and science career expectations and the impact of the spheres of influence on these to be investigated. Data were analysed using thematic analysis. Collectively, data provided a detailed account of students' experiences in science across three age groups; 12 to 13; 14 to 15 and 16 to 17 through an academic year.

The range of students' career expectations and attitudes observed are categorised. Categories identified in all ages include *Scientists, The Ambivalent, Non-Scientists* and *Resisters*. Both spheres impact on students' attitudes and career expectations towards science. To enhance recruitment to science post-16, helping students become aware of their attitudes and career expectations and the impact of these spheres of influence may be useful. Data show recruitment may be enhanced with effective intervention and curriculum enrichment opportunities.

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Abbreviations

AS Level	Advanced subsidiary (Year 12)
A Level	Advanced level (Year 13)
AQA	Assessments and Qualification Alliance
BERA	British Educational Research Association
BTEC	Business and Technology Education Council
CPD	Continuing professional development
CRB	Criminal Records Bureau
DBS	Disclosure and Barring Service (formerly CRB)
DCSF	Department for Children, Schools and Families
DfE	Department for Education
D&T	Design and Technology
FSM	Free School Meals. Meals provided by the Government for student who either they or their parents receive certain Government benefits.
GCSE	General Certificate of Secondary Education (Examinations taken by 16-year-olds at the end of secondary school).
GDP	Gross Domestic Product
I	Used to denote quotes from interview sessions
IOP	Institute of Physics
ISA	Individual Skills Assessment. A controlled GCSE practical examination which contributes to the overall GCSE science grade.
KS1	Key Stage 1: Years 1-2 (for children aged 5-7)
KS2	Key Stage 2: Years 3-6 (for children aged 7-11)
KS3	Key Stage 3: Years 7-9 (for children aged 11-14)
KS4	Key Stage 4: Years 10-11 (for children aged 14-16)
KS5	Key Stage 5: Years 12–13 (for children aged 16-18)
NVQ	National Vocational Qualification
OCR	Oxford, Cambridge and RSA Examinations (*see* RSA*)
OECD	Organisation for Economic Cooperation and development

Ofsted	Office for Standards in Education, Children's Services and Skills. Inspects and regulates services that care for children and young people, and services providing education and skills for all learners.
ONS	Office for National Statistics
PE	Physical Education
PISA	Programme for International Student Assessment
QCA	Qualifications and Curriculum Authority
RSA*****	Royal Society of Arts
RSC	Royal Society of Chemists
SATs	Standard Assessment Tests/tasks. The common term for the National Curriculum tests taken at the end of some Key Stages; key stage 1 (by 7-year-olds) and Key Stage 2 (by 11-year-olds). Formerly, taken at the end of Key Stage 3 (by 14-year olds) too before 2009.
SES	Social Economic status
SET	Science, Engineering and Technology
SOW	Scheme of work
STEM	Science, Technology, Engineering and Mathematics
TIMSS	Trends in International Mathematics and Science Study
TA	Teaching Assistant
UCAS	Universities and Colleges Admission Service
VA	Voluntary Aided
VRQ	Vocationally Related Qualification
D	Comment from student's diary.

Glossary of terms

Academy	A publicly funded independent school.
Double Award	GCSE course leading to two GCSE science qualifications in science based on content studied in biology, chemistry, and physics.
Comprehensive school	State funded school with no selection criteria.
Core Science	GCSE science course leading to one GCSE science qualification based on content studied in biology, chemistry and physics.
Data *corpus*	All data collected in this study.
Data set	Different groups from which data was obtained, for example science department data set.
Data sub-set	Types of data collected within each data set. For example, an interview data sub-set within the student data set.
Disadvantaged students	Students who have been eligible for Free School Meals at any point during the last six years and children looked after by the Government.
Faith School	State funded schools which choose what they teach for religious studies. They have a different admission policy to comprehensive schools.
Feeder Primary Schools	Primary schools (in a catchment area) whose students go to a specific secondary school.
Foundation stage	For children aged three to five.
Head of Year	Staff responsible for teaching and learning within a year group.
Independent school	Fee paying schools in England.
Mixed ability	Setting in which students of different academic abilities are placed in the same learning group or class.
National Curriculum levels	A set of eight bands set by the Government used to assess student's attainment prior to 2014.
National pupil database	A national database containing a wide range of information (e.g. ethnicity, prior attainment) about students and students.
Science busker	Student ambassadors who promote science within and outside Farne School.

Specialist schools	Schools with a focus on a specific subject with the aim of raising achievement, especially in that specific subject.
STEM ambassador	Volunteers from STEM related fields in the UK who promote STEM in society, especially in schools.
Sub-sample	Individual piece of data in the data corpus, for example an individual student's questionnaire.
Triple Science	GCSE course leading to three separate GCSE qualifications in biology, chemistry and physics.
Value-added	Performance measure which considers the impact of the school on a student's learning, attainment and progress.
Voluntary aided	State funded schools in which a trust or religious body also contributes to the building and maintenance costs.
WIKID	KS3 Scheme of work which uses a narrative approach to engage students by providing a context for each topic.

Statement of copyright

Acknowledgements

To you alone, O Lord, to you alone, and not to us, must glory be given because of your constant love and faithfulness (Psalm 115:1, Sunrise Good News Bible).

My gratitude goes to Dr. Vanessa Kind whose critical insight and constructive feedback ensured that this project was completed. The journey was tough and challenging but I got there in the end. Thank you. Professor Newton, thank you for your faith and encouragement; listen for the cock's crow at dawn!

To my parents, Stanley and Catherine Diriyai and siblings, especially, Dinipre, Ebizimo, Ebisindo, Womo and Temo, thank you for supporting me through every aspect of this journey. Durham was a challenging time and your support got me through the particularly difficult times. Woyengibarakemi, Seinitonkumo and Big brother Tari, thank you. My sisters-in-law, Sofinari and Nengimote, thank you for your support while I recuperated. Uncle Timi Alaibe, thank you for your financial support. God bless you all.

The Ndajis, my family in Durham – thank you. Julie Bowden, Alison and Richard Swarbrick, thank you for opening your homes to me for a chat or a meal. Linda from Keep Fit – I do not take those lunches for granted, they were always a good laugh. Paula and Sam – I owe you. Terri Edwards, thank you for your help with my writing. It's still a work in progress! Dr. Susan McCarthy, thank you for planting the seed of educational research.

My cousin and friend, Ebiere Iketubosin, you knew, you listened, you understood! To my friends, Jasper (who refused to settle for anything less than a PhD!), Lawrence, Sybil, Max, Judith, Ngozi, Bertha, Seyi, Mildred (my newly acquired sister) and Tayo; thank you.

Mamae and Uncle Bature, thank you for always calling to check on my well-being and progress. Tonye, Pastors Ekwe and James, thank you for strengthening my faith.

Barbara Parkinson at Leazes Road Library and staff at Bowburn Library, especially Christine, thank you for providing a welcoming and safe place to study. Last but by no means the least, Suzanne Mulligan, thank you for being a steady source of support and encouragement.

Dedication

Dedicated to the memories of Dr. Per. Morten Kind and Professor. W.A.L Izonfuo.

Chapter 1: Introduction

''STEM (Science, Technology, Engineering, and Mathematics) is everywhere. Our nourishment, our safety, our homes and neighbourhoods, our relationships with family and friends, our health, our roles, our leisure are all profoundly shaped by technological innovation and the discoveries of science''.

- Office of the Chief Scientist, Australian Government, July 2013

1.1 Background to the research

This study explores attitudes and career expectations of students towards science in a 'specialist science' school. My interest in attitudinal studies developed from my own experiences as a student in secondary school and as a chemistry specialist teaching physics, first, in a girls' only and later in a mixed gender comprehensive school which were both in England.

As a student in secondary school, I found biology interesting because it explained how the human body works and the concepts were easy to understand. Chemistry was my favourite subject, thanks to an experiment with an African beetle containing fluids which proved to be acidic when tested with litmus paper. This simple experiment got me hooked on chemistry. In contrast, physics was my least favourite subject. I struggled to understand concepts which appeared abstract, taught in lessons that were mostly didactic involving minimal student participation.

My negative feelings towards physics persisted into teaching with my lessons being mostly teacher-led. I had inadvertently become my physics teacher in secondary school. Professional development courses at the Science Learning Centre in York (www.stem.org.uk, n.d.) and work with a Teaching and Learning Coach (TLC) from the Institute of Physics (www.iop.org), improved my subject content knowledge (Shulman, 1986) and boosted my confidence in teaching physics.

Therefore, it came as a surprise to me when a student asked ‘‘Miss, why were you afraid?’’ after the publication of the physics GCSE (Glossary) examination results. Students had picked up on the difference in my teaching style in physics compared to biology and chemistry. My anxiety in physics had become their anxiety.

This led to the realisation that teachers could sub-consciously project their own personal attitudes about a subject unto their students. When I became Head of Science, with experience of teaching science in girls’ only and mixed-gender comprehensive schools, I became aware of gender differences in students’ attitudes towards science. Girls in the girls’ only school had no inhibitions in lessons, were keen to ask questions and participate in classroom discussions, while girls in the mixed comprehensive school were more reluctant to participate in classroom discussions, especially in physics lessons.

Together, these experiences precipitated my interest in investigating factors which affect students’ attitudes and aspirations in science, hence this study. This thesis is therefore an attempt to provide insights into factors which influence students’ attitudes and career expectations towards science by considering the perspectives of staff and students in a ‘‘specialist’’ science school. In addition, factors are explored within two spheres of influence, namely the personal and school levels.

1.2 The value of science and a science education

The philosopher, Herbert Spencer (1859) in ‘What Knowledge is of Most Worth’ argued that knowledge of science was most important because it is necessary for ‘‘direct self-preservation and the maintenance of life and health’’. Recently, Millar (2014) summarised the value of science in economic, utilitarian; democratic and cultural terms. For example, science is regarded as essential for economic growth and human development (OECD, 2000; Chiang, 2012; G7, 2017).

To this end, some countries are increasing the amount of money invested in research and development (R & D). R & D expenditure and intensity are two useful indicators in monitoring resources dedicated to science and technology (Eurostat, 2017). R&D intensity is R&D expenditure as a percentage of Gross Domestic Product (GDP).

For instance, member states of the European Union (EU) spent a total of over €300 billion on research and development in 2015, that is, R & D intensity of 2.04% compared to 1.76% in 2006. In the United Kingdom, (UK), this spending rose from £28 billion in 2006 to £31.8 billion in 2015, with a commitment by the current Prime Minister, The Right Honourable Theresa May MP to increase R & D intensity by up to £80 billion by 2027.

To sustain the levels of R & D needed for economic growth, there must be a corresponding steady supply of science graduates (academic and technical) to drive this.

1.3 Demand for graduates with science-related skills and qualifications

The value of science is evident in the rise and demand of graduates with science-related skills and qualifications. The UK's Commission for Employment and Skills (UKCES) projects that up to 10, 182, 000 roles are expected to open between 2016 and 2023 (UKCES, 2016) and by 2023, 640, 000 (about 6%) of job openings would be from ''core'' science research, engineering and technology related roles. The Royal Academy of Engineering (2012) estimates that an average of 100, 000 Science, Technology, Engineering and Mathematics (STEM) graduates and 56, 000 STEM technicians will be needed to meet the demand for 1, 000, 000 new science, engineering and technical professionals by 2020. Advances in technology and an ageing workforce means that demand for STEM graduates is also rising (UKCES, 2016).

However, there are concerns that the UK may not be producing enough STEM graduates to meet these demands especially in an increasingly competitive global market (Department for Business, Energy & Industrial Strategy, 2017). The Campaign for Science and Engineering (CASE), a lobby group in the UK, alleges that there is an annual STEM graduates' shortage of about 40, 000 in the UK (Main, 2015). In a recent paper, the Department for Business, Energy and Industrial Strategy (BEIS) 'Industrial Strategy: Building a Britain fit for the future', summed up the Government's concerns about skills shortages, noting "…we need to tackle particular shortages of STEM skills.

These skills are important for a range of industries from manufacturing to the arts" (BEIS, 2017 cited in National Audit Office, 2018). Figure 1.1 shows actual STEM recruitment shortages in 2015 and expected shortages in 2018 in different sectors.

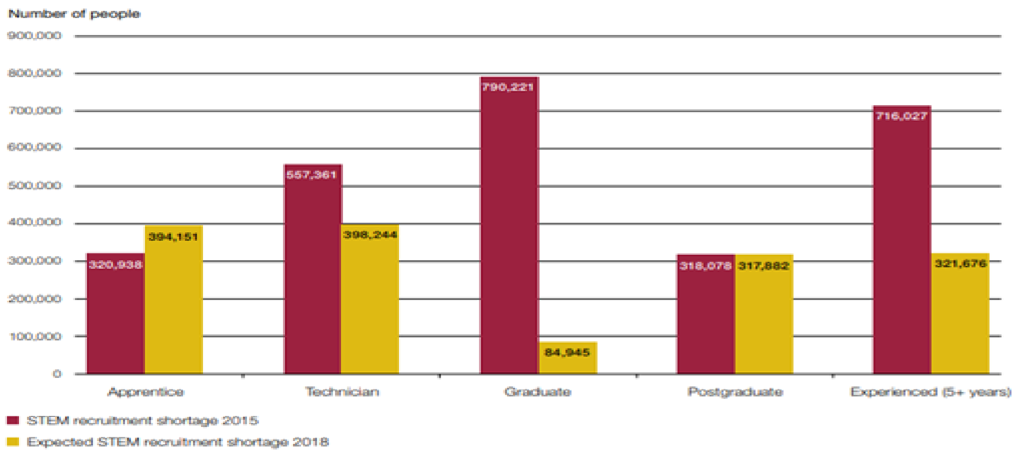

Figure 1.1: Estimate of employer reported STEM recruitment shortages: 2015 and 2018 (expected). *Source*: National Audit Office, 2018

Another source of concern is that some groups such as those from socially-disadvantaged background, minority ethnic groups and women are under-represented in STEM-related fields. Figure 1.2, for example, highlights the gender disparity in STEM-related employment between 2006 and 2016 and the projected difference between 2016 and 2023 in the UK.

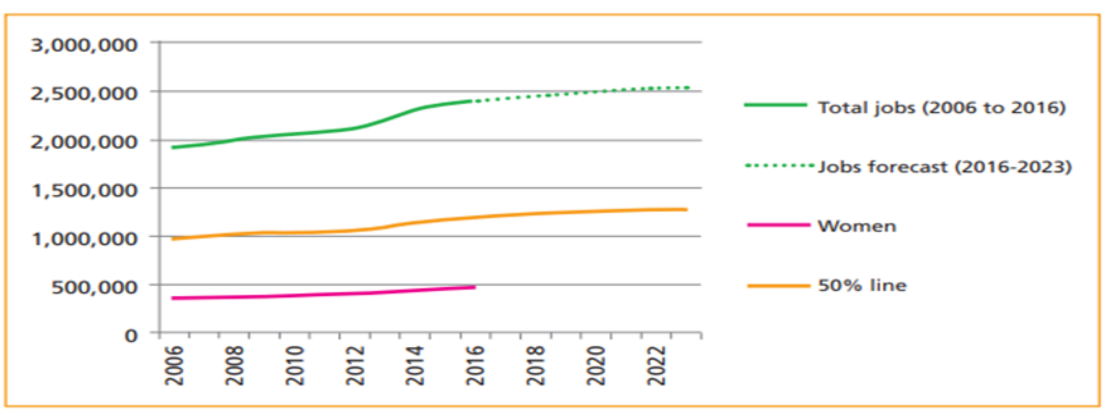

Figure 1.2: Number of women in Core Science, research, engineering and technology roles compared to the total workforce (Source: EDF energy, 2016)

This shows that the number of women entering into STEM-related employment has consistently hovered around the 500, 000 mark despite a total workforce of approximately 2, 000, 000. Similarly, in 2004, 91.9 % of academic staff in Physics institutions in the UK were male, while between 2004 and 2008, the figure was 88% (Institute of Physics, 2010).

Some researchers, for instance Smith (2010) and Smith & Gorard (2011) present a different perspective to these claims of shortages. Smith (2010) argues that the problem is not one of numbers but the type of sciences being studied. Smith (2010) investigated undergraduate participation in science subjects and concluded that over the past two decades, undergraduate participation in science subjects has remained stable. She notes a shift from ‘’core’’ science subjects such as physics, chemistry and biology to applied science subjects such as psychology and environmental science (Smith, 2010). The author argues that the apparent decline in undergraduate participation rates in science is because traditional (core) science subjects are not able to progress at the same pace as applied sciences. This, she claims creates an illusion of a ‘’shortage’’.

Smith’s claim regarding stable undergraduate participation rates of core science subjects compared to applied science appear to justify concerns about skills shortages rather than dismiss them. If the number of undergraduates in core science subjects remain stable over the years as demand increases for science graduates, then concerns may be justifiable.

In a follow up study, Smith & Gorard (2011) examined the first employment destinations of engineering science graduates between 1994 and 2009. The authors examined this group because they had the highest proportion of graduates in employment. They found that only less than half of the graduates entered into engineering science-related employment six months after graduation. Others ended up in non-engineering related roles including non-graduate roles such as waiting staff in restaurants or shop assistants. The authors surmise that perhaps the drive for more students to enter STEM-related careers, while marginally successful, probably also recruited those who were unsuited for science related careers in the first instance.

Thus, raising the question of the suitability of graduates being produced rather than a shortage of graduates produced in this sector. Secondly, the findings point to the possibility that increasing the number of STEM graduates may not be enough to address concerns about skill shortages if STEM graduates end up in non-STEM related fields of employment. Together, Smith (2010) and Smith & Gorard (2011) provide an alternate view of STEM skills shortage in the UK suggesting that the notion of a skills shortage is complex.

This study adopts the stance that concerns of science skills shortages at national levels emanate from underlying issues regarding students' experiences in science education prior to undergraduate participation in science-related courses.

As a first step, it is important to look at participation rates in science post-16, that is, after secondary school. This is discussed next.

1.4 Participation rates in science post-16

School science provides the foundation of knowledge from which careers in science and engineering develop (Millar, 2014). However, at the school level, concerns regarding post-16 science recruitment exists, especially in schools with post-16 provisions. Figure 1.3 shows the top ten most popular A-level (Glossary) examination entries in the past decade. This includes science subjects suggesting a reasonable share of A-Level entries.

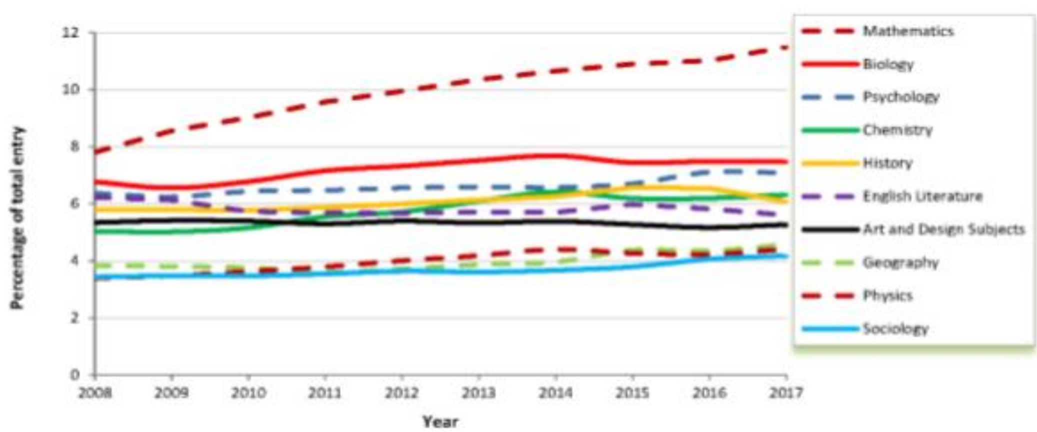

Figure 1.3: Top ten A-level entries between 2008 and 2017 (*Source:* Joint Council for Qualification, JCQ, 2018

However, when viewed by individual science subject and gender, differences between subjects emerge (Table 1.1). For instance, in 2017, 7.5% of students took A-level Biology, 6.3%, Chemistry and 4.4%, Physics. This uneven distribution has been consistent over the past two decades, with Physics' A-Level entries always being the fewest.

Subjects (A-levels)	Percentage of entries by gender across all subjects							
	2000	2005	2010	2013	2014	2015	2016	2017
Biology	4.8 3.8[a] 5.8[b]	6.9	6.8 6.4[a] 7.1[b]	7.5	7.7 6.9 [a] 8.3 [b]	7.4 6.5[a] 8.2[b]	7.5	7.5 6.3[a] 8.4[b]
Chemistry	2.3 2.4[a] 2.3[b]	5.0	5.2 5.8[a] 4.6[b]	6.1	6.4 7.3[a] 5.7[b]	6.2 7.0[a] 5.5[b]	6.2	6.3 6.9[a] 5.9[b]
Physics	2.7 4.2[a] 1.2[b]	5.6	3.6 6.2[a] 1.4[b]	4.2	4.4 7.6[a] 1.7[b]	4.3 7.4[a] 1.7[b]	4.2	4.4 7.7[a] 1.7[b]
(a) Boys (b) Girls								

Table 1.1: Percentage of General Certificate of Education (GCE) entries by gender between 2000 and 2017 (*Source*: Joint Council for Qualifications, 2018)

The numbers become significant when viewed by gender; girls taking A-level sciences show a marked preference for Biology, compared to Chemistry and Physics. Girls are under-represented in Physics, while boys are over-represented in Physics and under-represented in Biology. Girls perform slightly better than boys in General Certificate of Secondary Examination, GCSE (Murphy & Whitelegg, 2006b; Department for Education, 2010a) but this is not reflected in science A-level Physics entries. This suggests that female under-representation could be because of factors other than capability for science. Many reasons have been advanced for these numbers and students' post-16 science aspirations in science. These include socio-economic status (Gorard & See, 2009), self-concept (Haussler & Hoffman, 2002); gender (Archer et al, 2013); type of school (Chetcuci & Kioko, 2012; IOP, 2011); identity (Brickhouse, Lowery & Shultz, 2000) and the science curriculum (Osborne & Collins, 2000). These are discussed in detail in Chapter 2, the literature review.

1.5 Research aims and questions

Research evidence suggests students' positive attitudes to science diminish as they progress through education (Osborne, Simon & Collins, 2003; Bennett & Hogarth, 2009), becoming fixed at around 14 years old (Osborne, Simon & Tytler, 2008). A study conducted by the Royal Society (2006) found that 63% (n=1,141) of respondents in STEM-related employment had already started to think about a STEM career either before entry into secondary school or between the ages of 12 to 14.

This means that attitudes formed about science before the age of 14 may impact science aspirations once the compulsory phase of formal education is complete. Few studies explore factors which affect students' attitudes and career expectations from a whole school perspective, pre- and post- 14 years old. One such study, Reiss (2000) observed science lessons of twenty students from the start (ages 11/12) to the end of secondary school (ages 15/16). However, as the focus was on a small group of students, the author was unable to provide an overview of students' attitudes and career expectations during an academic year from a whole school perspective.

Secondly, considering that students are the focus of many attitudinal studies, their ''voice'' is relatively ''silent''. One possible reason is ''an implicit assumption that the only views of import are those of scientists and science educators'' (Osborne & Collins, 2001, p. 442). This is unhelpful. It is in considering students' views about their attitudes and career expectations towards science, that we further our understanding of patterns in science participation rates post-16 onwards.

Consequently, the main aim for this study is to give students that voice by investigating the factors that influence their attitudes and career expectations towards science pre– and post- 14 years old in a ''specialist'' science school. Secondly, as the data show girls are under-represented in physics, this study seeks to contribute to the existing body of knowledge on girls' attitudes and career expectations towards science, which may be valuable in making science learning opportunities more equitable.

To meet these aims, these research questions (RQ) were proposed:

RQ1: What factors do staff and students (ages 12 to 17) in a ''specialist'' science school believe affect students' attitudes towards science?

RQ2: Who aspires to a career in science?

RQ3: What precursors influence students' career expectations towards science?

1.6 Setting the context

This section starts with an overview of science education in England. Terminology or concepts used extensively which may be ambiguous are defined here. Other terms are defined in relevant chapters.

1.6.1 Science education in England

Education is devolved to the home nations of the UK, which means that policy differences exists between England, Wales, Scotland and Northern Ireland. To avoid any ambiguity, references, unless explicitly stated, pertain to England.

Education in England is free and compulsory at all state schools from the ages of five to sixteen. After this, children must be engaged in either education or training until the age of eighteen.

The majority of schools in England are mixed gender, non-selective comprehensive schools. Comprehensive schools accept students living in their local area and are not permitted to select students by ability or any other criterion. Local authorities decide a pupil allocation number for each year of entry, based on local demographic data and school popularity. When more students apply to a specific school than there are places available, local admission criteria are applied.

Science is taught as part of the National Curriculum (www.gov.uk/national-curriculum, n.d.). The National Curriculum prescribes subjects that are taught, and standards children are expected to attain. Subjects are classed as either ''core'' or ''foundation''. At the time of data collection, core subjects include Science, English and Mathematics, while subjects such as Physical Education (PE) are foundation subjects.

Teaching occurs in blocks of years which are referred to as Key Stages (KS). For example, in secondary school, KS3 covers ages 11 to 14, KS4 is ages 14 to 16, and KS5 covers ages 16 to 18 (*see* Glossary for full list). The content that must be taught in each Key Stage is described in a ‘’programme of study’’. Schools have the flexibility to introduce content in any order they wish, provided that at the end of each Key Stage, relevant material has been covered (National Curriculum in England, 2015).

To support medium and long-term planning to help schools implement the programmes of study, schools use guidelines called schemes of work (Department for Children, Schools and Families, 2008). Schemes of work consist of units that together cover the programme of study (Department for Children, Schools and Families, 2008).

In KS3, science is usually taught as a combination of biology, chemistry and, physics. In KS4, students experience science as a combination of all three or as individual subjects. Reasons for this position range from students’ subject choice/course to availability of teachers. In KS5, science is taught as individual subjects.

Between the ages of 15 and 16, most children will sit for the General Certificate of Secondary Education examinations (GCSE). At the time of data collection, GCSEs were graded from A* (highest) to G (lowest), with grades A*-C grades considered the best outcomes. Grade C is the minimum ‘’pass’’ standard.

1.6.2 School science and science in society

Science in this study refers to ‘’school science’’ rather than ‘’science in society’’. Research (Sjøberg & Schreiner, 2010) has shown that ‘’school science’’ rather than ‘’science in society’’ generates negative attitudes in students. This distinction is therefore a better predictor of students’ attitudes (Osborne et al., 2003). Where a reference is about science in society, this is stated explicitly.

1.6.3 Practical work

Practical work is used synonymously with science experiments to refer to lessons in which students carry out a practical activity in their science lessons. The term is not used here to describe practical work in which the teacher carries out a demonstration in front of students who merely observe or assist in the demonstration.

1.6.4 Setting

Setting is a practice in some schools in England in which schools place students in teaching groups based on some measure of prior attainment in core subjects (Ireson & Hallam, 2001). Based on this, students can end up in ''top sets'' comprising predominantly of students the school classes as ''high'' attainers, ''middle sets'' comprised of ''high'' and ''low'' attainers and a ''bottom sets'' where the majority of students are classed as ''low'' attainers.

1.7 Thesis structure

This thesis is divided into eight chapters. Following on from this chapter:

Chapter two focusses on the literature. Factors which affect attitudes and science career expectations are discussed under two spheres of influence. These are the individual and school spheres respectively.

Chapter three presents the theoretical framework for the study.

Chapter four describes the methodology and justification for the research design, which involved the collection of predominantly qualitative data through an academic year in a specialist science school.

Chapter five outlines the school's strategies in promoting positive attitudes and aspirations in science. In addition, staff views of the factors they believe affect students' attitudes towards science are presented.

Chapter six considers students' views of the factors that affect their attitudes towards within the school sphere of influence.

Chapter seven explores students’ career aspirations by focusing on the individual sphere of influence. Profiles of student typologies are reported drawing on precursors which impact career expectations.

Chapter eight concludes the study. Limitations and recommendations for future research are presented.

Chapter 2: Literature review

[Science] 'is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world...'

- President Barack Obama, March 23, 2015

2.1 Introduction

This chapter reviews relevant literature on factors that affect students' attitudes and career expectations towards science. The chapter starts with section 2.2, which provides a brief account of the literature used and how the sources were obtained. Sections 2.3 gives an overview of the terms attitudes and aspirations. In section 2.4, factors under the under the school sphere of influence are discussed, while in 2.5, the individual sphere of influence is considered. The chapter ends with section 2.6, which discusses implications of the review for the current study.

2.2 Identifying the literature

Literature on students' attitudes and career expectations towards science is diverse and extensive, addressing a variety of issues over time. To ensure that the review is topical, greater attention is given to studies published from 2000. Due to the researcher's personal interest and experience, there is an emphasis on girls and physics.

Relevant literature was identified through Boolean searches of online databases such as JSTOR, electronic journals such as 'Studies in Science Education', use of search engines such as Google Scholar and use of the University library database to identify books and ''grey'' literature. Grey literature focusses on the UK (e.g. Select Committee on Science & Technology reports), while academic literature is international.

2.3 Understanding students' attitudes and aspirations

The main aim of this study is to present students' views of factors affecting their attitudes and career expectations towards science. Understanding extant research on students' attitudes and aspirations towards school science provides a valuable framework for this study. Each sub-section starts with a definition of the key terms, attitudes and aspirations, followed by an overview of studies in these areas.

2.3.1 Attitudes towards science

The Cambridge Online Dictionary defines attitude as ''a feeling or opinion about something or someone, or a way of behaving that is caused by this'' (''Attitudes'', n.d.). However, in terms of research, the definition of the term is debated. Two variations are considered.

Krech, Crutchfield, and Ballachey (1962) argue that an "attitude" is made up of three components, namely the affective, behavioural and cognitive. Supporters of this definition (McGuire, 1985; Rajecki, 1990) describe the three components as: cognitive (beliefs or ideas component) - having to do with knowledge about the object; affective (like or dislike component) - feeling about the object and behavioural (the object component) - a tendency-towards-action.

Fishbein & Ajzen (1975) argue that the definition should focus solely on the affective component; behavioural and cognitive should be assessed separately. In relating this to ''science'', Gardner (1975) suggests making a distinction between attitudes towards science (affective aspect) and scientific attitudes (cognitive) provides clarity.

In this study, ''attitude towards science'' focuses on the affective, as this best meets research aims of presenting students' views of factors affecting their attitudes and career expectations towards science. Students' views are also presented from an interpretivist worldview (Chapter 4) which permits recognition of subjective reality. Consequently, ''attitude towards science'' is defined in this study as *'feelings students have about science, based on their beliefs about science.*

This is based on Kind, Jones & Barmby's (2007) definition of attitudes – ''feelings that a person has about an object based on their beliefs about that object''. This definition is sufficiently versatile to serve as an umbrella term for students' opinions about science whether it is positive, negative or neutral.

One well-known study which explored students' attitudes towards science is the ROSE (Relevance of Science Education) project. The ROSE project was an international comparative survey involving about 40 countries, which explored students' affective views about science education and their career expectations (Schreiner & Sjøberg, 2004). Jenkins & Nelson (2005) used questionnaire data from 1266 students aged 14 to 16 years from 34 schools who participated in the ROSE project in England to examine their attitudes towards school science and science career expectations. The authors focused on students' responses to sixteen questions on the section, my science classes (Jenkins & Nelson, 2005: 45, Table 1).

Findings suggest that overall students considered science interesting, but few preferred science to other subjects or wanted careers in science. Indeed, 79% of students' responded ''disagree'' or ''low disagree'' with the statement ''I would like to become a scientist'' (Jenkins & Nelson, 2005; 45, Table 1), while only 8% responded ''agree''. Gender differences were noted in statements like I like science better than most subjects; school science is rather easy, and I would like a job in technology. Girls were more likely to disagree with these statements than boys. This highlights some of the issues of gender disparity in science discussed in Chapter 1. Jenkins & Nelson (2005) also found that many young people had already made up their minds about whether or not to pursue a career in science before they started GCSE examinations. This reinforces the importance of generating positive interest in young children as students' attitudes toward science may become fixed by the time they are fourteen years old (Osborne & Collins, 2003).

However, as the survey focussed on students aged between 14 and 16, attitudes of students outside this age bracket are not considered.

Nonetheless, the findings were similar to previous studies which used different methods to obtain the data. For example, Osborne and Collins (2000) used focus groups to investigate students' views of the science curriculum, while the Department for Business, Innovation & Skills (2010) used an online questionnaire to collect data on students' views about school science.

Osborne & Collins (2000) conducted 20 focus groups with 144 students, aged 16 years old in England. They found that although students considered school science important enough to be in the curriculum, this was only in terms of career benefits rather than personal interest. Similarly, a survey of 500 14-16 year olds by the Department for Business, Innovation and skills (2010) found that science was the most popular subject but only 5% of students in the survey were interested in specific-science related careers. In total, 25% of respondents were interested in STEM-related careers such as engineering or medicine. STEM is an acronym for Science, Technology, Engineering and Mathematics.

These studies demonstrate a general consensus that though students find science important and interesting, this has not materialised into a corresponding interest in science careers. Jenkins & Nelson (2005) and Osborne & Collins (2000) report that part of the problem lies with school science in its current form. Students find the curriculum content- dominated, repetitive, assessment driven and lacking relevance to everyday life.

Consequently, students lose interest in science as they get older. However, The Department for Business, Innovation & Skills (2010) reports that students who have a positive interest in science tend to be those who participate in science-related activities out of school with their family. This included visits to museums and other science-activity centres. Another demographic which demonstrated positive interest in science were students from socially-advantaged backgrounds and boys (Department for Business, Innovation & Skills, 2010).

Reviews on attitudinal studies also contribute to our understanding of students' attitudes towards science. Osborne, Simon & Collins (2003) and Osborne, Tytler & Collins (2008) conducted reviews of research carried out in the 1990s to 2007. They report similar findings that factors affecting students' attitudes towards science are multifactorial. These range from parental influences to attitudes of peers and friends towards science.

2.3.2 Science aspirations

The Cambridge Online dictionary defines aspirations as ''something that you hope to achieve'' (''Aspirations'', n.d.). In this study, ''science aspirations'' or ''aspirations for science'' is limited to students' science career expectations. No attempt has been made to distinguish between aspirations and expectations as suggested by some researchers (e.g. Saha & Sikora, 2008) as this may narrow the scope of the study and not meet research aims. The phrase post-16 science aspirations refer to students' in Key Stages 3 and 4, and post-18 science aspirations to students in Key Stage 5.

Understanding students' aspirations can offer insights into their future career occupations. For instance, in a British Household Survey of 528 young people aged 15 years old between 1994 and 1999, Croll (2008) found that approximately half of them who aspired to certain careers ended up in those or similar careers five to ten years later, that is, when they were between 20 and 25 years old in 2004.

In a similar study in the US, Tai, Liu, Maltese & Fan (2006) used nationally representative longitudinal data to investigate if the science-related career expectations of 3,359 young people, approximately aged thirteen in 1988, predicted the bachelor's degrees they earned years later when they were approximately thirty years old in 2004. The authors found that approximately half of the participants with early science aspirations earned a science degree.

In contrast, only a third with early non-science aspirations ended up with science degrees. Tai, et al (2006) also noted that 34% of 13 year olds with science career expectations with average achievement in Mathematics gained science or engineering degrees compared to 19% of young people with non-science career expectations and high achievement in Mathematics.

Collectively, both studies point to the possibility that early science aspirations may be a better predictor of science careers than academic achievement. However, as phase one of data collection in both studies focussed on children aged between 13 and 15 in the late 1980s and early 1990s, it was useful to consider recent studies which investigated the aspirations of children in a different age bracket. Two studies are considered; the ASPIRES project and Drawing the Future

In the ASPIRES project, Archer et al (2013) investigated the career aspirations of 9000 primary school children in the UK, aged 10 to 14. Data were collected at three intervals; at the end of primary school (Year 6, ages 10 to 11), second year of secondary school (Year 8, ages 12 to 13) and third year of secondary school (Year 9, ages 13 to 14). Data sources included 19, 000 surveys, 170 semi –structured interviews involving 92 children and 76 parents. Findings indicate that trends in students' aspirations consistent with social class, gender and ethnicity. Children from socially-advantaged backgrounds were more likely to aspire to science careers, for example 23% of children from socially-advantaged backgrounds aspired to be scientists compared to 9% from socially-disadvantaged backgrounds. Similarly, boys are more likely to aspire to careers in engineering while girls preferred arts-related careers. Children from minority ethnic backgrounds are more likely to aspire to professional careers such as medicine.

Families and the home were the most important influences of children's aspirations. In interview, almost half (47%) of the children aspired to the same job as a close friend or family member. This was particularly true of children from socially-advantaged backgrounds. The second most influential source (33%) of young people's aspirations is the activities they engage in outside of school such as hobbies. The third source was the school (25%), especially for children who aspire to be teachers.

However, for students who aspire to science careers, the majority do not cite their science classes as their source of influence. Archer et al (2013) note that this may be evidence of inadequate career advice and information especially in Key Stage 3. Hence, when career advice is provided in Key Stage 4, it is ‘’too little, too late’’. Finally, young people are influenced by the media (18%) especially television, while 7% of the sample were motivated by the perceived financial benefits of the career.

In drawing the future (Chambers, Rehill, Kashefpakdel & Percy, 2018), 20, 000 primary school children aged 7 to 11 from twenty countries were asked to draw a picture of what they wanted to be when they grew up. The authors justify the use of drawings as a more useful data collection tool for younger children as it enables them ‘’tell a better’’ story (see Newton & Newton, 1992, 1998; Silver & Rushton, 2008).

In addition to drawings, the survey collected data on children’s gender, ethnicity, favourite subject, if they knew anyone in the occupation and if not why they had chosen that occupation. Of these, 13, 070 were from 146 primary schools in the UK and Channel Islands, representing 65% of the sample. The main findings from the UK sample indicate that children’s career aspirations are influenced by gender stereotyping, social class and who they know, especially family members and the media (Chambers et al, 2018). This trend was observed in the International sample as well. The most popular career aspirations were sports-related (21%, n=13, 070) while scientist was the 7th most popular occupation (4.2%). Other STEM-related professions were ranked highly as well; Vet (3rd), Doctor (6th), Engineer (11th). Mathematics was the most popular subject (33%) while science was ranked as the 5th most popular subject (7%). This suggests that students enjoy science in primary school and aspire to science careers before secondary school. Disaffection with science appears to start in secondary school (Osborne et al, 2003).

The studies reported above (Croll, 2008; Tai et al, 2006; Archer et al., 2013; Chambers et al., 2018) demonstrate the influence factors outside of the school’s sphere of influence can exert on children’s aspirations. They also suggest that early exposure to science may generate positive interest in science.

However, as they all focus on sub-groups of students in schools, they are unable to provide an overview of students' career expectations from a whole school perspective. Hence, there is a need for a study which explores students' career expectations from a whole school perspective. This will build on existing studies by investigating groups previously excluded.

The previous section provided working definitions for both ''attitudes'' and ''aspirations''. In addition, useful insights into issues surrounding both constructs were explored. These underlined the importance of school related-factors (e.g. the science curriculum and teaching) and individual oriented factors (e.g. social class and gender) in shaping students' attitudes and science career expectations.

In the next section, findings that students' attitudes and career expectations are influenced by school and individual related factors are explored in detail. Hence, factors are subsumed under these two spheres of influence; the school and individual. Each section starts with schools of thoughts followed by a review. For example, regarding gender and science, the established viewpoint is that girls are under-represented in physics and over-represented in biology so, studies such as Baram-Tsabari & Yarden's (2008), ''Girls' biology, boys' physics: evidence from free–choice science learning settings'' which investigated whether this viewpoint could also apply in non-school settings was excluded. Zohar & Boaz's (2005), 'Physics teachers' knowledge and beliefs regarding girls' low participation rates in advanced physics classes' which attempt to provide an explanation for this pattern was included.

2.4 School sphere of influence

The school sphere of influence describes school-related factors such as teaching and the curriculum. Research into school influences on students' attitudes and aspirations to science is limited. Extant studies indicate diverse factors such as teaching, leadership, type of school, school culture and the science curriculum influence students' science attitudes and career expectations.

Although the setting for this study is a secondary school, the review starts with the primary school phase as research identifies the age range, 8 to 14 years as fundamental to formation of students' attitudes towards science (Ormerod & Duckworth, 1975; Archer et al., 2013). Therefore, considering students' experiences of science in primary school is useful. Evidence shows that young children have positive attitudes towards science and have favourable views of the importance of science and the work that scientists do. However, their enthusiasm for science wanes and may become less positive as they approach secondary school. There is a lack of consensus about the point of decline.

In a study of primary school children at the end of Key Stage 1 (ages 6 to 7, Year 2) and end of Key Stage 2 (ages 10 to 11, Year 6), Turner & Ireson (2010) investigated attitudes of children to science. Data were collected using paired activities and interviews for younger children in Key Stage 1 and pre– and post- Test Science Attitude Related Questionnaires for older children in Key Stage 2.

The authors report that younger children (aged 6 to 7) were enthusiastic about science and their science lessons but became less positive about science as they progressed through primary school. Children's knowledge of science and the work of scientists was connected to the amount of 'cultural and science capital' they had built up from life experiences, for example through scientific excursions, books, television and friends and family. This corroborates findings of Archer et al (2013) and foregrounds the role of factors such as *cultural* and *science* capital (2.5.4) in students' attitudes and career expectations towards science.

Older children in the survey were less enthusiastic about science with their attitudes becoming fixed at the end of Key Stage 2 (end of primary school). However, by focussing on only children in Years 2 and 6, views of children between Years 3 and 5 are not captured leaving a considerable gap. Therefore, the authors are unable to show at what point children's attitudes towards science start to become hostile. The study mentions teachers as a main influence of children's views of science.

However, this is addressed from teachers' perspectives and experiences of teaching science with little reference to children's opinions of their teachers and teaching and how this affects their attitudes towards science. Yet, teaching is central to students' learning experiences.

Therefore, the next section looks at the effect of teaching on students' attitudes and career expectation in science.

2.4.1 Teaching

Teaching is likely to be a significant contributory factor towards students' attitudes to science (Osborne et al., 2003). Research highlights factors such as attitudes held by teachers towards science (Schibeci, 1981), pedagogical content knowledge, (Kind, 2009; Logan & Skamp, 2013), subject content knowledge, (Harlan, 1995; Newton & Newton, 2011) and teacher personality (Logan & Skamp, 2013) as affecting students' attitudes and career expectations towards science.

The concepts of subject content knowledge (SCK) and pedagogical content knowledge (PCK) provide a useful starting point in discussing this factor. Shulman (1986, 1987) introduced these concepts. SCK demonstrates understanding of what needs to be taught while PCK focusses on how this subject content is transmitted to the learners in ways which are thoughtful and suitable to their needs. Shulman (1986, 1987) believed that mastery of both concepts were useful to teaching.

In England, early years teaching is predominantly a female occupation. Men make up 12% of the teaching workforce (Mistry & Sood, 2013). As fewer women than men have first degrees in mainstream science, an implication arising is the possibility that the majority of primary school teachers have limited background knowledge in science. This suggests that children may be starting secondary school with limited knowledge in science.

Harlen (1995, 1997) examined Scottish primary school teachers' understanding and confidence in teaching science in relation to their academic background and teaching experience. Data were collected via survey responses of 514 teachers, followed by interviews and diaries from a sub-sample of 57 and 33 teachers respectively. Of the 514 teachers, 8% were male and 92% were female. Twenty had science–related degrees (that is, 4%) and of these, eighteen were biology–related degrees, suggesting a paucity of physical sciences related degrees.

Similarly, in an English study to explore pre–service primary school teachers' ideas of ''engaging'' science lessons, Newton & Newton (2011) found that in a sample of 79 pre-service primary school teachers, only four had a science-based first degree, while most held degrees centred on English and modern foreign languages. This suggests that many primary school teachers may lack adequate subject content knowledge in science.

A lack of subject content knowledge (SCK) may be problematic. Harlen (1995, 1997) found that one third of teachers in the survey attributed lack of confidence in teaching science to limited science knowledge. Teaching physical and technological science concepts compared to biological concepts were reportedly challenging. As a result, teachers avoided aspects of science they found challenging:

> ''They lacked the necessary knowledge and understanding either to respond to children's questions or to resolve situations where investigations failed to give the expected answers or equipment broke down…. … In science, for example, this may mean relying heavily on work cards with step-by-step instructions, emphasising expository teaching and underplaying questioning and discussion, and avoiding using any equipment that might 'go wrong'. In technology it may mean spending more time on construction and less on design, more on social aspects and less on control technology'' (Harlen, 1995: p. 9).

However, possession of SCK is no guarantee of good teaching (Newton & Newton, 2011) but teachers with extensive SCK are more likely to develop a wider range of teaching strategies than teachers with limited SCK (Kind, 2009). They are more willing to experiment and trial new teaching strategies than teachers with a SCK deficit (Harlen, 1995, 1997).

Nevertheless, if this is exploited correctly, teachers with a SCK deficit can teach effective lessons as they are able to teach difficult concepts from students' perspective (Kind, 2009).

Results from a longitudinal survey (Logan & Skamp, 2013) found that teachers' pedagogy content knowledge and personalities could influence students' interest in science. Students attribute their dislike of science to the teacher, either because of his/her personality. Student contrast experiences such as ''the teacher yells at us a lot'' with the ''class [and teacher] got on well'' (Long & Skamp, 2013).

This supports Hadden & Johnstone's (1983) position that attitudes will be positive in environments where teacher-student relationship is good. Students enjoyed science lessons when they were made to think, either through debating topical issues or carrying out practical activities. These contrasted positively with teacher-led lessons involving copying and note-taking (Long & Skamp, 2013). Some of the significant findings from the research about teaching were; establishing a good relationship with the students, providing clear instructions and introduction of topics that were relevant to a student's real life.

Similarly, Naugh & Watts, (2013) report that science pedagogy and curriculum content were important in generating girls' interest in science. They conducted 60 science and 20 non-science, non-participant classroom observations, 4 group interviews with students and 16 individual teacher interviews. Four schools with different ethos, for example, two were single-gender schools while the other two were mixed-gender schools. Naugh & Watts (2013) found that girls responded positively to lessons in which they were active participants compared to lessons that were didactic and textbook-based.

Shibeci (1981) found that although teachers wanted students to enjoy science they were unaware of reasons impacting on students' enthusiasm for science as they move upwards through school. Some teachers did not think that students' attitudes should be considered as important. They believed that fundamental concepts of science might be lost if the focus was on student enjoyment rather than learning (Shibeci, 1981).

The studies presented thus far focus primarily on what is wrong with science teaching and how it affects students' attitude to science; good teaching is addressed sparingly. Three studies which were undertaken with the main aim of identifying exemplary science teaching are presented. The purpose of presenting these studies is to present science teaching which engages students' interest in science and affects attitudes positively.

Wilson & Mant (2011a, 2011b) used 5044 questionnaire responses of 12-year-old (Year 8) students from 32 schools in England to identify classes in which students' responses to three questions were mostly positive; *Science is fun*; *I look forward to science lessons* and *Science lessons are interesting*. From these groups, the authors identified 11 classes (n=230) where more than 50% of the students in the class agreed with these statements. Of these, the views of six teachers and 153 students were explored. Wilson & Mant (2011a, 2011b) concluded that exemplary teachers had good explanation skills, contextualised their lessons, used practical work to consolidate learning, allowed students to think and problem-solve and used discussions in their lessons.

Darby (2005) conducted a smaller study involving one teacher and her class of 26 11-year-old students (that is, Year 7). She observed 38 lessons out of 65 in the academic year. In addition, Darby (2005) conducted 19 semi-structured focus-groups of a group of twelve students with two to three students per session and five informal interviews with the class teacher. Her findings were centred on two aspects of a teacher's pedagogy; *instructional* and *relational.* Aspects of instructional pedagogy which were highlighted included the teacher's ability to explain scientific concepts well, the use of class discussions to enable students to share their ideas and deepen their understanding and clarification – repetition of previous content to consolidate learning before introducing new concepts. Exemplary teachers' relational pedagogy centred on their passion for both teaching and science itself, the ability to create a welcoming classroom environment which aided learning and finally being supportive to students.

The third study, Fraser, Tobin & Lacey (1990) adopted a case study approach involving 20 teachers that had previously been identified as ''exemplary'' science teachers and ''non-exemplary'' teachers. Data were collected by observing eight lessons per teacher.

This was supplemented with questionnaires which assessed students' perception of their classroom environment. Tobin et al., (1990) concluded that exemplary science teachers managed and facilitated student engagement, used strategies which increased students' understanding of science, encouraged student participation in lessons and maintained a favourable learning environment.

Despite the different methods of data collection employed or sample size used in these studies, emergent themes were similar. A teacher's pedagogical content knowledge was of particular important. Exemplar teachers had both subject content and pedagogical content knowledge. Their extensive pedagogical content knowledge meant they were able to teach lessons which were engaging and able to make students enthused about science. Tobin et al's (1990) four assertions of exemplary teaching has elements of the findings from the other two studies and is therefore used in this study in Chapter 6 when discussing students' views of teachers as a factor which affects their attitudes towards science.

2.4.2 Leadership, school management and accidental effects

School leadership comprising senior school leaders and middle managers such as Heads of Departments are central to the management of the school. Decisions made at management level could impact on post-16 subject recruitment (Smithers & Robinson, 2007; Bennett, Lubben & Thompson-Hadden, 2013), curriculum provision (Smithers & Robinson, 2007; Bennett et al, 2013), school assessments and accountability measures (Hutchins, 2015; Worth & De Lazzari, 2017) and career information and advice (Cleaves, 2005; Archer et al., 2013).

<u>Post-16 subject recruitment</u>

Smithers & Robinson (2007) and Bennett, Lubben & Hampden-Thompson (2013) investigated the roles of schools in recruitment of students in post-16 science. While, Smithers & Robinson (2007) focussed on post-16 physics recruitment, Bennett et al (2013) examined chemistry and physics post-16 recruitment.

Smithers & Robinson (2007) investigated seventeen comprehensive schools in which post-16 participation rate in chemistry and physics was higher than the National average in England. Schools with similar characteristics such as GCSE performance, geographical location and students' eligibility for Free School Meals were then matched for comparison. Eligibility for Free School Meals is a useful indicator of social class. Data were collected from interviews with Heads of Science/Physics and documents including reports from Government Inspectors, that is, The Office for Standards in Education (Ofsted).

Bennett, Lubben & Hampden-Thompson (2013) used secondary data from the National Pupil Database (www.gov.uk/government/collections/national-pupil-database, n.d.) to identify schools with similar characteristics such as school size, selection criteria and students' social class. Schools selected for the study were identified as either having ''high'' or ''low'' recruitment based on the number of A-Level examination entries in chemistry and physics compared to the national average. Eight schools were paired, that is, 'high' recruitment against 'low' recruitment. Data were collected through interviews of staff and students, while school documents provided contextual data such as examination results and subject specialism of science teaching staff.

Together, both studies illustrate the importance of proactive and ''strong'' leadership at departmental and whole school level whether in terms of curriculum diversity or science teachers. For instance, Bennett et al (2013) found that school leadership divided into two categories; leaders who actively promoted science and leaders who adopted a neutral stance, that is, not promoting any subject.

Science departments in schools with proactive school leaders were complacent about recruitment into chemistry and physics as science was promoted at the highest level. Where school leaders did not actively promote science, a negative attitude prevailed within the science department as staff felt they had to "fight" for the recognition of their subject.

However, counter-intuitively, science departments in these schools were able to recruit more students to chemistry and physics post-16 compared to the former schools, as they adopted an assertive approach to post-16 science recruitment.

These findings point to departmental level proactivity creating a culture of expectation of progression to post-16 science. Thus, even within a specialist science school, the role played by the science department itself in promoting the subject may impact on students' attitudes and science career expectations.

Curriculum provision

Bennett et al (2013) and Smithers & Robinson (2007) found that schools offering a curriculum which included the complete suite of GCSE science courses had higher recruitment rates into post-16 science than schools that offered a narrower curriculum. The former schools offered GCSE courses including Triple Science and Applied Science thus offering a curriculum suitable for different academic abilities and career aspirations.

Schools with a narrower curriculum were also the same schools in which fewer students continued with science post-16. This suggests that courses available to students could influence recruitment into science post-16. Thirdly, schools in which the curriculum was narrower inadvertently grouped students of different academic capabilities. Hence, students with contrasting academic abilities studied together, creating a potential for challenging science learning experiences.

Collectively, these studies point to the possibility that school policies and management decisions whether through curriculum provision, class settings or promotion of a subject at the highest management level were indirectly influencing students' post-16 subject choices.

School assessments, accountability measures and the ''devaluing'' of science

Between 1991 and 2009, 10 to 11 year olds' knowledge and understanding of the ''core'' subjects, namely, English, Mathematics and Science, were formally tested at the end of primary school in a national examination called Statutory Assessment Tests (SATs). In 2009, SATs in science were abolished.

The end of these tests in science led to diversion of resources towards English and Mathematics, for which tests remain in place. One area in which this has had an impact is curriculum time available for science teaching (Ofsted, 2015).

Some schools teach science on a weekly basis, but others have reduced science teaching to some year groups and in some cases, science is not taught at all (Hutchings, 2015; Leonardi, Lamb, Howe & Choudhoury, 2017). This is done to prepare children for SATs in English and Mathematics (Hutchings, 2015) with schools reduced to what the National Union of Teachers (NUT) referred to as ‘’exam factories’’ (Hutchinson, 2015).

Similarly, in secondary school, successive Governments have attempted to rank schools by their success in achieving a high standard of results for 16 year olds at the end of secondary school. At the time of this study, schools were ranked in national league tables based on the proportion of 16 year olds who achieved five grades, A*-C including in English and Mathematics (Department for Education, 2016).

As with primary schools, this impacted on teaching time allocated to the three core subjects. The National Foundation for Educational Research (NFER), after accounting for changes in student numbers, found an average increase of approximately five percent in curriculum time for English and Mathematics (Worth & De Lazzari, 2017). In contrast, time allocated to science remained constant over the same period (Figure 2.1).

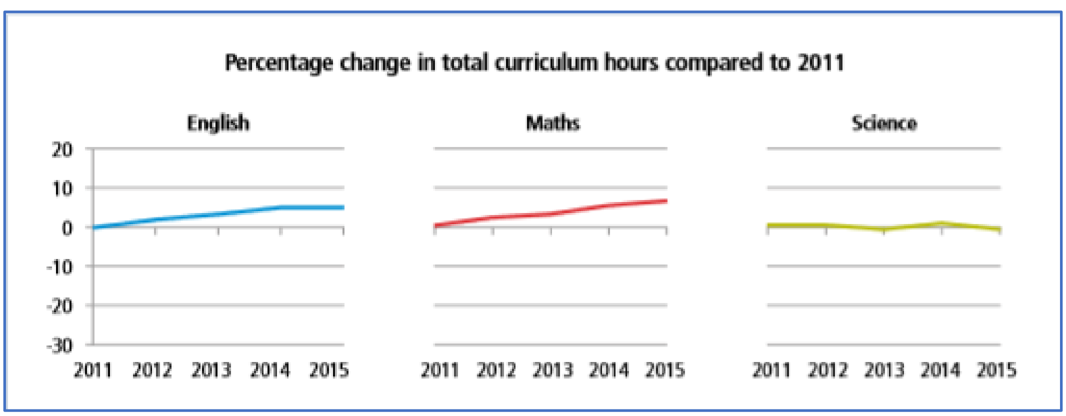

Figure 2.1: Changes in teaching hours in English, Mathematics and Science (Source: NFER)

Increasing curriculum time in English and Mathematics may raise the profile of English Mathematics at the expense of Science. Although there is no evidence that this affects students' attitudes towards science, a consequence of this may be the ''devaluing'' of science, despite it being a ''core'' subject.

Allocation of resources is not limited to curriculum time. In a report from inspections of over 1500 schools, The Office for Standards in Education, Ofsted (2015) found that some school leaders gave priority to Key Stages 4 and 5. Key Stage 3 was not a priority when allocating teaching time or assessments and monitoring of students' progress (Ofsted, 2015). For example, 85% of the school leaders interviewed said Key Stages 4 and 5 were staffed as a matter of priority over Key Stage 3. Consequently, Key Stage 3 classes were split between more than one teacher and in some cases were taught by non-specialists. Ofsted (2015) concluded that ''the quality of teaching and the rate of students' progress and achievement were not good enough'' because of the provision in Key Stage 3.

In section 2.4.1, the impact of subject content knowledge (SCK) on teaching was discussed (Harlen, 1995, 1997; Kind, 2009). This noted that teachers with limited SCK in science not only found teaching some aspects of science challenging (Harlen, 1995, 1997) but, they were also less likely to possess extensive teaching strategies. Therefore, use of non-specialist teachers to teach science in Key Stage 3 may unintentionally have a negative effect on students' science learning experience. Negative learning experiences may inadvertently affect post-16 science recruitment (Osborne et al, 2003).

<u>Career information and advice</u>

Career information supports students' subject selection post-16 (National Foundation for Educational Research, 2008; The Royal Society, 2011). However, career guidance provision in England is criticised as inadequate (Sainsbury, 2007). Evidence shows students aged 5 to 16 are unaware of the breadth of possible careers linked to science (Cleaves, 2005).

Cleaves (2005) investigated career choices of 72 secondary school students from six comprehensive schools in England over a three-year period. Data were collected from thirteen interview sessions at four intervals; at the start and end of Year 9, when students were aged 13 to 14, and in Year 10 when students were 14 to 15 years old and finally in Year 11 when they were aged 15 to 16.

The author identified three categories of students; those who already knew what they wanted and wanted to pursue a STEM subject or career; those who did not know what they wanted and could be persuaded to pursue a STEM career and those who were not interested in a STEM pathway regardless of any effort expended to change their minds. Students in the third category failed to see the utility of science. They also lacked awareness of science occupations (Cleaves, 2005).

Although Cleaves (2005) gathered data from interviews with 72 students, her findings were corroborated by the larger scale ASPIRES project (Archer et al., 2013; section 2.3.2. The authors report that students and parents had a narrow view of possible career options in science, post-16. There was widespread perception that science roles mean being a ‘’scientist’’, science teacher or medical doctor, illustrating a lack of awareness of the diversity of science. Hence, science is dismissed by some students as irrelevant before the last two years of compulsory secondary school, that is, ages 14 to 16.

Reasons for inadequate career guidance and advice in schools are varied. Career advice is provided by advisors, the majority of whom have little or no background in physical sciences (Munro & Elsom, 2000; Roberts, 2002). In some cases, students were advised against STEM subjects beyond the age of 16 due to the perception that they were ‘’hard’’ (House of Lords, 2006). Core subjects are compulsory to age 16. Hence, careers advice focusses on optional subjects and obtaining work experience (Munro & Elsom, 2000).

The possibility is that science as a compulsory subject acts as a disservice to recruiting post-16 courses. Also, the KS4 programme of study operational at the time Archer et al (2013) collected data included no references to possible careers in science, despite this document being portrayed as an ‘’important tool’’ in preparing the next generation of scientists.

An impact of this is discussion about the possibility of career guidance taking place in STEM lessons (Reiss & Mujatba, 2017). Reiss & Mujatba (2017) draw on the findings of the ASPIRES (Archer et al., 2013) and Understanding Participation rates in Mathematics and Physics projects (UPMAP, Mujatba & Reiss, 2014) to make their case. The authors argue that teachers could use lessons to increase awareness of the utility of science at the world of work rather than usefulness of science in society *per se.* In addition, teachers could use the importance of their ''voice'' to influence students' subject and career choices. However, changes in Government policy and funding to schools may make Reiss & Mujatba's (2017) propositions challenging for schools to implement.

These examples illustrate effects of school leadership and management on school policies. Leadership decisions in allocation of staffing and teaching time means that some young children start secondary school with limited conceptual understanding of science, and perhaps, a belief that English and Mathematics are more important than science. This viewpoint could be reinforced in secondary school where English and Mathematics have more teaching time compared to science.

Inadequate career advice and information may limit students' views of the opportunities GCSE or A-Level science qualifications offer. This is compounded when curriculum provision precludes some courses, thus limiting possible post-16 subject recruitment. This raises the possibility that schools, through their leadership and management decisions could fortuitously prescribe students' subject choices and science career expectations, post-16.

2.4.3 Type of schools: specialist schools

The type of school can influence students' attitudes and post-16 science aspirations. For instance, schools with availability of sixth form (Years 12 and 13) provision have a positive impact on post-16 subject choice and career aspirations (Foskett, Dyke & Maringe, 2008). Similarly, schools with single-gender schools (IOP, 2013) were found to have a positive influence on girls' science attitudes and aspirations respectively. However, as the context for this study is a specialist science school, discussion here is restricted to this.

The specialist schools programme was launched in 1994 by the Department for Education and Employment (DfEE). To qualify for ''specialist'' status, schools had to raise an unconditional sum of £50, 000 (£100, 000 prior to 1999) from private, charitable and/or business sources which was matched by the Government. These funds were ''ring-fenced'', that is, identified specifically for spending on facilities to impact interest and potentially enhance post-16 recruitment in the identified specialist subject.

Overarching aims of the programme (Ofsted, 2008) were to raise standards of teaching and learning in specialist subjects, raise achievement for students of all abilities, extend the range of curricular and extra-curricular opportunities available to students and develop a school character and ethos related to the specialist subject. In addition, development of work with local schools, sponsors and the community was anticipated. The specialist school programme ended with a change of Government following the UK General Election held in May 2010 (www.gov.uk, 2010).

Three Government-sponsored studies; Harris, Arthur, Dahl, Chapman & Muijs (2004), Ofsted (2001, 2005) and Jesson & Crossley (2006) report that the specialist programme impacted positively on school life. Harris et al (2004) focussed on ethos, specialisation and community links, while Ofsted (2001, 2005) and Jesson & Crossley (2006) investigated impact on attainment.

Harris et al (2004) examined eighteen specialist schools and thirty partner schools. Of the specialist schools, two had specialist status in science. Schools were chosen to represent a broad geographical spread, range of subject specialism and high academic achievement. The authors collected data through semi-structured interviews; face to face with various staff in the specialist schools and telephone interviews with staff in partner schools. They also used ''Conditions Survey data'' (Hopkins et al., 1994), which measure changes in internal school conditions such as school ethos. They concluded that specialist schools impacted favourably on school ethos, community links and subject specialisation. However, as there were 1686 specialist schools in England in 2004 (Ofsted, 2008) findings from Harris et al's (2004) study of 18 specialist schools is insufficient to evaluate success of the whole specialist programme.

Ofsted (2001, 2005) conducted a larger scale study with evidence compiled from three sources namely, inspection reports, GCSE examination results and school visits by Inspectors. In 2001, data were collected from 327 specialist schools in operation by September 1998 with visits by Inspectors to 46 of these schools, while in 2005, data were collected from 521 operational specialist schools as at September 2000, with visits to 52.

Similarly, Jesson & Crossley (2006) compared GCSE examination results of 1,838 specialist schools with those of 1, 090 non-specialist schools. Their analysis reveals 58% of GCSE students (ages 15 to 16) attending specialist schools achieved grades A*–C compared to 47% in non-specialist schools.

Collectively, Ofsted (2001, 2005) and Jesson & Crossley (2006) suggest that specialist schools impact positively on student attainment. For instance, Ofsted (2001, 2005) report that GCSE achievement average point score showed an overall improvement in specialist schools compared to the national average, while Jesson & Crossley (2006) report that specialists schools achieved higher value-added scores (Glossary) than non-specialist schools.

However, being Government sponsored, potential bias cannot be ruled out. Indeed, claims of success were contradicted by others (Levacic & Jenkins, 2004; Smithers & Robinson, 2009) who argue that although there is evidence to suggest that specialist schools are successful, these claims are over-stated. For instance, there is no evidence to suggest a causal link between school improvement and enhanced student attainment with specialist status. Rather, evidence suggests that students' social class could be a contributory factor to student attainment.

In their study on the effect of specialist science schools on A-level physics recruitment, Smithers & Robinson (2009) found that students in music specialist schools were more likely to obtain an A grade in A-level physics, than those attending specialist science schools. Data were collected from the National Pupil Database (Glossary) and other Government sources including the former database, 'Edubase' (now Get Information about Schools, GIAS).

The authors ranked schools in a ''league'' table of A-level Physics results. Specialist science schools placed fourth behind specialist schools in languages, mathematics and computing. Specialist music and languages schools tended to attract socially-advantaged students who started secondary school with prior academic attainment in primary school (Smithers & Robinson, 2007). Their research suggest that rather than looking at specialist school as the main reason for the ''success'' of these type of schools, other factors must be considered. For instance, in deciding to adopt specialist science status, some schools may have selected science as this subject was regarded as a ''strength'', achieving good examination outcomes and where appropriate, high levels of post-16 recruitment. In other cases, science was selected as school leaders recognised a need to improve science provision. Designation of specialist science status could enable appointment of effective and capable science teachers likely to improve students' examination results. Secondly, Smithers & Robinson (2009) argue that methods used to justify claims that specialist schools add a net value are flawed. They draw attention to Jesson & Crossley's (2006) primary use of data from the National Pupil Database noting this is incomplete at any given time.

Gorard (2010), similarly cautions against data obtained from the National Pupil Database (NPD) and the Pupil Level Annual School Census (PLASC) in making judgements about schools' effectiveness due to missing information. He notes that schools' effectiveness can be measured through other factors including ''students enjoyment of education'' and future student participation in education and aspirations (Gorard, p. 745).

Nevertheless, there is a consensus among authors that the nature of specialist schools necessitated changes in polices which impacted on provision of the specialist subject. The effects of these changes, as one would expect, may take time to emerge. One, was the development of a character or ethos which made the school synonymous with the specialist subject so that it impacted positively on students' attitudes and aspirations in the subject.

However, in many of these studies, students' views are excluded. Where student data are used, this is usually from secondary sources such as GCSE examination results. Hence, student ''voice'' in studies involving science provision in specialist science schools and how this impacts on attitudes and aspirations is silent.

As the context of this study is a specialist science school, this provides an opportunity to promote student voice by exploring factors they consider as affecting their attitudes and career expectations towards science. In addition, as most studies have focussed on GCSE examination outcomes, a cross-age study covering all Key Stages in a secondary school is useful.

2.4.4 School culture and ethos

Specialist schools were expected to develop an ethos which reflected their subject specialism. The Online Oxford Dictionary defines ethos as ''the characteristic spirit of a culture, era, or community as manifested in its attitudes and aspirations'' (''Ethos'', n.d.). Allder (1993) defines ethos in a school context as:

> ''the unique, pervasive atmosphere or mood of the organisation which is brought about by activities or behaviour, primarily in the realm of social interaction and to a lesser extent in matters to do with the environment, of members of the school, and recognised initially on an experiential rather than a cognitive level'' (p. 69).

Ethos is an elusive quality which may be difficult to investigate in a school context. The term is used interchangeably with ''climate'' (Department for Education and Science, 1977) and ''atmosphere'' (Department for Education and Science, 1989). Solvason (2005) investigated school ethos in a specialist sports college. She concluded that the notion of school ethos is vague. The requirement that schools develop an ''ethos'' to reflect their specialism was fundamentally a demand to change school culture.

She argues that ethos develops through changing culture, noting that the everyday ''cycle of events'' establishes school ethos. This might be because of its history developed through shared beliefs, tradition and practices.

Allder's (1993) and Solvason's (2005) work indicate that culture is more tangible than ethos because culture provides the foundation for a school's daily life. The term culture is therefore used in this study rather than ethos to investigate practices within a specialist science school. Evidence of a ''science culture'' can be collected within a time bound project such as this (5.3).

2.4.5 The science curriculum

Surveys show that students find science useful and interesting (Osborne & Collins, 2000; Sjøberg & Schreiner, 2005). However, although students recognise the importance of science in society they often fail to see the relevance of aspects of science especially of physical sciences (Osborne & Collins, 2000; Osborne et al., 2003; Holmegaard et al., 2014). The problem becomes acute for separate sciences; students find biology, especially human biology relevant because the link to everyday life is readily evident. In contrast, the immediate relevance of the physical sciences is hard to identify (Osborne et al., 2003). The apparent ''disconnect'' between science and everyday life impacts negatively on students' science experience.

In a study exploring students' views of the (then) science curriculum, Osborne & Collins (2000) conducted a total of 45 focus group discussions with 144 students, 117 parents and 27 teachers across three cities in England. Students found aspects of Key Stage 4 science, especially chemistry, unappealing.

For many topics, value lay in the knowledge provided for examinations rather than any intrinsic or personal interest (Osborne & Collins, 2000), a view echoed by teachers. Similarly, students did not see generic value in a science qualification compared to English or Mathematics (Osborne & Collins, 2000). Students' value for science equated to obtaining a qualification for traditional science roles. Osborne & Collins (2000) claim students' negative perceptions stem from the curriculum being ''content dominated, assessment driven and homogenous' (p. 6).

Students lack time to reflect on ideas taught in lessons and are not allowed to discover for themselves.

> Science teachers rush their students across the scientific landscape and offer an unvarying experience from the latter stages of primary school to the final days of secondary school, often repeating material, and eliminating any time-consuming activities such as practical work or the discussion of contemporary science'' (Osborne & Collins, 2000: p. 6).

This means that activities such as practical work which students enjoy and value (Braund & Driver, 2005; Abrahams & Reiss, 2012) are sacrificed for the teaching of curriculum content.

2.5 Individual sphere of influence

This section reviews research in the individual sphere of influence. Factors reported here are those directly linked to the individual such as interest and gender. In addition, factors indirectly linked to the individual such as family-related factors are considered. These include social class and science capital.

2.5.1 Interest

The concept of students' interest in science was introduced in the section on attitudes, 2.3.1. The literature on interest is diverse (Schiefele, 1991; Trend, 2005; Krapp & Prenzel, 2011). Two sub-concepts of interest are considered; individual or personal interest and situational interest (Schiefele, 1991; Krapp & Prenzel, 2011; Logan & Skamp, 2013). A third sub-concept, topic interest, contains elements of both personal and situational interest (Trend, 2005). However, as this can be subsumed under both personal and situational interest, it is not considered.

Individual or personal interest develops over time and is long lasting. Its development may be innate or from one's life experiences (Trend, 2005). This type of interest has been linked to choosing STEM careers (Maltese & Tai, 2010). Maltese & Tai (2010) interviewed 116 physics and chemistry scientists and graduates about the timing of their interest and source of interest in science.

They found that 66% (n=30) of women and 68% (n=40) of men reported developing an interest before starting secondary school. Forty-five percent attributed the initial source of their interest to personal interest, while 40% ascribed their interest to schools or educational based activity (e.g. science camps or competitions). Interestingly, when viewed by gender, 57% of the male participants were attracted to science by personal interest while 52% of the females attributed their initial interest to the school's influence.

Situational interest is fleeting, it is interest acquired ''by participating in an environment or context'' (Mitchell, 1993: p. 425 cited in Trend, 2005). For instance, students expressing interest in a topic or a practical activity in a subject they dislike. Interest in the topic or task of the moment does not equate to interest in the subject. Understanding of these differences in students' interest may be useful especially for teachers (Mitchell, 1993 cited in Trend, 2005).

2.5.2 Gender and science

Lydia Becker, a suffragette, wondered why men *''greatly outnumbered women in science''* (Becker, 1869). Today, gender remains a factor in attitudinal studies in science. Gardner (1975) noted that this is ''probably the single most important variable related to pupils' attitudes towards science'' (p. 1). Research consistently shows boys tend to have a more positive attitude to science compared to girls (Sjøberg & Schreiner, 2005; Haste, 2004).

However, difference in attitudes towards science may be undermined when science is viewed as a homogenous subject (Kind, Jones & Barmby, 2007). Girls, for example, are positive towards biology but not physical sciences. They are interested in biology–related themes such as biomedicine and biotechnology. Boys prefer computer science or software engineering (Adamuti-Trache & Andres, 2008; Holmegaard et al., 2014).

Researchers attribute gender disparity to social culture (Kahle & Lake, 1983; Smail & Kelly, 1984) alleging that girls lack opportunities to experience science when growing up, thus limiting their understanding and liking for science.

Elwood & Comber (1995) disagree, suggesting that the issue goes beyond understanding of physical sciences. They claim that girls have out–performed boys in GCSE science but are less likely to pursue a physical science post–16. This position is corroborated by the Institute of Physics (2011), which reports that although girls and boys are equally successful in GCSE physics, it is the fourth most popular post–16 subjects for boys and nineteenth for girls.

Other authors allege that ‘over–representation’ of boys studying the physical sciences rather than ‘under–representation’ of girls is the problem (Whitehead, 1996; Organisation for Economic Co–operation and Development, 2014). Similar patterns of ‘under–representation of girls in physical sciences are seen internationally, for example, in Kenya (Chetcuti & Kioko, 2012), Mauritius (Naugah & Watts, 2013), France (Stevanovic, 2013) and the United States (Tan, et al., 2013). Together, authors above indicate that gender differences in post–16 science recruitment are caused by a range of tightly interwoven factors.

A review of literature into gender and science by Brotman & Moore (2008), provides a useful synthesis of research. The authors examined 107 articles on ‘girls/gender and science’ published between 1995 and 2006 from seven journals[1], including five major peer–reviewed science education journals. The authors report their findings under four themes, which they claim represent trends in science education. These were; ‘’equity and access, curriculum and pedagogy, nature and culture of science and identity’’ (p. 971).

They note that although the themes were chosen to permit in–depth analysis of their review, they reflected shifts in trends of studies in gender and science education in roughly chronological order.

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[1] Journal of Research in Science Teaching (JRST), Science Education (SE), International Journal of Science Education (IJSE), Research in Science Education (RISE), Journal of Science Teacher Education (JSTE), as well as American Educational Research Journal (AERJ) and Gender and Education (GE),

Brotman & Moore (2008) found that while there was a decline in studies which explored *equity and access* and *curriculum and pedagogy*, there had been a corresponding rise in studies which explored the *nature and culture of science* and *identity*.

Studies on equity and access focussed on inequalities girls experienced in the classroom as well as differences in girls' and boys' achievements, attitudes and participation. In addition, studies which sought to make science more accessible for girls were considered.

Some curriculum and pedagogy research presented the argument that curricula and pedagogy need to change to recognise the interests of girls. Others examined intervention strategies designed to make the curriculum and science teaching ''gender inclusive''.

In studies on the nature and culture of science, focus was on the need to challenge the portrayal of the nature and culture of science in the classroom and in society. The intersection between race, gender and class were considered here, for example, the need to challenge the belief that science is a domain for white men, which excludes other marginalised groups, like girls and minority ethnic groups. The views of teachers were also considered in this theme.

Finally, studies on identity which highlighted the need to include identity in the discourse on gender and science education. These studies argue that gender is an important part of identity, therefore understanding of identity inform our thinking on how girls and boys engage with and learn in science.

The themes indicate an overlap of issues, highlighting once again, the complexities regarding students' attitudes towards science and career expectations. As one of the overarching aims of this study is to make science more equitable, these themes provide a foundation for the rest of the review. Some of these themes are discussed in detail.

''Gender of science'', gender stereotyping and conformity

The notion that science has a ''masculine'' image (Brickhouse, Lowery & Schultz, 2000) and is taught with methods which may favour ''white, western males'' (Reiss, 1993) is well documented. Television and other media often portray scientists as 'male, geeky and nerdy' (van Langen & Dekkers, 2005) which feeds this cultural narrative. Research evidence suggests this perception can find expression even in young children. Newton & Newton (1992, 1998) and Silver & Rushton (2008) invited children to draw ''scientists'' in an attempt to probe their preconceived ideas. The drawings showed that the majority of children, from as young as six years old viewed scientists as male or non-gender specific.

Newton & Newton used Chamber's (1983) 'Draw–a–Scientist-Test' to explore the views of children in North East England. In the first study, 1143 children, aged 4 to 11 from eighty primary schools participated while the second study, 1000 children, aged 4 to 11 group from five primary schools completed the test.

Silver & Rushton (2008) conducted their study with a sample of 120 students, aged 9 to 10 years old from four primary schools in South East England. Questionnaires were administered with a section inviting children to draw what scientists and engineers do. Both (Newton & Newton, 1992, 1998 and Silver & Rushton, 2008) report that a majority of children depicted scientists as male. Foundations of gender stereotyping in science are established early. This raises the possibility that if children see scientists as mostly men, then girls may not aspire to science careers.

Indeed, Archer et al (2013) found that girls, aged 11 to 14 who participated in the ASPIRES study (2.3.2) who lacked science aspirations shares similar traits, including gender stereotyping. They seek employment involving nurturing or caring for people or animals (for example, as teachers or nursery workers).

Secondly, they choose roles that conform to their view of femininity, so aspire to becoming actresses, models or to work in the beauty industry generally. Thirdly, their lack of science aspirations is reinforced by personal experiences of shopping and dressing up to go out which are ''feminine'' events in everyday life.

Science roles do not automatically seem to fit this view, so are discarded. Parents of girls in the study think of science as masculine and not feminine; art is for girls and science is for boys. This leads young girls to choose careers that conform to a traditional societal image of femininity.

The exclusion of older girls, that is, 15 to 18 year olds from these studies means that further work is needed to understand the career aspirations and barriers, if any, that older girls encounter in science at the point they make decisions about prospective careers. Therefore, a cross-age study involving both younger and older girls is useful.

Gender and physics

Research into gender and physics is extensive. Murphy & Whitelegg (2006a), for the Institute of Physics, reviewed 117 papers published from 1990 to 2005, comprising books, journal articles and conference papers. These focussed on 11 to 16 year old students in the UK or from countries with an educational system similar to the United Kingdom's. Studies were grouped into six themes based on research focus: interests, motivation, course choices and career aspirations; relevance and curriculum interventions; teacher effects; single-gender schooling and groupings; measures and perceptions of difficulty; entry and performance patterns in physics. A majority of studies adopted quantitative approaches to data collection and analysis. They note few studies in England which explore how students' experiences of science, including physics, affect their attitudes and future aspirations in science.

Three important determinants impacted on girls' attitudes and aspiration in physics: 'how students saw themselves in relation to the subjects, now and in the future' (or self–efficacy in physics), a ''personally supportive teacher'' and their experience of school physics (Murphy & Whitelegg, 2006a, p iii). These are summarised.

Girls' self–efficacy in physics is more likely to decline compared to boys as they go through secondary school. This impacted on their attitudes and aspirations in physics.

A supportive teacher was particularly important especially for girls with negative self-efficacy in physics. Some teachers had low expectations of girls in physics and this persisted after Key Stage 4, but support provided by teachers had a more positive impact on girls than on boys.

Negative experiences of school physics are more influential in students' attitudes and aspirations than positive ones. Girls are more likely to engage positively with physics when tasks are placed in social contexts. Social contexts are atypical of secondary physics. When contexts are provided, these rely on examples which are more familiar to boys. Consequently, some girls have a negative experience of physics, finding it increasingly difficult as they progress through secondary school, while others find it at odds with their interests.

Teaching was addressed in section 2.4.1 and therefore not repeated here. However, a less important factor despite a widespread perception held by teachers and students was the belief that physics was a ''difficult subject''. Teachers and students attributed the perception of difficulty to mathematical demands which increased as students progressed through school. In addition, students, especially girls report that the pace at which content is taught hinders their ability to understand concepts, thus strengthening their perception of physics as a difficult subject at Key Stage 4.

Findings from studies published recently (Mujatba & Reiss, 2013; Institute of Physics, 2017) suggest that these factors persist. In a survey of 15 year old students, that is, students in the penultimate year of secondary school, Mujatba & Reiss (2013) explored the intentions of students to study physics post-16 when it is no longer compulsory.

Data were collected via survey responses from 5034 students from 137 schools in England during the 2008 to 2009 academic year. The authors report that girls are less likely to cite positive school physics experiences compared to boys. Girls have lower self–efficacy in physics relative to boys. This supports findings from Murphy & Whitelegg' (2006a). Girls, despite expressing similar liking for their physics teachers are more likely to report that teachers are less supportive in lessons and rarely encourage them to continue with physics post-16.

Follow up studies on Murphy & Whitelegg's (2006) by the Institute of Physics (2012, 2013, 2015, 2017, 2018) show gender imbalances persist. The Institute of Physics is a membership society which seeks to advance physics in society (IOP, n.d.). The persistence of gender disparity reinforces the need for research like this study which looks beyond A-level physics recruitment to factors in the school and individual spheres of influence to explain these differences.

2.5.3 Family-related factors

Familial influence on young people's aspirations was introduced in section 2.3.2. This was based on the premise that young people aspired to careers in which they knew someone (e.g., family or close friend) in the same profession (Archer et al., 2013; Chambers et al., 2018). For others, their source of influence was through engagement in out of school activities. These examples are rooted in the concept of capital. The Online Oxford Dictionary defines capital as ''a valuable resource of a particular kind'' (''Capital'', n.d.). Closely connected to these concepts is the notion of social class. How these interconnected concepts influence students' aspirations is discussed by focusing on science capital and how this may develop.

Bourdieu (1986) introduced three forms of capital; economic, cultural and social.

> ..Economic capital, which is immediately and directly convertible into money and may be institutionalized in the forms of property rights; as cultural capital, which is convertible, on certain conditions, into economic capital and may be institutionalized in the forms of educational qualifications; and as social capital, made up of social obligations ('connections'), which is convertible, in certain conditions, into economic capital and may be institutionalized in the forms of a title of nobility (p. 243).

Economic capital is all about purchasing power. A family's economic capital determines the amount of money that is readily available to them at any given time.

Cultural capital is what is acquired to equip oneself in society, for instance, learning a foreign language, acquiring an academic qualification or skills are all examples of cultural capital.

Social capital is rooted in the belief that people are influenced by the community or network they are embedded in (e.g. friends and family). The community or network can be seen as a resource which can be used thus, making it a form of capital (Field, 2003).

Put simply, social capital means ''relationships matter'' but better still, it is a combination of what you know and who you know that matters most (Field, 2003).

Social class

Closely related to the forms of capital described above is the notion of social class. It is well documented that social class influences educational outcomes (Reay, Davies, David & Bell, 2005; Webber & Butler, 2007; Gorard & See, 2009). This can be attributed to the privileges associated with social class, for example, more educational opportunities, access to financial resources, occupational awareness and a support network of friends and families (Sewell & Shah, 1968).

For instance, Gorard & See (2009) analysed secondary data obtained from two large datasets; the Pupil-level Annual Schools Census (PLASC) and the National Pupil Database (NPD) to examine the possibility of a link between social class and participation and science attainment. Gorard & See (2009) use eligibility for Free School Meals (FSM) and the English Indices of Deprivation to determine students' social class. They found that students from socially-disadvantaged backgrounds were less likely to continue with science or other subjects compared to students from socially-advantaged backgrounds. They were also less likely to obtain necessary grades to continue with science, post 16, compared to their peers. Other researchers also found that social class influences participation in science (e.g. Wobmann, 2003; Webber & Butler, 2007).

Social class and science capital

In linking this to the forms of capital, the notion of science capital as conceptualised by Archer et al (2013) is introduced. Bourdieu (1986) believed that possession of cultural capital enabled the beneficiary to obtain a better paying job or enhance their social status and thus, expand their social network. However, acquisition of cultural capital may only be possible in some instances, if the individual has access to economic capital, that is, financial resources.

Bourdieu (1986) believed that the more economic capital people had, the more likely they were to acquire cultural capital which they could transfer to their children through a process of *social reproduction.* Bourdieu explains:

> The notion of cultural capital presented itself to me, in the course of research, as a theoretical hypothesis which made it possible to explain the unequal scholastic achievement of children originating from the different social classes by relating academic success, i.e., the specific profits which children from the different classes and class fractions can obtain in the academic market, to the distribution of cultural capital between the classes and class fractions (Bourdieu, 1986; p. 244).

In other words, children tend to embody their family's goals and values. For instance, children whose parents are highly educated are likely to have high academic aspirations (Bourdieu, 1986).

From this notion of cultural capital, Archer et al (2013) conceptualised ''science capital''. Science capital can be seen as a form of science-specific cultural capital. A family may possess science capital themselves through science qualifications, science-related occupation or participation in science-related activities. This is likely to socially-reproduce through in their children. The acquisition of this form of capital enhances the likelihood of science aspirations. This is not to say that possession of science capital automatically generates interest in science careers, it only makes science aspirations more ''thinkable'' (Archer et al., 2012). Archer (2013) defines science capital as ''science-related qualifications, knowledge, interest, literacy and contacts'' (p. 13). Science capital can be used to explain patterns in students' participation and aspirations in science.

> 'Children's aspirations and views of science are formed within families, and these families play an important role in shaping the boundaries and nature of what children can conceive of as possible and desirable and the likelihood of their being able to achieve these aspirations' (Archer et al., 2012: p. 22).

As discussed (Gorard & See, 2009), social class has an impact on student's aspiration in science. Relating this to science capital, Archer et al (2013) found that those from socially-advantaged backgrounds are more likely to acquire science capital because of their economic capital, compared to those from socially-disadvantaged backgrounds. This means they have the resources to enable their children participate in science-related activities such as visits to science museums.

Archer et al (2013) found that science capital can be developed through participation in out of school science-related activities. Indeed, before the concept of science capital gained momentum, other researchers (Jarvis & Pell, 2005; Braund & Reiss, 2006; Stocklmayer, Rennie & Gilbert, 2010) had identified the importance of the role of out of school science factors in generating students' positive interests and engagement with science. The National Association for Research in Science Teaching (2003) issued a policy statement which outlines the importance of out of school science-related factors:

> Learning rarely if ever occurs and develops from a single experience. Rather, learning in general and science learning in particular, is cumulative, emerging over time through myriad human experiences, including but not limited to experiences in museums and schools; while watching television, reading newspapers and books, conversing with friends and family; and increasingly frequently, through interactions with the internet. The experiences children and adults have in these various situations dynamically interact to influence the ways individuals construct scientific knowledge, attitudes, behaviours and understanding (Dierking, Falk, Rennie, Anderson & Ellenbogen, 2003: p. 109).

As school children between the ages of five and sixteen spend only around 18% of their waking hours per day in formal education (Bransford, 2006, cited in Gokpinar & Reiss, 2016), what happens out of school is equally as important as what happens in school. Out of school activities can enhance students' understanding and meaning of science. Critics of this form of learning point out that learning hardly takes place because the emphasis is on enjoyment and engagement rather learning *per se* (Shorthand, 1987, cited in Braund & Reiss, 2006).

Nevertheless, out of school science-related activities cannot be dismissed completely because of their potential to generate positive interest. For instance, Jarvis & Pell (2005) investigated attitude changes, of 300 primary school children, aged 10 or 11 years before, during and after a visit to the UK National Space Centre. They administered a survey to students before, immediately after and two to five months after the visit. Jarvis & Pell (2005) found that although girls were less enthusiastic about space compared to boys, overall, they were more positive about space after the visit. However, the children's enthusiasm declined five months after the visit. This shows that out of school factors can generate interest even if it is not sustainable over a long period.

Classification of social class used in study

Having established the link between social class and the concept of science capital, it is important to identify the classification of social class used in this study. This is important because different researchers use different measures for social class. For example, Wobmann (2003) used number of books in the household while Webber & Butler (2007) used residential postcodes. This makes comparisons difficult.

Social class is determined in this study using the occupation of parents/guardians. Although occupation is not the only determinant of social stratification as stated above, it is a useful indicator of students' social background. There are different classifications based on occupation, for example, the National Readership Survey (www.nrs.co.uk, n.d.) and the National Statistics Socio-economic Classification (www.ons.gov.uk, n.d.). The NRS classifies social class into five grades (NRS, n.d.) while the NS-SEC uses eight (Office of National Statistics, 2010). This study adopts the NS-SEC classification as this is a Government's official grading of social class based on occupation.

The eight social classes (ONS, 2010) are:

1. Higher managerial, administrative and professional occupations, e.g., chief executives, senior police officers.
2. Lower managerial, administrative and professional occupations, e.g., nurses, midwives, secondary school teachers.
3. Intermediate occupations, e.g., paramedics, post office and bank clerks.
4. Small employers and own account workers, e.g., manager or proprietor of a restaurant.
5. Lower supervisory and technical occupations, e.g., mechanics, electricians.
6. Semi-routine occupations, e.g., receptionists, fitness instructors.
7. Routine occupations, e.g., pipe fitters, welding trades.
8. Never worked and long-term unemployed.

Classes 1–4 are considered socially-advantaged, while 5–8 are classed as socially-disadvantaged (ONS, 2016). Social class is used synonymously with socio-economic status in this study.

2.6 Implications for the current study

Collectively, this body of evidence suggests that factors which affect students' attitudes and career expectations towards science operate in two spheres of influence; the school and individual. Therefore, investigating either sphere of influence in isolation may result in limited understanding of factors affecting students' attitudes and career expectations towards science.

Methodologically, attitudinal studies tend to be short-term or ''snapshot'' studies, in which data are collected usually as a one-off occurrence (e.g. Mujtaba & Reiss, 2013; Holmegaard, Madsen & Ulriksen, 2014). They also tend to limit students' responses to fixed category responses. While these are suitable for statistical analysis, they are unable to provide meaningful substance and context behind students' responses (Lyons, 2006). As contexts for these studies vary, meta-analysis is required to garner generalisations for new contexts.

Longitudinal studies which could provide useful insights and contexts for attitudinal changes and aspirations are rare (e.g. Reiss, 2000; Archer et al., 2013). These studies are necessary to extend our understanding of how students' attitudes and career expectations towards science develop and change over time. For example, Reiss (2000) and Archer et al (2013) provide useful accounts of factors influencing students' attitudes and aspirations in science.

However, neither presents an overview of changes in attitudes and career expectations from a whole school perspective during an academic year. Attitudinal studies in secondary schools also tend to focus on specific age groups. This means that at any given time, some Key Stages are excluded. This study investigates students' attitudes and expectations towards science across all three Key Stages in a secondary school, thus providing a whole school perspective in an academic year.

This study adopts a qualitative approach exploring students' views about their attitudes and expectations towards science. Students' from three year groups will be sampled to capture attitudinal changes across three Key Stages.

This approach is appropriate for the timeframe of this study generating useful insights from a whole school perspective which can inform thinking about how the individual and school spheres of influence impact attitudinal change and career expectations. This ensures a holistic standpoint is presented.

The next chapter discusses the theoretical framework guiding this study.

Chapter 3: Developing a theoretical framework: identity and self-efficacy

"If students hold stereotypes that portray scientists as a different ''kind of person'' than themselves, those students might conclude they are not 'science people.' This mismatch between a student's personal sense of identity and a science identity can hamper persistence in STEM."

Schinske, Perkins, Snyder & Wyer, (2016).

3.1 Introduction

The previous chapter reviewed the literature on attitudinal studies in science. Two spheres of influence were considered. Post-16 science participation rates in England exhibit gender differences most acutely in physics compared to biology and chemistry. Social class, gender stereotyping and self–efficacy appear central in determining students', especially girls' attitudes towards, and aspirations for science. These are factors in the individual sphere of influence. Hence, there is a need to explore the complexities surrounding students' attitudes and career expectations towards science by drawing on existing social theories which place the individual at their operational core. Identity theory meets this mandate.

3.2 Defining identity

The notion of identity is generally associated with the domain of psychology. Erikson's (1968) theory of psychosocial development provides a useful context for the use of identity in science. The author theorised that meaning and purpose in life are discovered through a process of identity development. External factors, parents and society all impact on this process. He identified eight stages of psychosocial development from childhood to adulthood; infancy (0-18 months), toddler (18 months to 3 years), pre-schooler (3–5 years), school age (6-12 years), adolescent (12–18 years), young adult (18–40), middle aged adult (40-65) and late adult (65+).

Erikson (1968) claims that at each stage of development, individuals experience psychosocial crisis which may be resolved successfully or not. Successful completion results in psychosocially ''healthy'' individuals equipped with necessary skills for crisis resolution, while unsuccessful completion results in psychosocially ''unhealthy'' individuals.

In the early stages, stages 1 to 4, identity development is influenced by what is done to the individual. For example, parents providing a safe and nurturing environment for a child to develop a sense of trust. At stage 5, identity development is influenced by what a person does. While the potential for identity development exists in all stages, at stage 5, the adolescent stage, this is at its peak.

Stages 4 and 5 are of interest to this study. Stage 4 covers primary school educational phase and stage 5 covers secondary school to post-16. In stage 4, relationships, other than with family members begin to take on significance. For example, relationships within a school start to form, so parents are no longer the sole authority in a child's life. At this stage, teachers become important, so a child starts to seek approval from parents and teachers. Positive reinforcements results in 'industry' (competency). A lack of encouragement causes a child to doubt their ability which may result in difficulty in mastering skills or concepts. The concept of positive reinforcement or lack of it is similar to Bandura's (1997) verbal persuasion (3.3).

Similarly, in stage 5, associations and affiliations to people and ideas are made. In this stage an individual begins to think about their future in terms of careers, relationships and role in society. Failure to discover one's identity and corresponding role in society may trigger a so called ''identity crisis'' or role confusion (Erikson, 1998).

From a social science perspective, the term identity has different meanings. Two definitions are considered. Gee describes it as 'the ''kind of person'' one is recognised as ''being'' at a given time and place (2000, p.9). This suggests that people have multiple identities which changes with social context.

Jenkins (2008) describes identity as

> .. … the human capacity …..to know 'who's who' (and hence 'what's what'). This involves knowing who we are, knowing who others are, them knowing who we are, us knowing who they think we are, and so on: a multi-dimensional classification or mapping of the human world and our places in it, as individuals and as members of collectivities. It is a process (identification) not a 'thing'. It is not something that one can have, or not; it is something that one does (p. 5).

These characterisations imply once again that identity is dynamic and relational; it does not exist in isolation. The social and individual components are equally important. From an educational perspective, identity emphasises the role of the individual and expands our view to include social structures (Wenger, 1998). Therefore, identity can be a useful analytic tool in understanding schools and society (Gee, 2000). Two perspectives on the use of identity as a theoretical framework are presented: a broad educational perspective (Gee, 2000) and a science education perspective (Carlone & Johnson, 2007; Brickhouse, Lowery & Schultz, 2000; Aschbacher, Li & Roth, 2010).

3.2.1 Identity in education

Gee (2000) proposes four ways of viewing identity, that is, what it means to be a certain kind of person in education. The author notes that these are not discrete categories but ways in which to recognise how identities are formed and 'sustained'. Each perspective depends on recognition by either an institution, individuals or a group.

Nature perspective or N–Identity: Identity imposed on an individual by nature. The individual or society has no control over it; it is a 'force' of nature. For instance, being born a twin is a 'force of nature'. N–Identities are validated through recognition from institutions or affinity groups and discourse, that is, the other three perspectives.

Institutional perspective or I–Identities: I–identities are positions conferred on individuals by institutions which imposes rules or laws upon the individual. They define 'who' or 'what' a person is.

Being a student, for example is an I–Identity which can either be a ‘calling’ or an ‘imposition’ depending on how passively or actively, the student fulfils this role within the boundaries of a school.

Discursive perspective or D–Identity: Discursive identities are individual traits which are reinforced through social interactions. Like I–identities, D–identities can either be passive or active depending on whether it is viewed as an ‘ascription’ or ‘achievement’.

Affinity perspective or A–Identity: identity acquired through allegiance or membership of a group with common interests. A–identity is sustained through participation or sharing of experiences.

At the core of Gee’s four perspectives is the notion of an *interpretive system,* that is, how others see us. Perception can be historical or cultural based on traditions, rules of an institution, discourse, or shared interest of affinity groups. However, the problem with Gee’s notion of identity in this study is its inability to explain how others develop the knowledge needed to recognise an individual’s identity. Adopting Gee’s theory in this study means reliance on the assumption that ‘’others’’, for example, staff and other students may recognise an individual’s identity. This may be unreasonable in a time-bound project as this.

3.2.2 Identity in science education

Some researchers, especially feminist theorists (Carlone & Johnson, 2007; Brickhouse, Lowery & Schultz, 2000; Ascbacher, Li & Roth, 2010) focus on the notion of identity in science. They speculate that students, especially girls, who are unable to see themselves as scientists are less likely to have science-related career expectations. Science is viewed stereotypically as the preserve of white Western males (Reiss, 1993). This notion of exclusivity precludes students from seeing themselves as a ‘’science person’’. Therefore, while white Western boys might relate to this image of scientists, students from other backgrounds, especially girls, who cannot identify with the masculinity of science, are less inclined to pursue science-related careers (Brickhouse & Potter, 2001).

Some researchers (Carlone & Johnson, 2007) use identity as a model to explain how under-represented groups, such as women from ethnic minority backgrounds, in science-related occupation negotiate their place in the workforce. In addition to stereotypical norms about science, Carlone & Johnson (2007) point to the nature of school science. They claim that the current model of science taught in schools presents science as a ''finished body of knowledge''. This narrow view alienates some students from a career in science (Carlone & Johnson, 2007).

Taken together, these point to the possibility that developing positive attitudes and career expectations in science requires students to discover who they are in science. This is what researchers refer to as ''science identity''. Calabrese Barton (1998) defines ''science identity as ''who we think we must be to engage in science'' (p. 379). Brickhouse (2001) expands on this definition and describes science identity as students' perception of who they are, their ability in science and what they want to do and become in science. It requires understanding of one's self in relation to the past and future. Both definitions suggest that science identity is not fixed. It is a process of discovery, negotiation, and reflexivity in relation to science.

> Identity refers to ways in which one participates in the world and ways in which others interpret that participation. Identities are maintained on performances in which one makes a claim on an identity and then judges the viability of that identity against the reactions of others (Brickhouse & Potter, 2001; p. 966).

This process of ''identification'' requires self-categorisation and evaluation (McCall & Simmons, 1978 cited in Stets & Burke, 2000; Jenkins, 2008). Identity may therefore be useful as a theoretical framework in explaining how and why some students develop science career expectations while others do not.

Secondly, the concept of science identity permits recognition of the importance of social interactions in framing students' perception of who they are and what they want to be in science. This is important as this study utilises the research philosophy of interpretivism which acknowledges subjective reality (4.3).

Having established the rationale for the use of identity as a theoretical framework, the next section discusses studies which use this concept to investigating students' attitudes and career expectations towards science. Four studies are considered. These are discussed in pairs based on similarities in the research approach. Brickhouse, Lowery & Schultz (2000) and Aschbacher, Li & Roth (2010) are discussed first followed by Tan, Calabrese Barton, Kang & O'Neil (2013) and Gonsalves, Rahm & Carvalho (2013).

Brickhouse, Lowery & Schultz (2000) explored the identities adopted by four African American girls, aged 12 to 13 attending a secondary school in a socially deprived area in the US. Participants were chosen because of their interest in science and either race or social class. Data were collected mainly through interviews of students, parents and teachers; lesson observations, student diaries and focus groups over an 18 month period. They found that students must constantly negotiate the identities they adopt at the borders between the home, school and science. Students who adopted a 'good student' identity (Brickhouse et al., 2000), that is, students who were well behaved and followed instructions fitted with the 'science identity' within the school community. These students were encouraged by teachers. However, students who failed to conform to this identity were judged less favourably by the school and their science teachers.

Aschbacher, Li & Roth (2010) explored the persistence of 33 students from six different schools in the US who expressed an interest in a STEM career in the 10^{th} grade (ages 15 to 16). Students chosen were from different ethnicities and social class. Through surveys and interviews over a 3-year period, students' career aspirations were revisited in the 12^{th} grade (ages 17 to 18). Three groups of students were identified; ''High Achieving Persisters'', ''Low Achieving Persisters'' and ''Lost Potentials''. Lost Potentials were students who were no longer interested in a STEM career in the 12^{th} grade. Poor experiences of science and lack of encouragement from teachers coupled with interests in non–science careers made it easy for this group of students to change trajectories. In addition, school counsellors provided little encouragement, describing science as ''hard'' and ''not for everyone''.

In contrast, ‘’Persisters’’ – those who stayed in the STEM trajectory, found support in from the school and home. For these students, their science identities were reinforced by the support they received which contrasts with Lost Potentials for whom this support was non–existent.

Brickhouse et al (2000) and Aschbacher et al (2010) show that in addition to students managing conflicts of identity, for example, their self-efficacy in science; support from both home and school is necessary to persist in science. They note that students who receive support from the school and home are likely to develop science career expectations than students who do not.

Tan, Calabrese Barton, Kang & O’Neil (2013) and Gonsalves, Rahm & Carvalho (2013) use the concept of identity and figured worlds to examine students’ attitudes towards, and aspirations for science. The concept of identity and figured worlds was first introduced by Holland, Lachicotte, Skinner & Cain (1998) as a means of sense-making and self–development. Holland et al (1998) posit that people are social and cultural beings who inhabit different ‘worlds’ through human agency. For example, children play with objects and attach different meanings to the objects depending on the ‘world’ of interest at the time. Holland et al (1998) called these ‘worlds’ figured worlds defining it as:

> A socially and culturally constructed realm of interpretation in which particular characters and actors are recognised, significance is attached to certain acts, and particular outcomes are valued over others (p. 52).

Figured worlds becomes embodied over time through continual participation. The more one participates in a figured world, the more one gets familiar with it, thus enabling the participant to author their identity within it. Tan et al (2013) and Gonsalves et al (2013) use this concept of figured worlds to explore how girls negotiate their identities in science in and out of school in the US and Canada respectively.

Tan et al (2013) studied 16 non–White girls, aged 11 to 13, from four secondary schools situated in socially deprived areas in the US. The authors suggest that girls author different identities depending on social context. Girls can author their own identities which they are able to modify depending on the figured world (school, science club or home) they occupy at any given time. Hence, identity is not fixed or single but fluid and multiple. Tan et al (2013) distinguish between ‘’narrated identities’’ – who girls think they are and want to be and ‘’embodied identities’’ – what they do. Students for whom there is no conflict in their narrated and embodied identities in science are more likely to persist in science especially when there is support from teachers, peers or family.

Gonsalves et al (2013) used a science club to demonstrate how six girls with different ethnicities in Canada engage in identity work through discourse. Over a twelve week period, they used stories to discuss a range of topics including science related topics, filming each session. From this data and subsequent interviews with the girls, they found that for most students their figured world view of science and scientists is built on the knowledge of science and scientists developed from school and home. Hence, the closer the figured world of science and scientists resembled students’ figured world of science created from home and school, the easier it is for them to aspire to a science career.

Taken together, these studies use the notion of identity as a tool in understanding students’ attitudes and career expectations towards science, highlighting the importance of students developing a science identity if they are to aspire to a career in science. In addition, they point to the importance of the role of the school and home in supporting students’ attitudes and career expectations in science.

The studies reviewed also suggest that we recognise the role of self-efficacy in shaping students’ identity career expectations in science (Brickhouse, 2001). Therefore, the science identity discourse may be incomplete without recognition of the role of self-efficacy in the process of science ‘identification’ (McCall & Simmons, 1978 cited in Stets & Burke, 2000). This means that we recognise the conscious and sub–conscious ways students, especially girls, negotiate and make meaning of their place in science and author their science identities. Self-efficacy is discussed.

3.3 Defining self–efficacy

In this study, self-efficacy is used synonymously with self-concept and self-perception. Self-efficacy is not a substitute for self-esteem or confidence; it is dynamic and context dependent (Bandura, 1997). Self-efficacy refers to ''beliefs in one's capabilities to organise and execute the courses of action required to produce given attainments'' (Bandura, 1997: p.3).

These beliefs in turn affect views and actions including aspirations and career pursuits (Bandura, 1989). This suggests that it can influence how people think they can perform a certain activity or behave in any given situation. Self–efficacy can therefore be seen as a component of identity (Brickhouse, 2001). Self–efficacy involves cognitive, affective and behavioural processes thus making it a useful tool in developing our understanding of how students learn, think and act in science.

For the purpose of this study, self–efficacy in science is defined as *students' beliefs in their ability in science.* This definition complements the definition of attitudes adopted in this study (2.3.1) which focusses on the affective and behavioural.

Bandura (1997) identified four sources of self–efficacy: mastery experience; vicarious experience; verbal persuasion and physiological and affective states.

Mastery experiences deal with successful performance in previous tasks. Success in a previous task increases self–efficacy while previous failure in a similar task decreases self–efficacy towards a proposed similar task. Perceived failure has a stronger influence on self–efficacy than perceived success (Bandura, 1997).

Bandura considered mastery experience as the most dominant source of self–efficacy as this is based on first-hand knowledge of one's performance.

Vicarious learning experiences are those based on observing others, for example, observing fellow students perform a similar task. The greater the similarity to the observer, the more impact their success or failure will have on the observer's self–efficacy. Positive vicarious learning opportunities can increase an individual's self–efficacy.

Verbal persuasion experiences are based on feedback received from influential or significant people about their capabilities. For example, teachers are influential persons in schools who provide feedback to students. The more positive the feedback, the higher the students' self–efficacy and the more negative the feedback, the lower the students' self–efficacy. Verbal persuasion is comparable to feedback in identity formation (3.2.2).

Physiological and affective states, for example, moods, stress, anxiety and physical comfort can affect self–efficacy. How people react or feel when performing a task can affect their self–efficacy in performing a proposed similar task. For example, perspiring profusely in a previous public speaking engagement will likely reduce one's self–efficacy in subsequent speaking engagements. However, through human agency, that is, acts done intentionally, one can exercise some control and reduce reminders of their inefficacy (Bandura, 1997).

Consequently, this study uses identity and figured worlds as a framework to improve our understanding of factors which affect students' attitudes and career expectations in science. Adopting the framework of identity and figured worlds underpins the spheres of influence being considered in this study – the individual and the school. In addition, the recognition of the concept of self-efficacy is necessary as a students' science identity can be reinforced by their self-efficacy in science (Tan et al., 2013). Students who doubt their capability in science, that is, their self-efficacy, are less likely to develop a science identity. Similarly, students for whom science at school or at home is different from their figured worlds of what science and scientists do are less likely to aspire to science careers (Gonsalves et al., 2013).

However, as the studies cited above investigate these concepts with a limited selection of students, insights from a whole school perspective are lost. By framing this study within the context of three Key Stages taught within a particular specialist science school it is possible to explain why some students choose to pursue science post-16 and others do not from a whole school perspective. This is especially useful as students in a specialist science school are expected to develop a science identity (2.4.3).

Chapter 4: Methodology

..To level all individuals to a statistical mean overlooks the uniqueness of individuals…

-Cresswell (2013)

4.1 Introduction

This chapter describes how research questions raised in Chapter One were answered by empirical data collection. The chapter begins by outlining the timeline of the study and revisiting the research questions. Section 4.2 discusses the underlying philosophical perspective. Section 4.3 explains the rationale for adopting a case study research design. Section 4.4 gives an account of the pilot study. Sections 4.5 describes ethics and access and 4.6 sampling considerations respectively. Data collection methods are discussed in section 4.7. Section 4.8 describes the data collection process. Section 4.9 discusses data analysis. The chapter concludes with section 4.12, a summary.

4.2 Research timeline and questions

The study commenced in the 2013/14 academic year. A pilot study was conducted in July and September 2014, while the main study commenced in September 2014. Table 4.1 provides a quick overview of research questions (RQ) identified in Chapter 1, data collection methods and location in the thesis.

Research Questions	Data sources and methods	Location in thesis
RQ1a: What factors do staff and students in a specialist science school believe affect students' attitudes towards science?	• Interviews • Documents	Sections 4.8.1
RQ2: Who aspires to a career in science?	• Group discussions • Questionnaires • Student diaries • Lesson observations	Section 4.8.2
RQ3: What precursors influence students' career expectations towards science?		

Table 4.1: Research questions, data collection methods and location in thesis.

Table 4.2 .summarises the timeline of the research project, including key events from inception to completion.

Dates	Activity
October 2013 to March 2014	Defining the scope and nature of the study.
April 2014	DBS application submitted
July 2014	DBS certificate granted
June 2014	Ethics application
June 2014	Ethics approval granted
July 2014 and September 2014	Pilot study
September 2014	Emails to Headteachers
September 2014	First day at Research site
March to June 2015	Medical suspension
November 2014 to June 2015	Main study: Observations
	Main study: Group discussions
	Main study: Interviews
June 2015 to	Main study: data analysis
April 2016 to September 2016	Suspension
September 2016 to April 2017	Medical suspension
April 2017 to March 2019	Writing up

Table 4.2: Research timeline

4.3 Research philosophy

The literature review shows students' attitudes towards science are complex and multi-factorial, hence their *science social world* is complex. Research probing this needs to be guided by a framework which recognises that social world knowledge is also multifaceted. Paradigms guide how social world knowledge is structured. Guba (1990) defines paradigms as a ''basic set of beliefs that guide action'' (p. 17). These underpin how the social world is studied and understood (Waller Farquharson & Dempsey, 2016). In educational research, paradigms can be subsumed into two broad categories; positivism and ''interpretivism'' (Cohen, Manion & Morrison, 2011; Hammersley, 2012). Interpretivism is used here to refer to paradigms (including social constructionism) that are anti-positivist (Sparkes, 1997).

Positivism assumes social world knowledge is revealed by direct observation and recording (Matthews and Ross, 2010). Positivists believe human behaviour is governed by rules, so events have a causal link (Cohen et al., 2011) evidenced by collection of empirical data (Hammersley, 2012). Positivism lends itself to collection of quantitative data which are analysed statistically. Social world knowledge is objective and independent of the researcher's beliefs and experiences.

In contrast, interpretivism assumes multiple truths or realities can be discovered. Reality is constructed by human agency (Waller, et al., 2016) and understood through shared experiences and beliefs of researcher and the ''researched''. Subjectivity is central to interpretivism as social world knowledge depends on individual interpretations. Burr (2003: p. 6) emphasises this stating 'there can be no such thing as an objective fact'. Burr explains:

> ''.….we take a critical stance toward our taken-for-granted ways of understanding the world, including ourselves. …..to be critical of the idea that our observations of the world unproblematically yield its nature to us, to challenge the view that conventional knowledge is based upon objective, unbiased observation of the world'' (2003: pp. 2-3).

This thesis is guided by interpretivism as this is consistent with aims of this study and the underlying theoretical framework. To understand how students' attitudes and aspirations evolve over time, students need to interpret and make sense of their world. Deeper understanding of any phenomenon emerges by ''talking directly with people, going to their homes, or places of work and allowing them to tell the stories unencumbered by what we expect to find or what we have read in the literature'' (Cresswell, 2013: p. 48).

Allowing students to give personal narratives means interpretations and perceptions of events would be diverse (Cohen et al., 2011). This suggests subjectivity which is consistent with an interpretivist approach but at variance with the positivistic stance of ''objective reality''. Secondly, an interpretivist approach recognises that subjective experiences and perception of events gained from the author's prior experience as a former science teacher may impact the study.

As a result, interpretivists typically utilise qualitative data collection methods, such as participant observation and in-depth or unstructured interviewing (Hammersley, 2012) as these occur in participants' natural settings. Hence, there was a need to ensure access to students as primary data sources, as well as teachers and where possible, parents. Utilising multiple sources enables detailed understandings of students' attitudes and aspirations to be constructed.

4.4 Research design

Following on from an interpretivist perspective, this thesis adopts a qualitative research approach to conduct a cross-age study of students aged 12 to 17. As seen in the literature review, relatively few studies of student attitudes adopt a qualitative approach. A qualitative approach permits exploration of the social science world of students and staff *in-situ* with minimal researcher intervention.

Reiss's (2000) and Tan et al., (2013) employ a similar approach. Reiss's (2000) study conducted in a comprehensive school in England involved observation of twenty-one students in science lessons for five years from Year 7 to 11 (aged 11 to 16). Reiss interviewed teachers, students and their parents. Although the small sample size meant findings could not be generalised, a detailed and insightful account of perspectives of science emerged.

Reiss's (2000) rationale was twofold; firstly, ethnographic studies that track science lessons over extended periods of time are rare; and secondly, tracking enhances understanding of students' experiences in science that are not revealed by alternative research designs. For example, quantitative strategies such as surveys provide useful insights when repeated at regular time intervals with the same set of respondents. However, surveys tend to take a 'snapshot' of a large population and rely on the quality of the survey instruments and responses.

Tan, Calabrese Barton, Kang & O'Neill (2013) carried out a longitudinal, three-year study of sixteen non-white, 11-14-year-old girls attending a secondary school in the US. This age range was selected to understand non-white girls STEM career choices.

The authors collected data annually in three ''spaces of interest'' (school, home and after school science club) and from three sources, interviews, artefacts and girls' written accounts of their science experiences. Interviews were conducted with parents and teachers. The small sample enabled detailed examination of factors influencing students' career choices.

This study adopts a similar research design by situating the study in a single school in the North East of England using a case study research design. A case study permits the investigation of real-life cases about social issues from a holistic standpoint (Merriam, 1998). By recognising context in any given situation, they provide useful insights into a social phenomenon. Hence, they help to explain 'how' and 'why' a social phenomenon occurs (Yin, 2009, p. 4). The ''setting'' or 'case' could be individuals, a school or an organisation (Wellington, 2000) or an event (Bogdan & Bilken, 1982, cited in Wellington, 2000).

The setting for this study is a former specialist science school given the fictional name ''Farne School''. As a former specialist science school, Farne School is a case of interest because specialist science schools were expected to develop an ethos which reflected their specialist subject (2.4.3), that is, science in this case. Taken into context, students in this school may be expected to develop science identities compared to students from non-specialist schools. Science identities make science career expectations more ''thinkable'' (3.2.2). In addition, possession of science identities suggests that the majority of students in Farne School may also have positive attitudes to science. However, previous studies involving specialist schools tend to focus on GCSE examination outcomes (Jesson & Crossley, 2006) and recruitment into post-16 science courses (Smithers & Robinson, 2007). They do not explore factors which affect students' attitudes and career expectations within the two spheres of influence outlined in the literature review. In addition, students' views of these factors are not usually considered. These possibilities make Farne School a case worth exploring.

As a specialist science school, Farne School is both unique and equally representative of many schools in England. The school is unique because of its science specialism and representative due to its non-selective admission policy which is common in comprehensive schools in England (1.6.1). Therefore, a case study design is appropriate as it permits the study of the peculiar and complex nature of a specialist science school such as Farne School (Stake, 1995; Simons, 2000). This is useful as the main purpose of this study is to explore the factors that affect students' attitudes and career expectations towards science pre- and post-14 years old within this specialist science school (1.5).

However, as case studies describe the ''particular rather than the general'' (Thomas, 2011), they are criticised for low generalisability, that is, they cannot be applied to the general population. This criticism is debated. Stake (1995) argues that the purpose of a case study research is primarily to understand the case being studied, that is, for instance, the students within this school, Farne School, and not students in other cases or other schools. From this viewpoint, the value of adopting this research design is in its contribution to our understanding of the factors affecting these students in this school and not in the selection of a sample which is representative of students in the wider population (Stake, 1995; Gobo, 2008). This also means recognising that the interpretation of findings may be subjective (Thomas, 2011).

Others (Wolcott, 1995, cited in Wellington, 2007) and Wellington (2000) argue that while each case is unique, none are so unique that findings cannot be generalised. Wellington (2000) emphasises this:

> In some ways all schools are the same, in other respects they are all different; similarly, for colleges, universities and employers (p. 99).

This argument can be applied to this study. Farne School is a comprehensive school for 11 to 18 year olds. Therefore, although the ethos in Farne School could be considered unique, features such as the locus, school population and internal organisation are not (Chapter 5). Therefore, findings could be generalised beyond the setting of Farne School using the principle of relatability (Bassey, 2000).

The case study approach is useful in educational research (Merriam (1998). In educational research, case studies can be grouped into descriptive, interpretive and evaluative (Merriam, 1998). Descriptive case studies are accounts of phenomena which occur within the data. They provide rudimentary information in areas where little research exists (Merriam, 1998).

Interpretive case studies build on ‘conceptual categories’ which provide evidence to support or challenge an existing theoretical position held prior to data collection. Data gathered are analysed inductively. Evaluative case studies are useful when judgement about a social phenomenon is necessary. Educational case studies can be descriptive or a combination of descriptive and any other. This study uses descriptive/interpretive design as this is most useful in meeting research aims of gaining in-depth understanding of students’ attitudes and aspirations in science as they progress through school.

4.5 Pilot study

Initially, the research was designed to track a cohort of students, aged 12 to 13, that is students in Year 8, from schools with contrasting science-based ethos. The rationale for this was that school ethos could impact on students’ attitudes and career expectations. This year group was chosen for two reasons as evidence indicates that students’ subject–oriented attitudes have not yet become ‘fixed’ (Osborne et al., 2003), so remain flexible. A pilot study was important to test data collection instruments for suitability and effectiveness. Two schools in the East Midlands where the researcher worked previously provided access, together with a third school in the locality of the main study.

The pilot study was conducted from July to September 2014. However, difficulties in gaining access before and after the pilot study necessitated a review of the research design to focus from a comparison of Year 8 students in a range of schools to use of one school only. So, findings from the pilot study are not reported as they became irrelevant to the current study. However, they provided a useful starting point in the development of data collection instruments such as interview guides and questionnaires which were used in the main study.

4.6 Research ethics and consent

Caution is required to ensure participants are not misrepresented by research processes (Bogdan & Taylor, 1998 cited in Berg & Lune, 2014). Hence, prior to the start of the study, approval was sought and obtained from the University's School of Education Ethics Committee (Appendices 1-2) which is consistent with British Educational Research Association (2011) ethical guidelines.

In addition to ethical approval, a Disclosure and Barring Service (DBS, previously Criminal Records Bureau) Certificate was obtained which permitted the researcher to work with students unsupervised.

After identifying potential participants, verbal and written consent were sought from individual participants. Oral consent was obtained from teachers whose lessons were to be observed which was supported by written consent.

Written consent (Appendix 3) was obtained from members of staff who participated in the study. In total, eleven members of staff participated. Staff participation and level of involvement are discussed in section 4.7.1.

Letters were sent to students' parents/guardians in participating classes explaining the project (Appendix 4). Parents/guardians gave permission for children/wards to participate in lesson observation, group discussions and to complete questionnaires. In addition, parents of students involved in group discussions provided written consent to participate. Students were able to opt out of group discussions at any time. Research aims were discussed with all participants. Participants were informed that they could withdraw from the study at any time. Data were gathered in confidence and not used for any purpose other than preparation of this thesis and related publications.

Data reported here, and photographs used in the study are used with permission from the school's leadership.

Names have been removed and substituted with pseudonyms for staff and students. Science groups are anonymised using gemstones and primary schools using the names of Rivers in North East England.

Primary schools whose students attend from schools outside what the school calls the ‘’Primary Cluster’’ (5.3.2) are grouped together as ‘Non-cluster schools’. The number of students from non-cluster primary schools are between one and three. Pseudonyms used for science groups and primary schools are summarised in Table 4.3.

Year group		Pseudonyms		
		Science groups		Primary Schools
Year 8	1	Emerald	1	Allen
	2	Pearl	2	Bain
	3	Garnet	3	Calder
	4	Sapphire	4	Don
	5	Jade	5	Nidd
	6	Moonstone	6	Tees
Year 10 Double Award Physics group	7	10 Topaz	7	Non-cluster schools
Year 12 AS Physics group	8	12 Ruby		

Table 4.3: Pseudonyms of science groups and primary schools

An ethical issue arose from preventing students making negative personal remarks about teachers and peers, while trying to collect honest responses. This was resolved by reiterating the purpose of the research and stressing the need to be honest and respectful of their peers and teachers.

4.7 Main study: sample selection

The sample used for any research should meet the proposed aims and provide enough data which when analysed, answer the research questions (Morse & Field cited in Braun & Clarke, 2013). In consideration of the spheres of influence identified in Chapters 1 and 2, sample selection occurred in two stages; school selection and identification of individual participants.

4.7.1 School selection: Farne School

Eighty-five percent of 11 to 16 year old students in England attend a state-funded secondary school and the remainder attend fee-paying independent schools. In selecting a school for this study, the school needed to be representative to help generalisability of findings.

Hence, consideration was given to schools with a fully comprehensive admissions policy (Glossary; section 1.6.1). In the area of North East England which provided the locus for the study, there are thirteen secondary schools for 11 to 18 year olds. Schools funded directly by a religious foundation (the Church of England or the Roman Catholic Church) were excluded to avoid faith being a factor in the school's ethos and student intake. Headteachers of the remaining schools were contacted directly by email (Appendix 5) in September 2014. Of the schools which responded, Farne School immediately provided contact details of the Head of Science, so I decided to work with this school.

At the time data were collected, the proportion of 16 year old students achieving five or more GCSEs including English and Mathematics, at the highest grades, referred to as A*s – C was a performance indicator used in judging secondary schools in England. Table 4.4 shows that Farne School's GCSE performance from 2003 to 2014 was consistently better than County and national figures.

Year	**Percentage of students achieving 5A*-C in GCSE including English and Mathematics**		
	Farne	*Hazel County*	*State funded schools in England*
2014	62.0	57.6	56.6
2013	70.0	63.1	60.6
2012	74.0	62.5	58.8
2011	71.0	60.0	58.2
2010	70.0	55.8	55.2
2009	61.0	48.7	50.7
2008	50.0	44.5	47.6
2007	53.0	42.3	46.8
2006	61.0	40.4	45.8
2005	77.0	51.3	57.1
2004	70.0	46.7	53.7

Table 4.4: Comparing percentages of 16+ students gaining 5 or more A*-C GCSE grades and equivalents including English and Mathematics at Farne School, the local county and nationally from 2004-2014

Farne School had a record of academic achievement in GCSE science examination and previously held ''specialist science'' status before the specialist school scheme was discontinued (2.3.3). Together, these features permit the investigation of students' attitudes and career expectations towards science and the potential benefits ''specialist status'' may have.

Access to this school also contributed to the decision to expand the scope of the study from students in Year 8 to a cross age study of students in Years 8, 10 and 12 respectively. As research evidence suggests that students' attitudes become fixed at fourteen years old, selection of these year groups provided the opportunity to explore the attitudes and aspirations of students pre- and post– fourteen years. These year groups ensured that data were collected in three Key Stages thus providing additional insights into factors that may influence attitudes and aspirations at these three distinct stages of formal education. Participants selected for the study are described next.

Staff sample

Staff in the study included teaching and non-teaching staff members. Of these eight were from the science department, while three were from the wider school community.

Five science teaching staff were involved, including the Head of Science, three teachers whose classes were observed and the Lead Teacher responsible for the Science department's role in Farne School's primary to secondary school transition programme. Their teaching experience ranged from four to twenty years.

Technicians, that is, non-teaching staff responsible for preparation of science experiments and purchase of science resources and equipment were selected for participation due to their indirect contributory roles in students' science experience. The technicians' working experience at Farne School ranged from four to eighteen years. This made it possible to obtain information about students' attitudes and career expectations towards science from a perspective that is not usually sought in attitudinal studies.

Mr. McKay who is a member of the senior leadership team has 28 years teaching experience, 23 of this at Farne School. He has been a member of the senior leadership team for 15 years, placing him in a position to provide useful information of the changes Farne School has undergone pre- and post- specialist science status.

Two staff members involved in Farne School's extra-curricular provision participated. This sub-group included a full-time non-teaching staff member, ''Mrs. McCarthy'' who holds the role of STEM and Enterprise Manager.

The teacher leading Farne School's Primary to Secondary School Transition Programme provided insights from a whole school perspective on the contribution of the science department to the school's primary to secondary transition.

Table 4.5 summarises this information, showing staff involved and level of involvement in the study.

Staff				**Involvement**
Science teaching staff				
Pseudonyms		**Specialism**	**Role**	
1	Mr. Hadfield	Biology	Head of Science	Informal discussions
2	Mrs. Natanson	Biology	Dep. Head of Science-KS3 (on leave at start of study)	Interviews Lesson observations
3	Mr. Martins	Physics	Dep. Head of Science-KS4	Interviews Lesson observations
4	Mrs. Sinclair	Biology	Science Coordinator for primary–secondary school transition	Interview
5	Mrs. Anthony	Chemistry	Substitute teacher covering Mrs. Natanson's science class at start of study.	Lesson observations
Science Technicians				
6	Mr. Case		Senior Technician	Interview
7	Mrs. Johnson		Technician	Interview
8	Mrs. Nicholson		Technician	Interview
Other staff				
9	Mr. McKay		Assistant Headteacher	Interview
10	Mrs. Mulligan		Teacher in charge of Farne School's primary to secondary school transition programme	Interview
11	Mrs. McCarthy		Staff in charge of STEM enrichment	Interview

Table 4.5: Farne School staff sample: pseudonyms, roles and involvement

4.7.2 Student selection

At the time of the study, 1200 students, age 11 to 18 attended the school. Approximately 400 were in the Year groups selected for the study. Studying all of them within the confines of the qualitative strategy employed in this study, would be inappropriate, so selection was required.

The next step was to decide which students should be investigated. Sub-groups were identified by purposeful sampling to provide additional insights. In Years 8 and 10, sub-groups were chosen based on academic attainments. Attainment of A*-C grades in GCSE examinations measures academic achievement (Department for Education, 2014). Hence, inclusion of students believed to be capable of at least a 'C' grade in GCSE science ensured that students in the sample were of similar academic ability/attainment. Based on this criterion, the Head of Science selected the following sub-groups in Years 8 and 10:

''8 Emerald'', Key Stage 3 (ages 12 to 13)

This is a class of thirty students comprising sixteen girls and fourteen boys. Students in ''8 Emerald'' were judged as working at Level 5 and above based on school assessments. Level 5 is the fifth band in a series of eight bands in the National Curriculum used to determine a student's attainment in school assessments prior to 2014 (www.gov.uk/national-curriculum, n.d.). Students in this band are expected to achieve at least a C grade in GCSE examinations.

''10 Topaz'', Key Stage 4 (ages 14 to 15)

These students are in the first year of Key Stage 4. ''10 Topaz'' is a GCSE Physics class of twenty-four students made up of fourteen boys and ten girls. Based on prior attainment, students in this class are expected to achieve at least a C grade in their GCSE examinations.

''12 Ruby'', Key Stage 5 (ages 16-17)

12 Ruby is an Advanced Subsidiary (AS) level physics class comprising twenty students; fifteen boys and five girls. Participants from this group attained A*-C grades in GCSE science (6.4).

Year 8

In addition to 8 Emerald, data were collected from the whole year group. Year 8 is a mid-point in Key Stage 3 so is a suitable point to collect data from students who are yet to choose their GCSE subjects.

Hence, data are collected from the entire cohort of students to generate a wider range of students' views regarding their attitudes and career expectations towards science.

Parents/Guardians

Parents/guardians whose children were involved in group discussions were invited to participate in the study; ten consented. Data were collected from this sub-group to support student data, thus improving reliability of data collected in the individual sphere of influence.

4.8 Main study: data collection methods

As mentioned earlier, case studies permit use of multiple data sources. Using multiple sources allows weaknesses in one method to be compensated by strengths of another (Denscombe, 2007) and permits data triangulation. This means observing a research issue from at least two different viewpoints (Flick, 2006), generating a complete picture of the research problem (Denscombe, 2007; Stake, 2005). Triangulation raises the quality and certainty of outcomes as more than a single source of evidence is applied to support a fact or event (Yin, 2009).

Methods such as documents which are used in both spheres are only discussed in the school sphere to avoid repetition. The data collection process is discussed separately in section 4.9. Figure 4.1 shows connections between data collection methods, research questions and the spheres about which they provide information. Methods used, and accompanying rationale are discussed in the next section.

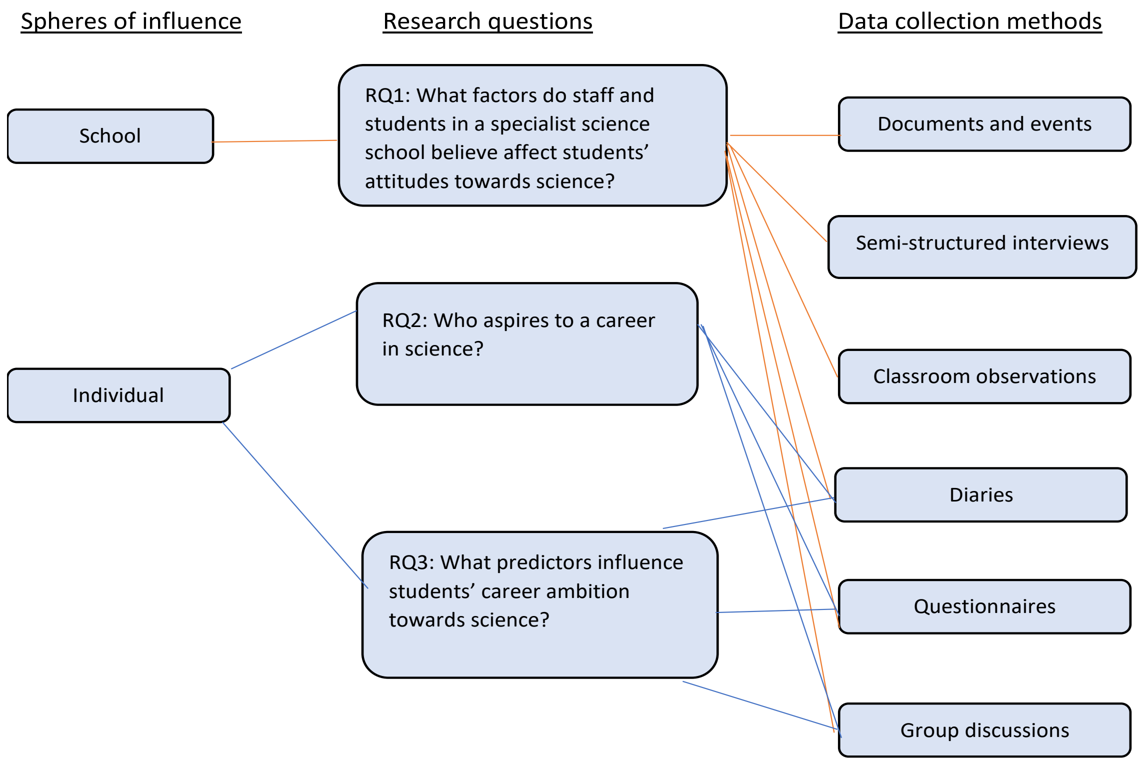

Figure 4.1: Spheres of influence, research questions and data collection methods

4.8.1 Data collection methods: school level

Data were collected from semi-structured individual interviews with science staff and members of the wider school community including a member of the senior leadership team; hard copy and electronic documents including the department's Handbook and school's website to provide insights about science provision from a wider school perspective. The data collection process for the school sphere of influence is discussed in section 4.9.1.

Semi-structured interviews

Interviews are conducted in a pre-determined location to elicit information from participants with minimal interruptions (O'Reilly, 2005). The interview structure adopted depends on the degree of flexibility the researcher requires. Interviews can be categorised as structured, unstructured or semi-structured.

Structured interviews triangulate survey data via pre-determined questions. They do not deviate from these questions and are asked in the sequence they appear in the survey, so results produced are standardised and objective (O'Reilly, 2005). Structured interviews were not used in this study because their inherent lack of flexibility makes in depth exploration of ideas difficult.

Unstructured interviews adopt the style of an informal conversation in which the researcher introduces topics to the interviewee who can respond as she/he wishes (O'Reilly, 2005). A disadvantage is that the interview may lose focus if the interviewee takes control. Data generated might be unsuitable for addressing research questions if the interviewee can deviate from research aims. For these reasons, this method was considered unsuitable for this study.

Semi-structured interviews combine elements of structured and unstructured interviews. A semi-structured interview focuses on areas of interest, allowing new questions to be introduced as appropriate (O'Reilly, 2005). This provides the researcher with an opportunity to check accuracy of events, thus improving validity. This method was used for data collection as the researcher and interviewee have flexibility; the interviewee can provide detail, while the researcher can refocus discussion as required.

Interview schedules varied depending on staff members' role. Teacher interview schedules were adapted from Shibeci (1981), Reiss (2000) and Naugah & Watts (2013). Technician and leadership staff interviews were based on professional experience. Schedules consisted of introductory questions followed by open-ended questions depending on the individual's role in the school. For example, the same schedule was used for science teachers (Appendix 6), while a different one was used for the senior leadership member involved in the study (Appendix 7). Questions focused on teaching strategies, students' attitudes in science, including by gender and teachers' role in promoting positive attitudes.

Documents

A document, defined as a 'record of an event or process' (McCulloch, 2017) is a convenient source of data (Merriam, 1988). Examples include diaries, newspaper articles and websites. Documents are useful data sources in conjunction with other methods. However, the value of documents is limited by the possibility that the information they offer is designed for a specific audience or purpose (Merriam, 1998). School documents used in this study include the schools' website, science department Handbook and schemes of work for the 2014/2015 academic year.

4.8.2 Data collection methods: student level

In this sphere, lesson observations, group discussions, questionnaires and student diaries were used to generate understandings of students' attitudes and career expectations towards science. How the data were collected are discussed in section 4.9.2.

Lesson observations

Observations can be covert or overt. Covert observations are carried out without participants' full consent and knowledge, so for ethical reasons were not suitable for this project. Overt observations (Reiss, 2000; Tan et al., 2013) make the researcher's identity known to participants so observations are conducted openly. Observations were carried out by participant observation to gain first-hand understanding of the dynamics of science lessons in Farne School.

Data gathered by this method are frequently associated with ethnography (Fetterman, 1998; Jones, 2010). Ethnography is a process and a product (Handwerker, 2001) documenting feelings, knowledge and behaviour of people within the context of their everyday lives. In education research, participant observation can be applied ''to understand such things such as classroom behavior, the learning process, group values and behavior, organisational management and change'' (Newby, 2014: p. 61).

The term ''participant observation'' combines two methods which are contradictory. *''To participate''* means getting involved, joining in, being subjective, and immersing oneself (O'Reilly, 2005). ''*To observe*'' requires being objective, keeping emotional and perhaps physical distance, being scientific, clear-eyed, unbiased and critical (O'Reilly, 2005).

The researcher as participant observer must address the dilemma of being immersed in the field to become part of the group under investigation, while simultaneously stepping back to be objective when observing the group. O'Reilly (2005) argues this feature is a strength, as by participating, the ''strange becomes familiar'' and by observing the ''familiar becomes strange''. Participation thus leads to deeper understanding of hitherto unfamiliar behaviours and norms. Similarly, observation of the field, leads to seeing the supposedly familiar with fresh eyes. Hence, the inherent tension in participant observation does not need resolution. Depending on purpose, one method can be dominant. Two types of participant observation were considered namely, *participant-as-observer* and *observer-as-participant*.

The *participant-as-observer* 'openly engages with the research group' (Watt & Jones, 2010) and the researcher's identity is known to the group. The researcher actively participates more than they observe. This role was unsuitable for this study as the author's past as a science teacher would increase the potential for researcher's bias and create the potential for unwarranted intervention in science lessons.

The *observer-as-participant* is the role adopted. In this stance, researcher identity is known to participants, thus meeting ethical requirements. The observer-as-participant is sufficiently detached to undertake observations and flexible to engage with the group to a limited degree (Watt & Jones, 2010). This means the researcher would only occasionally interact with participants (DeWalt & DeWalt, 2001). This role permits inclusion of research methods such as group discussions (Angrosino, 2007), thus providing a holistic perspective of the research problem being investigated.

A weakness of participant observation is subjectivity. This can stem from researcher bias, that is, his/her prior knowledge and interpretation of the social issue (Pole & Morrison, 2003).

Pole & Morrison (2003) dismiss subjectivity, pointing out that the method does not aspire to produce a ‘distanced, scientific and objective account of the social world, but rather an ‘account that recognises the subjective reality of the experiences of those who constitute and construct the social world (p. 5). This stance resonates with research aims and philosophy for this study which seek to provide an account of students’ attitudes and career expectations towards science while recognising the researcher’s background as a former science teacher.

Researcher reactivity, that is, the possibility of affecting people being studied (Hammersley & Atkinson, 2007; Pole & Morrison, 2003) is another weakness of participant observation. People, including students can alter their behaviour when an unfamiliar person is introduced into their environment thus distorting the true picture. How this is addressed is discussed in the data collection process, section 4.9.2.

Group discussions

Group discussions are like group interviews. They are discussions held between a researcher and more than one person (LeCompte & Schensual, 1999). Group discussions give participants a voice, enabling them to report from an insider’s perspective. They increase the number of participants and opinions beyond those obtained in one to one interviews (Denscombe 2007), allowing multiple answers. The range of responses and viewpoints generated by this method increases the representativeness of data collected by broadening the spectrum of opinions and views (Denscombe, 2007). They are useful in schools where access to individual students for in-depth discussions might be difficult to negotiate (Simons, 2009). Similarly, group discussions are beneficial in enabling students who may otherwise feel intimidated by one to one interviews to express their views (Simons, 2009). A disadvantage is that answers can be inconsistent. For example, interviewees may say they do something different from their actual practice. This need not be problematic if the researcher adopts the view that these type of interviews complement participant observations (O’Reilly, 2005). Hence, they can be used to explain what the participant observer sees and experiences (Fetterman, 1989).

Focus groups also generate views from a group of people. A focus group uses group dynamics to obtain information on a topic pre-determined by the researcher (Denscombe, 2007). This is designed for groups of six to eight participants (Morgan, 2006) who share similar knowledge or experiences of a social phenomenon. Focus groups can provide explicit insights into participants' thoughts and actions as they share and compare shared experiences (Morgan, 2006). Focus group discussions last between 1½ to 2 hours to allow participants' opinions to be heard (Denscombe (2007). Nevertheless, they have limitations. For instance, the researcher has less control of the direction of discussions as this, may depend on group dynamics.

Focus groups and group discussions provide insights of students' perceptions and observations about their science learning and context (Simons, 2009); information that may be difficult to obtain through individual interviews. In this study, elements of both methods were used to maximise access to students which were limited to 20 to 30 minutes per session. Stimulus material used ranged from participation in science-related activities at home, science in the preceding and current Key Stage, attitudes towards science, career aspirations and teaching.

Diaries

The use of documents as a data source was discussed in section 4.7.1 in the school sphere and is therefore not repeated here.

Questionnaires

Questionnaires consist of a list of questions designed to collect information from people directly (Matthews & Ross, 2010) about a research topic of interest. Questions can either be open or closed. Open questions collect unstructured data while closed questions collect structured data (Denscombe, 2007; Matthews & Ross, 2010). Open questions allow respondents to answer questions as they wish, thus generating a rich source of data. However, data analysis could be time-consuming as data gathered are unrestricted. Closed questions restrict respondents to a selection of two or more answers, thus providing data which could be easily analysed using statistical software.

However, restriction placed on respondents' answers means that depths of respondents' feelings or attitudes are not captured effectively. Questionnaires were used in this study to collect data from students. Open and closed questions were used for data collection to maximise the strengths of both types of questions. Questions were designed to complement data from other sources in the students' sphere of influence (Figure 4.1,). Two sets of questionnaires were produced to elicit relevant data from different sub-groups, namely student and parents/guardians questionnaires. Student questionnaires are discussed.

Student questionnaires

Questionnaires began with basic student information such as year group, gender, student name and primary school attended. Variations to this included GCSE course of study for students in Year 10 and GCSE examination grades and AS subject choices for students in Year 12. Questions in each area were modified to suit each year group. For example, in the section about science in the preceding Key Stage, students in Year 8 answered questions about Key Stage 2 (Appendix 8), Year 10 answered questions about Key Stage 3 (Appendix 9) while Year 12 answered questions about Key Stage 4 (Appendix 10). Table 4.6 shows links to research questions.

Questions	Areas covered	Research question addressed
1-10	Science capital: participation in science-related activities out of school	RQs 2 and 3
11-19	Prior science experience	RQ 2 and 3
20-21	Self-efficacy in science	RQ3
22	Role of Farne School in science experience	RQs 2 and 3
23-24	Science aspiration	RQ3
25	Social class and science capital: employment in students' families	RQ2 and 3

Table 4.6: Link between student questionnaire and research questions

Science capital and social class

Research literature suggests that participation in science related activities out of school influences attitudes and career expectations towards science (Calabrese Barton, 1998). This can contribute to the science capital a student possesses (Archer et al, 2013).

Participation in these activities is usually connected to social class (Archer et al., 2013). Hence, there is a need to collect information relating to students' science capital and social class. This information was collected in two ways:

Participation in science-related activities out of school: Questions in this section consisted of close and open ended questions. Together, responses were used to determine the amount of students' ''science capital''. Closed questions were binary questions requiring yes/no responses. The eight items in this section were aggregated as follows based on participation in science activities out of school: *Low*: participation in 1–3 activities*;* *moderate*: 4-6 and *high:* 7-8. It is of course understood that this can be regarded as arbitrary, however, grouping the activities this way enables comparisons to be made between students in the study.

Background information of employment in students' families: these questions provided information on employment status and occupation types in students' families. This was used to determine students' science capital and social class.

Science experience: prior and current

Science provision in schools vary. Therefore, awareness of students' prior science experience may be useful in understanding their science backgrounds. Questions in this section ranged from frequency of science lessons to students' understanding of science concepts. Seven binary questions requiring yes/no responses provided this information (Appendix 8). In addition, there was an open–ended question which required students to recall their most memorable science lesson and provide a reason why this was memorable. As Farne School has a science emphasis, students' views of the schools' role in science provision was explored.

Attention is drawn to questions 11 and 19 (Table 4.7) which uses negative and positive responses to reflect students' opinion on the difficulty of science. By wording questions this way, chances of students responding in a set way are reduced, while increasing the likelihood of obtaining more accurate answers (Cox and Cox, 2008).

When you were at primary school, did you…		Yes	No
11	Have science lessons each week?		
12	Find science difficult?		
13	Go on science trips (e.g. Centre for Life, MAGNA Science Adventure Centre, National Space Centre, the National Railway Museum, the Science Museum etc.)?		
14	Find science easy?		
15	Do science experiments?		
16	Have visits from shows such as 'Mad science?		
17	Enjoy doing science?		

Table 4.7: Excerpt on section on primary science experience from Year 8 questionnaire

Self–efficacy in science

These questions required students to rate their ability in science on a scale of 1–10, 1 being low and 10, high. Ratings are categorised as either *low*, *moderate* or *high* as follows: *Low*: 1–4; *Moderate*: 5–6; *High*: 7–10. The use of a rating scale for students to self-report their ability in science offered a cursory but effective way of establishing students' self–efficacy in science. This was followed by an open-ended question requiring an explanation for the ratings awarded.

Science aspiration

In this section, students were asked to rate the likelihood of pursuing a science-related career. As with self–efficacy, ratings are categorised as *low*, *moderate* and *high; Low: 1-4; moderate: 5–6; High:* 7–10. A follow up question requiring an explanation for ratings awarded was included to determine factors which affect students' aspirations in science.

4.9 Main study: data collection process

This section describes the data collection process, challenges encountered, and steps taken to mitigate them. Data were collected at two levels in the spheres of influence. In the school sphere, this was at departmental and whole school level, while in the individual level, this was at student and parent level respectively. Table 4.8 summarises data collected and times of collection.

Data collection method	From	To	School sphere		Individual sphere				
			Science Department	Whole school	Students				Parents
					Year 8	8 Emerald	10 Topaz	12 Ruby	
Questionnaires	Dec 2014	Dec 2014			√	√	x	√	x
	June 2015	June 2015			√	√	√	√	√
Group discussions	June 2015	July 2015				√	√	√	
Observations	Nov 2014	June 2015				√	√	√	
Diaries	Mar 2015	June 2015				√	√	x	
Documents	Nov 2014	July 2016	√	√					
Interviews	July 2015	July 2015	√	√					

Table 4.8: Overview of data collection process

4.9.1 School data collection process

Semi-structured interviews

Interviews were arranged via email, and occurred during the school day, lasting between 15 to 60 minutes. Interviews with science teaching staff were conducted in a teaching room or laboratory between lessons. Interviews with technicians were conducted in the science *preparation room.* The preparation room is used by science technicians to store and prepare chemicals/equipment for science experiments. Interviews with other school staff were conducted in their offices. All interviews were audio-recorded and transcribed. Table 4.9 indicates dates and duration of interviews.

Pseudonyms		Role	Date of interview	Duration
1	Mrs. Natanson	Deputy Head of Science-KS3	06.07.15	30 minutes
2	Mr. Martins	Deputy Head of Science-KS4	06.07.15 14.07.15	22 minutes 23 minutes
3	Mrs. Sinclair	Science coordinator for primary to secondary school transition	06.07.15	40 minutes
[redacted]				
4	Mr. Case	Senior Technician	10.07.15	19 minutes
5	Mrs. Johnson	Technician		21 minutes
7	Mrs. Nicholson	Technician		15 minutes
[redacted]				
		Other staff		
7	Mr. McKay	Assistant Headteacher	08.07.15 14.07.15	30 minutes
8	Mrs. Mulligan	Teacher in charge of Farne School's primary to secondary school transition programme	17.07.15	30 minutes
9	Mrs. McCarthy	Staff in charge of STEM enrichment	08.07.15	60 minutes

Table 4.9: Data collection via semi-structured interviews

Documents

Documents such as the science department Handbook for Academic Year 2014/15 were provided by the Head of Science. The programme of study for Year 8 was provided by the Deputy Head of Science, KS3. The school's website was used to provide additional contextual information. Table 4.10 summarises these information and reasons for their use.

Document	Date collected	Source	Relevance	Analysis
School prospectus	27.11.14	School website	Background to school ethos	Section 4.9
Programme of study	06.07.15	Heads of Key Stages	Describes content of the curriculum to be studied and the relevant year it should be studied.	
Science Departmental Handbook		Head of Science	Ethos of department and vision for science provision	

Table 4.10: Data collection via documents

Other data sources

Other sources of data collected include informal conversations with staff and attendance at events and visits to some institutions.

Informal conversations

This occurred during break and lunch times in the science office or staff room. Conversations with the Head of Science usually occurred this way. These conversations were recorded as field notes.

Events and visits

Attendance at a Year 12 Internship celebratory event and a Year 10 presentation provided supplementary information on the school's enrichment activities. A science lesson was observed at one of the feeder (Glossary) primary schools, Tees School. This provided additional information about Farne School's work with the wider community.

4.9.2 Student data collection process

Data collection occurred from September 2014 to July 2015. This included 17 hours of science lesson observations undertaken from November 2014 to July 2015. In addition, ten focus group discussions were conducted with a small number of students from the three participating science groups. Questionnaires were used to collect data from students and parents. Documents, such as student diaries and the school prospectus provided supplementary information.

Lesson observations

Lesson observations took place in science lessons taught to ‘’8 Emerald’’, ‘’10 Topaz’’ and ‘’12 Ruby’’. 17 Lesson observations were carried out over eight months from November 2014 to July 2015. Table 4.11 shows lessons observed in the study.

Class	Pseudonyms of teachers	Timetabled lessons/week	% observed based on access of 10 lessons/group	Dates	Time	Topic	Number of students	
							Girls	Boys
8 Emerald	Mrs. Anthony	3	50	29.01.15	10:20 - 11:20	Impact of volcanoes on communities	16	14
				06.02.15	10:20 - 11:20	Assessment		
				26.02.15	10:20 - 11:20	Impact of human activity on the environment		
				09.06.15	14:20 – 15:20	Communicating and collaborating in science		
	Mrs. Natanson			10.06.15	10:20 – 11:20	Assessment		
				11.06.15	10:20 – 11:20			
10 Topaz	Mr. Martins	2	50	19.11.14	11:20 – 12:20	ISA* revision lesson	10	14
				10.12.14	11:20 - 12:20	Reflection and refraction		
				12.01.15	13:20 – 14:20	Revision lesson		
				02.02.15	13:20 – 14:20	The Doppler Effect		
				23.02.15	13:20 – 14: 20	Resultant forces		
12 Ruby		3	60	27.11.14	10:20 - 11: 20	Revision of GCSE waves	5	15
				18.12.14	10.:20 - 11:20	Revision on past examination papers		
				22.01.15	10:20 – 11:20	Diffraction grating		
				12.02.15	10:20 – 11:20	Practical lesson		
				09.07.15	10:20 – 11:20	Student presentations on research projects		
				17.07.15	13:20 – 14:20			

Table 4.11: Overview of lesson observations (* Investigative Skills Assessment – see Glossary)

In participant observation, an open-mind is needed to observe what is going on (Simpson and Tuson, 1995). An open-mind does not mean approaching the field with no preparation or pre-determined ideas of what to observe. In this study, the research questions and aims of the study served as a guiding principle of what to observe. Lesson observations commenced at the start of the academic year. Observations were not limited to science lessons. For example, ‘’8 Emerald’’ was observed in a Mathematics lessons and a drama presentation, while an ‘’internship celebratory evening’’ was attended with ‘’12 Ruby’’. These initial ad hoc observations allowed students to become used to the researcher’s presence as staff member before actual lesson observations started. Being accepted as part of the school community, was useful when arranging group discussions

Regular observations occurred over four months from November 2014 to February 2015 (Table 4.11) on a three-week rotational basis as permitted by the Head of Science. Each science class was observed once in this cycle. Additional observations then occurred at the end of the academic year from June to July 2015.

How long a researcher should spend conducting observations is discussed. Wolcott (1975 cited in Sanday, 1983) recommends observations within schools should be of one-year duration. However, Fetterman (1998) argues six months is enough to observe behaviour patterns within any community. Paperman’s (2003) study of police surveillance of underground railway stations lasted three months, less than the time recommended by Fetterman (1998) but yielded rich and detailed description. This is reinforced by Angrosino (2007) who maintains that sustained, ‘’repeated and regular’’ observation provides understanding of any culture under study, rather than the length of time spent in the field. Accordingly, lesson observations undertaken in this study from November 2014 to July 2015 were considered enough to gain insights into how students’ attitudes about science change over time, in part due to input from science lessons. This timescale is like that used in observation studies reported elsewhere.

An observer as participant role can affect the behaviour of those observed as explained in section 4.8.1. To reduce this, minimal interaction with the social setting, that is, students in their science lessons was necessary. To achieve this, the researcher was positioned at the back of teaching rooms with focus on capturing student-student and student-teacher interactions. Positioning at the back of the room and making extended observations over an extended period reduce the impact of the researcher's presence (Reiss, 2000). However, as Hammersley (1997) points out:

> '…while, the ethnographer may strive to minimise her or his effects on the situation studied, no one can guarantee this; and sometimes the effects can be significant despite the researcher's best effort' (p. 164).

A participant observer becomes immersed in the life of the group under observation to become a ''knowledgeable tourist or a trusted outsider'' without ''going native'' (Watt & Jones, 2010). In practice, the personal challenge was resolving the tension between being a science teacher familiar with behaviour patterns in a science classroom and a researcher unfamiliar with this specific science setting. To resolve the issue of reverting to default 'teacher mode', the first lesson observation was spent observing everything and anything (Watt and Jones, 2010), from posters on the walls, classroom layout to students' behaviour. This generated a view of the setting from the perspective of a researcher rather than a teacher.

Subsequently, the scope for lesson observations narrowed to focus on events relevant to each year group. O'Reilly (2005), points out that observing broadly at the start and then narrowly towards the end can be ''iterative-inductive'', permitting the focus of the study to be determined towards its end. For example, one area of interest in 12 Ruby, the AS physics class, was teacher-student gender interactions. There are five girls in this physics class of twenty students. Hence, there was a need to investigate if this will be a disadvantage for the girls. Previous lesson observations had shown that students answered questions in ''12 Ruby'' in one of two ways, either because they volunteered themselves by a show of hand or because they were called upon by name.

Questioning is easy to record by counting; therefore, it was used as a method of determining potential teacher-student gender interactions. The lesson used for this exercise was ideal because it was split into two halves; the first was a teacher-led theory session which lasted for 30 minutes and the second half was a practical experiment. During the theory session, focus was strictly on keeping a tally on questions asked and gender of student who answered; questioning technique was not explored. Four girls and fifteen boys were present in the lesson. Each time Mr. Martins asked a question, the gender of the student was recorded (Appendix 11). The information generated was useful in making a judgement on girls' experiences in an AS physics classroom based on actual data collected rather than pre-conceived ideas garnered from literature or personal experience. Given that the boys outnumbered girls by three to one, the prospect of questions being answered was already skewed in favour of boys. However, questioning provided a simple visual and effective method of establishing student-teacher gender interactions and potential gender bias. This is reported in section 6.4.1.

Group discussions

Student availability was limited to 15 to 30 minutes per session, so to maximise the time available, sessions were conducted as quasi focus groups. These quasi focus group sessions permitted the use of the structure of group discussions and focus group sessions. Through these 'quasi focus group' sessions, valuable insights which would otherwise have been difficult to obtain were educed. Sessions were arranged with students after the second lesson observation in the school and lasted between 20 to 30 minutes depending on the year group. Sessions were conducted primarily as group discussions with a stimulus focus introduced for group discussions. Attendance in each session varied, typically between 4 and 8 students per session. Table 4.12 summarises this information. All sessions were audio-recorded. Nine sessions were held in total; five with ''8 Emerald'', three with ''10 Topaz'' and one with ''12 Ruby''.

Classes	Number of sessions	Date	Length (minutes)	Number attending	Stimulus material
8 Emerald	6	11.06	15	13	Factors affecting learning (e.g. time of day, room, teacher)
		18.06	15	8	
		25.06	15	9	Perception of science
		02.07	15	6	Practical work
		09.07	15	8	Science experience in Primary School
10 Topaz	3	08.07	30	5	Participation in science-related activities out of school Science in the preceding Key Stage Practical work
		13.07	33	6	Stereotypical images Current school experiences
		16.07	30	6	Career aspirations Role of school in science learning
12 Ruby	1	14.07	20	4	Internship Programme The role of teachers AS Subject choice STEM Enrichment Manager

Table 4.12: Data collection via group discussions

Diaries

Students involved in the group discussions were provided with notebooks to keep a diary of their science learning experience, making notes of their thoughts on events, lessons and anything that created a positive or negative experience about science. Ten were handed out, four were returned. Three were from ''10 Topaz'' and one from ''8 Emerald''. Although two were initially returned from ''12 Ruby'', students were asked to continue making entries in their diaries.

When asked for the diaries, students could not produce them. This incident with ''12 Ruby'' underlines the importance of collecting and storing data when it is available even when it appears incomplete, otherwise valuable data may be lost regardless of the researcher's best effort to retrieve them.

<u>Questionnaires</u>

Data were collected according to the timetable shown in Table 4.13. In *Phase 1*, one hundred and fifty questionnaires were distributed to Year 8 and twenty to ''12 Ruby'' in December 2014. Due to examination pressures, ''10 Topaz'' were not involved in this phase of data collection as agreed with the Head of Science. *Phase 2* questionnaires were distributed and returned in June 2015, a month before the end of the 2014/15 academic year. Questionnaires were distributed to parents of students who participated in the group discussions. Data were collected at these times so that phase *1* serves as a reference point for students' attitudes and aspirations in science and phase 2 as the end-point. Together, comparisons could then be made between students' attitudes and aspirations at the start and end of the academic year. In phase 1, the return rate was 60%, and 75% including parent questionnaire in phase 2. Table 4.13 summarises questionnaire distribution and collection. Only 42 students completed both phases of data collection. The trajectories of some of these students in relation to their aspirations in science are reported in Chapter 7.

Groups	**Phase 1** December 2014				**Phase 2** June 2015			
	Distributed	Returned	Discarded	Sample used	Distributed	Returned	Discarded	Sample used
Year 8 (including 8 Emerald)	150	90	7	83	150	115	8	107
10 Topaz	X				25	25	5	20
12 Ruby	20	12	-	12	12	5	-	5
Total	170	102	7	95	187	145	13	132
Total used in study: 227 Number of students participating in phases 1 and 2: 42								

Table 4.13: Data collection via questionnaires

4.10 Main study: data analysis

Data analysis involves finding ‘meaning’ in data (Guest, MacQueen & Namey 2012). The method of analysis depends on the nature of the data. This section describes how data generated were analysed. Data analysis employed is primarily qualitative. Statistical analysis beyond the use of rudimentary percentage calculations and frequency of responses are not considered. The use of the statistical software, SPSS, version 20 software (IBM SPSS, 2016) enabled data manipulation, thus reducing time that would otherwise have been spent extracting data or cross-referencing information within data. Two methods of qualitative analysis were considered in this study: grounded theory and thematic analysis.

4.10.1 Grounded theory

In grounded theory, data collection and analysis occur simultaneously (Gibbs, 2007). The process generates rich data used to develop a plausible theory about the phenomenon under investigation (Braun & Clarke, 2006). Theme discovery and development depends on constant comparison and theoretical sampling (Gibbs, 2007). Theoretical sampling involves data collection and analysis followed by collection of more data from new cases until saturation, that is, the point at which no further themes are discovered. Theoretical sampling, which is central to grounded theory, was considered unfeasible in this study as access to participants, especially teachers and students, was limited by time and availability. Therefore, grounded theory was not considered for data analysis.

4.10.2 Thematic analysis

Thematic analysis is the primary method applied in this study. This supports the interpretivist position (4. 3) of a socially constructed world. Thematic analysis is ‘’a method of identifying, analysing and reporting patterns (themes) within data’’ (Braun & Clark, 2006; p. 79). Unlike, grounded theory, thematic analysis is not linked to a specific theoretical framework, thus making it flexible and accessible (Braun & Clarke, 2006). Theoretical flexibility makes this a useful research tool for organising and describing data in detail (Braun & Clarke, 2006).

Furthermore, interpretation of aspects of the research topic is permissible (Boyatzis, 1998 as cited in Clarke, 2006). Analysis drew on the works of Braun & Clark (2006) and Boyatziz (1998), while King's (2012) Template analysis was used to create a coding template. Template analysis is used for any kind of textual data, allowing organisation of relevant themes identified in data in a meaningful and useful manner (King, 2012). This made it suitable for data collected in this study (Figure 4.2), which were mainly textual such as interview transcripts, diaries and open-ended responses in student questionnaires. Table 4.14 summarises the main stages in thematic analysis (Braun & Clark, 2006) which were modified to suit this study.

Phase		Description
1	Familiarising yourself with the data	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas
2	Generating initial codes	Coding interesting features of the data in a systematic fashion across the entire data set, collecting data relevant to each code
3	Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme
4	Renewing themes	Checking if the themes work in relation to the coded extracts (level 1) and the entire data set (level 2), generating a thematic map of the analysis
5	Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme
6	Producing the report	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back the analysis to the research question and literature, producing a scholarly report of the analysis

Table 4.14: Steps in thematic analysis (Braun & Clarke, 2006, p. 87)

Steps in analysis

Steps 1 to 3 were steps in the analysis of each data set, so these are reported as a generic summary, followed by detailed descriptions of steps taken within spheres of influence.

Step 1: Data familiarisation

Data familiarisation is a continuous process. However, audio transcription, data cleaning and entry can accelerate this process. A selection of audio recordings of group discussions and interviews were transcribed using Express Scribe, a free transcription software (www.nch.com.au, n.d.).

Questionnaires were checked for completeness. Incomplete questionnaires, that is, student questionnaires missing whole sections and personal identifiable data such as names, gender and science groups were discarded. The number of complete student questionnaires in total were 227. Of this, 95 were from phase 1 and 132 from phase 2. Pseudonyms were given to each respondent as well as schools to preserve anonymity. Transcription and open-ended questionnaire responses were collated into *Microsoft Office Word*, 2016. Closed-ended questionnaire responses were entered in *Microsoft Office*, 2015 Excel spreadsheet, after which data were cleaned and then exported into SPSS version 20 for further analysis.

Steps 2: Generating initial codes

Codes are words or short phrases used to represent portions of data (Miles & Huberman, 1994). Coding makes searching data easier, enables comparisons and identifications of patterns requiring investigation. Appendix 12 shows an excerpt of student questionnaire responses and how these was initially coded.

Step 3: Searching for themes

Themes are patterns 'found in the information that at minimum describes and organises the possible observations and at maximum interprets aspects of the phenomenon' (Boyatzis, 1998: p.4). Themes emerge inductively, or ''bottom up'' and deductively or ''top down'' (Boyatzis, 1998; Braun & Clarke, 2006). Inductive themes are identified from data, so they are data-driven (Patton, 1990 cited in Braun & Clarke, 2006).

Deductive themes are identified through the researcher's subjective experience or literature review, so are theory-driven (Ryan & Bernard, 2003). Theme emergence is dynamic and iterative (Braun & Clarke, 2006; Denscombe, 2007). Thus, the researcher moves ''back and forth'', making comparisons with codes, categories and concepts that have been developed (Miles & Huberman, 1994). The coding template produced is applied across the data set. To save time in a small scale, time bound study such as this, the spheres of influence identified in Chapter 1 were used as '*a priori' themes*. *A priori* themes accelerate the initial coding phase (King, 2012).

Once, *a priori* themes were identified, segments or responses relevant to research questions from each data set (Figure 4. 2) were marked and coded to the corresponding theme using *Microsoft Office Word, New comment* function (Appendix 13). Data were then analysed by the sphere of influence under which they were collected.

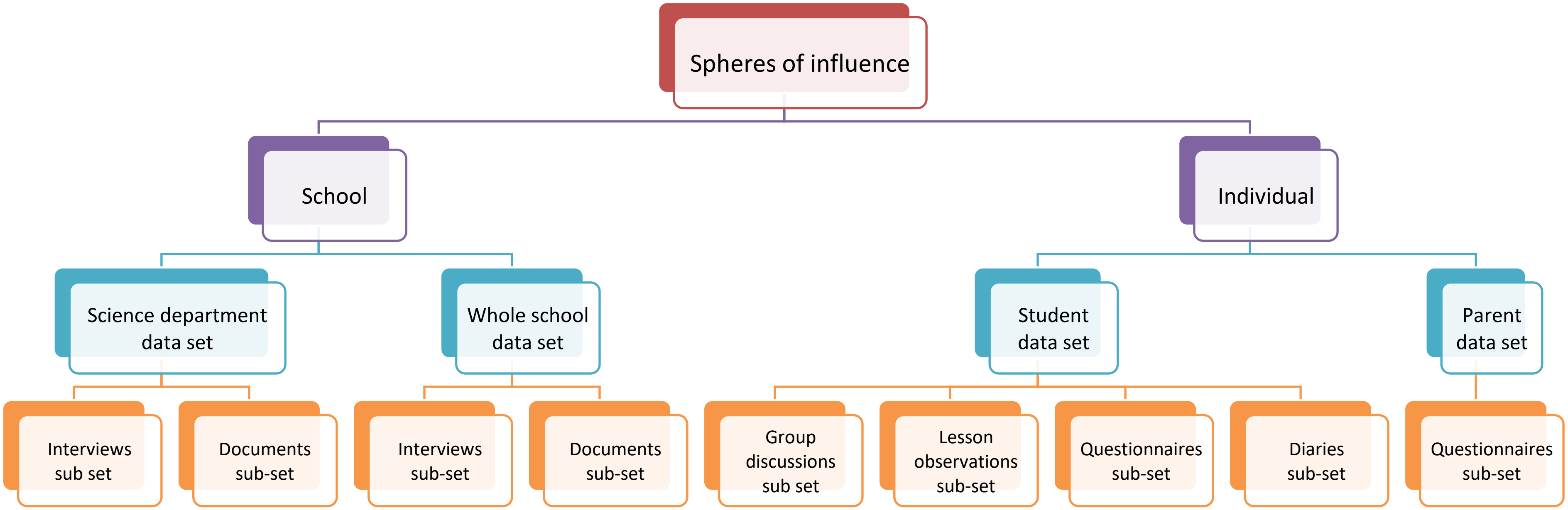

Figure 4.2: Sources of data and spheres of influence

4.10.3 School data analysis

RQs 1a and 1b were designed to investigate how a 'specialist' science school such as Farne School promotes positive attitudes and aspirations in science. Sub–sets within each data set were therefore probed for explicit or implied references to promotion of positive science attitudes and aspirations. Examples are drawn from each sub–set.

Staff Interviews

Excerpt from technicians' response to the importance of his/her role in the department is used here to illustrate analysis of staff interviews. This example was chosen as it exemplifies how data which may initially appear irrelevant could provide supporting information. For example, the themes 'professional competencies and 'workplace relationships and values' were discovered from analysis of interviews with technical staff, whose role may be disregarded when considering factors which affect students' attitudes and career expectations towards science.

In the first phase of coding, quotes from raw data were used as *in vivo* codes, that is, codes which use participant's own terms (column 1, Table 4.15). Coding this way was useful in identifying codes while capturing participants' inherent subjective experience (Stringer, 2014 cited in Saldana, 2016. However, due to the range and quantity of data, this approach of coding extensively and searching for potential themes was inappropriate as it increased the potential of getting lost in the data while being time consuming. Instead, coding was done primarily as a means of providing answers to research questions without excluding secondary themes which may be pertinent.

In the second stage of analysis, similar *in vivo* codes were then grouped to form a new set of codes as shown in column 3. This process was dynamic as it involved constant editing. In the third stage, similar codes from column 3, were grouped to form themes which are shown in column 4. This process was repeated for all staff interviews.

Themes identified were then used in conjunction with themes from analysis of school documents to produce a thematic map (Figure 4.3).

Raw Data	*In vivo* code	Codes	Theme
Q: How would you describe your role in the success of the department?			
1: I think it's quite important because if the teachers don't get the right equipment in the right time and in the right place, it can stop lessons going ahead, you know, they would be delayed. So, I think a Science Technician's job is very important. You've got to know a little bit about what you are doing to even just do your everyday job. Mr. Case., who is an absolute encyclopaedia, is brilliant because he knows more, he probably knows more than all the teachers put together! I think it's very important that we do our job efficiently and have a good rapport with the teachers and things; which we do.	'quite important' 'Right equipment in the right time' 'can stop lessons' 'Know a little bit' Mr. Case is an absolute encyclopaedia' Brilliant and knows more than all the teachers put together' 'important that we do our job efficiently' 'Good rapport with teachers which we do'	Recognition of importance of role Organisation Wealth of information Good working relationship with teachers Negative impact of poor preparation Efficiency	Professional competence Work place relationships and values

Table 4.15: Excerpt from staff interview showing *in vivo* codes

Documents

Documents were explored for corroborating evidence to claims about Farne School's promotion of positive attitudes and aspirations to science. Data from the science department's Handbook is used here to explain how this process was carried out. The Handbook is a useful document which provides useful information such as the organisation of the department and its visions and goals. As the Handbook was provided as a Word document by the Head of Science, it was easy to upload the document into NVivo 11.

NVivo is software which aids qualitative data analysis (www.qsrinternational.com, n.d.). Using the 'Query' function, a word frequency search was conducted. This provides a synopsis of words used, which can either be displayed as a 'cloud' or a table. A word frequency search has the advantage of rapidly identifying words without limiting the word search to researcher's categorisation (Silverman, 2014). Therefore, it was a useful preliminary tool in probing data for references to promotion of positive attitudes without being fixated on the words 'attitudes', expectations (or 'aspirations'). This was repeated for other school documents including programmes of study and curriculum statements.

As a first step, words which occurred at least ten times were extracted. This was to ensure that words which may be relevant were not discounted. These were 102 in total (Appendix 14.). Words which occurred at least 20 times were then considered, these were 59. Findings are reported in Chapter 5.

Data triangulation: school sphere of influence

Themes identified from interviews and documents analysis were then used to create the thematic map, Figure 4.3, which summarises science provision in Farne School. This provides supplementary information to RQ1 – what factors do staff and students in a specialist science school believe affects students' attitudes and career expectations towards science?

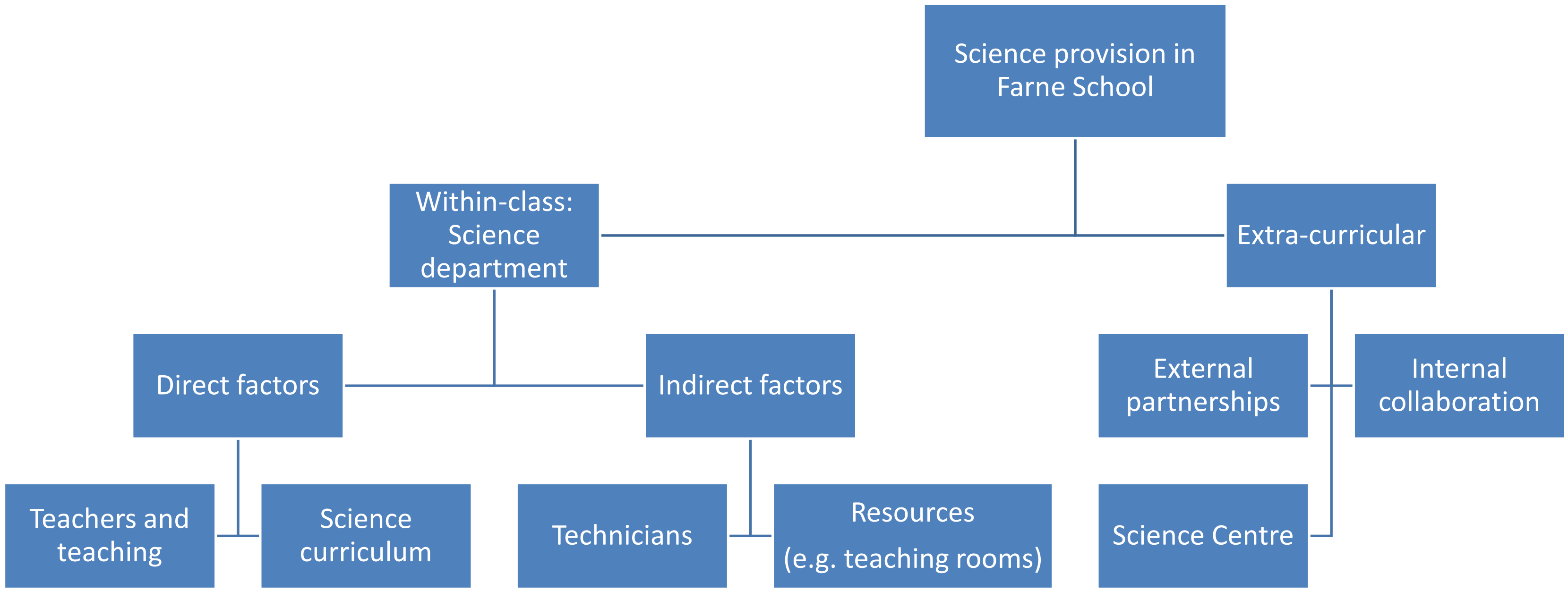

Figure 4.3: Science Provision at Farne School

4.10.4 Student data analysis

Analysis of student data occurred in two ways, thematic analysis followed by quantitative analysis using SPSS, version 20.

Developing a template

Step 1: Data were first reduced by coding students' questionnaire statements into an Excel spreadsheet (Table 4.16), rather than using in vivo codes as was done with the school data. This organised the data, making it manageable and easier to match codes to respondents.

Data reduction and initial coding									
ID	Expn MstEnjyd	Expn LstEnjyd	BestPScLsn	ExplBPSL	ScAbRtg	ExpnJobRtg	JobInvlSc	SchHelp	Explntn
ABBEY	X	X	X	X	X	X	X	PRACTICALS	
ABBOTT	X	X	X	X	UNDERSTANDING	Career-driven	YES	YES	
ADDISON	OPPORTUNITY TO EXPERIMENT	NO OPPORTUNITY TO EXPRMT	SALT CRYSTALS	WATCHING IT GROW	LIKE SCI	ASTROPHYSICIST	YES	ACTIVITIES	
BETSY	ENJOYMENT	X	MAKING TOOTHPASTE	ACTIVE PART	UNDERSTANDING	VET RELATED	YES	ACTIVITIES	
BETTY	FUN	LEAST FAVOURITE	MODELLING THE DIGESTIVE SYSTEM	EXCITING	PERFORMANCE	LIKE SCI	YES	ACTIVITIES	TEACHER NOT GOOD AT EXPLAINING
BEVERLEY	DISCOVERY	DISAGREEMENT	SALT CRYSTALS	ACTIVE PART	ENJOYMENT	LACK OF ENCOURAGEMENT FROM TEACHER	NO	NO	TEACHER DOES NOT ASK HER QUESTIONS OFTEN
HALEY	ENJOYMENT	BORING	SALT CRYSTALS		LIKE SCI	LIKE SCI	YES	ACTIVITIES	TEACHER NOT GOOD AT EXPLAINING
HAPPY	X	X	FILTERED WATER	ACTIVE PART	PERFORMANCE	OTHER JOB	NO	ACTIVITIES	
ALARIC	FUN	LEARN NOTHING	X	X	PERFORMANCE	UNDECIDED	UNDECIDED	RESOURCES	
MADONNA	FUN	BORING	FILTERED WATER	FUN/INDEPENDENCE	PERFORMANCE	UNDECIDED	UNDECIDED	ACTIVITIES	
ALBAN	INNOVATIVE	X	X	X	UNDERSTANDING	STRONG INTEREST IN SCI	YES	ACTIVITIES	KNOWLEDGE OF THINGS NOT YET TAUGHT
BRYANT	X	X	X	X	PERFORMANCE	WILL DO GCSE SCI	YES	ACTIVITIES	HIGHEST LEVEL IN CLASS
BRUCE	X	X	X	X	X	X	X	X	
BRUNO	X	X	X	X	ENJOYMENT	MANY ROLES NEED SCI	YES	ACTIVITIES	ENJOYMENT MAKES IT EASIER
BEATRIX	X	X	X	X	PERFORMANCE	UNDECIDED	UNDECIDED	SCIENCE SCH	
BELINDA	INDEPENDENCE	TOO EDUCATIONAL	OIL ON FIRE	Doing things	PERFORMANCE	DANCER	NO	SCIENCE SCH	
ANGELA	ALL	ALL	NONE GOOD	ALL BORING	PERFORMANCE	SCI BASED JOB	YES	NO	

Table 4.16: Excerpt from initial coding in student sphere

Step 2: A preliminary template, Table 4.17 was then created using Year 12 (n=10) open-ended questionnaire responses. Being the smallest data sub-set made it easier to examine the data thoroughly. Two themes were identified; personal and school-oriented factors.

A priori themes		Codes		RQ
1	Personal-oriented factors	1.1	expectations and career goals (including diametrically opposed goals)	2 and 3
		1.2	Remuneration	
		1.3	Popularity and demand for science roles	
		1.4	Attitude to science	
		1.5	Desire to answer 'the question of the universe'	
		1.6	Benefits of a science-related qualification (e.g. University admissions)	
		1.7	Understanding	
		1.8	Achievement	
		1.9	Performance	
		1.10	Enjoyment	
2	School-oriented factors	2.1	Resources	1 to 3
		2.2	Curriculum days	
		2.3	STEM related activities	
		2.4	After school clubs, e.g. STEM Club	
		2.5	Safe environment to ask questions	
		2.6	Regular practical work	
		2.7	Dissemination of relevant information	
		2.8	Collaborative partnerships	
		2.9	Limitation of practical work due to costs	

Table 4.17: Preliminary coding template

Step 3: Themes were compared across questionnaire responses of all year groups, modified and used to produce the initial coding template, T1 (Table 4.18). Another theme generated from data (that is, an inductive theme), *subject-oriented factors* which did not fit with either themes was added. At the end of this stage, the template, T1 was a list of codes relevant to research questions. This was modified by grouping similar codes, which reduced the number of codes to create template, T2 (Table 4.19).

Themes		Codes				RQs
1	Personal-oriented factors	1.1	Expectations and career goals	1.9	Enjoyment	2 and 3
		1.2	Remuneration	1.10	Interest in science	
		1.3	Popularity and demand for science roles	1.11	Hard work	
		1.4	Attitude to science	1.12	Family influences	
		1.5	Desire to answer 'the question of the universe'	1.13	Desire to improve people's understanding of science	
		1.6	Benefits of a science-related qualification	1.14	Self-efficacy	
		1.7	Understanding			
		1.8	Achievement			
2	School-oriented factors	2.1	Resources	2.9	Limitation of practical work due to costs	1 to 3
		2.2	Curriculum days	2.10	Trips	
		2.3	STEM-related activities	2.11	Teaching	
		2.4	After school clubs e.g. STEM club	2.12	Regular visitors	
		2.5	Safe environment to ask questions	2.13	Monthly tests and progress tests	
		2.6	Regular practical work	2.14	School facilities	
		2.7	Dissemination of relevant information	2.15	Prior school experiences	
		2.8	Collaborative partnerships			
3	Subject-oriented factors	3.1	Concepts comprehension (difficulty, simplicity, contradictions, illogicality)			1 to 3
		3.2	Value of science			
		3.3	Frustrations with practical work			

Table 4.18: T1, initial coding template

Themes		Codes				Similar codes	
1	Personal-oriented factors	1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9	Expectations and career goals (now 1.1) Remuneration (now 1.1) Popularity and demand for science roles (now 1.1) Attitude to science (now 1.2) Desire to answer, 'the question of the universe' (now 1.1) Benefits of a science-related qualification (now 1.1) Understanding (now 1.3) Attainment (now 1.3) Enjoyment (now 1.2)	1.11 1.12 1.13 1.14	Interest in science (now 1.2) Hard work (now 1.3) Family influences (now 1.4) Desire to improve people's understanding of science (now 1.1)	1.1	Career goals Remuneration Popularity and demand for science roles Benefits of a science qualification Desire to improve people's understanding of science Desire to answer questions of the universe
						1.2	Interest in science Attitude to science Enjoyment
						1.3	Understanding Attainment Hard work Self-efficacy
						1.4	Family influences
2	School-oriented factors	2.1 2.2 2.3 2.4 2.5 2.6 2.7 2.8	Resources Curriculum days STEM related activities (now 2.2) After school clubs e.g. STEM club (now 2.2) Safe environment to ask questions (now 2.2) Regular practical work (now 2.1) Dissemination of relevant information (now 2.3) Collaborative partnerships (now 2.3)	2.9 2.10 2.11 2.12 2.13 2.14 2.15 2.16	Limitation of practical sessions due to costs (now 2.1) Trips (now 2.3) Teachers and pedagogy (now 2.1) Regular visitors (now 2.3) Monthly tests and progress tests (now 2.2) School facilities (now 2.1) Frustrations with practical sessions (now 3.1) science experience (now 3.3)	2.1	School facilities Resources including budgets, cost of practical activities Teachers and pedagogy
						2.2	Curriculum days STEM related activities Monthly tests and progress tests After school clubs e.g., STEM club Safe environment for asking questions
						2.3	Dissemination of science-related information Trips Regular visitors Collaborative partnerships
3	Subject-oriented factors	3.1 3.2 3.3	Concepts comprehension Value of science Science experience	3.4	Frustrations with practical work		

Table 4.19: Modified initial coding template, T2

Step 4: The second and final modification involved creation of coding hierarchies by grouping similar codes together to form categories. A coding hierarchy has many benefits (Gibbs, 2007). First, the hierarchy helped with transforming codes from a list to a template thus making relationships between codes evident. Second, categorising codes increased data familiarisation. Data familiarisation permitted insights into students' social world view which would otherwise be difficult to ''see''. Third, hierarchies eliminated code replication as it made spotting duplicate codes easier. Fourth, a code hierarchy permitted posing multifaceted questions of the data, thus enabling identification of patterns and themes within and between cases.

Data triangulation: student sphere of influence

The modified initial template, T2 was then applied across the entire student data set (that is, including diaries, group discussions and lesson observations) to create the final template, T3 (Table 4.20). At this stage, factors such as teachers and pedagogy were added. The final template, T3 (or 'thematic map') does not ignore contradictions or inconsistences in data. Indeed, these tensions may be useful in explaining accounts that deviate from predominant patterns (Braun and Clark, 2006). For example, the codes 'intrinsic interest in science' and 'interest in science' can both be categorised as 'attitudes towards science'', however, they have been categorised as ''aspirations'' and ''attitudes'' to maintain the context in which students have used them.

Themes		Categories		Codes		RQs
1	Personal-oriented factors	1.1	Aspirations	1.1a 1.1b 1.1c 1.1d	Career path Remuneration Benefits of science qualifications Intrinsic interest in science	2 and 3
		1.2	Attitude to science:			
		1.2a	Positive attitudes	1.2a.1 1.2a.2 1.2a.3	Enjoyment of science Liking for science Interest in science	
		1.2b	Negative attitudes	1.2b.1 1.2b.2 1.2b.3 1.2b.4	Dislike for science Boredom Lack of interest in science Lack of enjoyment in science	
		1.3	Personal attributes	1.3a 1.3b 1.3c 1.3d 1.3e 1.3f 1.3g	Hard work Positive outlook Self-efficacy Anxiety in learning science Understanding Attainment 	
		1.4	Family influences	1.5a 1.5b	Science capital Social class	
2	School-oriented factors	2.1	Resources	2.1a 2.1b	Equipment: books and websites School facilities School budget	1 to 3
		2.2	Curriculum-related events	2.2a 2.2b	STEM related activities Trips	
		2.3	General support	2.3a 2.3b 2.3c 2.3d	Provision of safe learning environment After school clubs e.g., STEM club Dissemination of information Tests and mock examinations	
		2.4	Collaborative partnerships	3.4a 3.4b 3.4c	Cross-curricular activities Career events Community partnerships	
3	Subject-oriented factors	3.1	Science curriculum	3.1a 3.1b 3.1c	Contradictions and illogicality Perceived difficulty of science Relevance and content	1 to 3

		3.2	Practical work	3.2a 3.2b	Unreliability of experiments Importance of experiments	
		3.3	Teacher influences:			
		3.3a	Personal attributes			
		3.3b	Pedagogy	3.3b.1 3.3b.2 3.3b.3	Explanation Questioning Teaching style and strategies	
		3.3c	Support	3.3c.1 3.3c.2	One-to-one sessions during break and lunch times Encouragement	
		3.4	Science experience	3.2a 3.2b	Primary science experience Secondary science experience	

Table 4.20: Final coding template, T3

Student classification based on reported career aspirations

The final stage of thematic analysis in the student sphere was to probe the data for answers to RQ2: 'who aspires to a career in science?' Questionnaire responses were used in 'cutting and sorting' analysis. Cutting and sorting is a useful technique for identifying sub-themes. This was done twice. First in January 2015, after receiving phase 1 questionnaires (n=95) and second in July 2015 after receiving phase 2 questionnaires (n=132). Reviewing data in the two collection periods, enabled data to be examined afresh for comparisons. This requires openness, flexibility and willingness to modify categories. Sorting and cutting were carried out in three steps.

Step 1: 227 students' statements were printed, after which hard copies were physically cut into individual statements (Appendix 15). Of these, 12 from phase one and 18 from phase two lacked enough information for categorisation and were therefore discarded. In the end, 83 statements from phase 1 and 114 from phase 2 were used.

Step 2: Following cutting, statements were sorted into piles. Initial sorting focused strictly on whether a student desired to pursue science post-16 onwards. Four categories of students emerged at this stage; *Scientists*, *Non-Scientists*, *The Ambivalent* and *Resisters*. Table 4.21 shows how students were categorised in both data collection points.

Category	**Girls (G), Boys (B)**									
	Phase 1: December 2014				**Phase 2: June 2015**					
	Year 8		Year 12		Year 8		Year 10		Year 12	
	G	**B**	**G**	**B**	**G**	**B**	**G**	**B**	**G**	**B**
Scientists	11	18	1	7	20	21	3	1	0	3
The Ambivalent	15	7	1	0	9	6	2	0	1	0
Non-Scientists	7	5	0	0	8	5	0	0	0	0
Resisters	6	4	0	1	15	17	1	1	1	0
Total	39	34	2	8	52	49	6	2	2	3
	83				114					

Table 4.21: Student categories and times of data collection

Step 3: Following initial categorisation, categories were re-sorted based on students' attitudes towards science. Coding responses in this stage was iterative as categorisation was constantly checked and modified. This is like Marton's (1986) approach, where code words are used to differentiate key aspects of variation rather than focusing on individual experiences. Statements which did not fit into already identified categories were used as prompts for re-categorisation. Students' responses were then checked again for similarities and differences. This process was repeated until no new categories were identified. There is no definitive stage when categorisation is complete (King, 2012) but the process is at an apposite stage when new categories are no longer being identified.

Categories were further classified into sub-groups as it became evident that there were distinctions within each category. For example, within the Scientists category, three sub-groups; ''*Captivated*'', ''*Career-driven''* and ''*Pragmatic*'' were identified. These groups were identified based on students' reported motivation for pursuing a science career. Captivated Scientists indicate an interest in science careers because of an innate liking for science. The ''Career-driven'' is motivated by interest in a specific science occupation while the ''Pragmatic'' is interested in a science career based on the recognition of the utility of a science qualification or a science career. Sub-groups identified within other categories include ''*Positive''* and ''*Neutral*'' in the *The* Ambivalent category; *''Positive"* and *''Career-driven''* within the ''Non-Scientist'' category and ''*Positive*'', ''*Neutral*'' and ''*Negative*'' in the ''Resister'' category. Figure 4.4 shows the ten variations while Table 4.22 describes variations with statements which exemplify them.

These were checked independently by the supervisory team. Differences were debated until a consensus was reached that variations identified were representative of students in the sample.

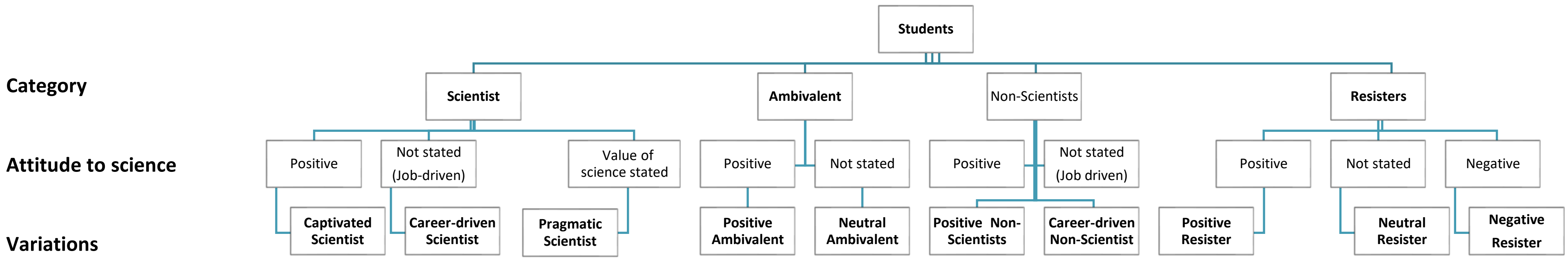

Figure 4.4: Variations in student categories and their attitudes to science

Category	Description	Exemplar statements
Scientists: students express a desire for a future in science post-16 onwards. There are three variations; captivated, Career-driven and pragmatic.		
Captivated Scientist	Students' desire for a science future is based on a liking, fascination for science or intrinsic interest in science. Students who express any uncertainty about their future in science are excluded from this group. Anthea is a good example (*see* The Ambivalent category).	CARY (male, Year 8): 'I love science' FRANCES (female, Year 12): I have always enjoyed physics and would like a career in it. ADDISON (male, Year 8): I would like to get a science-based job because I would like to help improve the human race understanding of it.
Career-driven Scientist	Students who are motivated by a science career. They make up the largest number of scientists.	CYNTHIA (female, year 8): I want to be a marine biologist ADDISON (male, Year 8): I would like to work on my science, so I can be an astrophysicist. EFFIE (female, Year 10): I want to be a designer.
Pragmatic Scientist	Students who express a desire to pursue science based on a recognition of its value. They make up the smallest number of scientists.	DARREN (male, Year 12): Physics is a lucrative job field and its highly linked to engineering ALMA (female, Year 8): I am quite good at science and would like to use my strengths to my advantage. Also, most roles have something to do with science. BRUNO (male, Year 8): There are lots of roles which use it.

Category	Description	Exemplar statements
The Ambivalent**:** students express uncertainty in their post-16 science aspirations. There are two types; positive ambivalent and neutral ambivalent.		
Positive Ambivalent	Students who express a positive reference to science	CHARITY (female, Year 8): I would like to but I'm not sure. ANTHEA (female, Year8): I enjoy science, but I am not certain what I want to do after school. ATWATER (male, Year 8): I don't know what I want to do for a job, but I enjoy science.
Neutral Ambivalent	Students who only express uncertainty about their post-16 science aspiration without reference to their feelings about science.	ALANA (female, Year 8): I might or might not decide if I want a job to do with science. BRADLEY (male, Year 8): I have no idea what I want to be. ALARIC (male, Year 8): I might but I might not.
Non-Scientist: students express an interest in art/humanities-based career. As with science-based aspirations, students who express any uncertainty about their future are excluded. There are two types; positive and neutral.		
Positive Non-Scientist	Students express a positive reference to science.	CHAD (male, Year 10): I enjoy science, but I want to be in the movie business. AUDREY (Female, Year 8): I enjoy science greatly, but I have always wanted to be Prime Minister and/or a lawyer. TALIA (female, Year 12): I like physics a lot but find myself more attracted to business.
Career-driven Non-Scientist	Students do not express any reference to science.	CHERISH (female, Year 8): I want to be a lawyer. ALGER (male, Year 8): I really want to be an accountant BELINDA (female, Year8): I want to be a dancer.

Resisters: Students express a disinclination to pursue science post-16 and do not state where their career interests lie. This includes positive and negative references to science. There are three types; positive resister, neutral resister and negative resister.		
Positive Resister	Students indicate a positive reference to science.	CAESER (male, Year 8): I like science at school, but I wouldn't like a job to do with it. BETTY (female, Year 8): I don't want to, but it would be fun.
Neutral Resister	Students express no desire to pursue science and do not state any feeling towards science	ADDRIENNE (female, Year 8): I don't want to do a science job when I'm older. BALDWIN (male, Year8): I want to be something else and I'm not interested in science roles. FELICITY (female, Year 8): I don't want anything to with science.
Negative Resister	Students express a negative reference to science.	DOREEN (female, Year 10): Do not have a great passion, couldn't see myself doing it. CYRIL (male, Year 8): I don't like science. Eartha (female, Year 8): Science is one of the subjects I panic in.

Table 4.22: Categories, variations and exemplar statements

In addition, some of the categories identified are similar to Vermunt's (1992) categorisation of students in higher education. The author identified five motivational orientations among students in higher education; *certificate oriented* - concerned about getting a degree; *vocationally oriented* - interested in becoming a member of a certain professional community; *self-test oriented* - concerned in proving their ability in realising a personal goal or capacity; *personally interested* - working from a personal interest in the subject studied and *ambivalent oriented* - various motivations to learn, but nothing specific.

Although the method used in arriving at these categories is distinctly different to the current study, as is the type of students (Vermunt, 1992), the underpinning factor in arriving at categorisation is student motivation. For example, the Career-driven *Scientist* and *Career-driven Non-Scientists* categories are like Vermunt's *vocationally oriented* who are motivated by a desire for a specific role. Similarly, the *captivated scientist* is comparable to the *personally interested* whose motivation is an innate interest in the subject. However, The Ambivalent category in this study is so named primarily because of students' uncertainty about their future in science in addition to motivation by factors which do not fit into other categories. Figure 4.5 summarises the categorisation process used.

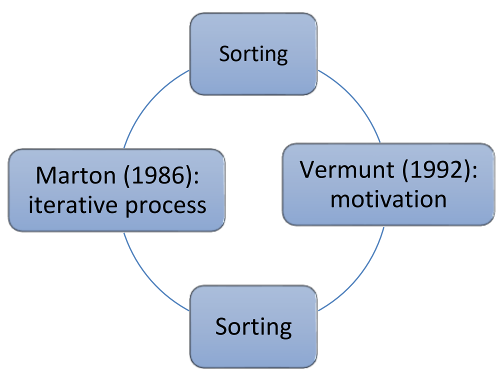

Figure 4.5: Process of student categorisation

Quantitative analysis of questionnaire responses

Questionnaire responses from the excel spreadsheet (Appendix 16.) were re-coded using numbers to make it compatible with the SPSS software. This involved data cleaning, for instance removing students with missing information where inclusion of their data may make comparisons between groups or individuals problematic. The final excel spreadsheet was then exported into SPSS, version 20 for analysis.

4.11 Presenting findings and citing sources

Ninety-five students participated in phase one and 132 in phase two of the data collection process. Hence, data used in reporting findings in the results chapter (Chapters 5 to 7) may vary.

In Chapter 6, students' views about students' attitudes are drawn from students in ''8 Emerald'', ''10 Topaz'' and ''12 Ruby''. These students were involved in at least two forms of data collection, that is, observations, group discussions, questionnaires and diaries.

However, in Chapter 7, findings on students' science career expectations are drawn mainly from 42 students in Years 8 and 12 who participated in phases one and two of data collection. The use of this small sub–sample limits the representativeness of findings, but this is compensated for by enhanced reliability of findings reported. Secondly, by reporting on students who participated in both phases, reasons why students' career expectations change through an academic year can be obtained.

Quotations from diaries and interviews are mainly reported verbatim to preserve the integrity of respondents' views. However, to improve clarity, quotations are sometimes paraphrased, especially where colloquial terms have been used. Interview sources are denoted with the letter 'I' and diary sources with the letter 'D'.

4.12 Summary

This chapter described the methodology used in the current study. The procedures were guided by an interpretivist social world view. Data were collected at different phases through the academic year from students and staff in a specialist science school in England. Data were analysed using thematic analysis. Themes generated were used to produce a template which provided a starting point for explaining changes in attitudes and career expectations towards science across year groups over an academic year in this cross–age study. Four broad categories of students namely *Scientists*, *The Ambivalent, Non-Scientists* and *Resisters* were identified. Findings are presented in the subsequent three chapters.

Chapter 5: Science provision and the school's view of factors affecting students' attitudes towards science

''..I think that's probably one of the biggest challenges you have as a teacher, that barrier that students have built in their heads before they get to your classroom is very difficult to break down''

Mr. Martins (Physics teacher for 10 Topaz and 12 Ruby in Farne School, 2015)

5.1 Introduction

In the previous chapter, the methodology and methods were presented. In this chapter, factors which affect students' attitudes towards science are presented from the school's perspective. Findings are drawn from data collected via semi–structured interviews and documents. This chapter provides a descriptive account of science provision in Farne School, including staff' views of factors affecting students' attitudes towards science. The chapter starts with section 5.2 where contextual information about Farne School starting with it is history is given. This is followed by 5.3 which discusses science provision in the school. In section 5.4, teaching and non-teaching staff members' views of factors affecting students' attitudes and career expectations towards science are discussed. Section 5.5 provides an overview of issues raised in sections 5.3 and 5.4. The chapter ends with a summary in section 5.6.

Information presented here was accurate when it was obtained between 2014 and 2017.

5.2 Background and history of Farne School

The 1944 Education Act provided free secondary school education for all pupils in England (legislation.gov.uk, n.d.). This led to a tripartite system of education which included ''grammar schools'', ''secondary modern schools'' and ''technical schools''. Eleven-year old children in their final year of primary school sat for an examination, known colloquially as the ''11-plus'', that determined the type of secondary school they would attend. Students achieving the highest scores in this examination proceeded to grammar schools while students scoring lower marks attended secondary modern or technical schools.

Dissatisfaction with the ’’11-plus’’ examinations (Sumner, 2010) led to calls for educational reforms and a move towards a system of education that was more inclusive (Gillard, 2018). In 1965, the Government released ‘’Circular 10/65’’ which directed Local Education Authorities (LEAs are responsible for Education provision within counties) to convert to comprehensive schools (Department of Education & Science, 1965). Comprehensive schools are state funded schools, which admit students in a catchment area without selection criteria (1.6).

Farne School was founded in 1965 under this climate of educational reform as one of three comprehensive school formed from an existing grammar school (Richardson, 1998). Most buildings still in use at the time of this project were constructed as the school developed, particularly from 1972 to 1976 (Vasey, 1999). From this time, the school has undergone other changes including the acquisition of ‘’specialist science’’ status in 2004.

‘’Specialist’’ subject comprehensive schools originated in 1994. Under this policy, following a successful application to the Government (Department for Education and Skills, 2001), schools were given a one–time grant from national Government to support provision of the chosen specialist subject, to be matched with an equivalent sum from local private businesses creating a £100, 000 fund (2.4.3). In interview, the Head of Science, who was in post at the time, reported that the specialist subject funds were used to refurbish existing science laboratories. Prior to this, each laboratory was furnished with four wooden student benches, a teacher’s desk, basic sinks and gas taps. In addition to modern furnishing and equipment, the refurbished laboratories have desktop computers, students’ bags and coats storage facilities, blackout blinds and electronic whiteboards. The specialist scheme ended in 2010 (2.4.3).

The most recent change to Farne School’s status occurred in 2011, when the school became an Academy. This followed Government policy in 2010, which permitted all schools to become Academies (Department for Education, 2010). Academies receive funding directly from Government, running effectively as small businesses with minimal involvement from the Local Education Authority. Thus, Academies have control over their budget, curriculum and staffing (Department for Education, 2010).

From 2000 to the time data were collected, the school was judged as either ''good'' or ''outstanding'' by Government inspectors (Ofsted, 2000, 2005, 2012).

5.2.1 Location and environment

Farne School is located in a residential area near a city in Hazel County in North East England. The site comprises green fields surrounding buildings referred to as 'blocks' that mainly date from the 1970s. Efforts have been made to keep the building well–maintained with fresh paint, exterior cladding, good signage and lighting and high standards of cleanliness. Fences and trees bound the site. The surrounding area (Figure 5.1) has areas of open green spaces. A student entrance is maintained separately from a staff and visitor reception. The site is gated in two loci: one for pedestrians only, while the second provides vehicular access. Efforts have also been made to provide a comfortable exterior environment with picnic tables, trees, sports pitches and paved walkways.

Figure 5.1: Surrounding green spaces around Farne School

5.2.2 Student intake

Farne School is a mixed-gender school, which enrolls students, aged 11 to 18. At the time of the study, approximately 1000 students aged, 11 to 16 and 200 aged, 16 to 18 years old were on roll. The 16 to 18 years old are post–secondary students comprising the 'Sixth Form'' (Glossary). These students choose to remain at or transfer to Farne from other schools.

The number of students was above the national average of 950 students (Office of National Statistics, 2013). Most students are of White British heritage. A small proportion of students speak English as an additional language (EAL). Students come from diverse economic background ranging from socially advantaged (NS–SEC, 1-4) to socially disadvantaged (NS–SEC, 5-8). National Statistics Socio–economic classification (NS–SEC) classifications was defined in section 2.5.4. At the time data were collected, Hazel County was in the top 30% of the most deprived local authorities in England (Index of deprivation, 2015).

However, this is not reflected in the number of students on Free School Meals (FSM) which was 14%. This figure is below the national average of 16.3% (Office of National Statistics, 2014). Free School Meals is a measure of low family income (Department for Works and Pensions, 2013). The small proportion of students on FSM could be an indication that the majority of students in Farne School come from socially-advantaged backgrounds. Indeed (63%, n=83) of students who participated in phase 1 of data collection were from socially-advantaged backgrounds (7.3.1).

5.2.3 GCSE Science outcomes

Historically, students perform well in GCSE examinations overall (Table 4.4, section 4.7.1) and in science. Table 5.1 shows that the number of students achieving at least two science qualifications at grades A*-C has been consistently above County and National figures. On average, this figure has been above 60% except in 2008 when it was 55%. A revised programme of study was introduced in 2006 with first examination based on the new content in 2008 (The Office of Qualifications & Examinations Regulation, Ofqual, 2009). This could account for the results that were below 60% at both county and national levels as students and teachers, especially may be unfamiliar with the revised content.

Year	Percentage of students achieving 2 A*-C grades in Science (to the nearest whole number)		
	Farne School	Hazel County	State schools in England
2014	81	70	72
2013	63	78	73
2012	98	82	75
2011	83	87	75
2010	66	68	62
2009	70	58	54
2008	55	49	50

Table 5.1: Percentage of students achieving 2 A*-C grades in science

5.2.4 School Leadership and vision

At the time data were collected, Headteacher, Mr. Lasslett, who was appointed in 2013, led Farne School. A leadership team was also in place. This team included two deputy Headteachers, thirteen Heads of departments and seven Heads of Year (Glossary).

The School's stated vision is founded on three guiding principles; respect, responsibility and right attitude. These are defined as follows on its website:

Respect – ''Demonstrating consideration for all members of the school and the local communities through high standards of behaviour and co-operation''.
Responsibility – ''Demonstrating an understanding and acceptance of the expectations of the school in relation to issues such as punctuality and attendance, uniform and personal organisation''.
Right Attitude – ''Demonstrating high aspirations and levels of commitment in all areas of learning'' (*Source*: School website, 2015).

The school's vision suggests senior leaders are attempting to develop a school community in which students recognise the importance of their role as individuals and members of the wider community. Hence, the focus on the development of social skills in addition to academic attainment. However, there is no evidence of the school's science specialism on its website.

Section, 2.4.3 discussed the notion that specialist schools were expected to develop a character which reflected their specialist subject. However, lack of explicit reference to a science specialism does not mean the school may not have developed its own unique culture of science through its science provision. Practices, which underline a science specialism are explored in the next section. Note here, that the specialist science scheme ended in 2010 with the election of a new National Government. The discontinuation of the specialist schools scheme may have negated the need for an explicit reference to a subject specialism.

5.3 Science provision

This section describes science provision in the school. In addition, practices which the school alleges encourages positive attitudes and career expectations towards science are presented.

Findings suggest that Farne School uses a two–pronged approach in its science provision; within class and extra–curricular. A previous Headteacher, Mrs. Mullins who led the school for twelve years, initiated this model for the teaching of Science, Technology, Engineering and Mathematics (STEM) subjects. Mrs. Mullins was active in local and national science education charities and policymaking organisations (I[2]: Mr. McKay, Assistant Head Teacher). She helped Farne achieve specialist science status in 2004.

Based on this model, the science department focussed on the delivery of a science education as prescribed in the National Curriculum (National Curriculum, 2014) while out-of-class enrichment opportunities involving ‘’real-life’’ STEM-based activities and work experience were provided simultaneously (I: Mr. McKay). Hence, a decision to employ an ‘’Enterprise and STEM Enrichment Manager’’ (the STEM Enrichment Manager) to manage extra-curricular provision in STEM subjects.

[2] I: used to denote interview sources

Based on the researcher's findings, the STEM Enrichment Manager was one of two people employed in a similar role within the UK at the time of data collection. Counterintuitively, Mrs. McCarthy, a candidate, with an Arts/Humanities background was preferred over a candidate with a degree in physics. The school's rationale for this decision was that this enhanced the likelihood of equal promotion of each STEM subject which may have been a potential problem had someone with a science background been appointed (I: Mr. McKay). Findings relating to this specific role are reported in section 5.3.2. Strategies for science provision are discussed next.

5.3.1 Within-class provision: the science department

This section starts with an overview of the science department starting with the staffing structure and description of teaching rooms. A detailed account of organisation of teaching is presented in Key Stages 3 and 4 as this is the compulsory stage of pre-16 education. A brief account of KS5 is also presented.

<u>The science department</u>

At the time data were collected, the Science Department comprised thirteen staff; ten teachers and three technicians (Glossary). The teachers included one specialist physicist, four chemists and five biologist. Mr. Hadfield, who is a biologist, is Head of Science. Two teachers hold responsibility positions as Deputy Heads of Science. These are Mrs. Natanson, with responsibility for the Key Stage 3 (1.6.1) programme and Mr. Martins, with responsibility for Key Stage 4. Mr. Martins is the only teacher with a physics specialism.

Mr. Case, Mrs. Johnson and Mrs. Nicholson comprised the team of technicians. Mr. Case is the senior technician. Each technician has responsibility for a specific subject. Mr. Case was responsible for physics, Mrs. Johnson for chemistry and Mrs. Nicholson for biology. Figure 5.2 shows the staff structure and specialism of teaching staff.

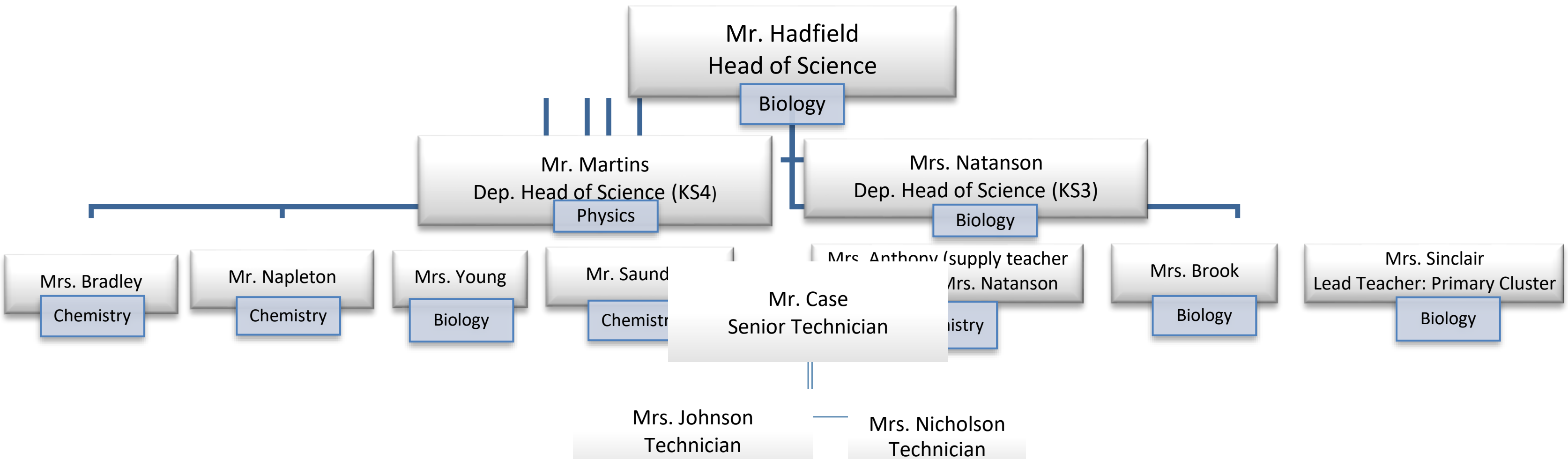

Figure 5.2: Staff structure and specialism of teachers in Science (source: Science Department Handbook)

Teaching rooms

Science lessons across all Key Stages take place in two types of rooms. For the purposes of this study, these are referred to as ''classrooms'' and ''laboratories''. There are six laboratories and four classrooms. Figure 5.3 shows the layout of a classroom and a laboratory.

Figure 5.3: Layout of a classroom and laboratory

Laboratories have specialist furniture arranged in a layout that comprises a teacher's desk at the front and an interactive white board directly behind. Seven student workstations face the teacher desk; three in a front row and four in a second row towards the rear of the room. Each workstation seats six students. The workstations are fixed, meaning that seating arrangements cannot be changed. All are equipped with electrical sockets, sinks and gas taps. The middle workstation in the front row is used for teacher demonstrations. A set of shelves is provided at the door for students to place bags and outdoor coats. Students take a pencil case and books to workstations. In addition, five desktop computers for student use are situated in the corner furthest from the entrance.

Classrooms have furnishings that are of a lower standard than the laboratories. This comprises moveable tables arranged around facility points that provide sinks and gas taps. A teacher desk at the front of the room and a whiteboard complete the furnishings in the classrooms.

Students' work are displayed on the walls of laboratories, classrooms and corridors. This usually depicts diagrams or articles about scientific processes. In addition, posters are displayed. They range from information about career opportunities in science to aspirational quotes by famous scientists. Large posters of the periodic table in different forms was common in many classrooms and laboratories. Photographs of student trips and visits to science event centres are also displayed.

Organisation of teaching: Key Stage 3

Students are allocated into teaching groups called ''sets'' (1.6.4). Sets comprise approximately 26 children usually divided evenly between boys and girls. How students are placed in teaching groups differs by year groups. In year 7, students' teaching groups are based on their prior attainment in primary school, that is, Key Stage 2 data on English and Mathematics. In Year 8, students' science sets are based on their year 7 attainment in English, Mathematics and Modern Foreign Languages (*Source:* KS3 Programme of Study, 2014/15). An argument used by Farne School leaders for use of prior attainment is that students with similar learning needs can be taught together.

However, this can be problematic for two reasons. Students' science teaching groups may be unsuitable, and not reflective of their science ability, as setting is based mainly on attainment in English and Mathematics. An assumption is made that students' attainment in science is likely to be similar to that in English and Mathematics, and that this is unlikely to change on transition from primary school. This may impact negatively on the support students receive. Secondly, students who are placed in ''middle'' sets are less likely to thrive as teachers try to meet the diverse needs of this group of students.

Setting in science occurs for the first time in Year 9 (*Source*: Science Department Handbook, 2014/15) when teaching groups are organised based on prior attainment in science in Years 7 and 8. Year 9 is the ''critical'' 13 to 14 age bracket where attitudes reportedly become fixed (Osborne et al., 2008).

This means students who have had a negative experience of science prior to Year 9 are less likely to develop positive attitudes and expectations towards science. They may therefore be less inclined to consider science, post-16.

Teaching time

Science is taught three times each week throughout Key Stage 3 (Table 5.2). Each teaching group is allocated one teacher for all three lessons as far as timetabling constraints permit (Science Department Handbook, 2014/15). This means that in many cases, teachers have sole responsibility for a teaching group but may split classes with other science teachers.

Key Stage 3		Age	Teaching hours per week
Year group	Number of teaching groups		
7	6	11 - 12	3
8	6	12 - 13	3
9	6	13 - 14	3
Total hours of teaching per year group in KS3 = 117			

Table 5.2: Teaching hours in Key Stage 3 in an academic year

KS3 curriculum

Teachers teach ‘’WIKID science’’ to all year groups in Key Stage 3. WIKID is a wordplay of the word ‘wicked’ used in this instance to mean ‘’cool’’ or ‘’fun’’. WIKID science is a purchased scheme of work (SOW) that adopts an inquiry–based and applications–led approach to science. The SOW comprises units and resources, which underpin the KS3 Programme of study for science. Mrs. Natanson (Deputy Head of Science, KS3) claims an inquiry–based SOW like WIKID science provides context for science topics, enhancing relevance for students.

> We teach WIKID…. It’s inquiry-based learning, so the kids have more ownership, every subject is linked to a job, so the kids are seeing the science in the workplace as well. So, we're trying to develop that aspect of it, because traditionally you would just teach atoms and elements, with zero connection to the real world… ….We're all very aware that yes, we're a core subject, but not many of our students are going to go on and use science in the future, so they need to just recognise areas of science that's relevant to everyday life and hopefully try and use it… …do something in the future with science (I: Mrs. Natanson).

As Year 8 is the participating KS3 group in the study, examples are drawn from this year group, for example, Table 5.3 shows units from the WIKID scheme of work. Units boldened in Table 5.3 were units taught during lesson observations. The SOW for KS3 is shown in Appendix 17.

Mrs. Natanson reported that the structure of the units and content in WIKID science fitted with the mode of assessment used for practical work in GCSE science examinations, known as an ''Individual Skills Assessment (ISA)''. ISAs are GCSE practical science examinations, which contribute to the overall GCSE science grade. The inquiry–led nature is shown in the structure of the ''units'' where students take on different ''roles'' designed to mimic real-life work scenarios. A comparison between the units in WIKID science and the KS3 programme of study for science (Appendix 18) show that the units mirror the programme of study in the National Curriculum (*Sources*: WIKID SOW, KS3 POS).

Units	Student role and mission	Link to KS3 National Curriculum Programme of study in science	Personal learning skills
Design a home	**An energy entrepreneur designing carbon zero houses**	**Energy (I, II)**	**Independent enquirer/Team workers**
		Decision making	
Species at war	An ecologist in a national park modelling and managing ecosystems	Food webs	Independent enquirer
		Biodiversity	
		Scientific argument	
Studio magic	An expert making sound recordings and light shows	Waves (energy)	Independent enquirer
		Scientific explanations	
		Multicultural science	
Pyrotechnics	A chemist designing a firework display	Elements	Effective participators/team managers
		Patterns in reactions	
		Risk	
		Planning an investigation	
Catastrophe	**A geologist trying to save people from volcanic eruptions**	**Changing Earth (I, II)**	**Effective participators**
Live and kicking	Making better lifestyle choices for yourself	Cells	Creative thinkers
		Causes of behaviour	
		Working with evidence	
		Variables	

Table 5.3: Excerpt of WIKID Units and links to KS3 National Curriculum programme of study in science

The teaching calendar (or programme of study) for the 2014/15 academic year is presented in Appendix 18 (*Source*: School website, 2015). This shows an even division of time between biology (30), chemistry (28) and physics (28).

Table 5.4 shows an excerpt of Year 8 science content taught in Term 2 when lesson observations commenced. The content indicates that students experience lessons which are theoretical and practical. Topics are taught in teaching blocks depending on the amount of content involved, after which students sit for end of topic assessments. In addition to end of topic assessments, students sit for end of term assessments comprising contents from all three sciences. Prior to end of term assessments, a week dedicated to revision, which the department calls ''consolidation week'' is used to prepare students for these assessments.

Week commencing	Teaching block unit	Number of lessons Biology: 30 Chemistry: 28 Physics: 28	Discipline
Term 2			
5th Jan	Ecosystems	9	Biology
12th Jan	Ecosystems		
19th Jan	Ecosystems		
26th Jan	Adaptations	7	
2nd Feb	Adaptations		
9th Feb	Assessment: Ecosystems & Adaptations	3	
Half Term			
23rd Feb	Metals	5	Chemistry
2nd Mar	Metals		
9th Mar	**Consolidation week**		
16th Mar	**Assessment week: Magnetism, Ecosystems, Adaptations & Metals**		
23rd Mar	Ceramics, Composites, Polymers	2	Chemistry
1st Apr	Earth	2	
Easter holidays			

Table 5.4: Teaching calendar/programme of study for Year 8 in Term 2

The last two units of the WIKID course are taught in the first term of Year 9, after which students sit for an end of year assessment. Once the WIKID content is completed, students begin their KS4 programme of study in the third term of Year 9.

This enables the school to take advantage of the flexibility of the National Curriculum by introducing KS4 content in Year 9 rather than in Year 10 (National Curriculum, 2014).

Organisation of teaching: Key Stage 4

In 2009, The Department for Children, Schools and Families (DCSF) published a guideline for science provision in schools. This suggested ''pathways'' schools could adopt to ensure that they met the statutory requirements of providing students with the opportunity to study either GCSEs in Core and Additional Science or GCSEs in Triple Science (Glossary).

Science qualification such as Business and Technology Education Council (BTECs) could be offered in addition to GCSE sciences (DCSF, 2009). Schools with specialist STEM subject status such as Farne School were expected to offer GCSE Triple Science. Hence, following the curriculum and assessment guideline, Farne School provided a range of educational opportunities via KS4 ''pathways'' (*Source:* KS4 programme of study 2014/15). At the time of data collection, Farne School offered three KS4 pathways, numbered 1, 2 and 3 (*Source*: School website, 2015).

Pathway 1 is described as a ''work–based'' route. This route comprises mainly BTEC courses in which students are assessed primarily on a portfolio of tasks based on ''work–related'' contexts. Farne School places students who they have classified as ''low attainers'', that is, students who may have achieved poorly academically on this route. Students in this pathway take part in work experience projects in organisations in the county.

Pathway 2 is similar to pathway 1, but there is a balance between GCSE and BTEC qualifications. Students ranked by the school as ''middle attainers'' are placed on this route.

Pathway 3 is a ''traditional'' GCSE-based route. Students with prior academic attainment, that is, those the school has classed as ''high attainers'' are placed on this route.

Each pathway allegedly provides choices students can make. All students study ''core'' subjects (English, Mathematics and Science) and at Farne, this includes Physical Education (PE) and Religious Education (RE) as seen in Figure 5.4.

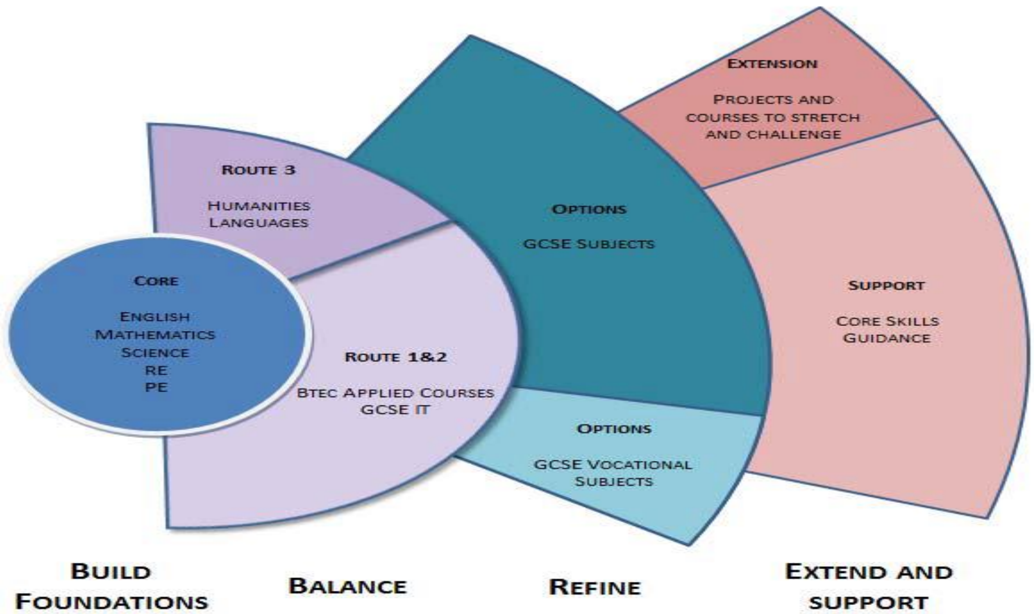

Figure 5.4: Pathways and options blocks in KS4

PE was added to fulfil school policy to support students' physical wellbeing (*Source*: School website, 2015). Provision of RE is a statutory requirement, but the school includes an assessed programme to help ensure students take the subject seriously.

The school's aim for all students regardless of pathways is to achieve qualifications such as GCSEs and BTECs with those on ''pathway 3'' obtaining GCSE qualifications, ''pathway 1'' mostly BTECs and ''pathway 2'' obtaining an even split of GCSEs and BTECs (Mr. Hadfield).

In science, the aim is for students to obtain GCSE science qualifications as seen in Table 5.5. The department uses two examination boards; Oxford, Cambridge and Royal Society of Arts (OCR) for pathways 1 and 2 and Assessment and Qualification Alliance (AQA) for pathway 3 (*Source*: Science Department Handbook, 2014/15). In interviews, Mr. Hadfield claimed that the breadth and depth of content covered by the different examination boards make them suitable for students in different pathways.

Through informal discussions with Mr. Hadfield it became apparent that the AQA suite of examinations was considered ''difficult'' and therefore suitable for students ranked by Farne School as ''high attainers'' while OCR Gateway Science was considered ''easy'' and therefore suitable for students ranked as ''low'' and ''middle'' attainers.

Subject	Qualification	Examination Board (or awarding body)	Pathway
Biology	GCSE	AQA	3
Chemistry	GCSE	AQA	3
Physics	GCSE	AQA	3
Core and Additional Science	GCSE	AQA	3
Gateway Science	GCSE	OCR	1 and 2

Table 5.5: Suite of GCSE science qualifications and pathways in KS4

The decision-making process raises the question of whose interest is served in the pathways students end up in. First, students are not involved in the decision-making process. They are advised of their pathway by senior leaders based on factors such as ''prior achievement, expected achievement and teacher professional judgement'' (*Source:* School website, 2015). Second, students' choice of subjects are limited to the ''options'' provided in each pathway (School website, 2015). They can only choose from these ''option blocks''. Option blocks are used by some schools to manage their resources in terms of deployment of teachers and facilities. Constraints imposed by the use of option blocks can be problematic for some students who are forced to make a choice between two subjects in the same block. The effect of option blocks on AS subject choices is discussed in Chapter 6.

Furthermore, ''enrichment'' opportunities provided to students vary by pathways. Students in pathways 1 and 2 are offered support in ''core skills''. Farne School uses the term ''core skills'' to refer to competency in numeracy and literacy (KS4 programme of study, 2014/15), while students on pathway 3 are offered ''extension opportunities'' which are allegedly designed to ''stretch and challenge'' students on this route.

Another area of interest is the practice of enrolling students for examinations with different examination boards. This is not uncommon as some schools use this tactic to maximise the chances of securing positive GCSE examination outcomes (West, 2010; Meadows, 2015). Although this may in turn boost the school's ranking in performance league tables (2.3.2), some students inadvertently end up in courses they are either academically unsuitable for and/or uninterested in. For example, the science department only offers GCSE science courses but there are students who may be better suited to BTEC courses which adopt a work-based approach rather than GCSEs which are examination-based. The school's claim that pathways are chosen to suit students' academic abilities and career expectations is arguable.

All of these suggest that students are funnelled into pathways consisting of pre–determined subject choices which limit their subject choice. This is not unlike findings of Smithers & Robinson (2007) and Bennett et al (2013) who reported that students' post-16 subject choices were influenced by curriculum provision and school leadership's decision (2.4.2).

Curriculum time and teaching groups

KS4 science teaching groups are organised independently from those for other subjects, including English and Mathematics. Teaching groups (sets) are organised within the three pathways. Pathway 3 comprises five sets. Of these, sets numbered 1, 2 and 3 are aiming to take GCSE Triple science, that is, three GCSEs in science, one each in Physics, Chemistry and Biology; sets 4 to 5 are aiming to take GCSE Double Award. This programme features all three science subjects, but these are examined together and lead to two GCSEs, hence the term ''Double Award''. ''10 Topaz'', the class observed in this study is in ''set'' 4. Pathways 1 and 2 comprises one ''set'' each with ''set'' 6 in ''pathway 2'' and ''set'' 7 in ''pathway 1''.

Science is taught as individual subjects for the first time in Farne School in KS4 with teachers assigned for each subject. However, as there is only one specialist physics teacher in the department, some physics classes are split between chemistry specialists.

For example, physics in ‘’10 Topaz’’ is split between Mr. Martins (physics specialist) and Mr. Saunders (chemistry specialist). Teaching time is allocated as shown in Table 5.6. Pathways 2 and 3 have six hours of teaching time divided evenly between individual subjects. Pathway 1 has less teaching time due to the route being mostly course–work based (Mr. Hadfield, Head of Science).

Key Stage 4	**Age**	**Teaching hours/week**		
		Pathway 1	Pathway 2	Pathway 3
Year 10	14-15	5	6	6
Year 11	15-16			

Table 5.6: Teaching hours in Key Stage 4

Organisation of teaching: Key Stage 5

In KS5, subject specialists are responsible for individual science subjects. The science department uses the AQA examination board for her ‘’sixth form’’ (AS/A2) science provision (*Source*: School website; Science Department Handbook). An outline of the programme is provided in Appendix 19). Each science AS/A2 subject is allocated five teaching hours/week as shown in Table 5.7.

Key Stage 5	**Age**	**Teaching hours per week**
Year 12 AS	16-17	5
Year 13 A2	17-18	5

Table 5.7: Post-16 science teaching hours

5.3.2 Extra-curricular provision

The school’s website and staff interviews refer to practices which the school claims exemplifies efforts to promote positive attitudes and career expectations towards science. These are discussed starting with extra-curricular provision managed by the science department followed by those managed by the ‘’STEM Enrichment Manager’’.

Activities managed by the Science department

Science ''Primary Cluster''

As part of the role as a specialist school, Farne School works with the local community to promote its specialist subject. One way Farne achieves this is supporting local primary schools (elementary, ages 5 to 11) to improve teaching and learning in science. Children attending these schools transfer to Farne after Year 6 (last year of primary school). Teachers at Farne School liaise with eight primary schools supplying a majority of their Year 7 intake in a support group referred to as a ''Cluster''.

The Cluster began in 2004 when Farne acquired specialist science status. The Cluster is led in Farne School by Mrs. Sinclair, a biologist specialist. The programme supports teachers in Cluster schools who are not science specialists who may have limited subject content knowledge (I: Mrs. Sinclair). Mrs. Sinclair organises ''primary skills days'' to work directly with children and regular meetings with primary school teachers to share best practice on teaching strategies and assessment. Farne School considers work with teachers and children from the Cluster an important part of its science provision. Information about both were gathered through documents and discussions (primary skills day) and observation (teachers' meeting).

''Primary Skills Day''

Farne School has held an annual ''Primary Skills Day'' since 2005 (Mrs. Sinclair). The belief is that these ''days'' equip students with scientific enquiry skills before they start secondary school. Science is promoted through demonstrations and participation in science experiments for which their primary schools may not be resourced for (I: Mrs. Sinclair). On a Primary Skills Day, children in Year 6 and their teachers from the Cluster primary schools visit Farne School. Farne School's science teachers arrange ''hands on'' tasks and science experiments designed using everyday items for the primary school aged children. For example, for states of matter, chocolates are used to demonstrate melting from solid to liquid. Children write a report using ''prompts'' which enable them to produce reports corresponding to National Curriculum levels (Glossary).

Cluster Teachers' meeting

The meetings support teachers in their teaching and assessment techniques (I: Mrs. Sinclair). Seven primary school teachers attended a meeting to which the researcher was invited to. During the meeting, Mrs. Sinclair presented anonymised exemplars of Farne students' work for staff from the primary schools to assess and award a National Curriculum level. Curriculum levels awarded by Farne School teachers were then presented for comparisons. This exercise was ostensibly useful in developing primary school teachers' science assessment techniques. The meeting lasted for 90 minutes. On interview, Mrs. Sinclair advised that meetings usually follow this format.

An opportunity arose to visit a school within the Cluster. This provided an opportunity to explore the usefulness of the Cluster from an alternative viewpoint from Farne School. Tees School comprises approximately 200 children and 12 teachers. The school is situated in a village near the city. Mrs. Brooks is the lead teacher for science in Tees School as well as teacher in charge of Year 6. The school does not have a science laboratory, so practical activities take place in regular teaching rooms (Mrs. Brooks, Tees School). Mrs. Brooks relies on Farne School, the ''Cluster'', parents and local organisations for science teaching resources. Practical work focusses on development of scientific enquiry skills. Children in Year 6 receive daily lessons in reading, literacy and numeracy. Science is usually taught on alternate Wednesdays. Mrs. Brooks' science class comprises of 13 girls and 17 boys. The children had visited Farne School in Years 4 and 5 during a Primary Skills day where they participated in practical work.

The visit to Tees School appeared to corroborate Farne School's belief that the Cluster was a useful part of its science provision. Children claimed they were keen to attend Farne School in part because they looked forward to practical work in science. Mrs. Brook's believed that the Cluster had improved her practice, stating that shared resources and teaching strategies had improved her confidence and subject content knowledge. This in turn had improved her pedagogical practices.

However, comments from the children indicated that the Cluster had become an indirect ‘’recruitment tool’’ which supports Farne School’s primary to secondary transition programme. Children were keen to attend Farne School because of the assumption that *primary skills day* were typical of science provision in Farne school. This was not the case as was observed in lessons (Chapter 6).

Participation in science education research

The science department also claims that participation in educational research projects is part of its science provision and promotion. Students who participate in projects benefit as they engage in science in contexts different from normal science lessons (I: Mr. Martins). At the time of the study, the school was involved in a pilot project funded by the Department of Education. The project, Improving Gender Balance (Institute of Physics, 2014) was designed to enhance recruitment of girls into A–level physics. Managed by the Institute of Physics and the National Science Learning Centre, twenty–six schools including Farne School participated. This involved a series of interventions called ‘’strands’’ for girls in Years 9 to 11 (IOP, 2015). The project ran from 2014 to 2016. Farne School participated in ‘’Strand A’’ which focussed on improving girls’ confidence and resilience in studying physics. Although the programme was intended for all girls in years 9 to 11, Farne invited only students in sets 1 and 2 from Year 10, studying GCSE Triple Science to participate (Mr. Martins). Two girls from ‘’10 Topaz’’ (‘’set 4’’; Double Award course) expressed interest in the project and were allowed to participate. This brought the total number of girls taking part from four to six.

Participation required fortnightly sessions during lunchtime through the academic year. In the final session at Farne Science Centre, students presented their work on the project with other girls from local participating schools. The researcher observed this final session. Figure 5.5 shows the poster presented by Farne School including the girls from ‘’10 Topaz’’. Students’ perception of events like this are discussed in Chapter 6.

Figure 5.5: Students' poster from students' participation in Improving Gender Balance

Activities managed by the STEM Enrichment Manager

As discussed in section 5.3, Farne School employed, Mrs. McCarthy as a full–time, non–teaching member of staff into the role of ''STEM Enrichment Manager'' to manage extra-curricular science provision. The purpose of this section is primarily about extra-curricular science provision, therefore views from other staff are presented as well. Examples are chosen to highlight the diversity of extra-curricular science provision and Mrs. McCarthy's role. In describing the rationale for her role, Mrs. McCarthy explains:

> Mrs. Mullins, our Headteacher … …. wanted somebody who could bring that informal education aspect to our students. So, we've got teachers who could provide the formal, which is great, but [Mrs. Mullins] wanted somebody who would … bring those two worlds together, and hopefully at the end of school we would have really rounded young people who would be employable, so they've got their academic qualifications, but they've also experienced all of this [enrichment opportunities]. … It was massively forward thinking, it had never been heard of, a school taking that risk … [I: Mrs. McCarthy].

Mrs. McCarthy's responsibilities range from the recruitment of older students as mentors to younger students to participation in national science events and competitions. She acts autonomously, so has little contact with departments teaching STEM subjects, that is, Science, Mathematics and Technology. As enrichment activities requiring student attendance may occur during lesson times, friction arises between Mrs. McCarthy and STEM teachers.

> I do describe myself as 'Marmite'[3]; you either love me or hate me... So, some teachers love me, some teachers just see me as a real burden to them because I'm constantly pulling students out of lessons to do activities. So, some people really like me, some people really don't. But I'm here for the young people; I'm not here for the teacher [Mrs. McCarthy).

Over the years, the role has evolved to include management of the school's science centre and development of partnerships with local businesses. At the time of data collection, fourteen organisations, including four universities were involved with Farne School. The Farne Science Centre and the school's post-16 internship programme are discussed. Contributions from Mr. McKay (Assistant Headteacher) and science teaching staff provide additional context.

Farne Science Centre

Farne School participated in a bid to be part of the Science Learning Centre Network (I: Mr. McKay). The National Science Learning Centres Network was conceived after a report, S*cience in Schools*, highlighted the need for professional development in science teaching (Select Committee on Science and Technology, 2001). The centres' aim was to develop teaching and learning in science so that young people were encouraged to engage with science and ultimately pursue 'scientific study or employment' (Baroness Ashton of Upholland, 2001). The first National Science Learning Centre was established at the University of York in 2004. Regional centres were proposed to promote teachers' access.

Mrs Mullins, Farne School's Headteacher at the time, championed a Science Learning Centre on site, which opened in 2005. Mr. McKay explained:

> [Mrs. Mullins] as a Headteacher, was very concerned about the shortage that she heard about … science graduates, and in Science A levels, and in pupils choosing science. So, she was very keen, as a Headteacher of this school, to promote science in every way possible.

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[3] Marmite: a food spread

And so, she, … had the idea for a centre that would train Science teachers, that would be an innovative building, which this one is, on our school site; and I remember being in the meeting …. So, from a vision, really, that she had to have this kind of centre of excellence, and I was in the meeting where she said, 'it's just an idea'. ...Two years later we were sitting in the building'' (I: Mr. McKay, Assistant Headteacher).

At the time data were collected, the Science Learning Centre network had ended. However, Farne School retains the facilities. The Centre continues to host conferences and events that enhance science teaching and learning. Figure 5.6 shows the layout of some of the facilities at the Centre.

Figure 5.6: Farne Science Centre

Mr. McKay believes that the Science Centre is integral to the school's science provision stating:

It has always been used as a place where exciting and different and unusual science lessons could happen. So, we have always had [children] going up from the science [laboratories] …to the Science Learning Centre… … different science lessons, has happened up there. So that's part of the history of this school, and I think that's one of the reasons why, in addition to the fact that we've been a science [school] for those times when the science [schools] were really up front in Britain…That's an important part of the history of this school and the way it has promoted Science.

However, there was no evidence of the Science Centre being used for science lessons during the data collection period. Events in the Centre observed by the researcher included a Year 12 ''celebration'' to mark the end of an internship programme and the Institute of Physics research project involving ''10 Topaz''. Students' views of the Science Centre are discussed in Chapter 6.

''Post-16 Internship'' programme

The school runs an ''internship'' programme in collaboration with local businesses and universities in the North East. Each internship provides a one–school year work placement for a Year 12 student. In 2014/15, internships were offered in six areas: STEM Leadership, Medical Science, Law and Politics, Sports, Creative Arts and Leadership and Management. Year 12 students may apply to participate. The programme is popular (I: Mr. McKay) so, usually more students apply than placements available ensuring competition. Students submit a personal statement and are interviewed by a panel comprising Farne School senior leaders and the ''STEM Enrichment Manager''. Farne School leaders regard this programme as an essential element of students' science learning.

> Having access to these relationships inspires students to consider STEM careers for the future and enables them to gain experiences that they may not receive elsewhere. Enabling students to take part in additional STEM enrichment activities is vital for the development of their communication skills, their initiative and facilitate their motivation to succeed (*Source:* School website).

The science department recommends students to the selection panel (Mrs. Natanson, Deputy Head of Science, KS3; Mr. Martins, Deputy Head of Science, KS4). Successful applicants have achieved high grades in GCSEs including English and Mathematics and are usually studying at least three A–levels (Mr. Martins). The novelty and high status of the programme was noted in interview with Mr. McKay who stated:

> ''I never heard of any other school doing anything like it, but the relationship has been developed with different groups of industries in the local area''.

As interns, students spend time weekly in the partner organisation working on a project relevant to their A–level programme and/or career objectives.

The STEM leadership internship involves working with mentors from industry, including STEM Ambassadors. STEM Ambassadors are volunteers from STEM-related fields of employment who work with schools to promote science. One outcome of the internship programme is the expectation that students gain practical work experience from working with mentors, and in some cases, see connections between curriculum content and science in the workplace.

> ‘’It’s been quite impressive because the [children] have grown; some of them … talk about their own personal development in understanding the world of work out there, and they say, ‘I realise why I have to learn this in my A levels because I saw people using this stuff in the world of work”, so it’s a really interesting project’’ [I: Mr. McKay].

Although the programme exposes students to career opportunities in STEM related fields, students who are not classed as ‘’high’’ attainers in GCSE examinations are precluded from participation. Teachers explain the highly academic selective nature of the internship programme is unavoidable because interns must be capable of combining academic work with the internship. Interns are expected to work independently to ‘’catch up’’ on missed classwork in their spare time

> The internship is a very busy programme and it involves students being out of lessons a lot, having to catch up on a lot of work themselves and being more independent. It's got to be a group of students that can manage that and thrive rather than students [who] struggle with their A levels. So, we try to be quite careful with that [I: Mr. Martins].

Although this may be reasonable, the selective process of the internship programme contributes to the narrative that students aspiring to science careers are ‘’high’’ ability, as less able students are disqualified if their GCSE grades are not up to the school’s accepted standard. Hence, students who may otherwise benefit from an internship are excluded from participating. Students’ views of these practices including the internship programme are discussed in Chapter 6.

This section provided a descriptive account of science provision at Farne School focussing on in-class and extra-curricular provision. In the next section, the school’s views of factors affecting students’ attitudes and career expectations towards science are discussed.

5.4 Farne School's views of factors affecting students' attitudes and career expectations towards science

This section examines the factors affecting students' attitudes and aspirations from the standpoint of Farne School. Data are drawn from interview sessions with teaching and non-teaching staff in the science department and Mr. McKay, a member of the senior leadership team.

5.4.1 Teachers' perspectives

Teacher interview data suggest that factors, which they believed, impacted negatively on students' attitudes and career expectations towards science were outside their control. These include students' perception of science, curriculum time and content, pressure of examinations and support of school leadership.

<u>Students' perception of science</u>

Teachers believe that preconceived ideas acquired through friends, families and the media result in students' belief that science is a ''difficult'' subject.

> Generally speaking, [science is] seen as a hard subject, which I don't think is particularly helpful, so a lot of students will switch off … by Years 8 and 9, because they think …it's just hard. And it's probably not because it is hard, it's just that attitude that they're getting from the outside world… [I: Mrs. Natanson, Deputy Head of Science, KS3; Teacher for ''8 Emerald''].

> … There's a perception in society that science is too hard for most people and that it's not useful for most people. … I think the average member of the public would often miss the usefulness of science in a lot of everyday applications and also would overestimate how difficult it is to get into science. I think we see a lot of that in Farne. There's students in the school society that aren't interested in science and again [are] … affected by what they experience outside of school [I: Mr. Martins, Deputy Head of Science, KS4: Teacher for ''10 Topaz'' and ''12 Ruby''].

Teachers also believe that the perception that science is ’difficult’’ is intractable, thus limiting the impact they have in encouraging positive attitudes and career expectations towards science.

> So, I think that’s probably one of the biggest challenges you have as a teacher, that barrier that students have built in their heads before they get to your classroom is very difficult to break down [Mr. Martins].

The views expressed by teachers highlight the role students’ preconceived ideas about science plays in students’ attitudes towards science. First, preconceived ideas can be positive or negative. Positive ideas form part of what Archer et al (2013) refer to as science capital (2.5.4) noting that possession of science capital can be a positive influence on students’ science attitudes and career expectations towards science. However, teachers’ views at Farne School suggest that if these ideas are negative, this could result in what the researcher has called ‘’destructive science capital’’ as this results in aversion to science.

Second, teachers’ reference to students’ perception of science as ‘’hard’’ being a barrier to their teaching of science also raises the question of the effect of a teacher’s own preconceived ideas about students on their own practice. For instance, teachers who believe that students will not engage with science because they find it ‘’hard’’ may themselves as teachers subconsciously erect barriers they may be unaware of. Mr. Martins’ reference to the ‘’difficulty in breaking down’’ students’ perception of science as a ‘’hard’’ subject demonstrates this. His statement reflects his own subconscious preconception to students perception of science as ‘’hard’’, thus exacerbating an existing problem even if his views are justified.

<u>Curriculum time, content and support of school leadership</u>

Students’ responses to English and Mathematics compared to science were noted. Mr. Martins suggested students ranked by Farne School as ‘’low’’ or ‘’middle’’ attainers, for example, those in pathway 1, were more apathetic to science compared to Mathematics.

> Even compared to maths and you might think those students would hate maths as well, but there … seemed to be a … [proportion of] students that didn't really mind maths and they were quite happy to work for their maths GCSE, but when it came to their science, they were really switched off straight away [I; Mr. Martins].

> Because [science] is three subjects … [students] think, this is a [large] amount of content that's … expected for [one or] two GCSEs …it's quite daunting and that's probably where they get this idea that science is hard [I: Mrs. Natanson].

Mr. Martins and Mrs. Natanson attribute student apathy to the volume of content and perception that science is a ‘difficult’ subject with ‘complex ideas’. They suggest this creates mental barriers that some students are unable to overcome.

> They find the amount of content in science not only challenging but also irrelevant to everyday life. Therefore, they are less likely to enjoy science. I can't do this, I'm not going to bother [I: Mr. Martins].

He noted that this is not the same with students ranked by the school as ‘’high attainers’’. These students, Mr. Martins claim, persist until they understand difficult concepts. They were more likely to seek support from teachers and families compared to students classed as ‘’low’’ and ‘’middle’’ attainers (Mr. Martins).

> I guess with the more academic students …. If they've got parents or family that are more academic outside of school, even if they find science difficult and they don't see themselves as scientists in the future, they're often more willing to …. …. work hard for it and try and do the best they can. Whereas, … the less academic students, once they see what science GCSE's like, they find it such a leap from where they are in their everyday experience, that they just give up [Mr. Martins].

Mr. Martins believes that part of the problem is insufficient curriculum time noting that time allocated to teaching science is not commensurate to the content which must be taught. Hence, there is an increase in teaching pace as examinations get closer which some students find challenging. Mrs. Natanson, disagrees.

She believes that students’ prioritisation of English and Mathematics over Science reflects the value placed on science by the school’s senior leadership team.

Mrs. Natanson notes that allocation of ''extra resources'' to English and Mathematics delivers ''mixed messages'' to students.

> I think [children] also struggle with science, because it's not got the support from senior management, as English and Maths do. So, they keep being told 'you need your English, Maths and Science'…, but then it's not being supported by the extra intervention that English and Maths classes would get, but then the [children say], 'but you told us it's just as important as English [and] Maths. So, I think that perspective is skewed as well. … that doesn't help the students [I: Mrs. Natanson].

The organisation of teaching in Key Stage 4 (5.3.1) appears to support Mrs. Natanson's claim of more resources being directed towards English and Mathematics compared to science. Pathways 1 and 2 are provided with extra ''support'' in ''core skills'' (numeracy and literacy) but not in science. The likelihood exists that some students may develop a belief system that science has no utility compared to English and Mathematics and is therefore disregarded.

Mrs. Natanson's perception that ''extra resources'' were allocated to English and Mathematics compared to Science is consistent with earlier findings (Hutchinson, 2015; Worth & De Lazzari, 2017). Allocation of more curriculum time to English and Mathematics (Worth & De Lazzari, 2015) or ''extra support'' provided in English and Mathematics compared to Science may deliver subliminal messages to students that these are the ''main subjects'' (DCSF, 2008 as cited in Hutchings, 2015) to focus on. This emphasis on English and Mathematics is an unintended effect of Government policies which is sometimes reinforced through school inspections by the Government. An example was mentioned in Government Inspectors' report from Don School – a Cluster school (5.5.1, p. 140) which focussed on literacy and numeracy (5.5.1) with science mentioned as an example of an event students' enjoy, rather than as a subject.

<u>Relevance of science and pressures of national examinations</u>

Teachers claim to promote science positively in lessons by highlighting links between science and everyday life and discussing science–related careers. As these excerpts indicate, some topics lend themselves naturally to making these connections:

> So, if you're teaching about the effect of drugs and alcohol or smoking… this matters to them and you, you do probably reinforce that verbally more in that lesson, because … it's easy to connect them to the real world [I: Mrs. Natanson].
>
> Everything we do you need for your exam, to get your GCSE, but this, this is important for you as an individual," and you, you do probably reinforce that verbally more in that lesson… I don't know how consciously and subconsciously you do these things [I: Mrs. Natanson].
>
> I think on a lesson by lesson basis it goes back to the whole idea again of how do you engage them? How do you get them excited about learning science in science lessons? So, I think that plays a big part … … On the wider scale, you need to think about promoting science as frequently as possible, especially when it comes to things like 'Open evenings' where student get more of a choice about their subjects, but within lessons as well. As often as possible, just reminding students of how valuable …science is and therefore hoping that might gradually help to change their opinions. So … pointing out to them the wide variety of careers that would use science in some form [I: Mr. Martins].

However, conflicts in priorities arise as national examinations approach. Mrs. Natanson points out that at the start of the year it is possible to plan lessons using relevant context but as examinations approach (e.g. GCSE and A-levels), teachers become concerned about examination techniques:

> Sometimes I think probably the beginning of the year, you're quite conscious of these things. By the end of the year teachers… are probably just focused on exams. 'I need to get them through this' and it turns into more of an exam factory, which is not ideal, but that's the pressure that staff are under [I: Mrs. Natanson].

Mrs. Natanson's observation that classroom have become ''exam factories'' is part of a wider national problem. The notion of ''exam factories'' was raised in section 2.4.2. Creative and interesting lessons which may make science more engaging for students are abandoned in favour of aspects of the curriculum that may be tested in national examinations (Hutchinson, 2015). This leads to a narrowing of the curriculum.

The notion of ''exam factories'' is also linked to the use of different examination boards, especially the practice of switching to boards considered ''easy'' (West, 2010; Meadows, 2015). This was noted in section 5.3.1.

5.4.2 Technicians' perspectives

Staff other than teachers may impact indirectly on students' attitudes and aspirations. Research identifies technicians as an ''under-utilised resource'' in science departments (Hellier & Harrison, 2011). This view was echoed by the science technicians (Mr. Case, Mrs. Nicholson and Mrs. Johnson). They note that their knowledge and expertise may be under-utilised.

> I think a Science Technician's job is very important. You've got to know a little bit about what you are doing to even just do your everyday job. Mr. Case is an absolute encyclopaedia, is brilliant because he knows more, he probably knows more than all the teachers put together! I think it's very important that we do our job efficiently and have a good rapport with the teachers … which we do [I: Mrs. Johnson].
>
> ... [The department] had a little project about LDRs[4] and how to make a printed circuit board and place all the components. [The science teacher] didn't know. I went into the classroom two or three times and showed them how to build the board and how it should work. …I… showed them and …even the [children] that were [disruptive] got the principle ……. and … did quite well. So, technicians aren't just there for the equipment and resources [I: Mrs. Nicholson].

These comments suggest that technicians may be useful in providing positive support in practical lessons where teachers' subject matter or pedagogical content knowledge are limited. This is consistent with Hellier & Harrison's (2011) findings.

[4] LDR - Light dependent resistor

A striking comment in technician interviews was made by Mr. Case (senior technician) when discussing his observations of students' attitudes during the eighteen years he has worked in Farne School. He claims that making science compulsory compels students who may otherwise have chosen Arts/Humanities to become disruptive or apathetic towards science.

> Other than the way it has been assessed I don't think it's changed that much really, other than because [students] can't opt out of it now. We have a lot of [children] … tend to be the ones who [are disruptive] … On the old system they might have chosen to do Geography or D & T (Glossary) … rather than science and so when they get forced to do something there is a bit more resentment… if they don't like a subject, they tend to be more disruptive and they just don't put as much work into it as they would into a subject they do like [I: Mr. Case].

Although these claims may be true, the data suggest that the notion of interest in science is complex. This is discussed in section 6.3.3.

5.4.3 Senior Leadership's perspective

The views of the senior leadership team presented by Mr. McKay are discussed. This includes the science curriculum and student-teacher relationship.

<u>Science curriculum</u>

Mr. McKay believes that part of the problem lies with the science curriculum being too restrictive. He believes that this limits the number of practical lessons teachers could use to make science more engaging.

> ..I think that's a shame, but the curriculum is the way it is, and they have to get through the material, and there's some parts of the curriculum where there really isn't very much you could do in practical… you know, practical kind of laboratory setting.

Mr. McKay's comment suggests the amount of content required to be taught forces a trade-off between teaching creative lessons and content. In other words, creative lessons may generate positive interests in science, but this does not produce positive examination results. This supports Mrs. Natanson's point and Hutchinson's (2015) findings about schools being ''exam factories''.

Similarly, Meadows (2015, cited in Hutchinson, 2015) reported that in some cases, teachers resorted to what Meadows (2015) referred to as ‘’question spotting’’, that is, teachers anticipate questions that may come up in national examinations and tailor their teaching to suit these. In extreme cases, some specification content are not taught at all (Meadows, 2015 cited in Hutchinson, 2015). These practices may improve examination outcomes and the schools ranking in league tables but may not promote positive interest in science.

Student-teacher relationship

Another area Mr. McKay believes affect students’ attitudes towards science is the relationship between students and teachers. He explains that students are likely to develop an interest in a subject where the relationship with their teacher is positive.

> My experience as a teacher in general is that the quality of the relationship that the kids have with the teacher they have that year has a big, big influence on whether or not they’ll do the subject.

He explains that as a member of the senior leadership team involved in meetings with parents and students, it is not uncommon for students to base their post-16 subject choices on the relationship with the subject teacher.

> I think that if they had a good time in the lesson; if they felt that they were looked after and that they were helped, …..even kids who are not really keen on the subject will still think, oh, this is okay. And that’s particularly obviously for A-level; at GCSE they don’t have any option, they have to choose it anyway, but at A-level quite a big number choose it, and that’s I’m sure because they felt like they got a good deal out of their Science lessons here.

However, another point of interest is Mr. McKay’s comment that at KS4 students do not have an option in choosing their subjects. This supports the conclusion drawn in section 5.3.1 that the so called ‘’pathways’’ may be designed to maximise the school’s position in league tables rather than students’ interest.

5.5 Overview of science provision and school's views of factors affecting students' attitudes and career expectations towards science.

The previous section described science provision in Farne School and staff members' views of factors affecting students' attitudes and career expectations towards science. Teacher preconception, ''exam factories'' and under-utilisation of resources, for instance the science centre and technicians were discussed in the previous section and are not repeated. Others are reviewed.

5.5.1 Limitations of the Primary Cluster

The primary cluster was allegedly designed to improve subject and pedagogical content knowledge respectively of primary school teachers from feeder primary schools. This is managed through meetings with teachers from the primary schools and ''primary skills'' day. However, as the aim of this study is to examine factors which affect students' attitudes towards science, the impact of the cluster focuses on students rather than teachers.

To examine the impact of the cluster, a comparison was made between students in Year 8 from the cluster schools (n=45) and those from non-cluster schools (n=24). Responses are based on students (n=69) who provided answers to all questions in the primary school section of the Year 8 questionnaire (Appendix 8). Looking at Figure 5.7 this shows that experiences between students from cluster and non-cluster schools are similar.

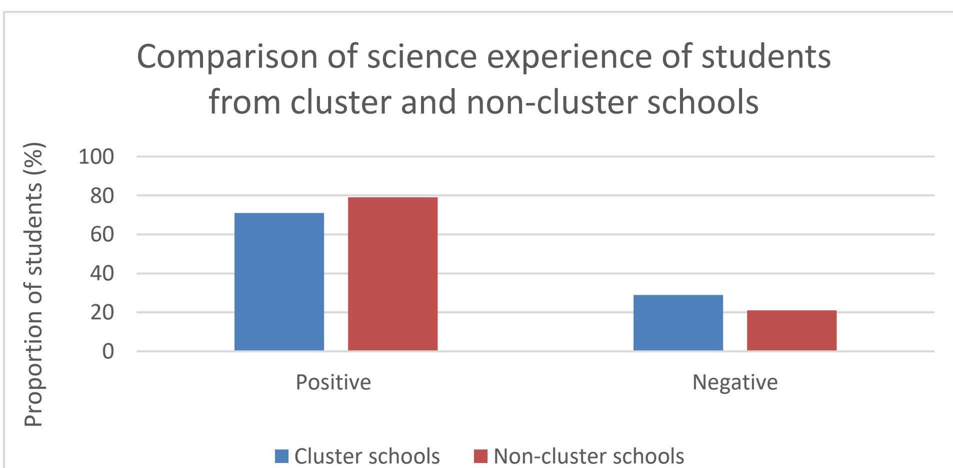

Figure 5.7: Comparison of science experience of students from cluster and non-cluster schools

For instance, 79% (n=24) of students from non-cluster schools report positive science experiences compared to 71% (n=45) of students within the cluster. This suggests that the impact of the ''primary cluster'' on students' science experience prior to attending school at Farne School may be inconsequential. Farne School itself has no evidence to support claims that the cluster is successful. A comparison was then made between schools within the cluster. Figure 5.8 indicates that with the exception of Don School, students from the cluster schools had positive science experiences in primary school.

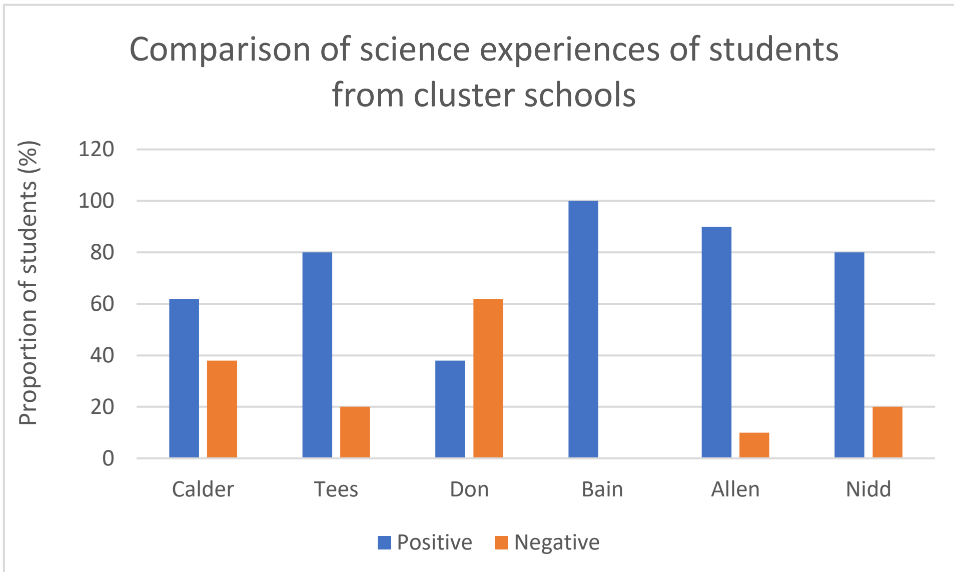

Figure 5.8: Comparison of science experiences of students from cluster schools

To explain this difference, Don School's website and Government's inspection report at the time of data collection were examined for its science provision. The website showed that at the core of Don School's curriculum is literacy and numeracy; science teaching is secondary and irregular. The Government inspection report showed that Don School was judged ''outstanding'' by inspectors (Ofsted, 2013). However, the report, as was the case for the other cluster schools, only focused on Reading, English and Mathematics. The only reference to science in the report is a ''science day'', which inspectors cited as an example of the kind of activities students enjoy.

Science day is an event in which students work alongside over 200 adults on a wide range of practical activities during a school day. Schools in the UK hold events like this especially, during ‘’British Science Week’’. Science week is a ten-day program coordinated by the British Science Association with funding from the Department for Business, Energy and Industrial Strategy (British Science Association, 2015).

The science day event cited in Don School’s inspector’s report is itself not unlike the Primary Skills day held by Farne School. Activities such as Science day and Primary Skills day, though useful and engaging, may be insufficient to sustain positive science experiences if everyday science experience is poor as is the case with students from Don School.

In section 4.10.4, students were grouped into four categories; *Scientists*, *The Ambivalent*, *Non-Scientists* and *Resisters* based on their reported aspirations for science. Students in the *Resisters* category were identified as students who do not have science career expectations. However, further analysis of the student data revealed that the majority of students in Year 8 (8, n=11) within the study who were identified as Resisters (4.10.4) attended Don School. This could mean that some teachers in the ‘’Cluster’’, still lacked the confidence to teach science in their primary schools (Newton & Newton, 2011; Murphy, Neil & Beggs, 2007). Due to limited subject and pedagogy content knowledge, they may be reluctant to put themselves in situations where these weaknesses become apparent. They may, therefore, be constrained to adopt teaching strategies which maximise their professional teaching skills but limits the content and practical activities of the science curriculum which students experience (Harlen & Holroyd, 1997).

The proportion of *Resisters* from this school implies that interventions such as the Cluster may influence aspects of science experiences such as assessments and attainment while having little impact on overall student science experience. A plausible reason for this was that the programme was set up at inception to improve assessment outcomes and not improve students’ science experience. Hence, they may be unable to address fundamental issues such as the SCK of the teacher or for that matter, resources available to science teaching (for example, curriculum time) within these primary schools.

Therefore, claims by Farne School that the Cluster is a useful tool in its promotion of positive attitudes among students before they start at Farne School may, be an exaggeration of the Cluster's success and is debatable.

5.5.2 Disparity in science provision

Other areas of the school's science provision indicated a pattern of inequality. This was evident in the organisation of teaching at both Key Stages 3 and 4 (5.3.1) and in the selection of students for extra-curricular activities. For instance, in Key Stage 3, students are placed in ''sets'' based on attainment in science in Year 9. This means that in the first two years of secondary school, English and Mathematics are prioritised over science.

This pattern is repeated in Key Stage 4 where students in pathways 1 and 2 are provided with ''extra support'' in English and Mathematics but not science, despite science being a ''core'' subject. This could account for students being prepared to put in extra effort (Mr. Martins, p. 150) in Mathematics for example, but not science despite the school being a specialist science school. Secondly, students selected for participation in extra-curricular activities are students whom the school has ranked as ''high ability'' based on prior academic achievement. This is discussed in section 6.6.1.

5.5.3 Promotion of positive science aspirations: department or whole school?

Evidence of promotion of positive science aspirations was sought from other sources such as documents and lesson observations.

<u>Documents:</u>

The stated aim of the science department is 'to provide through the exploration and study of science, a coherent educational experience that will enable students to acquire the understanding and knowledge to:

1. become confident citizens in a technological world able to take an interest in scientific matters
2. recognise the usefulness and limitations of scientific methods and appreciate their applications and relevance to everyday life and other disciplines
3. be encouraged to pursue and be suitably prepared for further studies in science'.

(Science Department Handbook, 2014/15; p.8).

Departmental documents such as the Handbook and programmes of study were analysed for evidence of especially, stated aim, number 3 above. Figures 5.9 to 5.10 show the results of the word frequency count of these documents (4. 10.3). The Handbook (Figure 5.9) which can be considered as a policy document underpinning the purpose of the department, indicates that departmental focus is on predictable obligations such as teaching, learning and assessments. A similar pattern was observed with the KS3 and KS4 programmes of study (Figure 5.10).

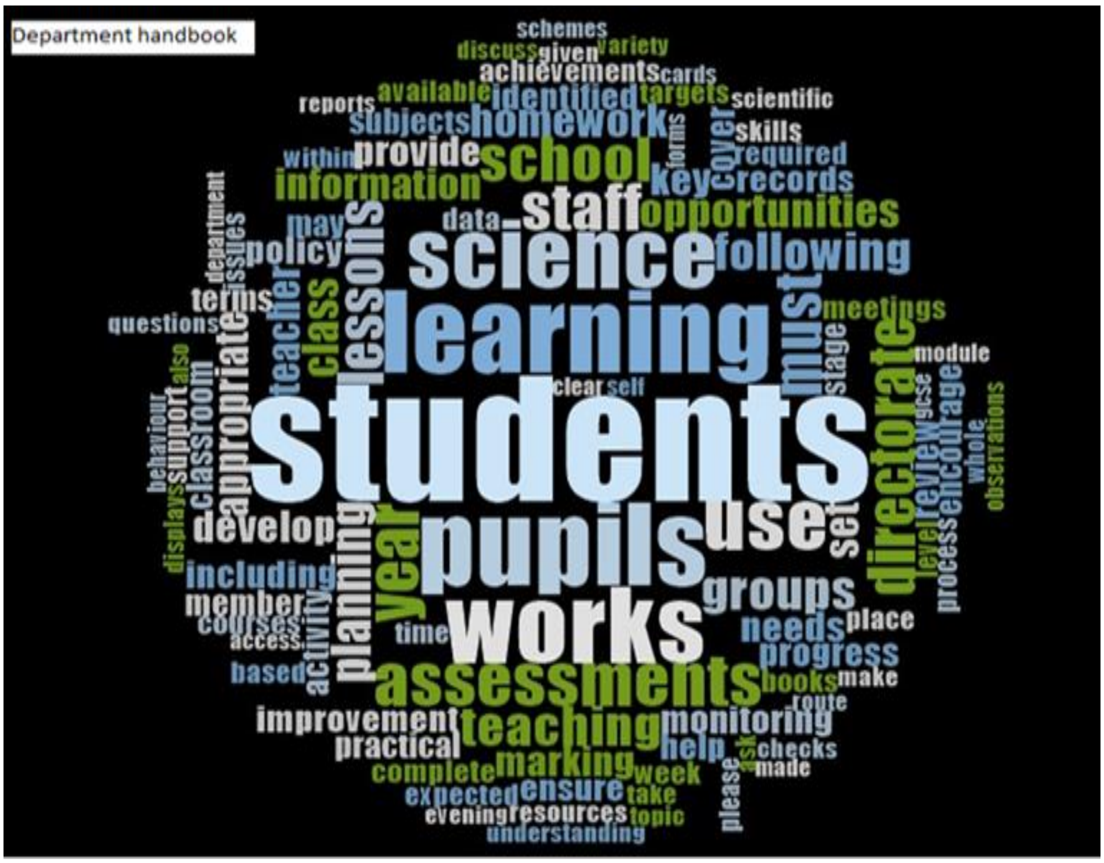

Figure 5.9: Word cloud of Science Handbook

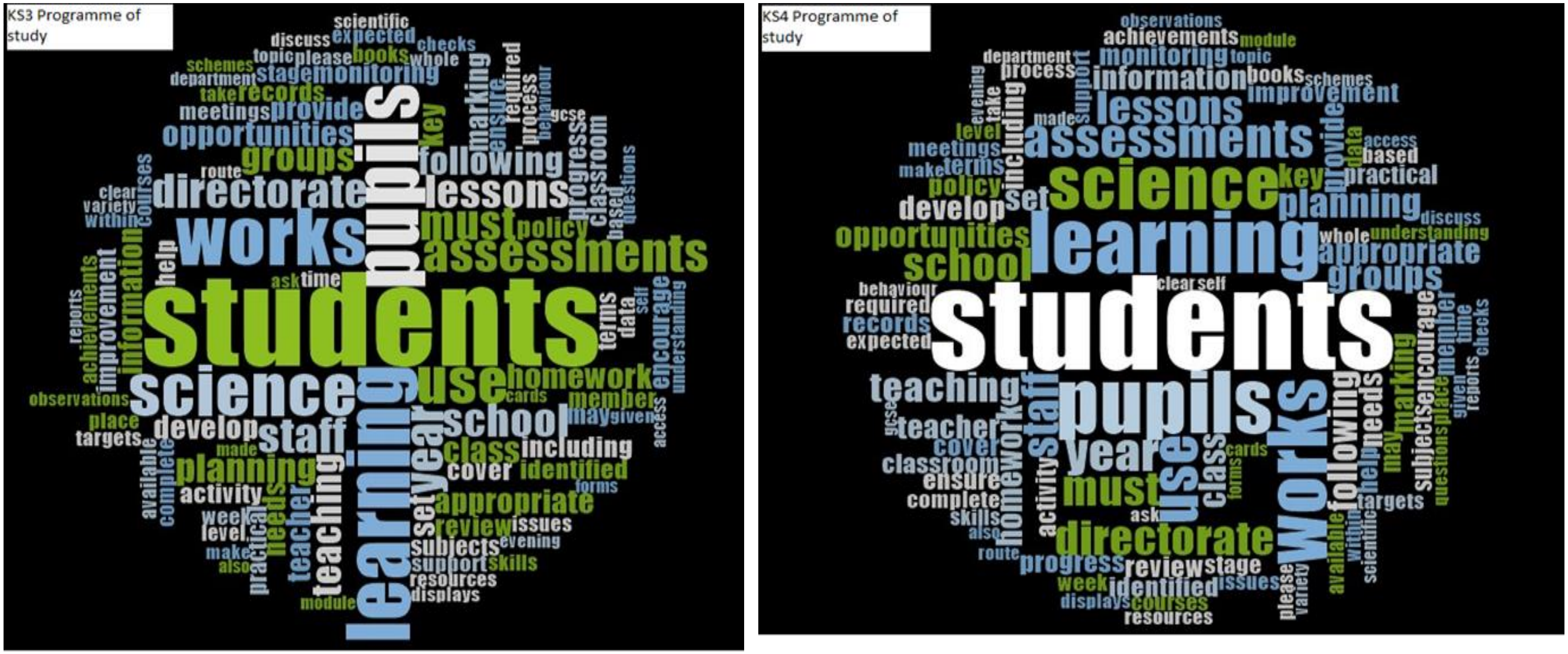

Figure 5.10: Word cloud of KS3 and KS4 programmes of study

To put this in perspective, a sample of the most frequent occurring words in the department are shown in Table 5.8. An excerpt from the list can be found in (Appendix 14). Word repetition could be a useful pointer to issues of importance (Ryan & Bernard, 2003). This shows an emphasis on teaching, learning and assessments. Similarly, less repeated words can also be a pointer to the value or lack of value placed on them. For example, as seen in Table 5.8, the word ''attitudes'' occurs four times but this is in relation to student behaviour in lessons. The word, aspiration or related words do not occur at all but words associated with teaching, learning and assessment occur approximately 800 times.

Science department documents					
Most frequent				**Words related to attitudes, aspirations, enrichment opportunities**	
Words		Count		Words	Count
	Students, pupils	238		Scientists	2
	Learning Knowledge Lessons Teaching Teacher	188 451 59 47 33		Gender Girls	6 2
	Science	81		Attitudes	4
	Staff, department	112		Aspirations	0
	Assessment Monitoring Data Homework Marking	82 29 22 37 32		Citizen	2
	Achievement Attainment	19 15		Visits/trips Opportunities	10 35
	Set Group	35 36		Internships/ placement	1
	Policy	30		Interest	4
	Class	39		Engaging/creative	2

Table 5.8: Sample of word frequency in departmental documents

This appears to support the notion that science provision within the department is focussed on teaching and learning rather than active promotion of positive attitudes and career expectations. However, as there may be gaps between policy and practice, it is possible that the science department may be more active in promotion of science than is evident in the documents examined.

A similar analysis of the school documents such as the prospectus reveal that words associated with aspirations, extra-curricular activities and employment appear more frequently compared to departmental documents. It is in the school documents that the word ''aspirations'' appear twice, implying that career expectations are promoted at whole school level.

Lesson observations

In addition to documents, evidence of promotion of positive attitudes and career expectations were sought in lesson observations. Contrary to Mrs. Natanson and Mr. Martins claims to promote science in their lessons (5.3.2), this was not evident beyond the teaching of curriculum content especially in lessons observed with ''8 Emerald'' (Mrs. Natanson) and ''10 Topaz'' (Mr. Martins). However, in ''12 Ruby'' (Mr. Martins' AS physics class), promotion of science events and discussions around science careers were observed. A possible explanation for a lack of active promotion of science and science careers in Key Stages 3 and 4 could be that teachers assume that the WIKID scheme of work does the promotion work for them. Another reason for a lack of promotion of science careers in lessons was made by Mrs. Natanson who stated that this may be possible at the start of the academic year, but it may be difficult to sustain as preparation of students for national examinations take precedence (5.4.1).

These findings suggest that promotion of positive attitudes and career expectations are managed mainly at a whole school level and not at departmental level. This supports the ''two–pronged'' approach in science provision but also raises the possibility that by limiting the role of the science department to teaching and learning, opportunities for science staff to provide valuable career advice are lost. This is important as the ''STEM Enrichment Manager'' does not have a science background and may therefore be unable to provide insights into science career opportunities as well as staff in the science department.

5.6 Summary

This chapter provided answers to the first part of RQ1 – factors which staff in a specialist science school believed affect students’ attitudes towards science. Data used were drawn from documents, semi-structured interviews and lesson observations. Analysis of the data indicated that Farne School adopts a ‘‘two–pronged’’ approach to the teaching and learning of science, that is, within-class provision managed by the science department and extra–curricular provision managed mainly by the STEM Enrichment Manager and the science department.

Science at the departmental level is limited mainly to the teaching and learning of science content described in the National Curriculum Science Programme of Study. Within the science department, technicians play an important role in science provision but appear to be an under–utilised resource. The notion of teacher preconception as a barrier towards teaching was also raised. Teachers note that the pressure of national examinations has led to classrooms becoming ‘‘exam factories’’ as they have to prioritise teaching content they believe are potential examination questions over creative and engaging lessons. The notion of inequality was also raised. The allocation of more resources to English and Mathematics by the school leadership team over science has resulted in students believing that these subjects are more important than science.

Claims of the school’s assertion that science is promoted at all levels were examined from data collected via interviews and documents. This indicated that science aspirations are promoted mainly at whole school level through extra-curricular activities managed by the STEM and Enrichment manager. However, this often results in conflict between the ‘‘STEM Enrichment Manager’’ and teachers in STEM departments. Other extracurricular activities such as the primary cluster which purportedly promotes positive attitudes toward science before students start secondary school showed that its success is limited. Students from within and outside the cluster report similar experiences of primary science.

The next chapter provides answers to the second part of RQ1 - students’ views of the factors that affect their attitudes towards science in the school sphere of influence.

Chapter 6: School sphere of influence: students' views of factors affecting their attitudes and career expectations towards science

Science is the subject you either love or hate

- Doreen: female, Year 10

6.1 Introduction

In the previous chapter, the school's views of factors affecting students' attitudes and career expectations towards science were discussed. This provided answers to the first part of RQ1. This chapter provides answers to the second part – students' views of factors they believe affect their attitudes towards science. Analysis of student data in Chapter 4 led to factors identified being grouped under three categories; school, subject and personal oriented factors. Factors within these categories overlap, for example, students in ''8 Emerald'' identify the teacher, a school-oriented factor, as a reason for their self-efficacy, a personally-oriented factor. To avoid repetition, factors are discussed in the most suitable section.

Students' views are reported from the three science groups in the study (4.7.2), generating a holistic standpoint across all Key Stages in Farne School. Exemplar statements are drawn from questionnaire responses, group discussions and lesson observations (4.9.2). In addition, excerpts from students' diaries are used. Quotations from diaries are identified with a 'D'. Quotations are reported verbatim in most cases, with the name, gender and year group of the student placed in brackets.

Self-efficacy was defined in section 3.3, as ''students' beliefs in their ability in science''. Self-efficacy was determined in this study by students rating their ability in science on a scale of 1-10 (4.8.2). The assignations, ''low'' (rating, 1-4), ''moderate'' (rating, 5-6) or ''high'' (rating, 7-10) are used to describe these ratings.

The chapter starts with section 6.2 which presents views of students in ''8 Emerald'' followed by 6.3, views from ''10 Topaz'' and 6.4, views from ''12 Ruby''. Section 6.5 provides an overview of students' attitudes across all three Key Stages, including students' perception of the schools' role in promoting science. The chapter ends with a summary, 6.6.

6.2 ''8 Emerald''

This class, 8 Emerald, is a ''mixed-ability'' group, students are expected to achieve at least a C grade in GCSE science examinations (Mr. Hadfield, Head of Science). The class comprises sixteen girls and twelve boys aged 12 to 13. During the 2014/15 academic year in which data were collected, 8 Emerald, had two teachers; Mrs. Anthony from September 2014 to March 2015 and Mrs. Natanson from April 2015 to July 2015. Mrs. Anthony is a substitute teacher who interrupted her retirement to cover for Mrs. Natanson (Deputy, Head of Science, KS3), who was on leave. Science is taught three times a week on Monday, Tuesday and Thursday. Lessons on Monday and Thursday occur in a traditional classroom while Tuesday's take place in one of the new laboratories refurbished from funds obtained when the school first obtained specialist status (5.2).

6.2.1 School–oriented factors

Factors identified by this science group range include the teacher, time of day in which lessons occur and teaching rooms used. These are discussed.

<u>Class teacher</u>

In explaining their reason for their self-reported self-efficacy, some students link this to their teacher. They imply that their self-efficacy in science, is impeded by their teacher's poor explanation skills. This is true, even of students who claim to like science or are ''good'' at it.

> I like science and research at home, but my teacher isn't too good at explaining [Haley: female, rating: 6].
>
> I am good at science and I like it. The teacher isn't very good at explaining [Betty: female, rating: 6].

Although ratings of 6/10 were labelled as ‘’moderate’’, students’ responses indicate this could be ‘’high’’ if their teacher’s explanation skills were ‘’good’’.

Another aspect of a teacher’s pedagogy linked to self–efficacy is questioning technique. This may affect student-participation in lessons, especially with students who consider themselves to be ‘’quiet’’ in nature. Beverley is a good example. She claims that because she is ‘’quiet’’, she rarely answers questions in lessons. However, her response indicates that beyond her quiet nature is a need for recognition by the teacher.

> I enjoy science and think it is a really good lesson but I’m one of those people who are quiet and let other people say the answer even if I know them. My teacher doesn’t often ask me anyway [Beverley: female, rating: 7].

Beverley’s response is an indication that activities such as questioning can be useful in encouraging student participation in lessons. The impact of the teacher on students’ career expectations towards science is also discussed in Chapter 7.

Time of day and teaching room

In a group discussion, students’ views of the time of day in which lessons occur, differed. However, when it came to science, there was a consensus that lessons in the mornings were preferable. Science lessons are taught twice a week in the mornings, Period 2 (10:20 to 11:20) on Monday and Thursday and once in the afternoon, Period 5 (14:20 to 15:20) on Tuesday. They claim that science can be ‘’hard’’ (e.g. Chapman, male) and the time of day affects their behaviour and comprehension. Having lessons in the mornings makes it easier to understand science concepts because students claim this is when they are most attentive.

> I like the lessons in the mornings because if it was in the afternoon, and we are doing an experiment, because science is sometimes hard to understand. So, you want to be awake for it. But if it’s at the end of the day, you might not take it in as much [compared to the mornings] when you have loads of energy [Chapman: male].
>
> You concentrate more in the mornings [Beverley: female].

Another related factor is the teaching rooms in which lessons take place. Morning lessons are held in a traditional classroom setting and afternoon lessons in the refurbished laboratories. Although students say they prefer the morning lessons, they do not like the teaching rooms in which these lessons occur. They prefer the refurbished laboratory, stating that more experiments are held in the laboratory. It is possible that preference for the laboratory over the classroom could be because of the amount of practical work carried out in the room, rather than liking for the room *per se*.

> I prefer Mr. Martins' lab because we seem to do more experiments there [Burton: male].
> I like Mr. Martins' room because we do more experiments [Chapman: male].

However, some students prefer the laboratory for its sake, noting that the furnishing and amount of light it allows in makes it better than the traditional classroom.

> I like it because it is light [Beverley: female].
> I like Mr. Martins' [laboratory] because it's a better room. I don't like them rubbish chairs [in the classroom]. I like the high ones [stools in Mr. Martins' laboratory] [Burgess: male].

6.2.2 Subject–oriented factors

Factors identified in this category include practical work and the nature of science.

<u>Practical work and the nature of science</u>

Students' preference for practical work was noticed in lessons observed as the conversation between this pair of students at the start of a lesson demonstrates.

> Are we doing an experiment? Yes! That's good [Burgess: male].
> No, I'm sure we will be copying out of a book [Burton: male].

Burgess goes on to explain that ''science is fun when we are doing experiments, but boring when we do writing''. However, despite students' excitement about practical work, they find them tedious, if the tasks become repetitive.

> It was like a few weeks ago we were doing …the different [forms of] energy and we were doing like quite a lot of practicals but like all very similar. After a while, it just got really boring because you knew what to do but you kept doing it [Beth: female].

This highlights the need for teachers to develop an extensive range of teaching strategies to sustain students' interest.

Another factor identified during a group discussion about practical work was a difference between science and subjects such as arts. Students claim that the nature of science limits their independence and opportunity to discover things for themselves.

> In Art, you have more freewill but in science it's specific things you have to do. I know it's for your safety but it's very restricted what you can do. Instead of being shown how to do … [an experiment]. … [It can] be explained and then you get to do it … For example, you can be told the safety parts of it … without being told everything [Abbie: female, Year 8].

Abbie's observation of practical work being too structured supports the notion that practical work follows a ''recipe'' approach in which the main objective is to ensure that students do what the teacher wants (Millar, Marechal & Tiberghien, 1999 cited in Abrahams & Reiss, 2012). Students are unable to make cognitive links between scientific concepts and practical work (Abrahams & Reiss, 2012). Practical work is therefore reduced to a ''hands-on'' task rather than a ''hands-on'' and ''minds-on'' activity (Abrahams & Reiss, 2012) which supports learning.

6.2.3 Personal–oriented factors

Personal-oriented factors presented include self-efficacy and personal attributes.

<u>Self–efficacy in science</u>

In section 6.2.1, self-efficacy was discussed in relation to school-oriented factors, namely, the teacher. In this section, personal-oriented factors which students have linked to their self-efficacy in science are discussed. These include, understanding and attainment and personal attributes.

Understanding and attainment

Understanding of science concepts and/or attainment in class assessments can affect students' self–efficacy in science. Students whose self–efficacy were classed as ''high'' in the study are likely to attribute this to their ability to understand science concepts and perform well in class assessments.

> I pick it up quick quickly. Also, I got [high marks] in my last assessment [Alina: female, rating: 9].

> I get quite high [marks] and understand most science ideas [Alma: female, rating: 8].

Students with high self-efficacy who like or enjoy science are likely to persist in science even when they encounter aspects of science, they find difficult. Addison and Bruno are good examples. Addison attributes his ‘’high’’ self-efficacy in science (10/10) to his liking for science, while Bruno links his to enjoyment of science.

> I like science and if I don’t understand something, I will work on it until I understand it [Addison: male, rating: 10].

> I enjoy it, so it makes it easier [Bruno: male, rating: 8].

However, students whose self-efficacy were classed as ‘’low’’ attribute this to difficulty in understanding science concepts or poor performance in class assessments.

> I am not that good [Archer: male, rating: 4]

> I am worst in class [Bond: male, rating: 4].

> I always need to get the information like loads of times [Abbott: male, Year 8; rating: 3].

Personal attributes

Some students attribute their reported self-efficacy ratings to their diligence in lessons. These students make a deliberate choice to stay focused in lessons. Exemplar statements below imply that ‘’high’’ self-efficacy is a reward for working ‘’hard’’ in lessons.

> I always try as hard as I can in lessons [Bailey: male, rating: 9]

> I feel I concentrate extremely hard and take in any useful information [Barbara: female, rating: 9].

However, for others science causes anxiety. A good example is Eartha, whose self-efficacy rating is the lowest in the sample, 1/10. Eartha’s comment below suggests that science is not the only subject she is anxious about.

> Science is one of the subjects that I panic in [Eartha: female, rating: 1].

However, this does not invalidate her position as it is evident that this is a barrier to a positive learning experience for her. The effect of Eartha’s anxiety on her career expectations in science is discussed in detail in section 7.2.4.

In this section, 8 Emerald students’ views of factors affecting their attitudes to science were presented. This included teachers’ pedagogy, time of day and teaching room, practical work, the nature of science and self-efficacy in science. The next section presents the views of students in 10 Topaz.

6.3 ‘’10 Topaz’’

‘’10 Topaz’’ is a GCSE mixed-ability Physics science class in ‘’set 4’’ (5.3.1). Based on prior attainment, they are expected to achieve at least a C grade in their GCSE physics examination (Mr. Hadfield, Head of Science). The class comprises fourteen boys and ten girls. Students are placed in a seating arrangement so that each workstation (5.3.1) sits between five to six students. Physics is taught on Monday (observations occurred on this day), by Mr. Martins, a physics specialist and on Thursday by Mr. Napleton. Mr. Napleton is a chemistry specialist.

Students in 10 Topaz only participated in phase two of the data collection process. Students’ views are drawn mainly from questionnaire responses from the whole group. In addition, three cases are used to explore students’ views in detail. These students named Dena, Doreen and Edwina have the most comprehensive data set drawn from questionnaires, diaries, group discussions and lesson observations.

6.3.1 School–oriented factors

Teachers were identified as a factor affecting students’ attitudes towards science based on responses from questionnaires and group discussions.

Class teacher

Student-teacher relationship

Student–teacher relationship can influence students' attitudes towards science. The dynamics of this relationship and its effect can be complex as seen by Edwina's comment below.

> I like my biology teacher. I like Biology. I cannot stand Physics because I dislike Mr. Martins'. Everything about science just bores me. I don't like it. Some of my teachers I like, some of them, I really don't. The reason I hate science is because the teachers I don't like, I don't pay attention' [year 7]. In Year 8, I had Mr. Martins who I have now, and he's put me off physics for life [Edwina: female, group discussion].

Edwina's statement demonstrates the impact negative relationships with her science teachers have had on the subjects they teach, with the effects evident through Key Stage 3, that is, Years 7, 8 and 9, to the present. This shows that students project the feelings they have towards a teacher to the subject. If the student-teacher relationship positive, it is likely to impact positively on the subject they teach. Similarly, when the relationship is poor, it could negatively affect students' attitude towards the subject.

However, changes in student-teacher relationships are not fixed, they can evolve as the academic year progresses. This was observed with Edwina in the second term. There was a notable difference in her behaviour and attitude in lessons. She was more attentive and willing to participate in lessons. For example, in one lesson, she had moved seats without Mr. Martins' permission, but he let her sit there for half of the lesson because as he explained, if she was engaged in the lesson, it was a small price to pay as ''you have to choose your battles'' (Mr. Martins).

In discussion, Edwina revealed that although she wanted to become a mental health nurse like her mother, she was unaware that her grades in physics counted towards her overall GCSE science grades. Her change in attitude occurred due to her own self–realisation that physics counted towards her final GCSE science grades rather than an improvement in her relationship with Mr. Martins.

Edwina's realisation of the importance of physics in the penultimate year of secondary school points to two possibilities. Her hostility to science and her science teachers, especially, Mr. Martins, may have created a barrier that was difficult to overcome.

The second possibility is that career advice and information in Farne School is inadequate. Although this was not explored, research evidence shows that career evidence may be inadequate in schools (Munro & Elsom, 2000; Cleaves, 2005) with students often unaware of the breadth of careers, science could offer them (Archer et al., 2013).

Personal attributes

Personal attributes of a teacher can also affect students' attitudes towards a subject. This includes empathy and fairness. Students respond favourably when teachers develop a personal interest in them and use the information as a teaching aid. The extract below from Dena's diary illustrates this.

> My favourite subject in science when it comes to teachers is chemistry because he understands me, makes me laugh and helps me learn things and understand things when I'm struggling. He also knows my favourite thing is football so he's able to link chemistry to this, which helps me understand it that little bit more [D].

Dena's fondness for chemistry is linked to her teacher's (Mr. Napleton) use of his awareness of her fondness in football and the effort he makes to support her learning. This is despite the possibility that chemistry is a subject she finds challenging.

Another attribute of teachers which influences students' attitudes is fairness. Students respond negatively when they think teachers discriminate.

> I dislike it when those who have better brains and grades are favoured and get more help [Doreen, female: D].

> Some teachers pay more attention [to] students who are already good who can get good marks. With students who are weaker, they only tell them to 'just try'' [Edwina, female: group discussion].

This suggests that students are more likely to respond favourably in lessons where teachers are considered impartial, giving everyone the same level of attention.

A striking part of both comments relates to the notion of students considered ‘’good’’ students or ‘’high’’ attainers in science. Students indicate that students who are purportedly ‘’high’’ attainers and ‘’good’’ students in science are provided more attention and support compared to students who are ‘’weak’’ in science. This is clearly a source of frustration for students who are not ranked as ‘’high’’ attainers. Doreen and Edwina’s comments support findings in section 5.5.2 that in Farne School, students ranked by the school as ‘’high’’ attainers are provided with more opportunities such as participation in extra-curricular events, compared to those ranked as ‘’low’’ or ‘’middle’’ attainers.

Pace of teaching and ineffective use of teaching time

Another area of discontent was the pace at which lessons were taught. This was problematic for some students as the GCSE examinations became imminent. Students’ note that the pace of teaching in Year 10 is ‘’rushed’’. This, they attribute to ineffective use of Key Stage 3. Chance’s comment during a group discussion demonstrates this.

> Teachers only care when you get to Year 10, because it’s GCSE. It’s rushed. Why didn’t we use Key Stage 3 to learn more stuff? [Male].

The notion of ineffective use of Key Stage 3 was also observed by Government Inspectors, who referred to this period of schooling, as ‘’the wasted years’’ (Ofsted, 2015). This was because this Key Stage was not considered a priority by school’s leaderships both in timetabling and staffing or general allocation of resources (2.3.2). Consequently, the quality of teaching and rate of students’ progress and achievement were inadequate (Ofsted, 2015).

The belief that teachers only pay attention in Year 10 because of the GCSE examinations. This highlights the dangers of an ‘’assessment culture’’. The emphasis on the impending examinations were observed in lessons observed with 10 Topaz and 12 Ruby. The pressure from teachers to cover curriculum content on time for examinations is inevitably transferred to students. Thus, students lose the pleasure of learning to the pressure of passing examinations.

This is similar to Osborne & Collins (2000) findings that students find the science curriculum content assessment-driven. This leads back to the notion of ''exam factories'' (Mrs. Natanson; Hutchinson, 2015) discussed in section 5.4.1. The science curriculum is discussed in the next section.

6.3.2 Subject–oriented factors

Subject-oriented factors reported by students include the curriculum and practical work.

<u>The science curriculum</u>

Curriculum content appears to be a factor affecting students' attitudes towards science. Students' views of the curriculum depend on their personal perception of its relevance to everyday life or future career expectations.

Utility of science subjects

Students respond positively to science subjects if relevance is evident to either everyday life or future endeavours. For example, in describing biology, Dena and Doreen draw attention to its relevance in everyday life. In addition, Dena identifies biology as her ''most important subject'' because of her interest in sports science.

> Biology is also something we need to know about for later on in life with things such as the reproductive system. I find this the most important subject because I think I may need it for my future career [Dena].

> I believe the lessons are useful as you learn about your own body and what it is capable of in great detail [Doreen].

Some students concentrate in some lessons but not others, depending on its perceived usefulness

> Depends on the type of science. I want to be a physiotherapist, so I pay attention in biology [Chance: male].

Chance' comment suggest a lack of awareness that all three science subjects count towards his overall GCSE science grades in the Double Award course (Glossary). This is similar to Edwina's attitude towards physics.

As suggested earlier, Chance and Edwina's selective response to the individual sciences may be an indication of inadequate career advice and information at Farne School.

Relevance of content and ''interest''

Other students respond differently to the individual sciences. A good example is Doreen. Doreen's response underlines the importance of addressing attitudes to individual sciences separately as these may be different (Kind et al., 2007).

> Science is the subject you either love or hate – I love physics. Honestly, I love physics, I feel like everything 'clicks.
>
> Chemistry??? Ahhhhh! What is it with me and chemistry, I just can't seem to 'click' and let things sink in, in one ear and out the other, I know I sound terrible but it's the truth.
>
> Biology? I find that it is okay. Within the subject some topics are easy, and others are tough (sic).

Doreen's positive response to physics shows that she has an innate understanding of, physics. Her preference for physics is contrary to studies which identify biology as the subject girls are likely to show a preference for biology, rather than physics (e.g. Kind et al, 2007).

Students are discouraged by curriculum content they consider irrelevant. This is true even of subjects previously identified as a favourite. For example, Dena previously identified chemistry as her favourite science but as comments below demonstrates, reactions to the same subject can be conflicting.

> Chemistry - I don't like things to do with rocks as I think it's pointless [Dena]
> Chemistry - I find things like how the world started and things with reactions interesting [Dena].

Dena's selective approach to chemistry, underlines the complexity of the concept of interest in science (Trend, 2005; Logan & Skamp, 2013). Students interest in science can either be ''personal'' or ''situational''. Personal interest is enduring, while situational interest is transitory (Trend, 2005; Logan & Skamp, 2013).

Therefore, students like Dena, whose interest is linked to aspects of chemistry, for example, ''*how the world started and things with reactions''* may respond positively to similar topics but negatively to other aspects of chemistry they have no interest in. In contrast, students like Doreen are likely to sustain their interest in physics because this is based on physics as a body of knowledge in its entirety, rather than aspects of physics.

Others see some content as fabricated and only useful for examinations.

> I cannot see myself in science. Chemistry stuff is made up. You learn so many things for the exam, which you are not going to use in the future, and you forget straight away [Dolly].

Dolly's comment above indicates that some content in chemistry are viewed with scepticism. If students believe that aspects of science are fabricated, then getting such students enthused about science may be problematic. The belief that some content may never be used in the future and therefore a waste of time makes this complicated. The statements below illustrates this:

> Maths, English and science are similar in that sense. You are not going to use everything in real life. I don't understand why I have to spend 5 years learnings about something I'm not going to use [Chance: male].

This shows that the issue of relevance is not peculiar to science as students question content taught in English and Mathematics as well.

<u>Practical work</u>

In responding to the open–ended question about their most memorable lesson (Appendix 9) in Key Stage 3, the majority of students in 10 Topaz (80%, n=20) identified lessons in which practical work was carried out. The notion of practical work being ''fun'' and a departure from the routine of lessons appear to be its appeal. Practical work elicits both positive and negative responses.

Practical work and positivity

Four reasons emerge for students associating practical work with science positively. Some students consider science ''boring'', so, practical work brings freshness to otherwise tedious teacher-led lessons.

> It was something different-not boring. Shows that science is not boring [Doreen: female]
>
> Provided a different perspective of science [Doris].

For other students, the more practical work involved, the more a topic is associated with being ''fun''.

> It was fun as it had loads of experiments [Effie: female on ''aliens''-biology]

Secondly, practical work enables students to appreciate the relevance of science, as otherwise abstract concepts suddenly obtain meaning. One of the most memorable lesson for students was a Year 7, Physics lesson on Forces. Students placed raw eggs in ''parachutes'' they had made in a previous lesson. The parachutes were then dropped from a first floor window to see if the egg would crack, if different variables were altered. Students' comments suggest that the lesson was memorable because they were able to make the connection to everyday life.

> We learnt about how we use different thing to slow people down when coming into the atmosphere [Clive]
>
> We dropped eggs out the window and made a parachute to see if it would survive [Edna]

Third, interest in a subject because of its usefulness makes it easier for some students to think positively about science. For example, Dora has an interest in biology because she wants to be a veterinary doctor. It is this interest that makes biology-related topics enjoyable. She describes a Year 7 lesson on DNA in which students were provided with footprints, fingerprints and hair samples to use in solving a murder case.

> Because I found it interesting, so I enjoyed it [biology].

Finally, practical work makes it easy to recall difficult concepts. Although this is not tantamount to understanding, it is the ability to recall ideas that makes it a positive experience for some students.

This appears to be important for students whose self-efficacy in science were judged as ''low'' in the study. They feel they are not ''clever'' enough to understand science. Dena's statement illustrates this point.

> It made me remember what we were learning so, I felt clever.

Practical work and negativity

Nevertheless, some students indicated that practical work, though memorable, did not make them think positively about science. Reasons given are varied.

One of these is relevance. If relevance is not evident, this may generate negative feelings. Dena's statement when describing practical work in relation to chemistry illustrates this:

> I dislike doing practicals, which don't show anything or … prove anything as it is a waste of time when I could be learning something important for my examinations. I also find some parts of chemistry hard which makes me dislike it even more because it's frustrating (D), [Dena: female].

Although Dena's dislike for practical work could be as a result of finding some aspects of chemistry ''hard'', her comments highlight the problems of ''recipe-style'' practical work (Millar, Marechal & Tiberghien, 1999 cited in Abrahams & Reiss, 2012) and prevalent assessment culture discussed in previous sections.

Another factor which affects students' response to practical work negatively is the teacher. Similar practical work content can elicit opposing responses depending on the teacher. In describing their most memorable lesson from Key Stage 3, Dora and Edwina identify the same forensic lesson. Dora's experience was positive while Edwina associates this lesson with negativity. The difference in their experiences is evident in their recollection of the practical work.

> Mr. Napleton made it interesting by using a crime story and made us act as detectives/Investigators [Dora].

> It was boring and my teacher [Mrs. Young] talked a lot and it didn't really sink in [Edwina].

The statements highlight the importance of a teacher's pedagogy and the effect it may have on students' attitudes towards science. Though, Edwina's negative response as seen in previous sections could be as a result of her hostility to her science teachers rather than their teaching style.

6.3.3 Personal–oriented factors

Factors identified in this category were interest and identity. Interest was discussed in the previous section and therefore, not repeated here. Identity is discussed briefly.

Students' perception of themselves in science can affect their attitudes towards science. Those who are unable to see themselves in science do not aspire to careers in science.

> ''I cannot see myself in science'' [Dolly].

> ''Do not have a great passion, couldn't see myself doing it'' [Doreen].

The notion of identity in relation to science careers is explored in detail in Chapter 7.

6.3.4 Science experience from Years 7 to 10

Students' attitudes towards science allegedly declines as they progress through secondary school (Osborne et al, 2003). In describing the differences between Years 7 and Year 10, students claim that the earlier years of school were more interesting than the later years. The reasons for these claims are reported.

Students believe that topics taught in Key Stage 3 were more interesting compared to Key Stage 4. They also believe that teachers used more practical work than they do in Year 10.

> [Year 7] … was interesting because they actually make the topics a bit more fun than they do now and added loads of experiments but now they just make you work all the time [Effie: female, Year 10].

In addition, teachers allegedly become more impatient as students get older. Thus, learning is affected as students have no time to understand one concept before a new one is introduced.

> They are not laid back. You have to stick to certain times [Dena].

> Teachers lose their patience a little bit quicker. If you don't get something in a lesson, everyone else has moved on because everyone understands it and you are like two topics behind because you don't get it [Edwina].

This is similar to Osborne & Collins (2000) claims that teachers ''rush'' through curriculum content, leaving students with insufficient time between topics to develop a deeper understanding of science.

Other students point to an increased emphasis on the use of scientific terms and how the use of these words or phrases were linked to attainment in class tests and assessments. In addition, the curriculum became more theory laden as the years progressed.

> [In Year 8]… You got to do a lot more practical and you kind of had to realise it was quite phrase wise. Like certain words would get you certain marks and stuff and it was more theory based'' [Doris: female].

Others disagree, pointing out that a student's learning experience depends on the teacher.

> Depends on your teacher. I like the way they teach. I loved Year 8 science, I loved Year 8. I had Mrs. Nicholson. She was the best teacher to be honest, but she has left [Chance].

Chance's comment is supported by Edwina's. Edwina's comments also underline the importance of student-teacher relationships.

> It was more interactive, you could do more practical stuff. Some people thought it was really interesting, but I just thought it was really boring [Edwina: on Year 7].

> It got a bit more boring because you were going through like PowerPoints, but you were just reading off the PowerPoints. Don't know if it was just my teacher. I had the same teacher as well [Edwina: statement made in reference to Mr. Martins on Year 8].

A probable reason for Key Stage 3, especially Year 7, being recalled with fondness could be due to the novelty of transferring from primary to secondary school. For some students, this may be the first time of experiencing science as primary school teaching as seen from comments below can be irregular.

> We didn't really do much science. Even though my main teacher in Year 6 and Year 5 did science at University, we really didn't talk about science [Dolly].
>
> We planted some herbs once [Doreen].
>
> We did one lesson. We had to do it because we knew we had to do science in secondary school. So, we had one lesson to make it look like we did science [Effie].

Students' assertion that primary science was irregular and, in some cases, non–existent support previous findings that primary science can be erratic (Ofsted, 2013). Year 7 is the time that students start to gain some independence, which may be lacking in primary school.

> You get more responsibility when you're in secondary school unlike in primary school when you rely on all of your teachers. In secondary school, you've got to fend for yourself [Chance].

These experiences point to the possibility that the early years of secondary school resonate positively with students compared to the later years. Secondly, as students' progress through school, particularly in Key Stage 4 and preparation for GCSE examinations begin, practical work which was once considered ''fun'' in Key Stage 3 may now be viewed as a hindrance to learning (Dena, 6.3.1).

6.4 ''12 Ruby''

''12 Ruby'' is an AS level Physics classing comprising twenty students, of which five are girls. Gender split is common in schools in England as boys are more likely to continue with physics post-16, compared to girls (Murphy & Whitelegg, 2006b, Royal Society, 2008). Only one student in the class transferred from a different secondary school in the county.

Recruiting 95% of the Physics class from the secondary arm of the school could be indicative of the school's specialist science status as the nature of a school could positively influence post-16 recruitments (Solvason, 2005).

Lesson observations involved the whole group, but cases reported here focus on students who completed questionnaires and participated in group discussions. Ten students, eight boys and two girls completed questionnaires in phase 1 (December 2014) giving a 50% return rate. Of these, five completed the questionnaire in phase 2. Nine have GCSE Triple Science qualifications, apart from Denzil, who has GCSE Double Award qualification (Table 6.1). The gender of students is only highlighted when referring to quotes from Talia and Frances, as they are the only girls in the sample.

The majority of students obtained the highest grades in the GCSE examinations as seen in Table 6.1. This is expected, as students who continue with physics post-16 tend to be students with prior attainment in GCSE (Bennett et al., 2013). All participants in the survey were involved in the school's internship program (5.4.4).

There is an overlap of factors. For example, timetabling constraints is a school-oriented factor, but this is linked to students' personal interests, which is personally-oriented. Hence, factors are discussed in the most appropriate section.

Pseudonym	Gender	GCSE grades			Secondary science		AS subject choice
		Biology	Chemistry	Physics	Easiest	Hardest	
Dexter	Male	A	B	B	Physics	Biology	Chemistry, Physics, Maths, Further Maths
Frances	Female	A*	A*	A*	Biology	Chemistry	Biology, Chemistry, Physics, Maths, Further Maths
Drake	Male	A*	A*	A*	Physics	Biology	Chemistry, Physics, Maths, Further Maths
Dennis	Male	B	B	B	Biology	Chemistry	Physics, Maths, Product design
Duncan	Male	A	A	A*	Physics	None	Chemistry, Physics, Maths, Further Maths
Dustin	Male	A	A	A*	Missing	Chemistry	Physics, Maths, Further Maths, History
Darren	Male	A*	A*	A*	Physics	Biology	Physics, Maths, Further Maths, History
Dominic	Male	B	A	A	Biology	Chemistry	Physics, Maths, Further Maths, History
Talia	Female	A*	A*	A*	Physics	Chemistry	Physics, Maths, Further Maths, History
Denzil	Male	C, B (Double Award)			Physics	Chemistry	Physics, Maths, Product design

Table 6.1: Gender, GCSE science grades, perception of secondary science and AS subject choice of 12 Ruby

6.4.1 School–oriented factors

School-oriented factors presented here include the teacher and timetabling constraints.

<u>Class teacher</u>

Students identify teachers as a factor affecting their attitudes to science. They claim that some personal attributes of the teacher, namely passion for their subject inspires a reciprocal reaction. In describing their favourite subject during a group discussion, no student identified a science subject as a favourite. Three out of the four participants in the group, identified Mathematics as their favourite subject because of the teacher's passion for her subject.

> She is enthusiastic about maths and it rubbed off on us [Dennis]

> I like Maths and she has a passion about it and it kind of came off in her lessons. It gives a good atmosphere to the lessons. She is excited about maths and it got us excited as well about maths [Talia: female].

Another characteristic of teachers which may affect students' attitude is the range of teaching strategies they use. When describing their most memorable lesson from secondary school (Appendix 10), Darren and Drake recall a physics lesson on the electromagnetic spectrum (EM spectrum). They claimed that a song which was used as a teaching aid for remembering the EM spectrum was delightful.

> Sir [the teacher] taught us the electromagnetic radiation spectrum. There was a catchy tune (sic). [Darren]

> Learning about the EM spectrum. There was a cool song that we all had to sing [Drake].

The use of an innocuous song as a teaching aid underlines the importance of teachers developing a range of strategies to generate students' interest in science.

Teachers can also alienate students from science if their explanation skills are poor or they choose not to provide answers to students' question.

> Overall, I always found [science] interesting. But you're told stuff, it's not explained. And you want to know more and [teachers] tell you, it's too complicated or 'we [will] get to that next year'. It puts you off because you want to understand more [Drake].

> I find physics fairly easy at times but try to concentrate too much on every reason behind things…. Although I don't like the uncertainty and the fact that we are being taught theories that have next to no proof and are just created by 'clever' professors and we have to accept them for the sake of physics [Dustin].

The assumption that students lack the ability to comprehend some science concepts is problematic. Nevertheless, teachers have to find a balance between teaching a planned lesson within the time allotted and providing answers to questions which may satisfy students' curiosity, though they deviate from the planned lesson. Dustin's comment raises the notion of credibility in science (*see* Dolly's comment, 6.3.3) Two plausible reasons for teachers' deflecting questions in this way are offered. Findings in this study suggest that teachers prioritise teaching curriculum content over engaging lessons as national examinations draw closer (5.4.1). Consequently, questions which may be considered irrelevant are dismissed. Another probable reason could be that teachers' subject content knowledge are limited, therefore questions which may expose this inadequacy are dismissed.

Exploring the issue of gender in 12 Ruby

Research evidence identifies the teacher as an important factor in girls' aspirations in physics (IOP, 2012). As girls are underrepresented in post-16 physics, 12 Ruby, an AS physics class comprising fifteen boys and five girls, presented an opportunity to explore the notion of gender bias. This was done by dedicating one lesson observation to questioning alone (4.9.2). The findings are presented.

In the lesson used for questioning, Mr. Martins asked a total of fourteen questions over a 30 minute teacher-led session (Appendix 11). Of these, girls only answered three questions, representing 21% participation in question time. Every time a named student, that is, someone who had not volunteered themselves, were called, it was a boy. Only once was a named girl, Frances, called upon to answer a question. It was unclear whether Mr. Martins called upon Frances because she was considered a ‘’good’’ physics student by both Mr. Martins and her peers. Both of Frances’s parents are physicists.

When asked about the difference in the number of times boys were called compared to girls, Mr. Martins explained that because the girls were in the minority, calling on them may make them ‘’uncomfortable’’. Although this may be a reasonable explanation, observations and informal chats with some of the girls indicated that they were comfortable in answering questions like the boys in the class. This indicates that Mr. Martins may have excluded the girls during this questioning session through a misjudged attempt to make them feel ‘’comfortable’’ in lessons. This may point to a wider problem of girls in physics classes who are already a minority, being further alienated by teachers, through sometimes well-intentioned, but unhelpful practices.

<u>Timetabling constraints</u>

Timetabling constraints affect students’ subject choices post-16, thus inadvertently, compelling them to choose between science and other subjects. In Key Stage 5, the use of ‘’option blocks’’ (5.3.1) from which students choose their AS subject choice creates a barrier for some students. This was the problem faced by Dominic, Talia and Dustin who had to choose between history and chemistry, which were placed in the same block.

All three opted for history rather than chemistry.

> Chemistry would not be needed for engineering/maths, but I recognise that is a very important subject, especially for industry [Dustin].

> Option blocks provided limited range of choices for me and [I had] … to find an appropriate balance between subjects I enjoyed and [those] required for university [Dominic].

> I would have taken chemistry instead of history as I believe that it would have given me a better chance of getting into a good university for a STEM course. I did just as well in history and chemistry, however I preferred chemistry [Talia, female].

Dominic and Dustin expressed no regrets in their choices. Though Dustin alludes to the importance of chemistry, it is evident that his decision was weighed carefully against university requirements for Mathematics or engineering. In contrast, Talia chose history because she enjoyed it but expressed regrets in choosing history over chemistry. Talia's dilemma underlines the effects of school-oriented factors on students' post-16 subject choices.

This supports Smithers & Robinson (2007) and Bennett, Lubben & Hampden-Thompson (2013) reports that school leadership's decisions affect post-16 recruitment. Nonetheless, students' decision to choose history over chemistry post-16 may not be unconnected to their perception of chemistry being difficult in secondary school. This is discussed in section 6.4.2.

<u>The Internship programme and the role of the STEM Enrichment Manager</u>

Students credit participation in extra–curricular activities to the STEM and Enrichment Manager stating:

> A lot less would happen [Drake].

> Nothing would happen. She does the extra stuff on top of lessons [Dennis].

In addition, they state that internship programme, which was coordinated by the STEM Enrichment Manager was instrumental in their career choices. The outcome of the internship programme varied by student.

For example, Duncan became more convinced that he will continue with science, but this was different for Talia who became convinced that science was not for her.

> If I hadn't had the experiences that I've had I don't think I would've ever considered either of these careers. I've always been interested in them. I don't know whether I would ever have seriously looked in those areas'' (physics and engineering) [Duncan].
>
> I like physics a lot and find it very interesting, but I find myself more attracted to maths/business [Talia: female].

Students' views about the internship programme suggests that exposure to the world of work provides them with the opportunity to evaluate their career choices in relation to the subjects they study. However, for students like Talia, this may result in a ''swing away from science'' (Dainton, 1968). Other factors which may have impacted on Talia are discussed in detail in Chapter 7.

6.4.2 Subject–oriented factors

This section focusses on students' perception of the individual science subjects and reasons for their AS science choices. Findings are drawn from students' questionnaire (Appendix 10) responses. In the section on AS subject choice, students were provided with four options to choose, *fits with Career/UCAS[5] choice; favourite subject; did well in GCSE exam; needed to fill timetable*. In addition, they had an opportunity to state a reason if this was not provided in the questionnaire.

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[5] UCAS (Universities and Colleges Admission Service) oversees students' application process for entry into universities and colleges.

Perception of secondary science

Research evidence suggests that students find physics the most challenging of the three sciences (IOP, 2012). To explore this notion, students' views about secondary science were explored. Only one student, Duncan, claimed to have found all three science subjects in secondary school easy. Duncan did not attend secondary school in Farne School. This may account for the difference in his perception of science in secondary school. Table 6.1 (6.4) summarises students' GCSE science grades, their ''easiest'' and ''hardest'' secondary science and AS subject choices. Findings are presented by individual subject.

Biology

Three students (n=10) identified biology as the ''easiest'' secondary science. Reasons are varied.

> It was mostly common sense [Dennis].
>
> Biology was easy but I did rubbish in the exam (B grade) [Dominic].
>
> It was mostly memory [Frances, female].

Similarly, three students reported that biology was their ''hardest'' secondary science. For these students, who are all boys, it appears that the perceived difficulty stems from a lack of interest in biology rather than from the nature of the subject *per se*. No girl identified biology as their most difficult science.

> Biology was my least favourite science subject, so I took less of an interest [Drake].
>
> I couldn't be bothered to learn the information [Darren].
>
> I didn't get it [Drake].

Chemistry

No student identified chemistry as their ''easiest'' secondary science. Six students (n=10) identified chemistry as the most difficult science in secondary school. Reasons given range from apparent contradiction in theories, difficult concepts to lack of teaching.

> Harder to get around the theories as they all seemed to contradict each other. I found the concepts hard to understand [Talia, female]

> It made zero sense [Dominic]

> Some of the formula were confusing to understand, however, I found it enjoyable [Denzil]

> The different compositions of elements [Dennis]

> Didn't really understand the fundamental concepts as we weren't taught them [Frances, female].

Considering the number of students (6, n=10) who found chemistry challenging and the reasons given, it is reasonable to infer that secondary chemistry teaching may have been inadequate. France's comment above appears to support this viewpoint. Students' experience of secondary chemistry demonstrates the importance of teaching and its impact on students' attitude towards science.

Physics

No student identified physics as their ''hardest'' science in secondary school. Indeed, half of the students in the sample, identified physics as their easiest secondary science. Students' reasons for physics being their easiest science includes understanding and its similarity to Mathematics.

> I understood it the most [Dexter].

> I really enjoy maths and a lot of physics is maths [Drake].

> I was always good at GCSE physics. I learnt it more easily than biology and chemistry [Duncan].

> It seemed to be more engaging than the other subjects, so I actually wanted to learn it [Darren].

> [Physics is] mostly maths, which I am confident at [Talia, female]

Students' preference for physics contradicts extant research which identifies physics as the least popular science subject (Barmby & Defty, 2006). This also highlights the importance of teaching and transferable skills. Students' reference to physics lessons being engaging and easy to understand reflects the quality of teaching they experienced. In addition, recognition of similarities between physics and Mathematics underlines the importance of students being able to transfer their skills and knowledge between subjects.

Perception of secondary science and AS science choice

Students' perceptions of secondary science were then compared to their AS science choices. Figure 6.1 shows that physics, which more than half of the students considered the easiest secondary science was the science with the highest post–16 enrolment. Similarly, biology and chemistry, which were identified as the most difficult sciences, had lower post-16 enrolments, compared to physics.

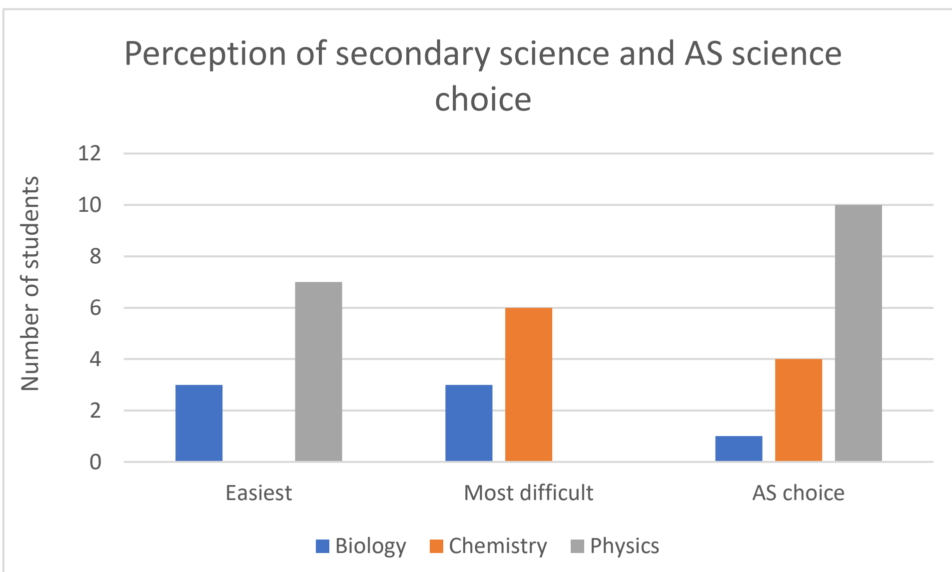

Figure 6.1: Students' perception of secondary science and AS science choice

Only one student, Frances, out of the three who claimed biology was their easiest secondary science continued with biology in AS. Of the six students who stated chemistry was their most difficult science, only one, Frances, continued with chemistry. Three others opted for History and two, Product Design. It is important to note that despite these students' claims of chemistry being their most difficult science, four had A – A* grades, while one had a B* in their GCSE chemistry examinations. The fifth student, Denzil, had C and B grades in the Double Award course. This suggests that attainment in chemistry may not have been a reason for the students' decision not to continue with chemistry in AS. A probable reason could be their self-efficacy in chemistry – doubts about their ability in science rather than their actual performance in science. The link between self-efficacy and post-16 science career expectations is explored in Chapter 7. The other three students who continued with chemistry were those who identified physics as their easiest science in secondary school. All students continued with physics even if it was not identified as their easiest subjects.

Reasons for AS subject choice

In the previous section, it was shown that students are likely to continue with subjects they find easy, post-16. This section looks at other reasons students choose a subject, post-16. This is explored, first from a wider perspective by including non-science AS subjects. These include other STEM subjects (e.g. Mathematics, Further Mathematics and Product Design) and History. This provides an opportunity to explore students' reasons from a holistic viewpoint before focusing on science.

Figure 6.2 shows students' reasons for choosing their AS subjects. This shows that overall, the most popular considerations are relevance to future careers, GCSE attainment and if the subject is a favourite.

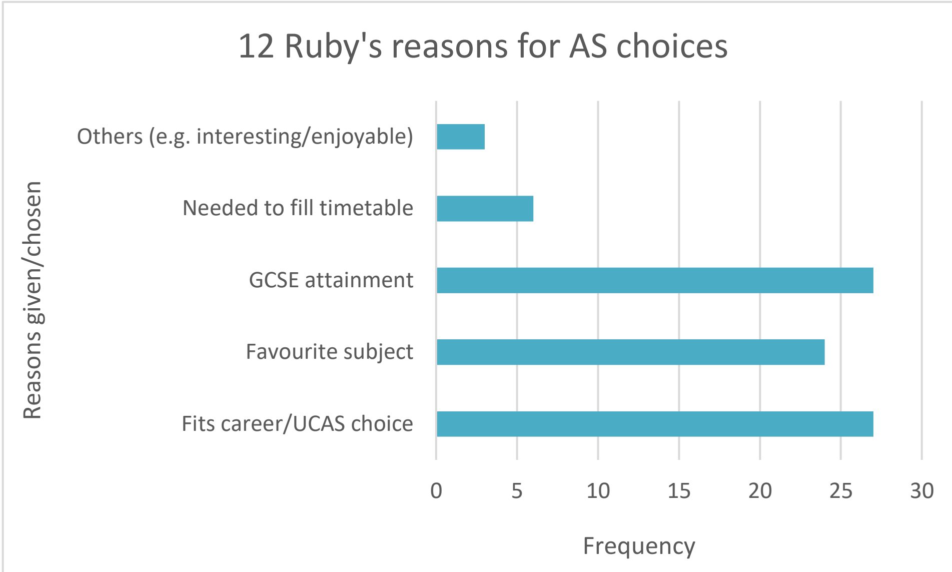

Figure 6.2: Reasons for AS subject choice

Since, all ten students in the sample chose Mathematics which is a STEM subject, a comparison was made between it and the individual science subjects.

Comparing students' reasons between AS science and Mathematics

Students' reasons for AS choice were most similar between Mathematics and Physics than the other sciences. Nine students chose Physics while eight chose Mathematics because of future career expectations. Similarly, eight students chose Mathematics because of prior attainment, while six chose Physics for the same reason. Mathematics and physic were also the only STEM subjects, students chose for either enjoyment or interest. In contrast, Chemistry was the only science subject chosen to fill a timetable, while biology was the only science in which only one student identified it as a favourite or needed it for a future career (Figure 6.3).

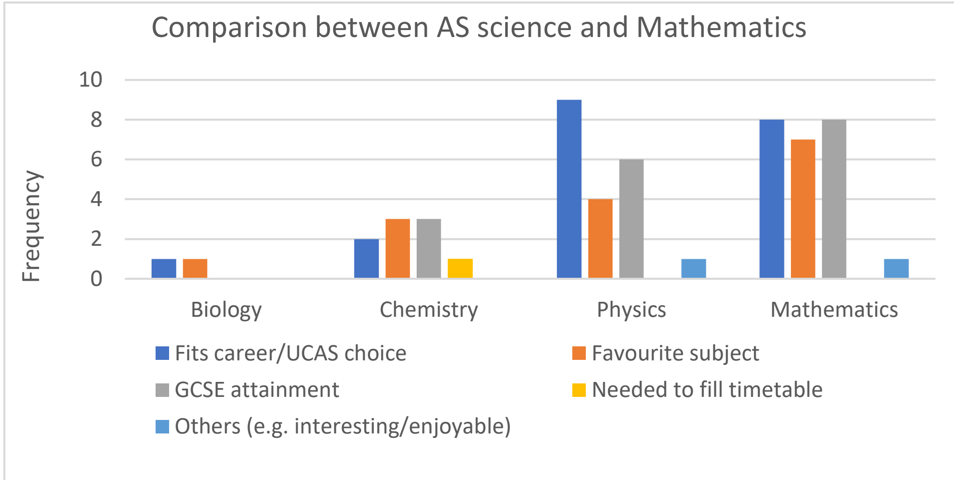

Figure 6.3: Comparing students' reason for AS Mathematics and science choices

Due to the similarities between Mathematics and Physics where students have indicated that their experiences were positive (6.4.1 and 6.4.3), reasons for AS science choices were probed further. This was examined by considering the most popular reasons for AS choices in relation to students' perception of science in secondary school.

Prior attainment, favourite subject, career choice and perception

For some students, prior attainment may be insufficient to overcome their perception of a subjects' difficulty. This is even in cases where their GCSE attainment contradicts their views on the subject's perceived difficulty. Drake, Darren and Dexter are good examples. Despite identifying biology as their most difficult science, they all obtained at least an A grade in GCSE biology (Table 6.1) but none continued with biology despite these grades. In contrast, Dexter, for example, chose to continue with physics and chemistry though he had B grades. This suggests that GCSE attainment on its own may not be enough for post-16 subject recruitment.

However, another explanation for these students' persistence in physics rather than biology could stem from their interest in pursuing engineering/physics careers.

Engineering courses do not usually require biology for entry into UK universities except in biotechnology/chemical engineering, in which case biology/chemistry may be required, in addition to physics and Mathematics (UCAS, 2015).

> I would like to be a physicist or an engineer as these both incorporate subjects that I enjoy [Drake, male].

> Engineering is in at the moment [Darren, male].

Finally, physics was considered the easiest in secondary school and may therefore be the reason it was considered the most favourite AS science choice compared to biology and chemistry.

6.4.3 Personal–oriented factors: the notion of identity

The way students ‘’see’’ themselves in science influences their attitudes towards science and science aspirations. In discussing reasons for subject choice, students talk about ‘’sciencey people. They explain that people who did not choose science were not ‘’sciencey people’’, thus, implying that it was natural for ‘’sciencey people’’ to prefer science.

> People who liked science always liked science. That’s what they preferred. Some people didn’t. They weren’t ‘’sciencey people’’ [Duncan, male].

The notion of ‘’sciencey’’ and ‘’non-sciencey’’ people underlines the importance of a science identity (3.2.2) and how this shapes students’ attitudes and career expectations towards science. As stated in section 6.3 identity is discussed in detail in Chapter 7.

6.5 Overview of students' views of factors affecting their attitudes towards science

The main aim of this study was for the student voice to be ''heard'' by exploring the factors affecting their attitudes towards science from their perspective. This was achieved in the previous section by reporting on the views of students from 8 Emerald, 10 Topaz and 12 Ruby. These year groups represent Key Stages typically taught in a secondary school. Students' views indicate that attitudes towards science are influenced by a range of factors. These were considered under three categories; the school, science as a subject and the personal. An overview of these factors are presented.

6.5.1 School-oriented factors

The role of the teacher and teaching

The role of the teacher and teaching may be the most important factor identified in this study. Areas of teaching identified by students as problematic in the data are discussed using Tobin & Fraser's (1990) framework of what exemplary science teachers do; *manage and facilitate student engagement*, *increase student understanding of science*, *encourage students to participate in learning activities* and *maintain a favourable learning environment*. Other frameworks exist (e.g. Wilson & Mant, 2011) but this provides a comprehensive framework for discussing the findings in this study.

<u>Manage and facilitate student engagement</u>

Pedagogy. Evidence from the data indicates that a diverse range of teaching strategies are useful in generating positive attitudes towards science. This is true whether it is in the use of a ''catchy'' tune to teach the EM spectrum (6.4.1) or the inclusion of context peculiar to individual students to explain concepts in chemistry (6.3.1). These strategies enhance student engagement with and understanding of science concepts. This is important as students claim the curriculum becomes theory-heavy as they progress through school.

Therefore, strategies which may have been sufficient in engaging students in the younger years may be ineffective as they get older. For instance, practical work which was considered ''fun'' and informative in Key Stage 3 may be seen as a ''waste of time'' in Key Stage 4, when national examinations become imminent. The use of Key Stage 3 is addressed in the next section.

Explanation skills. In addition to developing a wide range of strategies, it is important that teachers make their explanations clear. Haley and Betty link Mrs. Anthony's poor explanation skills to their self-efficacy in science (8 Emerald, 6.2.1), suggesting that poor explanation skills affect self-efficacy negatively. If students do not understand what is taught in lessons, they start to doubt their ability in science and lose interest (Lindahl, 2000). As would be seen in Chapter 7, students whose self-efficacy were classed as low are less likely to pursue a science career.

<u>Increase student understanding of science</u>

Teacher inflexibility in lessons. Students' enthusiasm for science may be suppressed if their natural curiosity or desire to increase their understanding of scientific concepts is dismissed (e.g. Drake, p. 186). Although teachers may be dismissive because of the need to teach relevant content, adopting a dismissive approach may be counterproductive as this may ultimately generate negative attitudes towards science.

<u>Encourage students to participate in learning activities</u>

Inclusiveness in lessons. Students' participation in science lessons can be influenced by the teacher's ability to make their lessons inclusive. This may be especially important with students who may be a minority, for example, girls in a male-dominated physics classroom (6.4.1) or students who are quiet in nature (6.2.1). These students may benefit from encouragement from the teacher even in activities such as questioning.

Maintain a favourable learning environment

Student-teacher relationships. Evidence (6.2.1, 6.3.1 and 6.4.1) indicate that student-teacher relationships affect students' attitudes towards science. These relationships begin to develop as early as Year 7 (*see* Edwina), progressing either positively or negatively as students progress through school. The data suggest that students project feelings about the teacher to science. For instance, Edwina's apathy towards physics because of Mr. Martins, despite needing physics for her GCSEs to become a nurse. Similarly, Dena's positive response towards chemistry because of her teacher reinforces the need for positive teacher-student relationships.

Personal attributes. Personal attributes of the teacher such as passion for their subjects, empathy for students and fairness can generate positive attitudes towards their subject. Students in 12 Ruby identified Mathematics as their favourite subject because of their teacher's passion for Mathematics. They claim that her passion created a ''good'' atmosphere which caused them to develop an interest in Mathematics. All ten students in 12 Ruby continued with Mathematics after secondary school.

Students want to be treated fairly and equally. The notion that some students, especially those ranked by the school as ''high'' attainers being given preferential treatment creates resentment amongst other students (6.3.1). A similar point was raised in section 5.5.2.

The role of the school

Career advice and information. The observation that some students in Year 10 were indifferent to the sciences they considered irrelevant to their chosen future careers in science implies a lack of awareness of the breadth of careers science offers (*see* section 6.3). It was not evident from the data whether this was due to inadequate career advice and information in Farne School or due to students' indifference.

Nevertheless, this observation reinforces the need for adequate career advice and information in schools, even in schools with a science emphasis like Farne School. Students realising that physics, for instance, may be useful in improving their GCSE examination science grade towards the end of the academic year in Year 10 is problematic.

Ineffective use of Key Stage 3. The National Curriculum permits schools to teach the curriculum in the order they wish provided prescribed content has been taught at the end of the relevant Key Stage (National Curriculum, 2014). Schools like Farne School take advantage of this flexibility to introduce the teaching of Key Stage 4 content in Year 9 (Key Stage 3). This means that content can be spread evenly through the academic years while teaching Key Stage 4 content. Effective use of this flexibility allows teaching to be spread evenly through the academic years. Poor implementation causes students to feel ‘’rushed’’ (6.3), thus generating negative feelings towards science.

6.5.2 Subject-oriented factors

Practical work. Students finding writing or note copying ‘’boring’’ compared to practical work is consistent with previous studies (Logan & Skamp, 2013). However, the views of students across the different Year groups indicates that students’ interest in practical work is complex. Students, especially in the younger years find practical work interesting, but some students, especially in the older years, do not.

As Logan & Skamp, (2013) found, finding the right balance between the use of practical work and non–practical work in science lessons can be difficult for some teachers to achieve. Perhaps, the complexity of the place of practical work in science lies in its representation to students. For example, it is common practice for science departments to lay out science experiments during events like the ‘’Primary Skills Day’’ (5.3.2) and ‘’Open Evenings’’. This is done as a means of creating a favourable impression about the science department and by extension the school as a suitable place for parents/guardians to send their children/wards to.

Open Evenings are days in which the school is open so that members of the public, usually parents and potential students are invited to tour the school. From the researcher's experience, experiments laid out during such events are usually chosen for their 'whiz–bang' effect to elicit positive reactions from the audience. As these events were created mostly for their 'wow factor', the essence of practical work is lost. This may create a false impression that this is typical of science lessons, especially with students in Year 6 who may not have had regular practical science work in primary school.

This was noticed with students in Tees School, a Cluster primary school (5.3.2) who stated that they wanted to attend Farne School because of the practical work they had participated in during a Primary Skills day. Hence, some students enter secondary school with high expectations of, and enthusiasm for science, driven in part by the false impression created by science departments during these events that practical work on display is normal in science learning. These events rarely discuss the theory behind the demonstrations on display. Hence, enthusiasm for science wanes for some students as they are faced with the reality that science is not only about practical work but theoretical which may be challenging for some students to comprehend. Indeed, Shibeci (1981) and Lindahl (2000) also found that students lose interest in science as they realise that there is more to science than practical work.

This approach to practical work in schools may diminish the role of practical work as an essential learning tool, as focus is shifted from the science behind the activity to the practical work on display. Hence, it is unsurprising that students are often more focussed on 'doing a practical' rather than thinking about the practical activity in terms of the science concept it supports (Abrahams & Reiss, 2012).

Therefore, for practical work to be viewed as a positive influencing factor, it is essential that it is utilised effectively and not relegated to the role of a marketing tool in science learning and recruitment into schools.

Secondly, the repetitive nature of some aspects of the science curriculum means that the novelty of discovery is lost. Practical work is carried out where the outcome is already known (6.2.3). This is linked to the nature of the National Curriculum in which some content are staggered throughout the course. However, schools have the flexibility to teach the National Curriculum content in any order, provided required content for each Key Stage is taught before the end of that stage (National Curriculum, 2014). The need to avoid repetition in science teaching was highlighted in Osborne & Collins (2000).

Perception of science. Students' perception of science exerts a powerful influence on their attitudes and post-16 choices. Students as young as twelve perceive science as a difficult subject with this perception becoming more defined as students progress through school and start to recognise the differences between the separate sciences. In Years 10 and 12, this distinction is complete, and perception of each science becomes more important. Students are likely to continue with science subjects they found easy in secondary school. Similarly, students are less likely to continue with a science they found difficult even if they obtained the highest grades in their GCSE examinations. For instance, more students continued with physics which they found easy in secondary school compared to chemistry (see Figure 6.1).

The use of option blocks in Key Stages 4 (5.3.1) and 5 (6.4.1) to control subjects selection means that when faced between a science subject perceived as difficult, for example, chemistry (6.4.2) and another subject (e.g. history) in the same option block, students are likely to discard science in favour of this subject. This is true even when they realise that the science subject may have enhanced their chances of studying a STEM-related course in the University (e.g. Talia).

6.5.3 Personal-oriented factors

The notion of identity. Students' comments of not being able to 'see' themselves in science or not being ''sciencey people'' point to the concept of identity, that is, who students think they must be to engage in science (Calabrese Barton, 1998: p. 379). They allude to the possibility that students go through a process of internalisation as they try to make sense of their place in science. Learning as discussed in Chapter 3 occurs both at home and in school. These can provide students with a ''window'' into the ''figured world of science''.

Students' views of this figured world may be distorted through the inequity of social structures provided within these communities. For instance, the subconscious bias of teachers when responding to students classed as ''high'' attainers compared to ''low'' or ''middle'' attainers or in choosing to question boys rather than girls in a physics class (6.4.2). The notion of identity is discussed in detail in relations to science career expectations in Chapter 7.

6.5.4 **Students' views of the school's role in promoting science**

In Chapter 5, science provision in Farne School was discussed, so, in this section, students 'views of the school's role in promoting science are considered. Figure 6.4 shows that overall students consider the school helpful in promoting science. At the start of the academic year in 2014, 88% (n=74) of students in the sample indicated that the school, other than their science teachers, had helped them in science, while at the end of the academic year in 2015, this was 79% (n = 95).

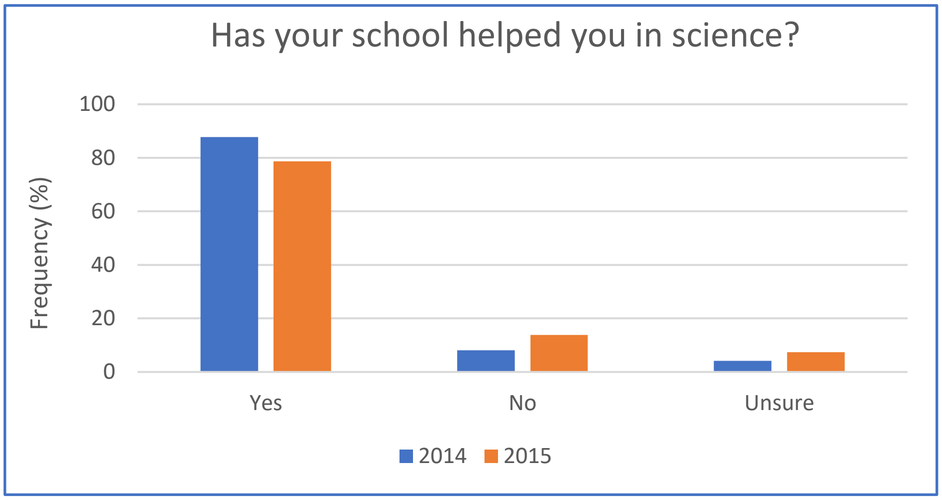

Figure 6.4: Students' views of school's help in science

Some students link the help they receive from the school to its specialist status. A note of caution is due here. It is possible that students' responses merely reflect a selection effect as the majority of students in the sample were purposefully selected based on previous academic attainment (4.7.2). Therefore, these positive views may not be applicable to students ranked as ''low attainers'' by the school.

> School is heavy on science, dominant in science [Drake: male, Year 12]

> ''Big department (science). It is a science school. Science is a favoured subject'' [Dennis: male, Year 12].

However, research evidence suggests that the nature of a school can affect students' attitudes and aspirations (IOP, 2015; Bennett et al. 2013). Specialist schools were alleged to affect students' outcomes (2.4.3). For example, Jesson & Crossley (2006) claimed that specialist schools had a positive impact on teaching and learning in the specialist subject. Though, the extent of the impact is subject to debate (Smithers & Robinson (2007).

When viewed by year groups, there was an indication that the perception Farne School was helpful in promoting science was common across all year groups (Figure 6.5). For instance, 78% of students in Year 8, 75% in Year 10 and 100% of students in Year 12 indicated that the school had helped them in science.

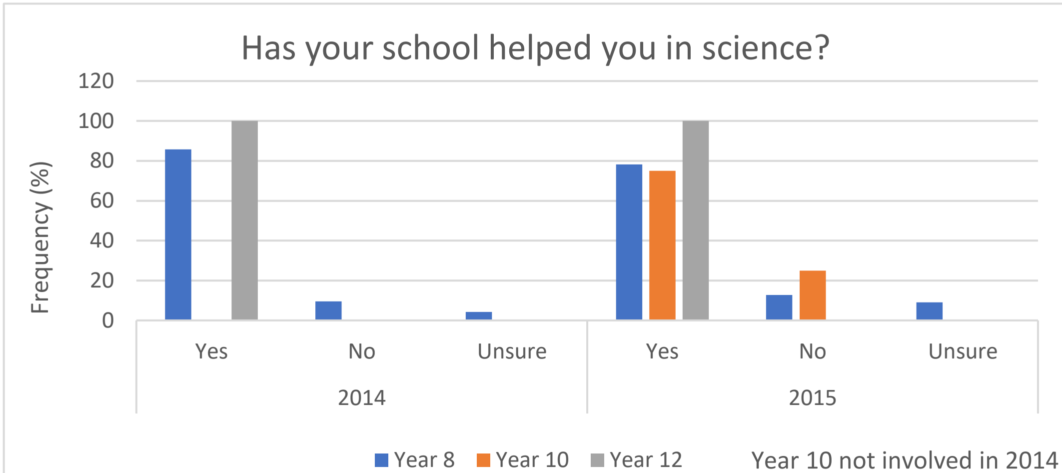

Figure 6.5: Students' views of Farne School's help by year group

Differences by gender were almost even. For example, in phase 1, 54% of the respondents were girls and 46% were boys (n = 74). Of these, 53% of students who said the school had been helpful were girls while 47% were boys. Similarly, in phase 2, 56% of girls and 44% of boys said that the school had been helpful in science. However, of the students who said the school was unhelpful or were uncertain about its help, there were more girls than boys in both cases.

In a follow up question, students were asked to describe ways in which the school had helped them in science. Responses are shown in Table 6.2. This indicates that the most common answers were extra–curricular activities. The term 'activities' is used here to describe events outside regular science lessons in which someone other than a science teacher is responsible for its presentation or delivery.

For example, visits from external science practitioners were classed as activities. Although, trips may be classed as an extra–curricular activity, this has been identified separately to capture the range of responses. Four students, one in 2014 and three in 2015 identified the Farne Science Centre (5.3.2) as an example of the school's help in science. Similarly, three students in Year 8 refer to the school being a 'science school' as evidence of the help they receive from the school. These students would have been in Year 5 in primary school when the specialist scheme ended in 2010. This suggests that despite the end of the specialist schools scheme, legacy of the school's previous specialist science status may still exist.

Responses	**N value**	
	2014	**2015**
Trips	5	6
Activities	29	27
Resources	6	5
Extra Support	9	13
Cross – curricular activities	6	9
Science Centre	1	3
It's a science school	1	2
Other	4	1
None	7	15
Missing	21	38

Table 6.2: Type of help provided by the school

Extra–curricular provision and potential bias

In Chapter 5, the notion of potential bias in science provision was raised (see the improving gender balance and internship programme). Students' views of this aspect of the school' science provision supports this viewpoint.

> They give support to higher sets. Science busking (Glossary) is given to sets 1 and 2. They give support to those who are already good. Sets 1 and 2 are on trips; university trips and engineering trips. Experiences not offered to sets 3 and 4 [Effie: female, Year 10].

The focus on a select group of students, the so-called ''high'' attainers by the school may subliminally send a message that science is for ''high'' attainers. As Hemsley–Brown (1999) found students' post–16 choices can be influenced by the ethos of pre–16 science provision. This means that students like Dena (female, 10 Topaz) who has an interest in science but does not feel ''clever'' enough may be discouraged if support is mostly available to a select group of students. This highlights the need for inclusion and fairness in extra–curricular science provision as students who may benefit most from the opportunity could be students outside this ''elite'' group identified by the school.

School facilities and resources

Students take pride in the specialist science status and the bespoke science centre. However, only students in Year 10 allude to evidence of this awareness during the group sessions. Although they were proud of the school being recognised in the community for its science emphasis, they lamented the state of the school's facilities, especially the buildings. Although students acknowledge that funding for refurbishment and upgrade of the school's facilities come from Government, the sense of frustration with the school facilities was still profound.

> [I am] not pleased with [the] facilities. Teaching and teachers [are] excellent overall. Not the facilities. I think overall, I like the teachers and the education that you get is actually excellent. The facilities isn't as good as it can be. Science has the best equipment overall. Being a science college, science gets a lot of money [Chance, male Year 10].

> It's not the school's fault but the money could be spent wisely. [There is] nothing to show that [Farne] school is a science college. Look at the facilities. Money spent on wrong things. Textbooks are falling apart and old. They waste money to look like our school's high tech [Dena, female, Year 10].

> I'd much rather have our school look rubbish and have the best equipment than ''high tech'' with hardly any equipment that works [Effie, female, Year 10].

These comments show that students are perceptive and more interested in the quality of the education they receive than in superficial restorations of the school's facilities.

Students also viewed the Science Centre as an event or conference venue rather than an extension of the science department.

> ''Science centre - only been there twice but it was not even science related'' [Dena: female, Year 10]
>
> ''It's mostly used for convention/event. I've never had any lesson in the Farne Centre'' [Chance: male, Year 10].

This could mean that contrary to the senior leadership's view (Mr. McKay, section 5.5.2) that the centre is an important part of the school's effort in promoting positive science; students consider the centre an under-utilised resource.

6.6 Summary

This chapter provided answers to the second part of Research Question 1 – students' views of factors they believed affected their attitudes towards science in the school sphere of influence. Group discussions, lesson observations, students' questionnaires and student diaries provided useful information.

Factors identified were categorised as school, subject and personal oriented. These indicate that factors which affect students' attitudes revolve around the curriculum, teachers and science as a subject itself. Personal factors such as interest are fluid. They change depending on the topic and students' perception of its relevance.

In younger years, the majority of students view practical work positively, partly because it makes lessons less monotonous. However, this fascination of practical activities starts to decline, as students become older. In Key Stage 4, when the GCSE examinations become imminent, some students see practical work as a barrier to learning sufficient curriculum content in time for examinations.

In Year 12, negativity towards practical work is almost non-existent, perhaps, because older students recognise that practical work deepens understanding of theoretical concepts.

All three year groups, especially Years 8 and 10 are impacted by their teachers. The most important references about teachers were in terms of pedagogy and personal attributes. No explicit reference was made about teachers' subject content knowledge. Teachers with extensive pedagogy content knowledge are more likely to inspire enjoyment and interest in science. Students are willing to work for teachers they like, and respect as opposed to those they do not.

Students in Year 10 report the most negative attitude to science while students in Year 12 were most positive about their science experiences. However, students in Year 12 still express concerns about difficulty in understanding some physics concepts, thus suggesting that even students, who choose to study science post-16, must persevere to remain in science. This is especially significant for students who only completed the Double Award course in Key Stage 4 as would be seen in the case of Denzil in the next chapter (7.4.2).

The next chapter moves on to look at factors in which affect students' career expectations towards science by considering the individual sphere of influence. Characteristics of the type of students who elect to study science are also considered.

Chapter 7: The individual sphere of influence: factors affecting students' career expectations in science

I enjoy science greatly, but I have always wanted to be Prime Minister and/or a lawyer

-Audrey: female, Year 8

7.0 Introduction

The previous chapter presented students' views of the factors which influence their attitudes towards science in the school sphere of influence. In this chapter, answers to research questions 2 and 3 are presented. RQ2 - *who aspires to a career in science* and RQ3 - *what precursors influence students' career expectations towards science* permit the exploration of factors in the individual sphere of influence which affect students' career expectations towards science. Students in the sample were identified by the Head of Science as ''middle to high attainers'' based on prior academic achievement. Data presented are based on responses of 83 students who participated in phase 1 of data collection. Of these, ten were from Year 12 and the remainder from Year 8. Exemplar cases are drawn from both year groups. In Chapter 4, four categories of students based on their aspirations for science were identified. These categories are discussed in detail in this chapter.

The chapter starts with section 7.1 which presents an overview of the categories, followed by 7.2, where exemplar cases from each category are presented. In section 7.3, categories are compared based on five factors, namely social class, science capital, science experience, self–efficacy in science and science aspirations. Self-efficacy in science was defined in section 3.3 and how this was determined was described in Chapter 4. Similarly, social class and science capital were described in section 2.5.4. The assignations ''low'', ''moderate'' and ''high'' used to describe students' self-efficacy, aspirations and science capital were explained in section 4.8.2.

In section 7.4, profiles for each category are mapped, while 7.5 uses the concept of identity, self-efficacy and figured worlds to explain why science careers may be attainable for some students and not others. The chapter ends with a summary in section 7.6.

7.1 Overview of categories

Students were classified as *Scientists*, *The Ambivalent*, *Non-Scientists* and *Resisters* based on questionnaire responses regarding their science career aspirations (4.8.2).

Scientists are students who aspire to a career in science. Three sub-groups were identified in this category; *Captivated Scientists* (CS), *Career-driven Scientists* (CDS) and *Pragmatic Scientists* (PS).

The Ambivalent are students who are undecided about their career aspirations. There are two sub-groups; *Positive Ambivalent* (PA) and *Neutral Ambivalent* (NA).

Non-Scientists are students who express an interest in Arts/Humanities based careers. *Positive Non-Scientists* (PNS) and *Career-driven Non-Scientists* (CDNS) were identified as sub-groups within this category.

*Resister*s do not state a career preference. However, unlike *The Ambivalent* who may allude to the possibility of a science-related profession in the future, students classified as *Resisters* exclude science in future career considerations. Hence, the placement of this group into a separate category. This category comprises three sub-groups; *Positive Resister* (PR), *Neutral Resister* (NR) and *Negative Resister* (NeR).

Figure 7.1 shows that the largest proportion of students were classified as *Scientists* (45%). A majority of the remaining students, comprising 28% of the sample, were classified as *The Ambivalent*. The least frequent classification was the *Resisters* category comprising 13% of the sample. *Non-Scientists* comprise the remaining 14%.

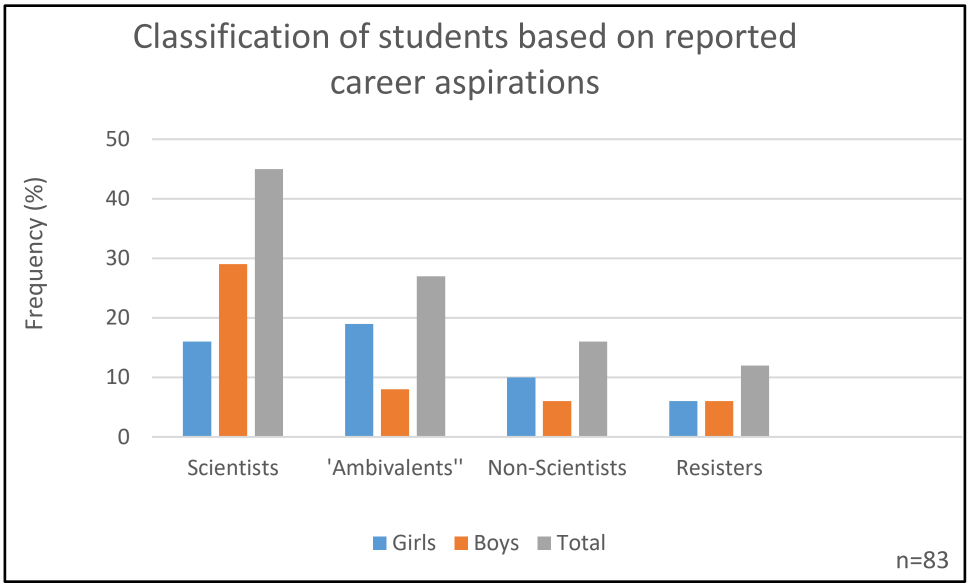

Figure 7.1: Student classification based on reported career aspirations

The small number of *Resisters* and high proportion of *Scientists* could be an indication that the majority of students in Farne School have positive attitudes towards science. This relates to data presented in section 6.5 which shows that students' attitudes towards science in Farne School is mostly positive. This may account for the high proportion of *Scientists* as positive attitudes towards science has been linked to science career aspirations (Chambers et al., 2018).

There is no direct evidence linking students' positive attitudes and career expectations toward science to the school's ''specialist'' science status. However, this possibility cannot be discounted because in addition to improving the teaching and learning of science, specialist schools such as Farne School were expected to enhance the recruitment of students into science post-16 (Ofsted, 2005). Secondly, students refer to the school's specialist status as evidence of help they have received from the school in the teaching and learning of science.

Analysis of students' classifications by gender shows that more boys (25) than girls (12) were classified as *Scientists*. This is consistent with findings in the literature that boys are likely to pursue science careers than girls (Archer et al, 2013).

In contrast, 29% of girls are classified as *Ambivalent* compared to 8% of boys. The higher proportion of girls in *The Ambivalent* category suggests that perhaps, girls do not start thinking about their career aspirations before Year 8, compared to boys in the same age group. Consequently, girls were more indecisive about their career aspirations compared to boys of the same age. Although, this could be an area of future research, the possibility that this is a spurious effect based on the sample cannot be disregarded.

More girls than boys were classified as *Non-Scientists*. This finding is consistent with previous studies which indicate that girls tend to aspire to non-science based careers compared to boys (Archer et al, 2013; Chambers et al, 2018). However, unlike the other categories, there is an even proportion of girls and boys in the *Resister* category. This finding does not support previous research which report that girls are more likely to express negative attitudes towards science compared to boys (Jenkins & Nelson, 2005).

Although, it is difficult to explain this finding, this might not be unconnected to Farne School's specialist science status and extra-curricular science provision which were examined in Chapter 5.

7.2 Exemplar cases and characteristics of categories

In the next section, an overview of each category and sub-categories is presented. This is then followed by ''case study'' students who exemplify variations within each category. This is presented in two parts. In the first part, cases are presented from students in Year 8. Each case is presented using questionnaire data obtained at the start and end of the academic year. In the second part, exemplar cases of interest from 12 Ruby, the AS physics class are presented. These include Frances, a *Captivated Scientist*; Talia, a *Positive Ambivalent* and Denzil, a *Negative Resister*.

Since, one of the aims of this study is to provide useful insights on gender disparity, girls are used as exemplars where possible. Thus, providing a useful insight into factors affecting girls' career expectations towards science. The gender of the student is only indicated if the case is male.

7.2.1 *Scientists*

Thirty-seven students were classified as *Scientists.* Of these, twelve were girls, including Frances. She was the only girl identified as a *Scientist* in Year 12. Table 7.1 shows the sub-groups, gender distribution and Year groups of students in the *Scientists* category. Half of the girls (6, n=12) in this category were in the *Captivated* sub-group. This suggests that the majority of girls identified as *Scientists* are motivated by their personal interest and liking for science rather than a specific science vocation, like the *Career-driven* or the utility of science, like the *Pragmatic.*

Sub-groups	**Year Group**			
	Year 8		Year 12	
	Girls	Boys	Girls	Boys
Captivated	5	6	1	2
Career-driven	4	10	0	2
Pragmatic	2	2	0	3
Total	11	18	1	7

Table 7.1: Gender and year groups within the *Scientists* category

The *Career-driven* sub-group comprises almost half (16, n=37) of the *Scientist* category, suggesting that the majority of students in the sample who expressed an interest in a science career did so out of a specific occupational interest. The *Pragmatic* sub-group had the fewest proportion (7) of students suggesting that when students think about their career expectations, the benefits of a science qualification may not be the primary consideration.

<u>The Captivated</u>

Fourteen students (6 girls and 8 boys) were identified. Their motivation for a future career in science is an innate liking for and/or interest in science. *Captivated Scientists* do not appear to be motivated by a specific science vocation. Characteristic statements about these students' science career expectations show these are single-minded and perceptive, for example:

I would like a science-based job because I would like to improve the human races understanding of it [Addison: male].

I joined my school and left all my friends for science. I love science [Haley: female].

Exemplar case: Brenda

Brenda was identified as socially-advantaged (NS-SEC, 1-4) with both parents in science-related professions as a physicist and chemist. Brenda's engagement with science out of school is high at 78%, that is, participation in seven of the eight activities listed in the questionnaire (Appendix 8). Camping is her favourite activity because she thinks it is 'fun' and allows her to ''spend time with nature''. However, Brenda dislikes talking about science with family because she thinks it is ''boring''.

Brenda attended Rye Primary School, one of the schools outside the ''Primary Cluster'' (5.3.2). Her recollection of primary science is ''positive'', describing a practical lesson investigating the effect of sugary drinks on teeth as the ''best'' primary science lesson she can recall. She reports that primary science lessons were regular but not weekly.

Brenda is judged by teaching staff to be a ''high'' attainer as she consistently achieves high marks for classroom-based science activities and homework. She reports high self-efficacy value of 9/10 but admits she sometimes struggles to understand some aspects of science.

Her likelihood of pursuing a science career is high at 7/10.

Brenda's interest in a science career is characterised by her simultaneously liking the subject but expressing uncertainty about pursuing science based on her parents' dissatisfaction:

I like science, but my parents work in science and they don't like their roles [2014].

By the end of the academic year, Brenda was still actively engaged in science-related activities at home, for example, camping and playing science games. Having achieved her target grade for the academic year, Brenda was judged as a high attainer by her science teacher. Although she reports that she finds some science concepts difficult to understand, her reported self-efficacy in science remains high at 9/10. However, Brenda appears more positive about pursuing science post-16. At this stage, Brenda makes positive comments about her parents' science careers, linking it to her accomplishments in science.

I am quite good at science and it runs in the family [2015].

The Career-driven

Sixteen students (4 girls and 12 boys) were categorised as *Career-driven Scientists*. Students in this category are motivated by their interest in a specific science vocation. Although the possibility exists that *Career-driven Scientists* may be motivated by their interest or liking for science, this has not been stated. The exemplar case, Aileen is discussed

Exemplar case: Aileen

Aileen was classified as socially-advantaged. One parent is a Nurse while the other is a Police Officer. Aileen engages in science-related activities at home, participating in five activities (that is, 63%) including visits to science activity centres such as museums.

Aileen attended primary school outside Hazel County. Her questionnaire responses suggests her primary science experience was ''negative''. She states that she did not enjoy science in primary school or find science easy.

She indicates that Farne School has been helpful in her current science experience.

Aileen self-reports moderate self-efficacy value of ''5''. She rates the likelihood of pursuing a science career as 10/10. Aileen is interested in a career as a Midwife.

By the end of the academic year, Aileen's participation in science-related activities was at 38% (n=3) compared to 63% (n=5) at the start. She identifies caring for animals as the activity she enjoys the most because she likes animals. Growing plants is her least favourite activity because she lacks the time. Aileen's reported self-efficacy value remains moderate at 5/10, citing difficulty in understanding physics concepts. Despite Aileen's difficulty with physics, she still maintains high aspiration to become a midwife.

The Pragmatic

Seven students (2 girls and 5 boys) were identified in this category. Although they have similar characteristics as the other two variations within the scientist category, they are different because their aspiration in science is driven by a recognition of the utility of a science career or qualification.

Exemplar case: Alma

Alma comes from a socially-advantaged background. Both parents are in full time employment as a Teacher and Optician. Alma's involvement in science-related activities out of school is high at 75%, including visits to science museums. Caring for animals is her favourite activity while playing with chemistry sets is the activity, she enjoys the least.

Alma attended primary school outside the ''Cluster''. She reports regular science lessons, though not weekly. Her science experience in primary school was mostly positive stating that she enjoyed science and found it easy. She recalls visits from 'science shows' as the best science lessons because ''there were lots of different experiments to do''.

Alma considers Farne School helpful in science by providing opportunities such as STEM club which help students in these subjects.

She self-reports high self-efficacy value of 8/10 stating that she achieves ''high'' marks in classroom assessments. She states that she understands most science ideas and concepts.

Alma rates the likelihood of pursing a science career as 9/10 because of her ability in science. She considers this a ''strength'' which could be exploited to her ''advantage'' noting that ''most jobs have something to do with science''.

Alma's interest in a science-related career is linked to her self-efficacy in science which is high. In addition, she recognises the utility of science in future employment, recognising that this can be used to her advantage.

Characteristics of Scientists

This section presented exemplar cases of students classified as *Scientists*. Analyses indicate that *Scientists* come from predominantly socially-advantaged backgrounds. They were judged as having moderate to high science capital based on their participation in science-related activities and parents in science-related careers. Participation in science related activities and influence of family in science-related careers may contribute to the development of children's science capital (Archer et al., 2013). This is explored in section 7.3.1.

Archer et al (2013) found that the measure of science capital a student possesses can influence their science career expectations. Similarly, students with family in science-related careers tend to develop interests in science-related careers themselves (Lyons, 2006; DeWitt et al., 2013).

However, science capital as defined by Archer et al (2013) implies that this may always be positive. This may not always be the case as seen with Brenda (7.2.1). Having parents in science-related occupations is usually a positive influencer but in Brenda’s case, her parents’ dissatisfaction with their science careers had become a negative influencer. The notion of ‘’destructive science capital’’ was raised in section 5.4.1. This term is used as it may reduce the likelihood of a future science career.

Scientists were also dominated by students whose self-efficacy in science were judged as moderate or high based on their reported ability in science. However, despite being ranked as high attainers by the school, some, for example, Aileen, find aspects of science, especially physics challenging. This finding corroborates previous research that girls may find physics challenging compared to the other sciences (Barmby & Defty, 2006). Although *Scientists* may find some aspects of physics challenging, their science aspirations range from moderate to high. This suggests that moderate science aspirations may be sufficient to overcome challenges in science.

In summary, findings indicate that that for students to be classified as *Scientists,* self-efficacy in science, science aspiration and science capital seem to be useful factors. In addition to these, a socially-advantaged background is beneficial.

7.2.2 *The Ambivalent*

Fifteen girls and eight boys were identified in *The Ambivalent* category. They represent the second largest category. Table 7.2 shows the gender distribution and Year groups of the sub-groups within *The Ambivalent* category.

Sub-groups	**Year Group**			
	Year 8		Year 12	
	Girls	Boys	Girls	Boys
Positive	5	3	1	0
Neutral	9	5	0	0
Total	14	8	1	0

Table 7.2: Gender distribution and year groups within *The Ambivalent* category

The Ambivalent category is dominated by girls. This suggests that girls are more likely to be uncertain about their career expectations. However, they are also more likely to retain a positive interest in science compared to boys. Case studies within each sub-group are discussed.

Positive Ambivalent: Ada

Ada comes from a socially advantaged background with both parents in full time science-related employment. Her participation in science out of school is high at 75%. She enjoys playing science games but dislikes growing plants.

She had a positive experience of science in primary school but laments the fact that there was only one science practical experiment in primary school. She attended primary school outside the Cluster.

Ada considers Farne School's science provision helpful because of ''science week'' and extra science activities outside of lessons.

Ada's reported self-efficacy value is high at 9/10. She notes that she enjoys science and performs well in class assessments, though she finds some topics more challenging than others.

At the start of the academic year, Ada was uncertain about her science aspirations stating:

> I'm not really sure what I want to be [2014].

She rates the likelihood of a future in science as 6/10 which has been labelled as moderate.

By the end of the academic year, Ada was less engaged with science out of school. Her reported self-efficacy remained high, though this was impacted by the science topic.

> Because it depends on the topic we are learning about. Some I am better [at] than others

Ada's science aspirations remained moderate at 5/10 though she become interested in a career in science. This interest originated in curiosity about the weather leading to the prospect of pursuing meteorology.

> Because I like learning about why the weather happens and I could get a job to do with it [2015].

Consequently, Ada was re-classified as a *Career-driven Scientist* by the end of the academic year. Ada's re-classification as a *Scientist* was linked to her interest in meteorology, highlighting the power of interest in specific vocations (Vermunt, 1992).

Neutral Ambivalent: Beverley

Beverley comes from a socially-advantaged background. Beverley's involvement with science out of school is low at 38%, though she enjoys visits to science centres such as museums. One parent is in full time employment as an IT specialist.

Beverley attended primary school within the Cluster and reports a negative primary science experience, with infrequent science lessons.

Her self–efficacy value is high at 7/10. She enjoys science and understands science concepts.

Although Beverley has an interest in pathology, the likelihood of pursuing this interest is low as she rates the likelihood of pursuing a science-based career as 3/10. She states that this is because she has other career interests. She attributes part of her uncertainty to a lack of encouragement from her teacher stating:

> I'm one of those people who are quiet and let other people say the answers even if I know them. My teacher doesn't often ask me anyway'. I really enjoy science but there are other things I like to do as well. I have an idea of two other roles so that's why I said 3. If my teacher made me feel more involved, then maybe I'd boost the number.

Beverley's assertion that she would 'boost the number' of the likelihood of pursuing a science career if her teacher encouraged her participation in lessons, underlines the importance of positive ''verbal persuasion'' of people of significance such as teachers in in students' learning experiences (Bandura, 1997).

At the end of the academic year, she enjoyed visiting science centres citing the opportunities to ''discover new things''. Although, her self–efficacy value was now moderate at 6/10, Beverley still enjoys science. She attributes the challenges she faces in science to physics concepts stating that this is the subject she finds most difficult to understand.

> I enjoy science but I'm not very good with physics because I don't find it easy to understand [2015].

Beverley's difficulties with physics is consistent with previous research that students, especially, girls, find physics challenging (IOP, 2012). However, she was now certain that science was not for her indicating an interest in Arts/Humanities. Beverley now rates the likelihood of a science career as 2/10 which is very low. Beverley was re-classified as a *Positive Non-Scientist* by the end of the academic year.

Characteristics of *The Ambivalent* category

They represent almost 30% of students (n=83) making them a category of interest and importance. Secondly, as the career expectations of these students are not fixed, they can change trajectory as was seen with Ada (7.2.2). Ada shows that *The Ambivalent* category can be potential *Scientists. The Ambivalent* category shares similar characteristics with *Scientists*. They come from socially-advantaged backgrounds, with one or both parents in science-related professions. Their science experience is mostly positive. Their self-efficacy ranges from moderate to high. However, their aspirations in science ranges from low to moderate. Those in the *Positive Ambivalent* category are the most likely to change to a science career compared to those in the *Neutral Ambivalent* category.

7.2.3 *Non–Scientists*

Twelve students (7 girls and 5 boys) were identified as *Non-Scientists* due to their interest in non-science careers. Table 7.3 provides background information of students in this category. As would be expected, no student in Year 12 was categorised as a *Non-Scientist.*

Sub-groups	**Year Group**			
	Year 8		Year 12	
	Girls	Boys	Girls	Boys
Positive	3	0	0	0
Career-driven	4	5	0	0
Total	7	5	0	0

Table 7.3: Gender distribution and year groups within the *Non-Scientist* category

There is an almost even split between girls and boys in this category, with some girls (3) retaining a positive interest in science despite a lack of interest in a science career.

Positive Non-Scientists: Audrey

Audrey is from a socially-advantaged background. One parent is an actor/writer while the other is studying to become a social worker. Her engagement with science out of school is high at 75%, participating in six activities. She enjoys visits to science museums most, because it enables her to learn, while she dislikes growing plants.

Audrey attended primary school outside the Cluster'' but within Hazel County. Her recollection of primary science is mostly ''positive'' stating that she enjoyed primary science and did not find science difficult.

She does not provide a rating for her self-efficacy in science. She claims she enjoys science, rating the likelihood of pursuing a science career as 6; this is moderate.

> I enjoy science greatly, but I have always wanted to be Prime Minister and/or a lawyer.

Audrey's quandary about choice of careers highlights students' narrow worldview of science and its utility in the workplace. As discussed in Chapter 6, this may be an indication of inadequate career advice and information available to students in Farne School.

Career-driven Non-Scientist: Alger (male)

Alger comes from a socially advantaged background with both parents in full time employment. One parent is an IT specialist while the other works in the catering industry. His participation in science out of school is low at 13%. Playing science games is the only science-related activity he participates in.

His primary science experience was negative. Alger cannot recall a memorable science lesson from primary school. He attended primary school outside the Cluster.

He has moderate self-efficacy value of 6/10 stating that he is neither ''brilliant nor ''terrible'' in science.

Although he has a moderate self-efficacy in science, he has no aspirations in science rating the likelihood of pursuing science as 1/10. Alger's ambition is to become an accountant.

By the end of the academic year, Alger had stopped playing science games; the only science-related activity he participated in at the start of the academic year. His self-efficacy value remained moderate at 5/10 using the same phrase:

> I am neither brilliant nor terrible.

Alger's aspiration rating increased to 3/10 but he continued in his non-science ambition of becoming an accountant.

Characteristics of *Non-Scientists*

Non–Scientists category tend to have low to moderate self-efficacy values in science. Students come from advantaged and socially disadvantaged backgrounds. Although one or both parents might be in full time-employment, it is not usually science-related as was prevalent with *Scientists*. Their participation in science-related activities also range from low to moderate. No Year 12 AS physics student was classified in this category.

7.2.4 *Resisters*

Eleven students (6 girls and 5 boys) were labelled as *Resisters*. Looking at Table 7.4, it is evident that girls are more likely to be *Resisters* than boys, though boys may retain an interest in science despite a lack of career aspirations for science.

Sub-groups	**Year Group**			
	Year 8		Year 12	
	Girls	Boys	Girls	Boys
Positive	0	2	0	0
Neutral	2	0	0	0
Negative	4	2	0	1
Total	6	4	0	1

Table 7.4: Gender distribution and year groups of students in the Resister category

Positive Resisters - Caesar (male)

Caesar comes from a socially-advantaged background with both parents in full time employment as a dental nurse and a managing director in a company which manufactures plastics. His participation in science-related activities out of school is low at 38%. His favourite out of school science activity is mending bikes. He dislikes visits to science activity centres such as museums.

Caesar attended Calder primary school, one of the schools in the Cluster. Science lessons were irregular but overall, his primary science experience was positive.

His reported self-efficacy value is high at 8/10, stating:

> I can do most things in science and can understand a lot of things.

However, Caesar's science aspirations is low, rating the likelihood of pursuing science as 3/10, stating:

> I like science at school. but I wouldn't like a iob to do with it.

Caesar's assertion of his ability in science and fondness for the subject are undermined by his low aspirations for science. Low aspirations in science is typical of the *Resisters* category.

Neutral Resisters- Bonnie

Bonnie comes from a socially-disadvantaged background. Both parents are in full time employment as a secretary and prison officer. Her participation in science out of school is moderate at 50%.

She attended Calder primary school, one of the schools in the Cluster. Her primary science experience was mostly positive as she enjoyed science in primary school.

Her reported self-efficacy value is high at 8/10. She claims that she is good at science and finds science concepts easy to understand.

However, Bonnie's science aspirations is low. She rates the likelihood of a science career as 3/10. She explains:

> Although I'm good in science, it is not my favourite subject.

Further probing revealed that Bonnie wanted to be a beautician or midwife. This indicates a lack of awareness of the importance of science in occupations like midwifery or the beauty sector. At the end of the academic year, Bonnie's self-efficacy value is high at 8/10. She now rates the likelihood of pursuing a career in science as 8/10, as she wants to be a nurse or a doctor. Consequently, she was reclassified as a *Career-driven Scientist* by the end of the academic year.

Negative Resisters- Eartha

Eartha comes from a socially-advantaged background with both parents working full time as physiotherapists. Eartha's participation in out of school science was calculated as 38%. Camping is her favourite out of school science activity. She does not like growing plants.

Eartha did not attend primary school within the Cluster. Her primary science experience is mostly negative.

Eartha reports very low self–efficacy. She rates the likelihood of pursuing a science career 1/10 stating:

> Science is one of the subjects I panic in [2014].

The likelihood of Eartha pursuing a science-based career is very low. The likelihood was rated as 1/10. She gives the same reason as above.

By the end of the academic year, Eartha's experiences of science within and out of school were similar. She rarely engaged in science-related activities out of school and had very low self-efficacy in science at 1/10. Similarly, the likelihood to pursue a science-based career remained unchanged at 1/10.

> I struggle very strongly in science and very unconfident [2015]

Eartha presents a good example of a student who associates science with an adverse physical reaction. Her doubts in her ability in science means she is less likely to persist with science beyond compulsory schooling. Secondly, as Eartha dwells on her perceived incapability to study science, she creates even more anxiety about science. Mallow (2010) characterised this reaction to science as *science anxiety*. Science anxiety is the general fear or aversion towards science concepts; scientists and science-related activities as a whole (Mallow, 1981 cited in Chiarelott & Czerniak, 1984). Chiarelott & Czerniak (1987) found that girls suffer from science anxiety as early as nine years old. Bandura (1993) reports 'it is difficult to achieve much while fighting self-doubt'. Hence, students like Eartha may not wish to pursue science. Her anxiety in science suggests that having both parents as scientists does not automatically build up positive science capital.

Characteristics of *Resisters*

Students come from mixed social backgrounds but the majority (6, n=11) in the *Resister* category from socially-disadvantaged backgrounds. They rarely engage in science-related activities out of school. They are the category with the least positive experience of science.

In this section, exemplar cases of sub-groups from Year 8 were presented. This shows that students were impacted in different ways by the teaching and additional science experiences they received during the academic year. For example, Beverley's aspiration in science is low because of a lack of encouragement from her science teacher (7.2.2) while Eartha experienced science anxiety (7.2.4).

However, others like Ada (7.2.2) and Bonnie (7.2.4) changed trajectory and developed interests in science careers. In the next part, exemplar cases from Year 12 are presented.

7.2.5 Exemplar cases of interest: Frances, Talia and Denzil

This section presents cases in Year 12 (12 Ruby). These cases were chosen for the following reasons. Talia and Frances are the only girls in the sample. Frances was classified as a *Scientist* while Talia was classified as a *Positive Ambivalent*. Denzil is the only boy in the sample who was not classified as a Scientist. He was classified as a *Negative Resister*. Exploring all three cases may provide useful insights of students' experiences and career expectations of students in an AS physics class.

Case 1: The Captivated Scientist - Frances

Frances comes from a socially-advantaged background with both parents who are physicist in full time science–related professions. Frances's extended family work in science-related professions such as medicine. Out of school, she visits science centres, watches science programmes on television and discusses science with family members.

She studies six AS subjects. These includes a European language and five STEM subjects (Biology, Chemistry, Physics, Mathematics and Further Mathematics). Based on her GCSE science grades, Frances can be described as a ''high'' attainer, having obtained the highest grades (A*) possible in all three GCSE science examinations.

She had a positive science experience in Key Stage 4, describing a liking for science because of its ''logicality'' and usefulness in providing ''answers to questions about the universe''.

Frances participated in the STEM leadership Internship programme (5.3.2). Frances's reported self-efficacy in science is ''high'' (physics - 8/10; chemistry - 8/10; biology - 9/10). She finds chemistry the most challenging, stating that it is the subject in which she feels the least confident. Although she finds physics challenging, this is the subject she enjoys the most.

She has high aspirations in a physics-related career, rating the likelihood as 10/10. Frances wants to become a research scientist.

At the end of the academic year, she still enjoys physics though she finds it challenging. Her self-efficacy in all three science remained high (physics – 8/10: chemistry – 8/10; biology – 8/10). Although she now rates the likelihood of pursuing a science career as 7/10, this is still high. Frances maintained a science-oriented aspirational trajectory throughout the academic year and decided to continue with all STEM subjects after AS.

Case 2: The Positive Ambivalent: Talia

Talia comes from a socially advantaged background with both parents in full time employment. Her parents are in science and mathematics-related professions. She described the effect this has on her:

> My parents both studied Maths and science. I grew up watching science programmes because they liked that kind of thing and listening to them talk about their jobs in science. It helped me get interested in it [2014].

Talia's science capital was judged as moderate based on her parents' profession and participation in science-related activities. Her participation in science out of school was 38%, that is, participation in three out of eight activities.

She enjoyed science in Key Stage 4, with physics being her easiest science. One aspect of Key Stage 4 science she found frustrating was the lack of resources and limitations of practical science activities.

Talia can be classified as a high attainer having achieved the highest grades possible (A*) in all three GCSE sciences. Talia enjoys science especially because it enables her to understand the universe. She has a high self-efficacy value in physics rating herself 8/10 stating:

> I achieve A [grades] in all mocks and assessments; however, I still find it difficult and I can see areas for improvement.

Talia has a strong interest in Business studies and Mathematics stating:

> I like physics a lot and find it very interesting, but I find myself more attracted to maths/business [2014].

She participated in the internship programme for Leadership and Management (5.3.2).

She rates the likelihood of pursuing a career in physics as 6/10.

Talia's comment about Business studies and Mathematics, suggests that she is conflicted about her choice of a career and future in physics after A-levels.

By the end of the academic year, Talia reported a lower self-efficacy value of physics at 6/10 compared to 8/10 at the start of the academic year. She was also re-classified as *Positive Resister* because she was no longer interested in a career in physics, rating the likelihood of pursuing physics 5/10.

> I like physics, but I'm not interested or good enough to continue with it [2015].

From Frances's and Talia's background information above, they have more similarities than differences. Both are from socially-advantaged backgrounds whose parents work full time in STEM-related professions. They both attended secondary school in Farne School and obtained A* grades in all three GCSE science subjects. At the time of data collection, A* was the highest grade possible in GCSE examinations.

Frances considered biology her easiest Key Stage 4 (Glossary) science, while physics was Talia's easiest. Chemistry was their most difficult science in Key Stage 4. Their AS subjects choices are shown in Table 6.1(section 6.4). Both found AS physics challenging and participated in the Internship Programme.

Despite these similarities, Frances and Talia chose contrasting outcomes at the end of the academic year. Frances maintained a science trajectory while Talia decided that physics was not for her. The only recorded differences in questionnaire responses was that Talia's self-efficacy declined. To gain a deeper understanding of the nature of these changes, individual cases are compared. This indicates why some students maintained unchanged trajectories through the academic year while others' trajectories changed positively/negatively. This is discussed in section 7.5.

Case 3: The Negative Resister – Denzil (male)

Denzil comes from a socially-disadvantaged background with only one parent in full time employment. His science capital was judged as moderate

He reports a positive secondary science. He found physics easy but found chemistry challenging citing difficulties with formulae and equations.

Although he found secondary physics easy, he reports a low self-efficacy in AS physics, rating himself as 4/10 because he finds some aspects of physics challenging.

Despite electing to study physics post-16 because of his interest in engineering, his rating of pursuing a physics-based career is low at 3/10.

Although Denzil did not complete phase 2 of the data collection process, there is no evidence to suggest that because he was classified as a *Resister* at the start of the academic year, he did not continue with physics at the end.

From the exemplar cases presented above and characteristics of these students, some factors appear to be common within some categories but not others. For instance, students in the *Scientists* and *Ambivalent* category come from socially-advantaged backgrounds with at least one parent/guardian working full time in science-related professions. From research evidence, this can influence students' science aspirations (Lyons, 2006; Aschbacher, Li & Roth, 2010).

In contrast, students in the *Resister* category were the least likely to have parents/guardian in full time employment in science-related roles. They typically have low self-efficacy values and low science aspirations. This indicates that factors such as social class, self-efficacy and science aspirations may be useful in predicting students' career expectations towards science. These are explored in the next section.

7.3 Precursors to students' career expectations in science

This section explores the connections between the factors identified in the previous section and the possible effect on students' career expectations towards science. This is done by comparing each factor in relation to the different categories. These factors will be referred to as precursors because they all appear to be based on prior experiences. Referring to them as precursors also differentiates them from factors identified in the school sphere of influence. Precursors explored include social class, science capital, self-efficacy in science, science aspirations and science experience.

7.3.1 Social class

Students' were classified as socially-advantaged (NS-SEC, 1-4) or socially-disadvantaged (NS-SEC, 5-8) by comparing their parents/guardians' occupations against the NS-SEC grouping (2.5.4). Students' parental occupations from which the classifications were determined are listed in Appendix 20. Table 7.5 shows that the majority of students in the sample (63%, n=83) come from socially-advantaged backgrounds while 29% were identified as socially-disadvantaged.

Socially-advantaged		Socially-disadvantaged		Not stated	
N	%	N	%	N	%
52	63	24	29	7	8

Table 7.5: Social class of students within the sample

Social class has been linked to STEM participation and recruitment (Royal Society, 2006; Aschbacher et al., 2010). Therefore, having a high proportion (63%) of students from socially-advantaged backgrounds suggests that for the majority of students in Farne School, aspiration to science careers may not be ''unthinkable'' (DeWitt et al., 2013). Indeed, 45% of students (n=83) in the whole sample were classified as *Scientists* as seen in Figure 7.2.

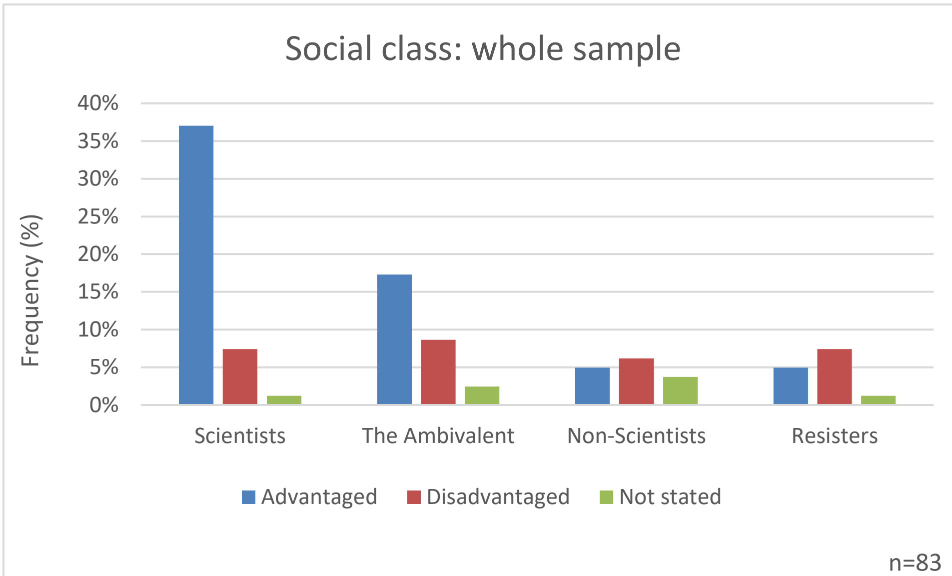

Figure 7.2: Social class of students within the whole sample

The second largest group of socially-advantaged students identified is *The Ambivalent* category which comprise 17% (n=83) of the whole sample. Students in the *Non-Scientists* and *Resisters* category have the lowest proportion of socially-advantaged students in the whole sample at 5% respectively.

The proportion of students from socially-disadvantaged backgrounds within all four categories are similar; *Scientists* (7%), *The Ambivalent* (8%), *Non-Scientists* (6%) and *Resisters* (7%). When viewed within categories, differences begin to emerge. Figure 7.2 shows that the *Scientists* category is dominated by socially-advantaged students (81%, n=37). A similar pattern is seen with *The Ambivalent* category where approximately 60% are socially advantaged.

While the *Resisters* category is dominated by socially-disadvantaged students (6, n=11), followed by *Non-Scientists* (5, n=12). However, as can be seen in Figures 7.2 and 7.3, more students within the *Non-Scientists* category did not state their parents' occupation compared to the other categories, hence, these values may not be truly representative of this category.

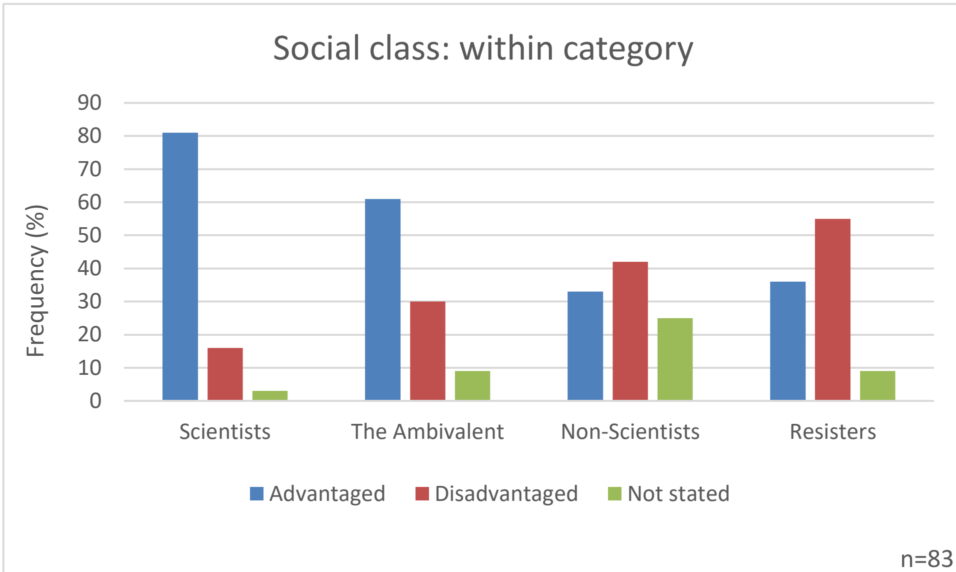

Figure 7.3: Social class within category

The findings that *Scientists* are dominated by socially-advantaged students while *Resisters* are mainly from socially-disadvantaged backgrounds point to the possibility that social class is a likely predictor of students' future science career expectations. This is consistent with previous work (Archer et al., 2013; Gorard & See, 2009). Archer et al (2013) and Gorard & See (2009) found that students from socially-disadvantaged backgrounds are less likely to continue with science post-16.

Although the authors were unable to provide conclusive evidence for this observation, the opportunities that social class provides cannot be discounted. For example, students from socially-advantaged backgrounds are more likely to have resources for out of school science opportunities such as visits to science activity centres compared to students from socially-disadvantaged backgrounds. One possible opportunity related to social class is science capital (Archer et al., 2013) which is explored next.

7.3.2 Science capital

Science capital was defined in section 2.5.4. In this study, this was determined using two measures: participation in science-related activities out of school and whether members of a student's family were in science-related professions.

Participation in science-related activities out of school

Students identified the number of activities they participated in from a list of eight items provided in the questionnaire (Appendix 8). For ease of comparison, this was aggregated as follows: Low: *1–3*, moderate: *4-6* and high: *7-8*. Looking at Figure 7.4, this shows that 63% (n=83) of students participated in at least half of the activities on the list. Only 10% participated in at least seven of the activities.

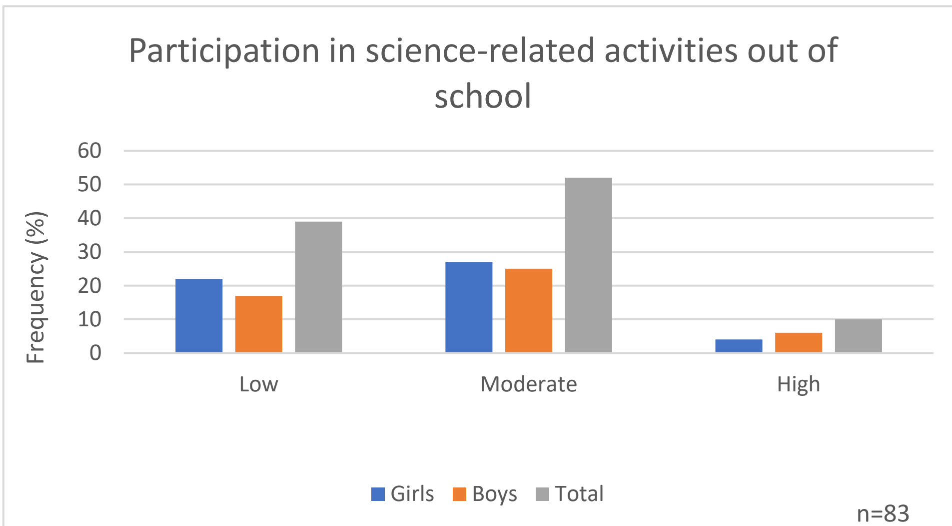

Figure 7.4: Participation in science-related activities out of school

Participation and popularity of each activity varied by gender. For example, more boys engage in science-related activities compared to girls. Science games was the most popular activity for boys. Boys' interest in games corroborates previous studies which show that boys are interested in aspects of science having to do with the *''technical, mechanical and, electrical''* *(*Sjøberg and Schreiner, 2010) compared to girls. In contrast, girls preferred caring for their pets, supporting previous findings that girls prefer biology related areas of science (Kind et al., 2007).

Findings indicate that students are less likely to participate in activities they dislike or consider boring. For example, students who identify discussions with family members as an activity least enjoyed attributed this to personal or familial dislike for science. This underlines the importance of family influence on students' interest. However, for students like Beatrice, her dislike for discussing science with family members stems from her brother being unsupportive when she provides a wrong answer.

> Because my brother will go on if, I got something wrong [Beatrice].

However, when they do participate in activities they dislike or find boring, it is usually at the behest of a family member rather than personal interest. In explaining why, she prefers one activity to the other, Anthea explains:

> I enjoy playing science games, e.g. minecraft more than growing plants because growing plants is something my mum makes me do but playing science games I do on my own.

This suggests that being in control is important for Anthea to engage in an activity which is evident when she plays science games but lacking when growing plants.

For others, some activities provide an opportunity to spend time with family and friends.

> I like camping because I like sport and the outdoors and being with friends and family. My grandpa is quite interested in science so I ask him things if I'm unsure. That is okay but not the most fun [Amanda].

Other reasons for not participating in an activity was the perceived difficulty of the activity. For example, girls do not like science kits such as chemistry sets or fixing gadgets because they find it ''too confusing''. This perceived difficulty of science kits may be transferred to science itself.

Students will participate in activities which stimulate their interest. They use terms such as ''fun'' enjoyment, and ''love'' to describe these activities. For example, the majority of students who looked after animals did so because of an innate love for animals or because they were born into a family which already had a pet.

> I love caring for animals [Alma].
>
> I enjoy science games (like Minecraft) because when I play the game, I forget it's about science and become inflicted (sic) in the game [Agnes].

Less common reasons were an opportunity for discovery, creativity, educational interest or if the activity was related to a career interest. Girls are more likely to identify career or educational interest as a reason for participating in an activity while this is not a consideration for boys. For example, in explaining why they enjoy visits to science-activity centres, Eunice and Beverly explain:

> I enjoy learning about our world and the things in it [Eunice].
>
> I can find things out that we don't learn at school [Beverly].

This corroborates findings that visits to science centres provide an opportunity for both learning and entertainment (Stocklmayer et al., 2010). However, some students dislike science centres for being too educational. This is because they equate anything educational as ''not fun''.

Participation by category

Participation in science-related activities was calculated based on the number of students involved in at least half of the activities on the list. Responses were counted and calculated as percentages. The results are shown in Figure 7.5.

This shows that students classified as *Scientists* are most likely to engage in science–related activities out of school (77%, n=37) compared to the other categories. Students in the *Resisters* category are the least likely to participate (22%, n=11).

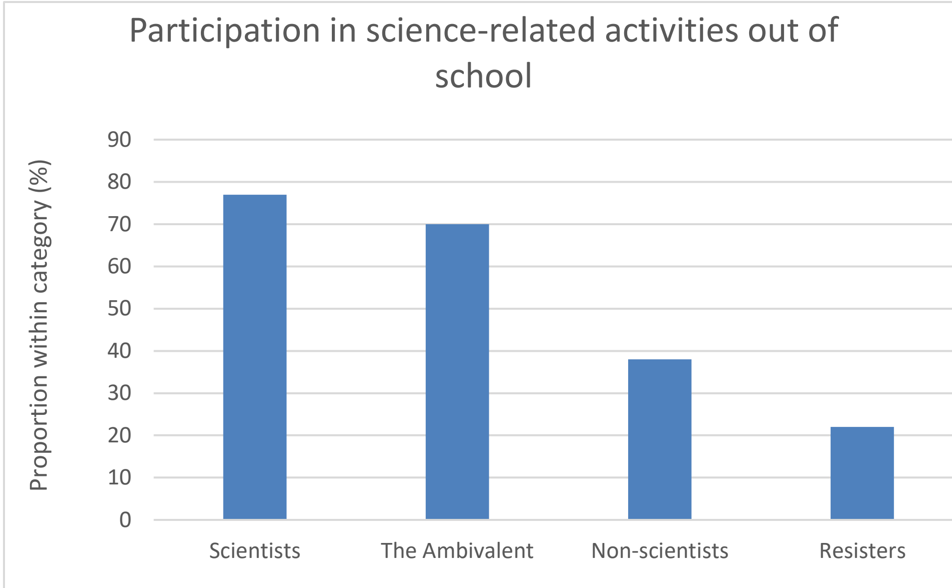

Figure 7.5: Students' participation by category in science-related activities out of school

This was evident in the exemplar cases described in the previous section. The difference between the two categories may not be unconnected to social class as students from socially-advantaged backgrounds may have the resources to participate in activities which may enhance their science capital (Archer et al., 2014).

Consequently, a comparison was made between students' social class and participation in science-related activities. Figure 7.6 appears to support the viewpoint that social class may be linked to participation in science-related activities out of school. For example, 81% (n=37) of students within the *Scientists* category were classified as socially-advantaged, while the number of students within the *Scientists* category involved in science-related activities was 77%. Similarly, 36% of *Resisters* were identified as socially-advantaged and only 22% (n=11) within this category engaged in science-related activities out of school.

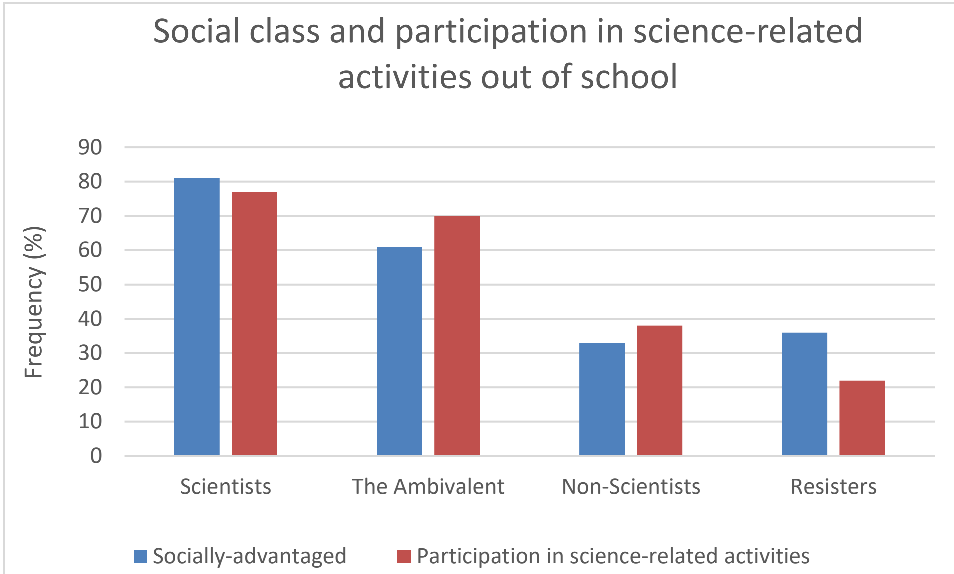

Figure 7.6: Social class and student participation in science-related activities out of school

Therefore, social class may impact on participation on science-related activities out of school. As participation in these activities can build up science capital (Archer et al., 2013), students from socially-advantaged backgrounds may have a higher amount of science capital than students from socially-disadvantaged backgrounds.

Family in science–related profession

This looked at whether at least one parent/guardian was in a science–related profession. In addition, science in the extended family was considered. Lyons' (2006) found that students who choose to study science past the compulsory stage had family in science–related employment or with extensive knowledge of science.

Figure 7.7 shows that students labelled as *Scientists* were most likely to have at least one parent in a science–related profession (26%), while *Non-Scientists* and *Resisters* were likely to have the least.

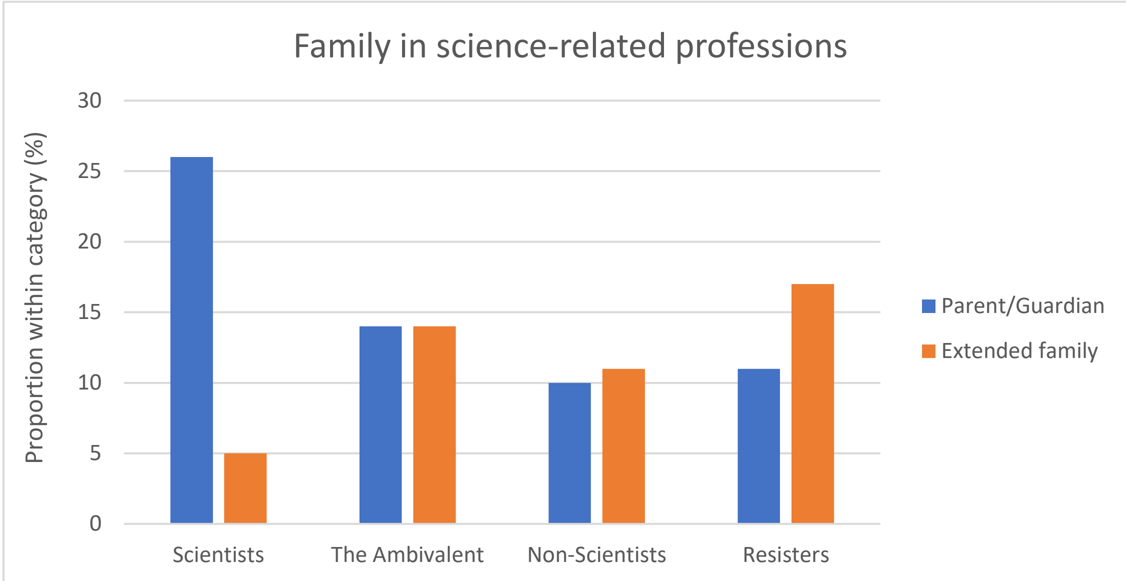

Figure 7.7: Family in science-related professions

Scientists have the smallest number (5%) of extended family members in science-related employment compared to the *Resisters* category (17%). This points to the possibility that parents/guardians' science-related profession is more influential than extended family members' as evidenced by the number of *Scientists.*

Based on these two measures, science capital was determined by calculating an average of students' scores. This shows that approximately half (51%, n=83) of students in the sample have a moderate amount of science capital. Only 9% of students in the sample have a high amount of science capital and these come from the *Scientists* category and contradictorily, the *Resisters* category as seen in Figure 7.8. *Resisters* had the highest proportion of extended family members in science-related professions as seen in Figure 7.7. This indicates that although science capital is important, it may be useful to also consider the sources that contribute to its development.

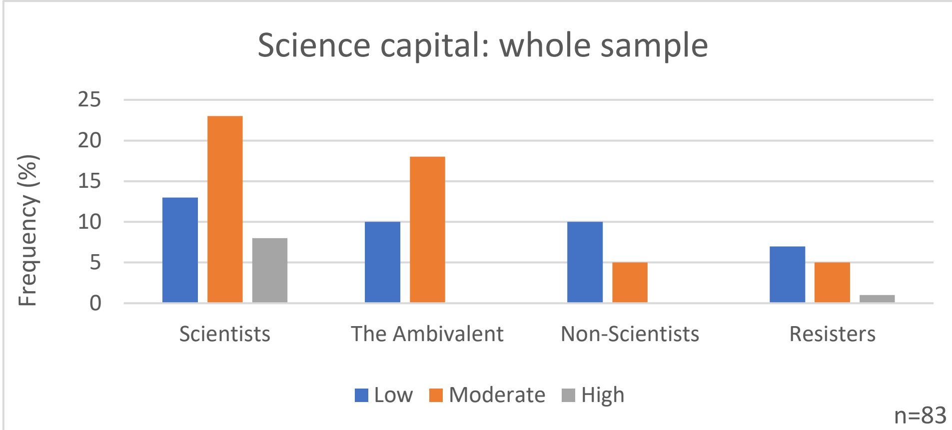

Figure 7.8: Science capital within the whole sample

When viewed by categories, Figure 7.9 shows that the *Scientists* (51%) and *The Ambivalent* (65%) categories are dominated by students with moderate science capital. *Non-Scientists* (67%) and *Resisters* (55%) comprise students with low science capital. Although *Scientists* have the highest proportion of students in the sample with a high amount of science capital, these students are the fewest within the *Scientist* category.

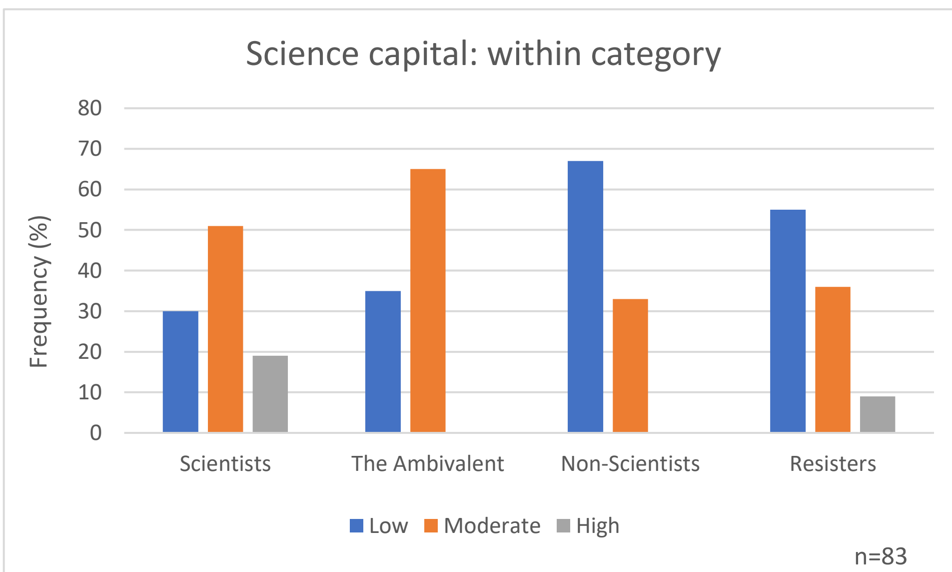

Figure 7.9: Science capital within categories

Collectively, these indicate that moderate amounts of science capital as seen in the *Scientist* category may be sufficient to develop interests in science careers. This supports Archer et al (2013) position that possession of moderate to high science capital can enhance students' participation in science-related careers. Therefore, from these findings, it is reasonable to infer that science capital may be a useful predictor in students' science career prospects. Hence, increasing science capital among other categories may raise students' science aspirations. However, as the *Resisters* category also had students with high amounts of science capital, this may be an indication that science capital may be insufficient as a sole predictor of science career expectations.

7.3.3 Self-efficacy in science

In this study, self-efficacy was determined by using students' self-reported ability in science as a measure. As seen in section 6.2.1, some students ascribed their self-efficacy to their teacher's explanation skills, while others linked it to their performance in class tests or understanding of science concepts. Hence a deeper look into this precursor is valuable.

This shows that within the whole sample, there is an equal proportion of students with moderate (43%) or high self-efficacy (45%). Of the number of students who report the highest self-efficacy in the sample, almost two-thirds are from the *Scientists* category. This is unsurprising as students will pursue a career in an area where they have the capability to do so (Bandura, 1997). Figure 7.10 highlights these information.

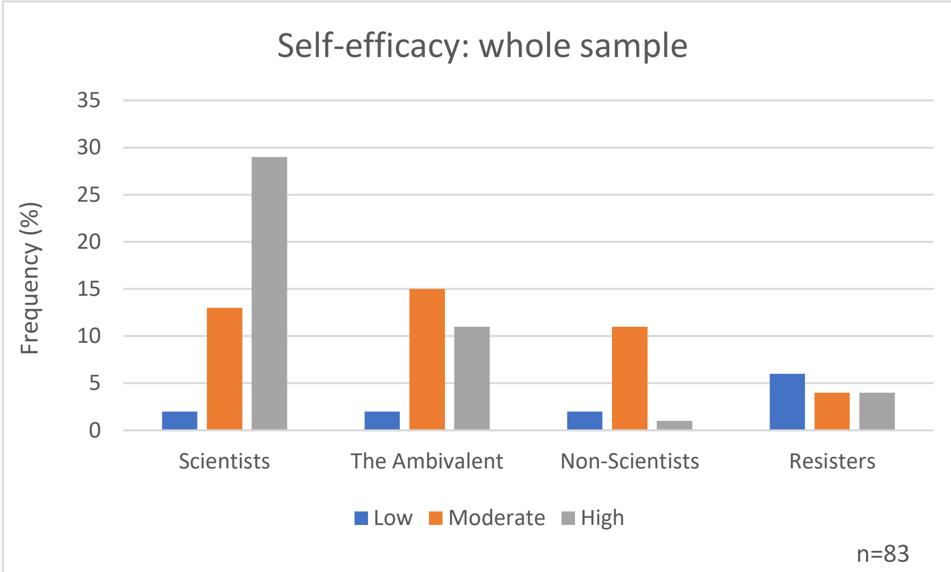

Figure 7.10: Reported self-efficacy within whole sample

At this point it is useful to note that *Resisters* can also have high self-efficacy in science. Bonnie, an exemplar case in section 7.2.4, whose self-efficacy was 8/10 is a good example. Values from 7 and above were classified as high. This indicates that a high self–efficacy in science may be insufficient to pursue a career in science if there is a simultaneous dislike of science.

Self-efficacy was then compared by categories as seen in Figure 7.11. This indicates that students classified as *Resiste*rs are most likely to be those whose self-efficacy in science are low. Similarly, students in the *Non-Scientists* category are likely to be students whose self-efficacy are considered moderate. *Scientists* unsurprisingly are dominated by students whose self-efficacy in science may be considered high.

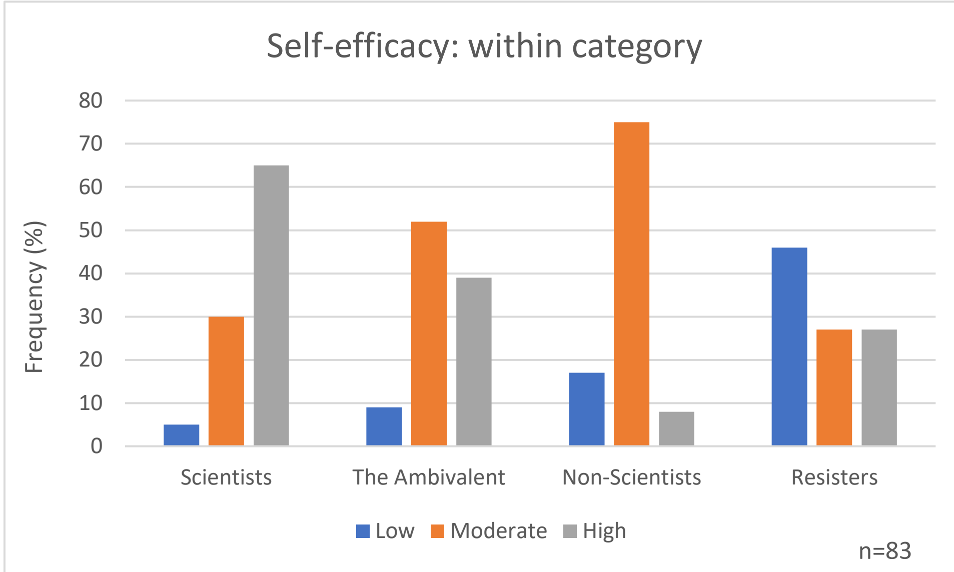

Table 7.11: Students' reported self-efficacy within categories

7.3.4 Science aspirations

Data are based on students' questionnaire scores on the likelihood of a future career in science (4.8.2). Contrary to expectations, this does not only apply to *Scientists* and perhaps *The Ambivalent* category, but to *Non–Scientists* category as well. For example, within the *Positive Non–Scientists* category, some students rate the likelihood of a future in science as five and above (e.g. Audrey: section 7.2.3); this was judged as moderate.

Looking at Figure 7.12, this shows that within the sample all categories have some measure of science aspirations. The majority (43%) of students in the sample have moderate aspirations for science. Only 22% have very high aspirations for science in the sample. These were all *Scientists.* As expected, all *Resisters* have low science aspirations.

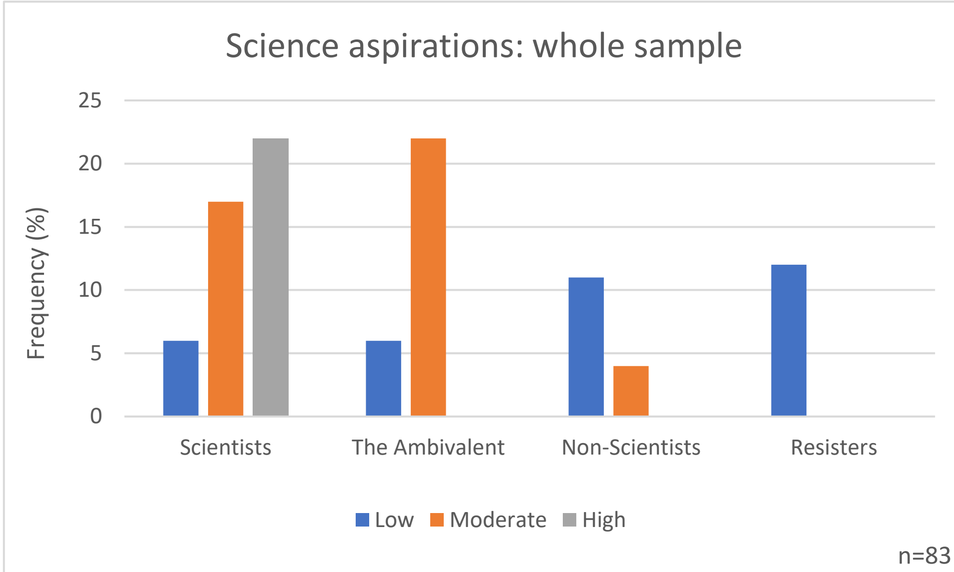

Figure 7.12: Science aspirations within the whole sample

To examine this precursor in closer detail, science aspiration was then considered within categories. This shows that 78% of students in *The Ambivalent* category have moderate science aspirations value (Figure 7.13).

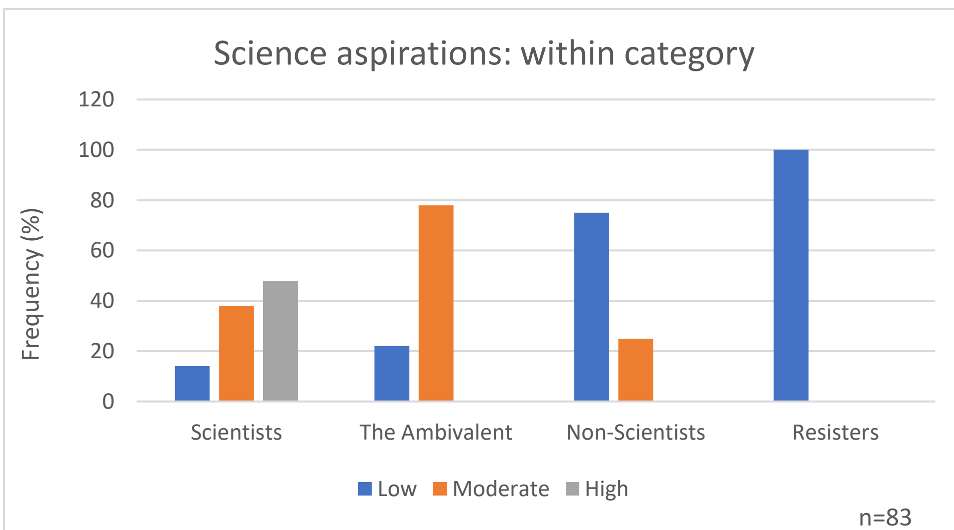

Figure 7.13: Science aspirations of students within categories

This reinforces the observation made in section in 7.2.2 that *The Ambivalent* category most closely resembles *Scientists* and may therefore be considered as potential *Scientists.*

7.3.5 Science experience

Science experience is discussed here as a precursor in this sphere of influence because perception of events depend on personal views and experienes. In Chapter 6, students presented their views of factors which affected their attitudes towards science. These varied by individual perception of the same event, thus highlighting students' personal preferences. The views of students in 10 Topaz regarding practical work is a good example. Dora and Edwna in recalling the same practical work content had opposuing views (6.3.1), suggesting that this is subjective.

Secondly, it is expectd that students with positve learning experiences of science are likely to aspire to science careers than students with negative experiences (Osborne et al., 2003). Hence, the inclusion within the individual sphere of influence. For ease of comparison, data used here are based on students' prior school science experiences.

As seen in Figure 7.14, S*cientists* are most likely to report the most positive science experiences followed by *The Ambivalent* category. *Non-Scientists* and *Resisters* in particular are least likely to report positive experiences in science. Experience in the previous educational stage can influence attitudes and aspirations in science (Gorard & See, 2009).

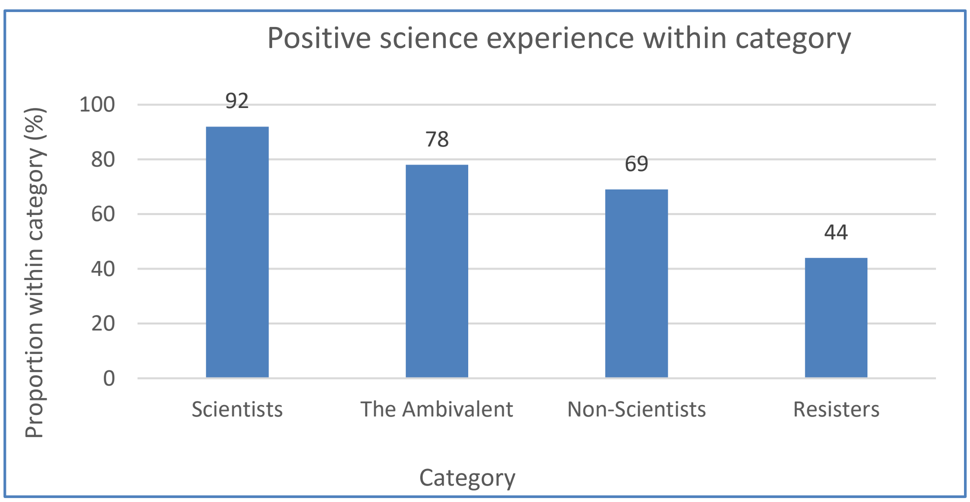

Figure 7.14: Positive science experience within categories

This section looked at five precursors, namely social class, science capital, self-efficacy, science aspirations and science experience. Two main themes emerge.

First, all five precursors exert influence over students' career expectations in science as shown in Figure 7.15. The degree of influence varies by categories. For instance, for students to be classified as *Scientists,* it appears that they must score highly in all five precursors. Having high scores in some but not all precursors is not enough to generate positive interest in a science career as seen in categories such as *Resisters*.

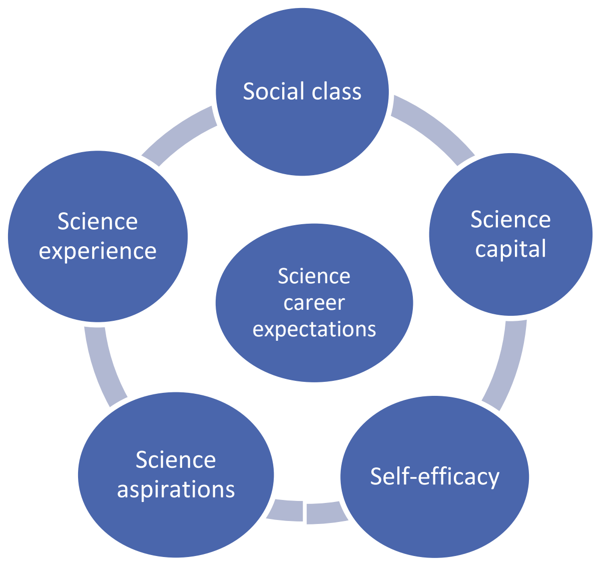

Figure 7.15: Precursors to students' science career expectations

Second, *The Ambivalent* category is the most comparable to *Scientists*, while the *Resisters category* is the most dissimilar. *Non-Scientists* and *Resisters* share the most similarities.

7.4 Profile maps of categories

In the previous section, it was established that five precursors exert influence in students' career expectations towards science. Although the degree of influence cannot be established from the data collected, they may be useful in predicting who aspires to a career in science. Based on this viewpoint, profile maps were developed for each category. Profile maps were created using a radar chart.

Radar charts provide useful visual comparisons between groups. Values used in developing the radar charts are based on the proportion of students from the sample whose responses were judged as moderate or high in three precursors; self-efficacy, science aspirations, and science capital. This was used as a reference cut-off point to create the profile maps and to make comparisons between categories easier.

This number varied depending on the precursor being considered, for instance, 53 students' science aspirations were judged as either moderate or high. Similarly, 49 students were identified as having moderate or high science capital. Therefore, to ensure that a reasonable comparison is made between categories, scores are presented by categories rather than within the whole sample. For example, based on the measures of science capital used in this study (7.2.2), five students (n=11) in the *Resisters* category were judged to have moderate or high science capital compared to 26 (n=37) in the *Scientists* category.

If a comparison were made by whole sample, this would mean a value of 10% (n=49) in the *Resisters* category and 53% (n=49) for the *Scientists* category. This is a difference of 43%. Although this is valid, it is exaggerated because of the number of *Scientists* in the sample. However, if comparisons were made by category, although the science capital score for both categories increases, the difference reduces to 25%. This is important because it gives an indication of how each category resembles the *Scientists* category.

Values used for social class remain and positive science experience remain unchanged.

As a first step, the profile of *Scientists* was developed, followed by profiles of the other categories. The profile of each category was then compared against that of the *Scientists* to identify similarities and differences.

7.4.1 Profile map of *Scientists*

The profile of *Scientists* (7.16) highlight the importance of these precursors to science career expectations. This shows that students who aspire to a science career score highly in all five areas. Self-efficacy (95%), positive science experience (92%) and science aspirations (86%) appear to be most important.

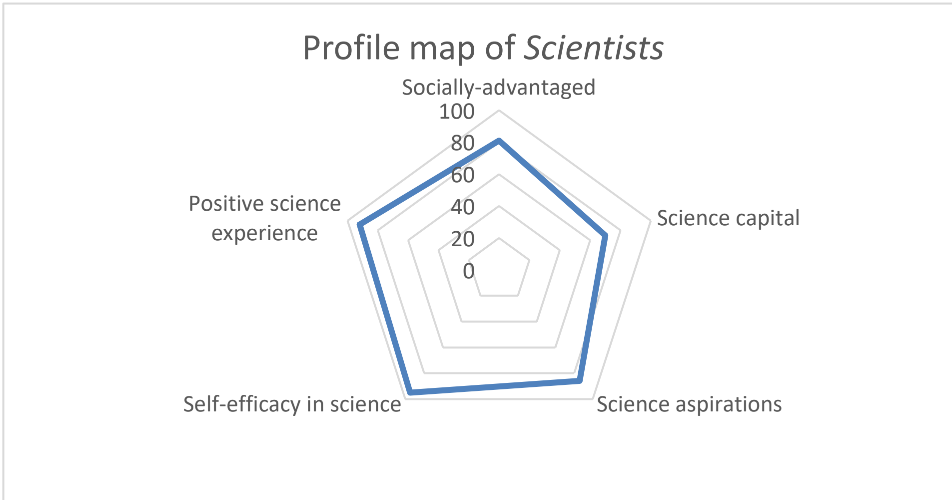

Figure 7.16: Profile map of *Scientists*

7.4.2 Comparison of the profile maps of *The Ambivalent* and *Scientists*

Figure 7.17 shows the profile map of *The Ambivalent* category. They record the highest score in self-efficacy (91%), followed by positive science experience (78%) and science aspirations (78%). They do not record high scores in their science capital (65%) and social class (61%). As social class has been linked to science capital (Archer et al., 2013), this may account for the similarity in the values of both precursors.

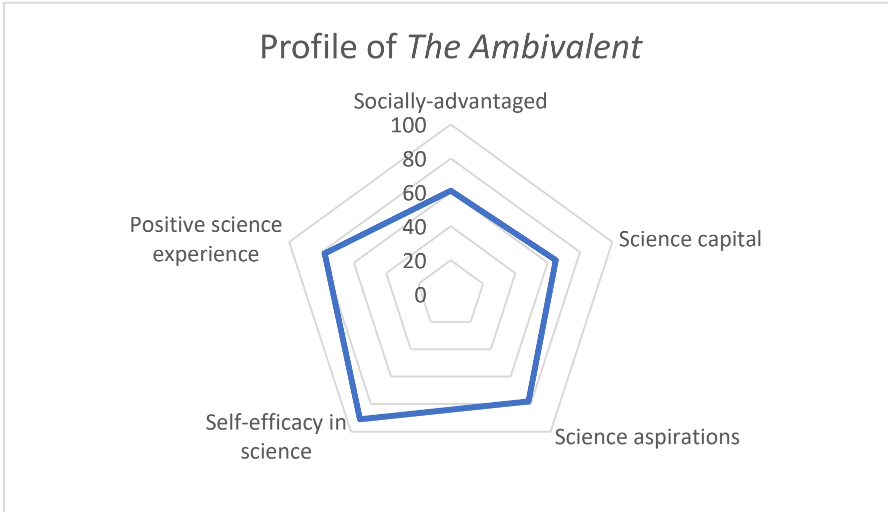

Figure 7.17: Profile map of *The Ambivalent* category

Comparing the profile map of *The Ambivalent* category against that of *Scientists* shows a striking similarity as seen in Figure 7.18. Both profiles align closely, especially in three areas, namely self-efficacy in science, science aspirations and science capital. Thus, making them a category of interest and importance. This reinforces the point made in the previous section that *The Ambivalent* category are potential *Scientists*.

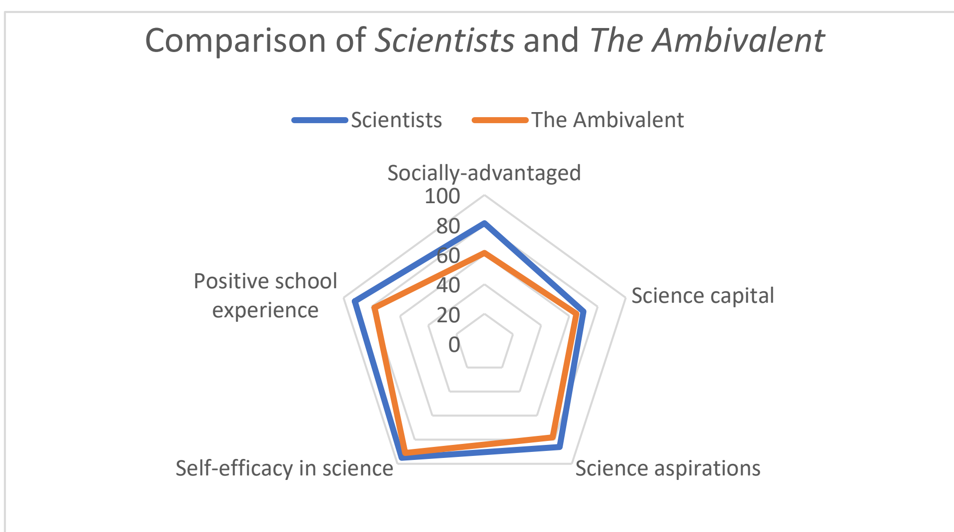

Figure 7.18: Comparison of the profile maps of *The Ambivalent* and *Scientists* category

They can change trajectory to science as seen with Ada in section 7.22. However, they can also become disaffected with science, as seen with Talia in section 7.2.5. Although Ada (Year 8) and Talia (Year 12) were in different year groups, the only difference was that Ada's self-efficacy remained high through the academic year while Talia's declined from high to moderate. This suggests that perhaps, self-efficacy may be the most powerful predictor of science career expectations with *The Ambivalent* category.

7.4.3 Comparison of the profile maps of *Non-Scientists* and *Scientists*

Non-Scientists record their highest scores in self-efficacy (83%) and positive science experience (69%) as seen in Figure 7.19. This suggests that that these are the areas they resemble the *Scientists* category. However, this shows that positive science experiences and high self-efficacy alone are insufficient to develop a career interest in science. Their science aspiration is low at 25%, which is unsurprising as their career interests lies in Arts/Humanities.

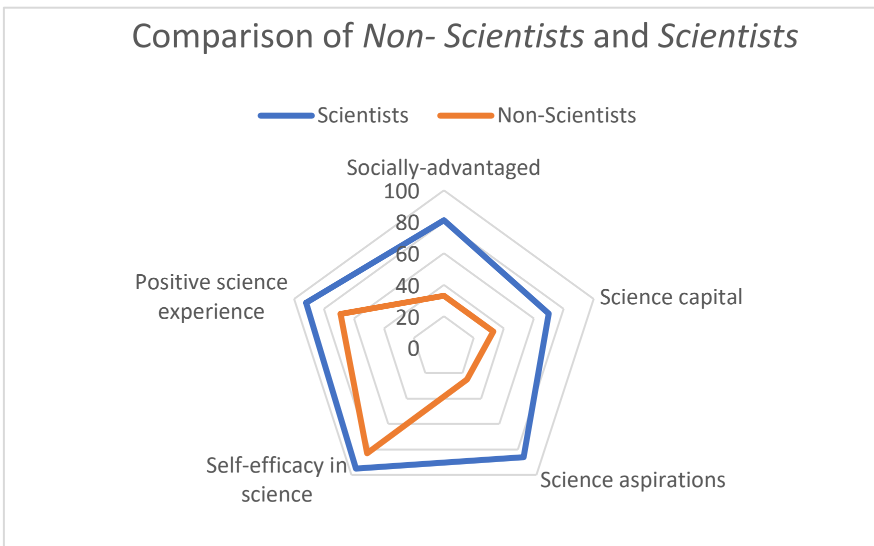

Figure 7.19: Comparison of the profile maps of *Non-Scientists* and *Scientists*

7.4.4 Comparison of the profile map of *Resisters* and *Scientists*

Students in the *Resisters* category shared the least characteristics with *Scientists*. A comparison of both profiles highlights these differences (Figure 7.20). Areas of closest resemblance to the *Scientists* are in their self-efficacy and science capital.

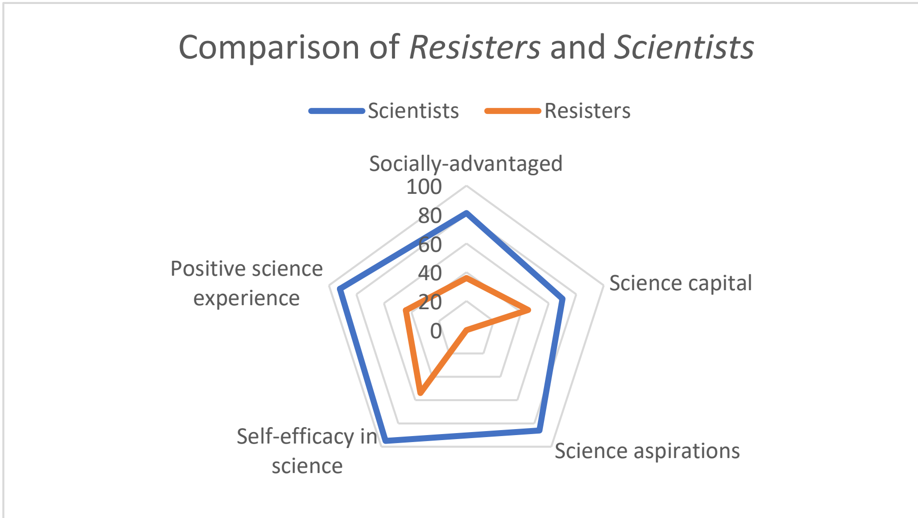

Figure 7.20: Comparison of the profile maps of *Resisters* and *Scientists*

In this section, profile maps of all four categories were developed. Comparisons were then made between the other categories against the profile of *Scientists*. They reinforce the position that *The Ambivalent* and *Scientists* are most similar, while *Resisters* were the least like *Scientists.* Following on from these, a continuum ranking sub-groups in relation to their career expectations towards science was created (Figure 7.21). This places the *Captivated Scientist* at the most positive end of the spectrum and the *Negative Resister* at the opposite end. *Captivated Scientists* are the most likely to maintain their interest in science careers because of their innate liking for science, while *Negative Resisters* are equally the most likely to maintain a lack of interest in a science career. Students classified as *Positive Ambivalent* are most likely to change trajectory to science provided their self-efficacy in science are sustained at high levels.

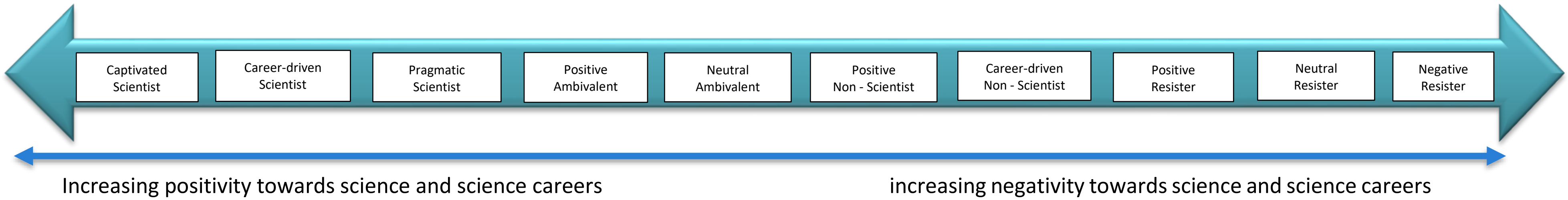

Figure 7.21: Continuum of positivity towards science and science careers

7.5 Theorising students' career expectations towards science

The previous sections identified differences between the different categories of students identified in the study. Profile maps and a continuum which highlighted these differences were developed. In this section, reasons for these differences are presented. The section is divided into two parts.

The first part uses the concepts of identity and figured worlds introduced in Chapter 3 to explain why science may be conceivable for some students but not others. For example, students classified as *Scientists* in this study who may label themselves as ''sciencey people'' (e.g. Duncan, male Year 12, section 6.4) and others who have no interest in science careers such as those classified as *Resisters* who cannot ''see'' themselves in science (e.g. Dolly, female, Year 10, section 6.3). For ease of comparison, the term ''sciencey people'' is used to refer to the *Scientists* category and ''non-sciencey people'', to the other three categories.

The second part uses the concept of self-efficacy to explain why some students who choose science post-16, continue along this path (e.g. Frances), while others become disaffected (e.g. Talia). Frances, Talia and Denzil were identified as cases of interest in section 7.2.5. They are used here for illustrative purposes. As a first step, their profile maps were developed using the same steps in the previous section.

7.5.1 Profile maps of Frances, Talia and Denzil

Profile maps were created for all three cases based on the five precursors described in the previous section. Scores are based on self-reported questionnaire responses (Appendix 10) For instance, Frances's self-efficacy in physics is 80%, based on a self-reported rating of her ability in physics as 8, on a scale of 1-10; her science aspiration is 100%, based on her rating the likelihood of pursuing a career in physics as 10/10. The same process was repeated for science capital as well.

Comparison of the profile maps of Frances and *Scientists*

Figure 7.22 shows the profile maps of Frances and *Scientists* in the sample. This shows close similarities, which is expected as Frances was classified as a *Scientist*

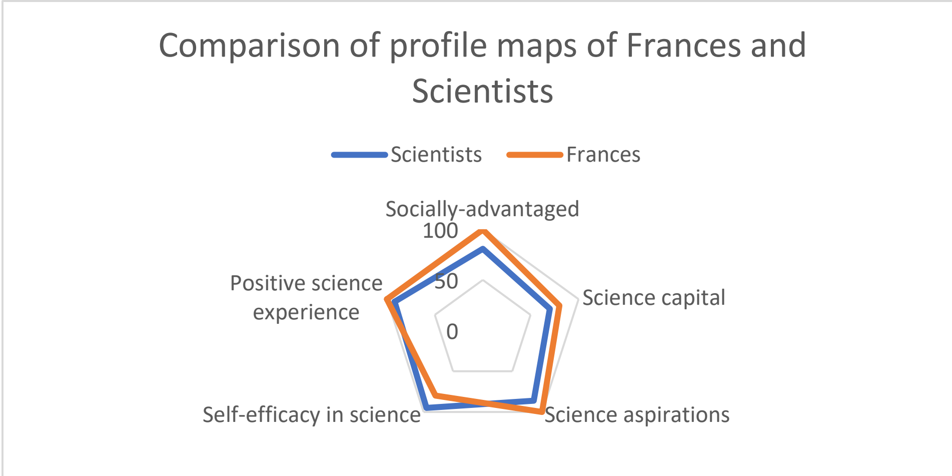

Figure 7.22: Comparison of the profile maps of Frances and *Scientists*

Comparison of the profile maps of Talia and *Scientists*

Talia's profile map was created following the same steps. A comparison of Talia's profile, a *Positive Ambivalent* and those of *Scientists* in the study (Figure 7.23) highlights the similarities between *The Ambivalent* category and *Scientists* described in section 7.4.2.

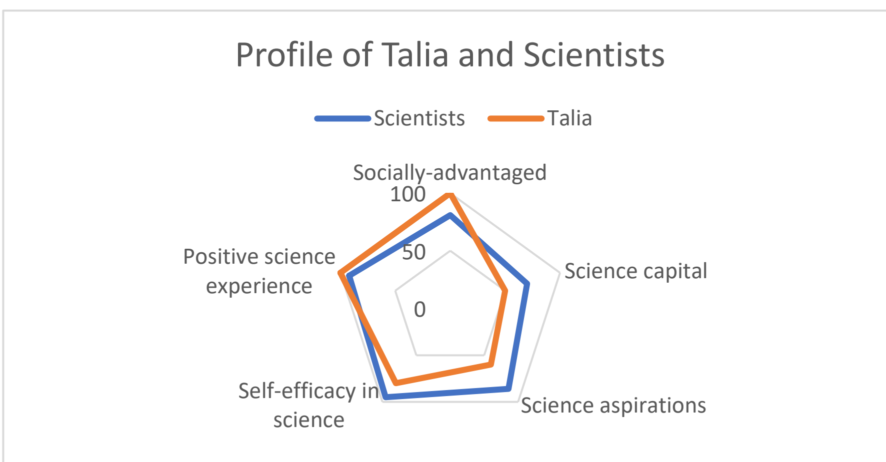

Figure 7.23: Comparison of the profile maps of Talia and *Scientists*

<u>Comparison of the profile maps of Denzil and *Scientists*</u>

Figure 7.24 shows a comparison between Denzil, a *Resister's* profile map and *Scientists* in the study. Denzil's profile map aligns closely only in his experience of Key Stage 4 science. This is expected as the *Resisters* category do not score highly in all five precursors.

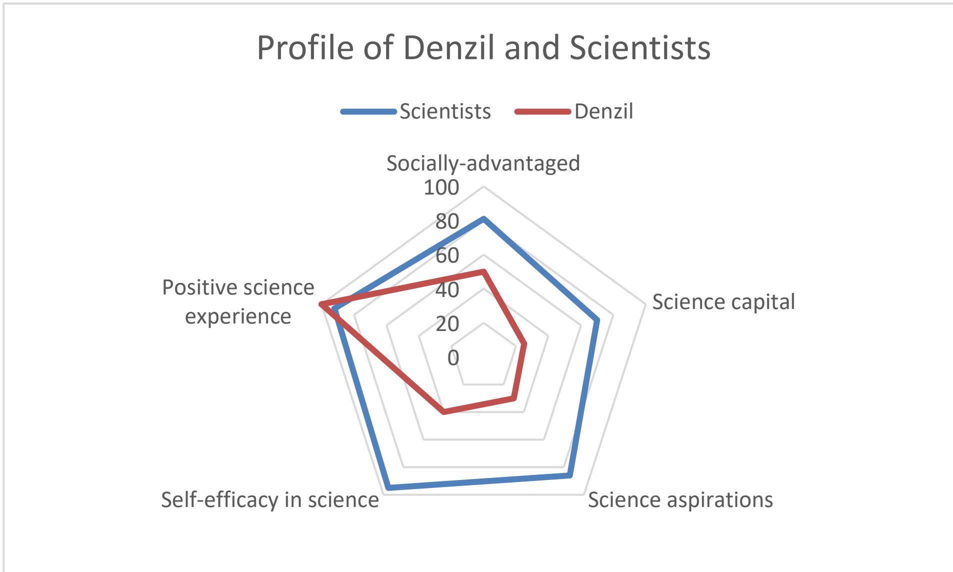

Figure 7.24: Comparison of the profile maps of Denzil and *Scientists*

Comparison of profile maps of Frances and Talia

The first step of comparison between the two girls was to compare their profile maps at the start and end of the academic year. Figure 7.25 shows the profile maps in 2014 and Figure 7.26, in 2015. At the start of the academic year in 2014, the profiles of Frances and Talia are similar, although Frances scores highly in all five precursors, especially in science aspiration. Frances's aspiration for physics can be described as unequivocal, while Talia's was ''moderate''. Talia's moderate aspiration for physics could be attributed to a simultaneous interest in Mathematics and Business studies.

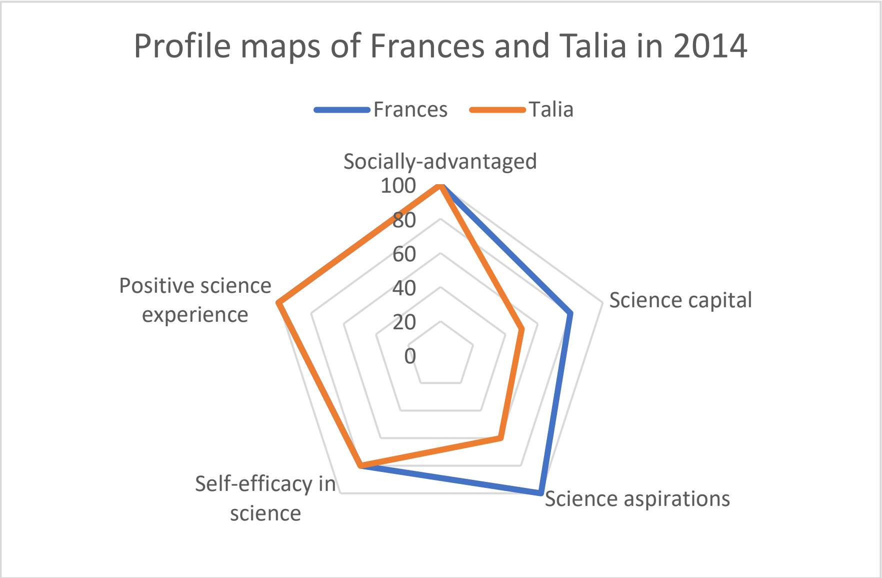

Figure 7.25: Profile maps of Frances and Talia in 2014

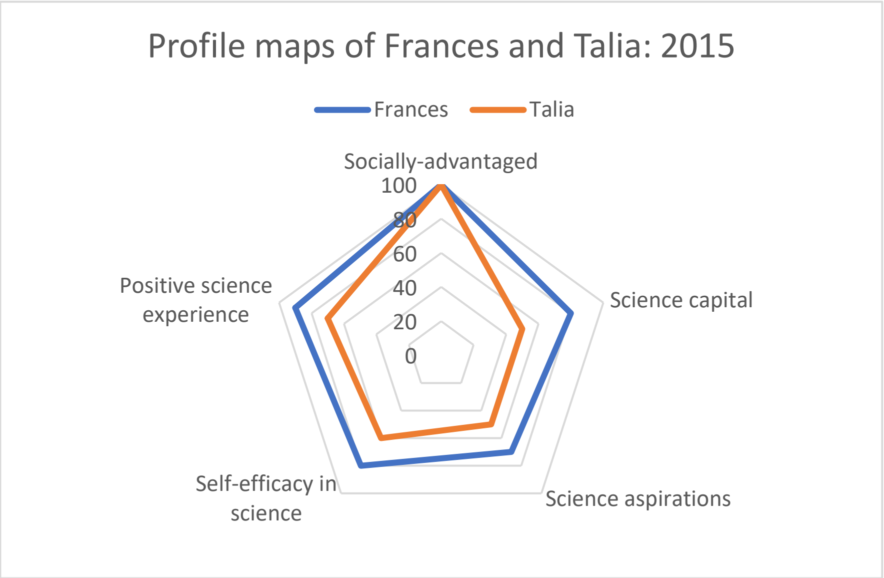

Figure 7.26: Profile maps of Frances and Talia in 2015

In 2015, there were changes in both profile maps. The most notable change in Frances's profile map was in her science (physics) aspiration. This was no longer at its peak, though it could still be considered high. Her self-efficacy scores and positive science experience had declined. Similar changes had occurred for Talia in the same precursors. Whereas in 2014, both profile maps were closely aligned in self-efficacy, social class and science experience, in 2015, there was a noticeable shift in Talia's profile map from Frances's in two areas; self-efficacy and science experience. Social class remained unchanged.

Possible reasons for these differences are discussed using the concepts of identity with figured worlds and identity with self-efficacy. The concepts of Identity and figured worlds provide plausible arguments for students' science career expectations while identity and self-efficacy explains why some students who choose science may change trajectory by the end of an academic year.

7.5.2 Identity and figured worlds

Students' stereotypical images of scientists and the work scientists do were addressed in the literature (2.5.3). These images are either reinforced or dismissed as students attempt to make sense of who they are in science and where they fit in. As students learn they construct and deconstruct their identities as ''sciencey'' or ''non-sciencey'' people. This process can be simple or complex depending on the precursors identified in the previous sections.

Gonsalves et al (2013) and Tan et al (2013) found that students author their own identities depending on the figured world (school, science club or home) they occupy at any given time. Identity, they claim, is not fixed or single but fluid and multiple. Similarly, students' figured worlds are not static. For example, the figured world of a science classroom may change depending on the activities and structure of lessons (Tan et al., 2013).

Within the figured world of students' homes, changes occur as well. This may happen for a number of reasons, for instance, social class or science capital. Students identified as *Scientists* (e.g. Frances, 7.2.5) come from mostly socially-advantaged backgrounds.

They also have one or both parents in science-related professions, which enhances their science capital. Similarly, students like Talia, who were classified in *The Ambivalent* category may share similar attributes (7.2.5).

These experiences have an impact on who they think they are and what they are capable of. For instance, female *Scientists* in the study like Frances, whose parents are both physicists inhabit a world where science is conceivable. Figuring science may occur through participation in science-related activities and family discussions. Their science worldview from both social and science capital perspectives is positive. For Frances, in particular, the stereotypical image of scientists as male is undermined by having a mother who is a physicist. It is unsurprising that she rated the likelihood of her aspiration in physics as 10/10. This is because the ‘’cultural border crossing’’ (Aikenhead, 1996) between the ‘’science world at home’’ and ‘’science world at school’’ (and by extension the figured ‘’world of science careers’’) for *Scientists*, like Frances, is possible. Therefore, being a ‘’sciencey person’’ is reasonable. This is also true for Talia.

However, for students in the *Resisters* category like Denzil (7.2.5) whose social and science capital may be ‘’low’’, this border crossing between the ‘’science world at home’’ and any figured ‘’world of science’’ may be problematic. Thus, science aspirations for these students may be ‘’unthinkable’’ (DeWitt et al., 2013).

Secondly, science classrooms through the range of activities, which occur in them, produce different figured worlds (Tan et al., 2013; Holland et al., 1998). Figured worlds involve social interaction between members (e.g. teacher–student and student-student), responsibilities of members and codes of conduct, which govern behaviour within these worlds (Holland et al., 1998). This creates multiple opportunities for students to author their identities. Teachers through their position of power, behaviour and actions can affect students’ identity work (Tan & Calabrese Barton, 2007). Subsequently, as students author their identities in science, some may struggle to see themselves as ‘’sciencey people’’ due to the influences of teachers within ‘’figured worlds of science classrooms’’. Teachers occupy a place of authority because of their position in the classroom.

They can affect students' identity work through their position of power, behaviour and actions (Tan & Calabrese Barton, 2007). For example, Mr. Martins through his position of power in the classroom automatically conferred ''positional identities'' of discomfort in answering questions to girls in his physics classroom (6.4.1). Positional identity is the position a person holds relative to others (Holland et al, 1998). Considered in isolation, this may be innocuous, however, as students depend on teachers for positive reinforcement of their capabilities (Bandura, 1997), a reluctance on his part to call on girls in his physics class to answer questions may be counterproductive. For students like Talia who had already started to question her identity in science as a ''good'' student, this may further undermine her science identity.

Another aspect of identity work considered here is the notion of ''narrated'' and ''embodied'' identities. *Narrated identities* are what students think they are and want to be and *embodied identities* are what they do (Tan et al., 2013). A conflict between this pair of identities may result in students' disaffection in science. Talia's identity work is similar to conflicts encountered when students' ''narrated identities'' and ''embedded identities'' become incompatible (Tan et al., 2013). Talia's *narrated identity*, that is, who she thinks she is and wants to be can be seen by her considering herself as ''good'' in science at the start of the academic year (7.2.5). However, being placed in a situation by Mr. Martins where she is not called during questioning sessions, undermines her e*mbodied identity*, that is, who she is, based on what she does or in this case, not allowed to do. This contradicts her *narrated identity* of being a ''good'' physics student.

Although the questioning session observed may be an isolated occurrence, traditionally girls are called on less often to answer questions (Tan & Calabrese Barton, 2007). Frequent incidences like this may negatively impact Talia's science experience. Therefore, the likelihood of persisting in science may diminish for Talia as a result of these conflicts in her identity work.

7.5.3 Identity and self-efficacy

The data suggest that students such as Talia in *The Ambivalent* category, self-efficacy may be a useful precursor for their sustained engagement in and retention of positive science aspirations. Therefore, if this is threatened, they are likely to become disaffected in science. Self-efficacy is believed to originate from a combination of enactive mastery experience, vicarious experiences, verbal persuasion and physiological and affective states Bandura (1997).

Bandura claimed that enactive mastery experiences was the most persuasive source of self–efficacy. For example, high standards of prior attainment in class assessments evidence a student's academic success. This develops their self–efficacy as students perceive themselves as capable students. Applying this to Talia and Frances suggests their high levels of prior academic achievement predicts their self-efficacy for science would have been high. Their GCSE grades equate to enactive mastery.

A second source of self–efficacy is vicarious experiences. Self–efficacy can be developed by comparing one's self with for example, peers in a classroom setting. Talia and Frances's success in class assessments in Key Stage 4 meant that they were always in the top sets in science. They were therefore in a place of comparable status with their peers. Their GCSE grades have further reinforced their self–efficacy and therefore validated their identity as 'good' science students.

Thirdly, self-efficacy is reinforced by verbal persuasion or feedback from a significant person. In schools, this is most frequently teachers. Mr. Martins, Frances's and Talia's physics teacher contributed to this.

Fourthly, self-efficacy is impacted by physiological factors, such as a sense of pride in accomplishments. Though there is no direct evidence of this, both girls are likely to have been proud of their academic accomplishments (Table 6.1).

Therefore, at the start of the academic year, the girls' experiences were almost identical. However, as the school year progressed, their experiences diverge. Talia participated in the Leadership and Management strand of the Internship programme while Frances participated in STEM Leadership. Talia explained her choice:

> It gave me more flexibility. I wanted to keep my options open. It kind of confirmed what was happening in my lessons. It's helped me decide I want to do Maths. [Talia, 2015].

This is in contrast to her statement at the start of the year when she had stated she liked physics a lot.

> I achieve A [grades] in all mocks and assessments, however, I still find it difficult and I can see areas for improvement. I like physics a lot and find it very interesting, but I find myself more attracted to maths/business [Talia, 2104].

Apart from the internship influencing her decision to pursue Mathematics instead of science, Talia had identified Mathematics as her favourite subject because of her teacher's passion.

> I like Maths and she has a passion about it and it kind of came off in her lessons. It gives a good atmosphere to the lessons. She is excited about maths and it got us excited as well about maths [Talia: female].

However, Talia's decision to not continue with physics may be linked to a decline in her performance in class tests.

> I like physics but I'm not interested or good enough to pursue it post sixth form [Talia, 2015].

High attainment contributed to Talia's self-efficacy, so any lack of attainment at the high levels to which she was accustomed to may now undermine this.

Secondly, comparisons with peers earlier acted as positive reinforcement, but may now have the opposite effect. As Talia compares herself with peers, she is no longer ''good enough'' to continue with physics.

Thirdly, as feedback from teachers may no longer be positive, this may further undermine her self-efficacy in physics. Physics, which was once the subject she was interested in has now, become associated with negativity.

Sources contributing to Talia's high self-efficacy in science prior to AS physics started to have less impact on her. By the end of the year, Talia had become convinced she could not maintain the identity of a ''good'' student in her AS physics class. Her self-efficacy value at the start of the academic year had declined from 8/10 to 6/10. Talia's experiences is consistent with research reporting that girls' loss of confidence in their physics ability, especially as concepts become more complex, leads to their not pursuing the subject (Krogh & Thomsen, 2005; Sharp, 2004).

In contrast, Frances's experiences were consistent through the academic year as evidenced by these statements at the start and end of the academic year.

> I find physics challenging, however I really enjoy it I have always enjoyed physics and I would like a career in it [Frances, 2014].
>
> I enjoy it, some concepts are challenging [Frances, 2015].

Despite finding physics challenging, Frances's self-efficacy values remained high at the start and end of the academic year at 8/10. Sources contributing to her self-efficacy remained the same. Hence, her decision to continue with physics, post-16, unlike Talia.

How students see themselves in science affects their science career expectations. This section used the concepts of identity, figured worlds and self-efficacy to explain why some students maintain a science trajectory while others do not. Students operate in different figured worlds including their homes and schools. Students familiar with the figured world of science at home, either though having parents in science-related professions or from participation in science-related activities may find it easy to relate to the figured world of school science.

Hence, science may be more thinkable for them. Students in the *Scientists* category are good examples, they are likely to see themselves as ''sciencey people. In contrast, students, for whom the figured world of science at home is unfamiliar may find it difficult to relate to the figured world of school science. This is common with students in the *Resisters* category. Other students' struggle with their science identity if their self-efficacy is undermined.

7.6 Summary

The aim of this chapter was to provide answers to RQ2 – who aspires to a career in science? and RQ3 – what precursors influence students' career expectations towards science? Data were obtained from student's questionnaire responses, lesson observations and group discussions.

Findings indicate that there are four categories of students based on their reported career aspirations. These were *Scientists, The Ambivalent*, *Non–Scientists* and *Resisters.* Each category comprises sub-groups with degrees of variation.

Five precursors were useful in determining students' the career expectations of these categories of students towards science. These were social class, science capital, science experience, self-efficacy and aspirations. Profile maps of each category were developed using a radar chart. The profile of *The Ambivalent* category resembled the *Scientists' category* the most, making this category potential *Scientists.*

The importance of each precursor varied within each category. For example, the majority of students identified as *Scientists* were from socially-advantaged backgrounds while the majority of students from the *Resisters* category were from socially–disadvantaged backgrounds.

The notion of identity, figured worlds and self-efficacy provided plausible arguments for the characteristic features of categories. Students who had developed some measure of science capital either because of their social class or interest in science were more likely to identify with the figured world of science than those who lacked social and science capital.

Familiarity with the figured world of science through interactions with science out of school, made it easier for some students to consider themselves as ‘’sciencey people’’ compared to ‘’non-sciencey’’ students for whom this may be unfamiliar. Teachers are important in the figured world of a science classroom as their position of authority may enhance or impede student’s identity work.

Students’ who choose science may become disaffected and decide science is not for them, if their science identity becomes undermined. This is true for students whose self-efficacy starts to decline. Students’ whose self-efficacy remain high are likely to maintain their science identity and science career expectations.

Chapter 8: Discussion

8.0 Introduction

In Chapter 1, concerns regarding gender disparity in science and potential shortages of science graduates or people with science skills were outlined. This coupled with the researcher's interest in students' attitudes formed the foundation of this study with an overarching aim of investigating factors which affect students' attitudes and career expectations towards science. Three research questions (RQ) were developed in this study:

RQ1: *What factors do staff and students in a specialist science school believe affect students' attitudes towards science?*

RQ2: *Who aspires to a career in science?*

RQ3: *What precursors influence students' career expectations towards science?*

A review of the literature indicated that factors affecting students' attitudes and career expectations towards science can be subsumed under two main spheres of influence; the school and individual. RQ1 deals with the school sphere of influence and RQs 2 and 3, the individual sphere of influence. The adoption of the research philosophy of interpretivism which permits the recognition of subjective reality led to the use of a qualitative approach. Data were collected through multiple sources namely documents, lesson observations, group discussions, semi–structured interviews and questionnaires. Findings were presented in Chapters 5, 6 and 7. This chapter presents a synopsis and implication of these findings. In addition, limitations of the study and recommendations for future research are presented.

Section 8.1 examines issues raised in the school sphere of influence while section 8.2 looks at the individual sphere. In section 8.3, the implication of these findings are discussed. Section 8.4 presents limitations of the current study while 8.5 discusses recommendations for future research. The chapter ends with 8.5, a summary.

8.1 School sphere of influence

Areas of the school sphere of influence which affected students in all three Key Stages included the curriculum, organisation of teaching and use of departmental resources and extra-curriculum provision. Of these, teaching was considered the most impactful.

8.1.1 Research question 1: What factors do staff and students in a specialist school believe affect students' attitudes towards science

The science curriculum

Staff and students identify the curriculum as a factor impacting students' attitudes towards science. Students consider some aspects of the curriculum irrelevant to everyday life or future careers. Thus, the likelihood of engaging with science is diminished as relevance is obscure. In contrast, staff believe that the volume of content in the science curriculum and time allocated for teaching are unequal. Therefore, focus in science classrooms become more about teaching curriculum content in time for national examinations rather than teaching science for its sake. This, some teachers believe, also leads to students' misconception that science is a difficult subject. Another aspect of the curriculum in which there was a consensus was in the restrictive nature of the science curriculum. This limits the opportunity of discovery for students thus, leading students to believe that science is dull and monotonous compared to Arts/Humanities subjects.

Another aspect of the curriculum which affects attitudes is the use of practical work. Overall, practical work generates positive interest, but this may start to decline as students get older. However, negative interest in practical work may not be unconnected to older students' anxiety that practical work use up time which could be used in teaching theoretical content as examination deadlines approach.

Teachers and teaching

Osborne et al (2003) noted that ''teacher variables are the most significant factor determining attitudes'' (p. 1070). Staff and students in Farne School recognise the importance of the role of the teacher in shaping students' attitudes towards science.

Both admit that students are more likely to develop a positive interest in science if the student-teacher relationship is positive. Students who have a negative relationship with their teacher or the way they teach are more likely to lose interest in science than those who have a positive relationship. Findings from this study also suggest that negative experiences with science teachers in the early years of secondary school can have a lasting negative impact throughout secondary school.

There is an overlap of attitude in science with a teacher's pedagogy and personality. Students respond positively in lessons where the teacher's pedagogical content knowledge (PCK) is extensive as lessons are less repetitive and more stimulating. They participate in lessons where the teacher takes a personal interest in their learning. Where this is coupled with either a teacher's sense of humour, fairness or enthusiasm for their subject, students are more likely to develop an interest in the subject. These corroborate previous studies which found that teachers can affect students' attitudes and interest (Krapp & Prenze, 2011; Logan & Skamp, 2013).

Negative student-relationships developed when children are as young as eleven have lasting effect on their attitudes even when they are older as seen with Edwina (6.3.1). Similarly, teachers with limited PCK science are less likely to inspire positive attitudes or aspirations in students towards science. Therefore, student-teacher relationships and teachers' PCK can affect students' attitudes towards science and post-16 science participation.

<u>School leadership and potential bias</u>

Students believe that the school leadership and sometimes, teachers have a hierarchical system of treating students. For instance, students believe that the school only starts to care about them when they reach Key Stage 4 because it is the start of GCSE examinations. Key Stage 3 was wasted. In addition, they believed the school prefers students whom they have ranked as ''high attainers'' by providing them with extra-curricular opportunities (6.5.4) at the expense of other students. This produces resentment.

Teachers also refer to hierarchical treatment but do so in relation to subject ranking by the school's leadership. They believe that although science is a core subject, English and Mathematics are preferred over science by the leadership team, causing students to think that science is not as important. This generates a more negative attitude towards science compared to English and Mathematics.

8.2 Individual sphere of influence

8.2.1 Research question 2: Who aspires to a career in science?

One of the significant findings of this study was the discovery of four categories of students; *Scientists*, *The Ambivalent*, *Non-Scientists* and *Resisters* and the variations within them. These categories were based on students' science aspirations. Within variations, *Captivated Scientists* are most likely to pursue a career in science because of their personal interest in science, while *Negative Resisters* are least likely to pursue science post-16 because of their dislike for the subject.

Placed on a continuum, *Captivated Scientists* are at the most positive end while *Negative Resisters* are at the most negative end of who aspires to a career in science. *Captivated Scientists* comprise a small proportion of students, for whom, a combination of precursors such as self-efficacy, positive science experiences and aspirations in science ensured that none of these students deviated from a science trajectory.

Similarly, *Negative Resisters* comprise a small proportion of students for whom the same combination of factors play a converse role in their chosen trajectory away from science. Low self-efficacy and negative experience in science drives their antipathy towards science.

Non-Scientists share similar characteristics with *Resisters* but do not express any negativity towards science.

The fourth main category of students are *The Ambivalent*. These were identified as students who were uncertain about their future in science. These students share similar characteristics as *Scientists.* Consequently, they were identified as potential *Scientists.*

8.2.2 Research question 3: What precursors influence students' career expectations towards science?

Analysis of the data show that five precursors: social class, science capital, science experience, self-efficacy and science aspirations are useful predictors of students' science career expectations. Students classified as *Scientists* score highly in all five. For instance, they are predominantly students from socially-advantaged backgrounds with at least one parent/guardian in full time employment in a science-related profession. Although there is no direct evidence from the data, it appears that their active participation in science-related activities out of school may be linked to their social class and parent/guardian science-related profession. Consequently, the majority of *Scientists* have moderate to high science capital. This is not the case with the other categories, especially the *Resisters* who the most dissimilar to *Scientists*.

Profile maps of each category were developed. These provided a simple but useful visual means of comparison between the three categories and *Scientists.* To gain a deeper understanding of the effect of these precursors, the concepts of self–efficacy, identity and figured worlds provided a framework for understanding how positive career expectations towards science develops. This provided useful insights into why some students persisted in a science trajectory while others deviated from this. Students identified as *Scientists* are more likely to fit into this tripartite framework while *Resisters* are most likely to be found outside this framework.

Students categorised as *Scientists* see themselves as ''sciencey people''. This identity is reinforced if science in their figured world of home is not a familiar concept. Science can become ''normal'' at home through activities like visits to science activity centres or discussions about science. This develops their science capital (Archer et al, 2013). Science capital can enhance science aspirations. This is reinforced if their self-efficacy in science is ''high'' as capability in science fits into the narrative of ''sciencey people'' being able to ''do'' science. These students are likely to claim that science ''clicks'' for them.

However, students who may initially see themselves as ‘’sciencey people’’ may start to question their science identity if their self-efficacy in science begins to decline (see Talia (7.2.5) Teachers are an important influence in the figured worlds of science classrooms due to their position of authority. Hence, they can be a source of positive or negative reinforcement of students’ science identity.

8.3 Implications of findings

Curriculum reform

Teachers and students reference the curriculum as a factor affecting attitudes. This suggests that curriculum reform may be necessary. Calls for curriculum reform are not new (Osborne & Collins, 2000) but there may be a need for reform involving different relevant communities. These include schools and higher institutions which teach science and industry and Government who have concerns about science participation rates. For example, research evidence suggests that girls prefer biology-related topics (Kind et al., 2007). Increasing gender-friendly topic areas such as medical physics in the curriculum could generate girls’ positive interest in physics as the current curriculum provides context in areas more suited to boys (Murphy & Whitelegg, 2006a).

Another issue indirectly linked to the curriculum is career advice and information. Students in the study in both Key Stages 3 and 4 were unaware of the breadth of careers related to science. For instance, at the start of the academic year, Bonnie (female year 8) was classified as a *Resister* based on her reported science aspirations. However, Bonnie, wanted to become a midwife but did not realise that she needed science for midwifery. Similarly, Edwina in Year 10 who wanted to become a mental health nurse, only started to develop a positive attitude towards physics and Mr. Martins, her physics teacher after she realised that her physics grades counted towards her overall GCSE Double Award grades.

Both cases demonstrate the need for adequate career advice and information both in terms of its timing and quality of information provided. Career advice is usually provided from Year onwards when research evidence alleges attitudes have become fixed (Osborne et al., 2003; Bennett & Hogarth, 2009). They also tend to be add-on events managed by a career advisor but as Munro and Elsom (2000) found, the majority of career advisers do not have science-related backgrounds. Hence, they are themselves unaware of the breadth of science-related opportunities available to students. Therefore, the advice they provide may be limited.

Section 8.2.2 highlighted the importance of social class and science capital in enhancing science aspirations. Students with low social and science capital are more likely to be unaware of science-related careers than those with moderate to high science capital and social class. Therefore, career advice from schools may be useful in plugging this gap. However, this is currently the responsibility of career advisers. Students may benefit more if career advice were embedded in science lessons as proposed by Mujatba & Reiss (2017). This could bridge the gap between science in the world of work and science at school, thus making science careers more attainable for some students.

Teachers and teaching

Findings from this study did not identify subject content knowledge as a factor which influenced students' attitudes in science. Investment in Continuing Professional Developments (CPD) can improve teachers' PCK. However, development of both PCK and SCK can positively influence students' science learning experiences. Secondly, findings from this study suggest that as students get older, they become less enthused about science. This supports a number of studies which report similar findings (Osborne et al., 2003; Bennett & Hogarth, 2009).

For example, practical work which were once considered enjoyable may lose their appeal as students start to prepare for their GCSE examinations. Teachers may therefore need to find a workable balance between retaining the 'fun' elements of their lessons while teaching curriculum content needed for National examinations such as GCSEs. Investment in CPD may help science teachers find this balance.

School leadership

Effective use of Key Stage 3 is important as schools which have been successful in student outcomes are those which take a longer-term view, appreciating that the early stages of secondary education have an impact on the later stages (Ofsted, 2015). As Chance (6.3.2) pointed out Key Stage 3 needs to be used effectively to avoid overloading students with GCSE content as national examinations become imminent. Secondly, as schools in which the senior leadership are interested in science tend to be more successful in recruiting students into science post-16 (Bennett et al, 2013), support for science must be a whole school initiative. One way science can be supported by senior leadership is to recognise its status as a core subject and accord it the same level of support and resources given to English and Mathematics.

Early categorisation of students

Sixty-three percent of people (n=1,141) in STEM-related careers started to think about their careers either before entry into secondary school or between the ages of twelve to fourteen (The Royal Society, 2006). Therefore, categorisation of students as young as twelve, as was done in this study may be useful in identifying students who are interested in science careers like *Scientists* in the study and potential *Scientists* like *The Ambivalent* category. Early identification could be useful for the following reasons.

Emphasis tends to be placed on students who are ''high'' attainers in science as the most likely source of recruitment of future scientists. These students tend to be ''high'' attainers in other STEM subjects as well as the Arts/Humanities. A good example is Talia who based on her AS physic choice, appears to be a ''high attaining potential scientist'' (Table 6.1, section 6.4). However, she is also a ''high'' attainer in Mathematics and Business studies, which is a source of conflict.

If Talia were categorised early, she may have been correctly identified as a ''*Positive Ambivalent* high attainer'' and not a ''high-attaining potential *scientist*''. Hence, Talia's conflicts and difficulties with physics may have been identified early and necessary support provided. As discussed in Chapter 7, despite opting to study physics post-16, Talia decided to pursue Mathematics rather than persevere in science. While, there is no guarantee that extra support provided would have produced a different outcome in Talia's case, the likelihood of a positive outcome for other students who may be in *The Ambivalent* category makes this valuable.

The Ambivalent are also likely to pursue science if barriers to their success in science are removed. For some students the barriers could be a lack of information of the benefits of a science-related qualification, while for others like Beverley (7.2.2), it is a lack of encouragement from the teacher.

Similarly, another source of recruitment into science post-16 is the *Positive Resister* category who share similar characteristics with *Scientists* and *The Ambivalent* category. These students may be persuaded to pursue science if barriers such as lack of teacher support are removed. Therefore, categorisation as early as Year 8 may be useful in identifying *Scientists* and potential *Scientists*. This may help science departments to increase their post-16 science recruitment. This is especially important as out of the five precursors identified, only science experience falls exclusively in the purview of science departments. However, by improving students' science experiences, science departments may influence students' self-efficacy and science aspirations. Social class and science capital are outside their sphere of influence.

8.4 Limitations of study

A main limitation was the sample size of the sub–groups within each Key Stage. This means that findings cannot be generalised to a wider school population. For example, the use of questionnaire data could have been extended to the entire cohort of Years 10 and 12, rather than limiting it to Year 8. However, as the locus and internal organisation of most comprehensive schools tend to be similar coupled with the rich data obtained from respondents, findings can generalised beyond the setting of Farne School using the principle of relatability (Bassey, 2000).

The purposeful selection of students the school considers ''middle'' and ''high'' attainers means that findings reflect the views of these sub–group of students and may not be representative of the wider school population. In addition, the study would have benefited from more sustained lesson observations of these sub–groups with fewer breaks between observations. This would have been useful in capturing positive and negative changes in students' attitudes from the start of the academic year to the end. However, with group discussions and students' diaries, useful data were still obtained.

Thirdly, another area of limitation was a lack of comparison of schools. For example, half of the *Resisters* in the study attended Don School so, further investigation of this school and others within the Cluster (5.3.2) may have been useful in determining how science provision in these schools affected students' science experiences. This would have generated data on primary science thus, providing a more comprehensive study on students' attitudes spanning four Key Stages.

In addition, lack of comparison between Farne School and a similar school without a science emphasis is another area of limitation. This would have determined whether the level of extra-curricular science provision at Farne School is common in schools of similar ethos. This would have also provided insights into the utility of a STEM Enrichment Manager in science provision in schools.

Fourthly, as a former teacher there was always the possibility of reverting to ‘’teacher mode’’ during the study. The potential for researcher bias was most likely to occur during lesson observations and group discussions with students. To mitigate researcher bias, lesson observations were undertaken with groups not involved in the study to develop observation skills while a pilot study undertaken helped to refine interviewing skills. In addition, triangulation of data from multiple reduced researcher bias.

8.4 Recommendations for future research

This study raises possible areas for future research. The first suggestion for further work is to explore some of the findings in this study. The possibility that students can be grouped into four categories regarding their aspirations for science could be investigated between schools with different ethos. For example, it would be useful to compare the category of students between schools with a science emphasis and those with no specific emphasis. Such research could seek to avoid the limitations of this study and explore other methods of investigation.

Secondly, it may be useful to develop an instrument to identify categories of students. Categorisation of students through thematic analysis was time–consuming and not definitive. Development of such a diagnostic instrument may speed up the process of identifying different types of students at the start of each Key Stage. This may help science departments to develop intervention strategies which target specific student perceptions and attributes in order to enhance post-16 science recruitment.

In addition, further work is needed to gain deeper understanding of how the precursors identified in this study influence students’ science career expectations and how they interact with each other.

Finally, better understanding of students identified in this study especially those who appear to fall at extremes or appear to be representative of general patterns may be beneficial to policymakers in education and industry.

8.5 Summary

This study contributes to the growing body of knowledge which portend that factors affecting students' attitude and aspiration towards science are multifactorial and complex. Two spheres of influence were considered as key determinants in this process with both being inextricably linked and ultimately impacted by Government policy. Through multiple sources of data, factors affecting students' attitudes and career expectations were identified.

Students were categorised as *Scientists, The Ambivalent*, *Non-Scientists* and *Resisters*. The career expectations of each category were considered using five precursors, namely, social class, science capital, self-efficacy in science, science aspirations and science experience. Students identified as *Scientists* had the most positive responses across all five. They were likely to identify themselves as 'sciencey people' and come from socially–advantaged backgrounds. However, in the other categories, positive responses varied by precursor. For example, students in the *Resisters* category recorded the second highest self–efficacy in science but this was evidently insufficient to overcome their aversion to a career in science (e.g. Bonnie, 7.2.4). The profile map of students in *The Ambivalent* category most closely resembles those of *Scientists* thus making them a potential *Scientists.* Differences between categories were explained using the concepts of identity, figured worlds and self-efficacy. This indicated that students' identity work is a complex process influenced by students' experiences within figured worlds of school and home. Students for whom there is no conflict in their identity work are likely to persist in science especially when there is support from teachers, peers or family. The converse is true for students who do not persist in science. However, as this study has shown, some students have an intrinsic preference for science while others do not.

Early identification of students' aspirations students may therefore be useful in identifying students such as those in *The Ambivalent category* whose career aspirations are not fixed. These students are most likely to be persuaded to study science if other factors such as their self-efficacy are sustained at moderate to high levels.

Appendices

Appendix 1:Ethics application

Durham University

School of Education

Research Ethics and Data Protection Monitoring Form

Research involving humans by all academic and related Staff and Students in the Department is subject to the standards set out in the Department Code of Practice on Research Ethics. The Sub-Committee will assess the research against the British Educational Research Association's *Revised Ethical Guidelines for Educational Research* (2004).

It is a requirement that prior to the commencement of all research that this form be completed and submitted to the Department's Research Ethics and Data Protection Sub-Committee. The Committee will be responsible for issuing certification that the research meets acceptable ethical standards and will, if necessary, require changes to the research methodology or reporting strategy.

A copy of the research proposal which details methods and reporting strategies must be attached and should be no longer than two typed A4 pages. In addition you should also attach any information and consent form (written in layperson's language) you plan to use. An example of a consent form is included at the end of the code of practice.

Please send the signed application form and proposal to the Secretary of the Ethics Advisory Committee (Sheena Smith, School of Education, tel. (0191) 334 8403, e-mail: Sheena.Smith@Durham.ac.uk). Returned applications must be either typed or word-processed and it would assist members if you could forward your form, once signed, to the Secretary as an e-mail attachment

Name: INEBIMO LEAK Course: PhD IN SCIENCE EDUCATION

Contact e-mail address: i.e.leak@durham.ac.uk Supervisor: DR. V. KIND

Title of research project: AN INVESTIGATION INTO THE IMPACT OF STUDENTS' GENDER AND IDENTITY ON ATTITUDES TO THE PHYSICAL SCIENCES

Questionnaire

		YES	NO	
1.	Does your research involve living human subjects?	✓		IF NOT, GO TO DECLARATION AT END
2.	Does your research involve only the analysis of large, secondary and anonymised datasets?		✓	IF YES, GO TO DECLARATION AT END
3a	Will you give your informants a written summary of your research and its uses?		✓	If NO, please provide further details and go to 3b
3b	Will you give your informants a verbal summary of your research and its uses?	✓		If NO, please provide further details
3c	Will you ask your informants to sign a consent form?	✓		If NO, please provide further details

4.	Does your research involve covert surveillance (for example, participant observation)?	✓		If YES, please provide further details.
5a	Will your information *automatically* be anonymised in your research?		✓	If NO, please provide further details and go to 5b
5b	IF NO Will you explicitly give *all* your informants the right to remain anonymous?	✓		If NO, why not?
6.	Will monitoring devices be used openly and only with the permission of informants?	✓		If NO, why not?
7.	Will your informants be provided with a summary of your research findings?	✓		If NO, why not?
8.	Will your research be available to informants and the general public without restrictions placed by sponsoring authorities?	✓		If NO, please provide further details
9.	Have you considered the implications of your research intervention on your informants?	N/A		Please provide full details
10.	Are there any other ethical issues arising from your research?		✓	If YES, please provide further details.

Further details

Lesson observations to track students' attitude to science

Continuation sheet YES/NO (delete as applicable)

Declaration

I have read the Department's Code of Practice on Research Ethics and believe that my research complies fully with its precepts. I will not deviate from the methodology or reporting strategy without further permission from the Department's Research Ethics Committee.

Signed [illegible] Date: 04-06-14

Proposal discussed and agreed by supervisor (for students) or colleague (for staff):

Name [illegible] on 12.6.14 (Date)

SUBMISSIONS WITHOUT A SYNOPSIS OF THE RESEARCH PROPOSAL WILL NOT BE CONSIDERED.
IF YOUR RESEARCH INVOLVES DATA GATHERING PLEASE PROVIDE DETAILS OF HOW THIS WILL BE HANDLED (INCLUDING CONSENT FORM). GENERIC CONSENT FORM AVAILABLE IN CODE OF PRACTICE

Appendix 2: Confirmation of ethics approval

Sent: 26 June 2014 12:43
To: LEAK I.E.
Cc: KIND V.

Dear Inebimo,

I am writing to inform you that your Ethics application for the research project

An investigation into the impact of student gender and identity on attitudes to the Physical Sciences

has been approved.

Regards

I have received the following response from the reviewer of your ethics application for the above project

"Please provide more information on the use of consent forms (beyond the opt out letter sent to parents). Will pupil and teacher participants be asked to sign a consent form? If so please supply a copy."

Please re-submit the ethics application form, and a copy of the consent form if applicable, to take into account these comments.

Thank you

From LEAK I.E.
Sent: 23 June 2014 09:32
To: Ethics application

Dear
Thank you for your email.

Please find attached the following documents in support of my application to the Ethics committee:

- consent form
- research proposal
- parent opt out letter
- Ethics form

Kind regards

Inebimo

Appendix 3: Example of staff consent form

School of Education
Leazes Road
Durham DH1 1TA
Mobile : [redacted]
Fax : + 44 (0) 191 334 8311
Email :
i.e.leak@durham.ac.uk

8th September 2014

Dear [redacted]

PhD Research study investigating Year 8 students' attitudes to STEM subjects

I am a full-time PhD student in the School of Education at Durham University under the supervision of Dr. Vanessa Kind and Professor Doug Newton. I write to seek permission to collect data for my study in your school.

My research interest is in students' (especially girls') attitudes towards science, Technology, Engineering and Mathematics (STEM) subjects in general, with a primary focus on the Physical Sciences and Mathematics. My interest developed from my experience as Head of Science in a mixed school and then an all girls' school in Nottingham.

I intend to explore attitudes towards STEM subjects at the point where students may begin to make decisions about future careers. Specifically, I would like to:

- observe a high ability Year 8 group in science and maths lessons weekly for up to 24 weeks across the 2014 – 2015 academic year
- work with a focus group of 4-8 students, split evenly by gender, from the Year 8 subject group
- conduct 1:1 interviews with volunteer Year 8 students from the subject group
- conduct 1:1 interviews with volunteer science and maths teachers
- invite Year 8 students across the year group to complete a questionnaire at intervals during the school year

I anticipate findings will be useful to you and colleagues in gaining a deeper understanding of how students' attitudes towards science and maths develop over time, and the factors influencing these.

The research will be conducted under Durham University's Code of Practice on Research ethics. Anonymity of the school and students will be maintained throughout and data will not be stored in a format that enables identification of any individual.

My contact details are shown at the top of the letter. Vanessa Kind and Doug Newton would also be pleased to discuss this with you. Their email addresses are: [redacted]

I would very much appreciate your help with this and look forward to hearing from you at your earliest convenience.

Yours sincerely,

Ms Inebimo Leak, BSc, PGCE, MRes

Appendix 4: Letter to attached to student questionnaires

School Science Project

June 2015

Durham University

School of Education
Leazes Road
Durham
DH1 1TA
Fax: + 44 (0) 191 334 8311
Email: i.e.leak@durham.ac.uk

CONSENT REQUEST FORM

TITLE OF PROJECT: An investigation into the factors that affect students' attitudes to Science

Please cross out as necessary

- Have you received any information about the study? YES / ~~NO~~
- Have you had an opportunity to ask questions and to discuss the study? YES / ~~NO~~
- Have you received satisfactory answers to all of your questions? YES / ~~NO~~
- Who have you spoken to? Dr/Ms......LEAK...................... YES
- Do you consent to participate in the study? YES/~~NO~~
- Are you aware that some sessions will involve audio or video recordings? YES/~~NO~~
- Do you consent to the use of the recordings after the end of the project? YES/~~NO~~
- Do you understand that you are free to withdraw from the study:

  * at any time and

  * without having to give a reason for withdrawing YES / ~~NO~~

Signed ....[redacted]................... Date ......8/7/15..............................

(NAME IN BLOCK LETTERS) ...[redacted]....................................

Approved by Durham University's Ethics Advisory Committee

School Science Project December 2014

Dear Parent/Guardian,

Request for Participation in Research project

I am a former science teacher and Head of Science, now working full time doing a doctoral research degree in the School of Education at Durham University. My interest is in students' attitudes to Science. The project should provide information to help design appropriate science courses for all children.

Part of my research involves collection of data from students and parents through the use of questionnaires and interviews. I would therefore be grateful if your child/ward would complete the attached questionnaire then return it completed to his/her science teacher.
I would also like to work with a small group of students to explore their ideas about science in more detail. Some sessions might involve the use of audio or video recording.

The research has been granted ethical approval by Durham University School of Education and will be conducted according to the University's research Code of Practice. All participants, including the school will remain completely anonymous. I also have a full, current DBS clearance.
I would be very grateful if you and your child/ward would consent to be involved in my project by returning the attached slip with the questionnaire.

Thank you very much indeed for your help.

Yours faithfully,
Ms. Ebi Leak
Doctoral research student
Durham University School of Education

Consent slip

I consent to participation in the project on attitudes to science. ☐

I consent to my child/ward participating in the project on attitudes to science. ☐

Child's name____

Parent's name____

Signature______________________ Date______________________

Appendix 6 : Science teachers' Schedule

Teacher__________________________Gender_____________ Specialism____________

Qualification______________________

Questions	
1.	What is your specialism? - What level do you teach this to?
2.	Do you teach any other subjects? (PE, geography, maths)
3.	Does it matter if you teach your specialist subject / not? If so how / if not, why?
4.	How long have you been teaching?
5.	Could you describe a successful lesson? What made it successful?
6.	Does the topic of the lesson influence the way you teach (your subject and the other sciences?)
7.	In what ways?
8.	What influences your choice of teaching strategy?
9.	What influences your teaching style most?
10.	What is the general attitude to science? Does it matter what the students think of science?
11.	Why is this?
12.	How do you encourage students to develop positive attitudes towards science?
13.	What factors influence students' attitudes towards science?
14.	Do girls and boys respond to science in the same way?
15.	Do students' attitudes vary by pathway? (At KS4 TS/ DA/ SA)
16.	Why do you think that is?
17.	Do you think that your specialism affects students' attitude to the separate sciences?
18.	How do you think students see themselves in science in Year 7?
19.	In your experience, does this change as they progress through school?
20.	What factors do you think influence the way students see themselves in science?
21.	What can be done to change this?

Appendix 7: SLG interview schedule

1.	Please state your name and position in the school
2.	What is your specialism?
3.	How long have you been in teaching?
4.	How long have you been in senior leadership? Has this always been in Farne or elsewhere?
5.	How long have you been in senior leadership at the school?
6.	There is growing concern in the UK about a future shortage of scientists, although there are people who disagree that there is a problem. What is your opinion on this?
7.	What is the general attitude to science as a whole?
8.	What is the attitude to science in school?
9.	What factors do you think influence a student's attitude to science?
10.	Do girls and boys respond to science in the same way?
11.	How do you think students see themselves in science in Year 7?
12.	In your experience, does this change as they progress through school?
13.	As a school, how is science promoted?
14.	What makes Farne successful in science?
15.	Is this sustainable given the changes in the curriculum and exams?
16.	In what ways can senior leadership help in promoting science?
17.	Science is no longer considered a 'core' subject. What impact has this had on the subject as a whole?

Appendix 8: Year 8 questionnaire

Name ____ Date______________________

Are you Female` ☐ or Male? ☐ (Please tick ONE box)

Secondary School _____________________________________Science Group ______________

Which Primary School did you go to? ____

This questionnaire is designed to find out what you think about science in school and society.
Your responses will be used in a Durham University School of Education research project. Please answer all the questions honestly. For each question, remember there is no "right" or "wrong" answer. Please follow the instructions for each question. **Your answers will only be used in this research project. They will be stored safely by code, not your name, and will not be shared with anyone in your school or at home.**

Thank you for your help.
Ms. I E. Leak
Durham University School of Education

Please tick YES or NO in this section

Do you spend time doing any of the following when you are not at school? For example, do you…	Yes	No
Visit science museums or science activity centres?		
Play science games, e.g. Minecraft, Space Engineers?		
Grow plants, e.g. vegetables, flowers?		
Mend/fix cars, bikes or gadgets?		
Talk about science with your family?		
Go camping?		
Care for animals, e.g. cat, dog, fish, birds?		
Play with radio-controlled cars/planes, electronics kit or a chemistry set?		

If you have ticked yes to any activity, please state the one you enjoyed the most__________________and the one you enjoyed the least__________________

Please say why you enjoyed one activity but not the other.

When you were at primary school, did you…	Yes	No
Have science lessons each week?		
Find science difficult?		
Go on science trips (e.g. Centre for Life, MAGNA Science Adventure Centre, National Space Centre, the National Railway Museum, the Science Museum etc.)?		
Find science easy?		
Do science experiments?		
Have visits from shows such as 'Mad science?		
Enjoy doing science?		

Please describe the best science lesson you remember from primary school.

Why was this the best science lesson?

Please rate your ability in science on a scale from 1 (low) – 10 (high) and put the number here_______________
Please explain why you gave yourself this rating.

How likely are you to choose a science-based job when you leave school? 1 (low) - 10 (high), put the number here__________
Please explain

Can you please describe how your school (other than your science teachers) has helped you with science?

Do you have any one in your family who does or did one of these jobs? Please circle all that apply to your family:

X-ray Technician	Doctor	Electrician	Park Ranger	Geographer	Science Teacher	Vet
Astronomer	Physicist	Pharmacist	Zoo keeper	Meteorologist	Nutritionist	Nurse
Chemist	Biologist	Police officer	Mechanic	Food Scientist	Gardener	Chef
Hairdresser	Land surveyor	Pathologist	First aider	Fire-fighter	Dentist	Pilot
IT specialist	Physiotherapist	Engineer	Cleaner	Social worker	Care Worker	Diver
Forensic scientist	Psychiatrist	Architect	Gas Engineer	Plumber	Environmental scientist	

Is there any job on the list that you would like to do? Yes/No
Please explain

Thinking about the adults at home, please say what their current jobs are:-

Parent / Guardian 1: ____

Parent/ Guardian 2:____

Thank you for your answers.
I would like to interview students about their ideas. Please tick here if you are willing to be a member of this group. ☐

Ms. I E. Leak
Durham University School of Education

Appendix 9: Year 10 questionnaire

Name ____ Date___________________________

Female ☐ Male ☐ **Science group**____

GCSE course: Single Award ☐ Double Award ☐ Triple Science ☐ Applied ☐

Primary School ____

This questionnaire is designed to find out what you think about science in school and society.
Your responses will be used in a Durham University School of Education research project. Please answer all the questions honestly. For each question, remember there is no “right” or “wrong” answer. Please follow the instructions for each question. **Your answers will only be used in this research project. They will be stored safely by code, not your name, and will not be shared with anyone in your school or at home**.

Thank you for your help.
Ms. E. Leak
Durham University School of Education

Here are some activities that you might enjoy doing or have done outside school.
Please tick “**Yes**” for each one that you **have** done. Please tick “**No**” for each one that you **have not** done.

No.	**When you are not in school, do you enjoy …**	Yes	No
1	Visiting science museums or science activity centres?		
2	Playing games such as e.g. Minecraft, Space Engineers?		
3	Growing plants, e.g. vegetables, flowers, houseplants?		
4	Mending/fixing cars, bikes or gadgets?		
5	Talking about science with your family?		
6	Going camping or doing survival-type activities?		
7	Caring for animals or pets e.g. cat, dog, fish, birds?		
8	Playing with radio-controlled cars/planes, electronics kit or a chemistry set?		
9	Watching science-based TV programmes, e.g. Brian Cox, David Attenborough, Deadly 60, etc?		

Choose an activity from the list that you enjoy doing. Please write the number here: _____________

Please explain why you enjoy doing this activity.

Choose an activity from the list that you do not enjoy. Please write the number here: _________________

Please explain why you do not enjoy doing this activity.

Here are some science-based activities that you may have done in school.

Please tick "yes" for any activity you have done. Please tick "no" for any activity you have not done.

No.	Have you… …	Yes	No
1	Been involved in science busking?		
2	Acted as a science mentor for another student?		
3	Done a science-based internship or work experience?		
4	Attended The Big Bang Fair, GCSE Science Live, "Ever Wondered Why?" Roadshow?		
5	Attended a university-based science event, e.g. a lecture or visit?		
6	Attended a careers event in or outside school?		

Choose an activity for which you ticked "Yes". Please write the number here: _________________

Did you enjoy this activity? Yes ☐ No ☐

Please explain your answer.

Did this activity make you think positively or negatively about science? Please tick. Positively ☐ Negatively ☐

Please explain your answer.

Please list all the science-based activities that you have done in school that is not on the list above.

Please state the ones which made you think positively about science.

Please state the ones which made you think negatively about science.

Thinking about science lessons in Years 7, 8 and 9, please describe ONE lesson that has stayed in your memory. Circle the year

Years: 7 8 9 Topic: Teacher:

Why do you remember this lesson?

Did this lesson make you think positively or negatively about science? Please tick: Positively ☐ Negatively ☐

Please explain your answer.

Appendix 10 : Year 12 questionnaire

Name____ Date______________________

Female ☐ Male ☐ Current school____

Secondary school if different to current school____

Primary School ____

This questionnaire is designed to find out what you think about science in school and society.
Your responses will be used in a Durham University School of Education research project. Please answer all the questions honestly. For each question, remember there is no "right" or "wrong" answer. Please follow the instructions for each question. **Your answers will only be used in this research project. They will be stored safely by code, not your name, and will not be shared with anyone in your school or at home**.

Thank you for your help.
Ms. I E. Leak
Durham University School of Education

Please say which AS subjects you are doing

1) 2) 3) 4)

Please explain why you chose each AS subject - please circle ALL statements that apply

1. Fits career and/UCAS choice / Favourite subject / Did well at GCSE / Needed to fill timetable / Other __________ (please state)

2. Fits career and/UCAS choice / Favourite subject / Did well at GCSE / Needed to fill timetable / Other __________ (please state)

3. Fits career and/UCAS choice / Favourite subject / Did well at GCSE / Needed to fill timetable / Other __________ (please state)

4. Fits career and/UCAS choice / Favourite subject / Did well at GCSE / Needed to fill timetable / Other __________ (please state)

Would you make the same AS choices today as you did in September? Yes/No
Please explain.

What GCSE Science results did you achieve? Please state your grades

Double Award____ ____

Biology ______________

Chemistry ____________

Physics_______________

When you are not in school, do you…	Yes	No
Visit science-related places e.g. a museum, Centre for Life, the National Space centres?		
Play science games, e.g. Minecraft, Space Engineers?		
Watch science programmes on TV?		
Talk about science with friends or family?		
Mend/ fix cars, bikes, gadgets?		
Grow plants, e.g. vegetables, flowers?		
Care for animals, e.g. cat, dog, fish, birds?		
Play with scientific toys, e.g. radio-controlled cars/planes, Chemistry set, electronics kit, crystal growing?		
Thinking back to secondary school, did you		
take part in science busking or mentoring?		
do any science based internship or work experience?		
participate in any science events ***organised by your secondary school*** either in or outside of school? For example, The Big Bang Fair, GCSE Science Live, Ever Wondered Why Roadshow?		
attend any University science event?		
attend a careers event in or outside school?		

Please describe the best science lesson you remember from secondary school

What makes this lesson stick in your mind?

In what ways did your secondary school (other than your science teachers) help you learn science?

What did you like best about science?

What did you like the least about science?

What made you decide to do science beyond secondary school? Please explain

Appendix 11: Lesson field notes during questioning

January 22nd, 2015: 10.20am – 11. 20am (Mr. Martin's AS Physics class)

Number present: 19 (15 boys + 4 girls).

As the students arrived, Mr. Martins announced that the second half of the lesson was going to be a practical session. At this stage, lesson observations had been going on since November, so this was a good opportunity to focus on one area of interest. In the first lesson observed in November, I noticed that each time a question was asked, and a student was called, it was always a boy. So, I decided that one lesson will focus on questioning and decided that this was a suitable lesson to record this. I used the first half of the lesson to focus on questioning- not the teacher's questioning skills but how girls and boys answer questions in the lesson. To make this manageable, no attempt was made to identify students except by gender.

B – Boy; G – Girl; T- Teacher; Q- question; S – students; C- comments

10.20am

Starter activity: On the board are two pictures which are side by side.

Q: What's the link?

B1 – diffraction

T: You are right. Well done. Last week we looked at diffraction.

Comment: T always uses the starter activity to link previous and current lessons.

T spends the next five minutes explaining the link between the two pictures.

10.25am

T introduces the topic – diffraction grating, stating the learning objectives. T refers students to the textbook where the learning objectives were taken from. This sets the expectation of the lesson.

Q: Why do the lines have to be so close?

G1 puts hand up and is called to answer.

T- excellent

Q: Are they all the intensity?

B2 answers

B3 answers

Q: Other observations?

B4 answers

Q: What's happening to the spacing?

B5 answers

10:30

T asks the class to make notes of what's important.

S - are focussed and engaged with the lesson.

Comment- There is some chatting going on, but this is all centred on the topic. From personal experience, class is very focussed. Not sure if this is because this is an AS class and behaviour is different to younger students. Behaviour in this group is markedly different to Year 10 physics with Mr. Martin. While students here are more engaged, Year 10 are apathetic and reluctant to participate in any aspect of the lesson.

*G- asks Q of her own.

Q: The red lines are…..

B6 answers

Q7: Gives a hint where there were no volunteers

G2 answers

B7 answers

G3 answers

B8 answers

B9 answers

Q:

B10 answers

B11 answers

T: I suggest you watch what I am doing. I will give you time to make your notes

Comment – *T intervenes at this point as many of the students were more engrossed in making notes rather than paying attention on the next stage of the lesson. This seems to be common in both Year 10 and 12 where students are fixated on writing almost everything down. This could be as a result of getting the facts down because of examinations, because students use notes taking down to make revision cards.*

T spends time to derive the diffraction grating equation. Advises that students must be able to derive the equation for the examinations.

C: *The spectre of examinations dominates both Year 10 and 12 lessons. Explanations are interspersed with reminders of GCSE and AS examinations. While the fault clearly does not lie with the teacher whose job is to ensure that students learn what is needed for examinations, the constant reminder of examinations appears that this is the only reason students study these subjects.*

10:50am 2nd half of lesson Practical session

T- no more than four groups as equipment are limited

Group 1: 4 boys

Group 2: 6 boys

Group 3: 4 girls, 2 boys

Group 4: 3 boys

C – Students got into groups based on where they sat. Group 3 had six students while group 4 had three students but Mr. Martins did not ask anyone to move from either group 2 or 3 to group 4 to make the numbers more even.

S get on with practical with very little input from Mr. Martins. Discussion again between students is mostly about the work. The atmosphere is very relaxed with plenty of laughter and good-natured teasing between students and even between students and Mr. Martins.

T goes from group to group reinforcing concepts. Checks progress (any measurements? Got any values? What do you think? did you make a note of how many lines/mm?).

11:05

T- if you haven't done so already, volunteer someone to clear up while the rest of you crunch some numbers.

C- As with any task with this group, someone volunteers to pack away without any input from Mr. Martins. Students are always well behaved and rarely need to be told what to do.

A boy from group 3 goes to group 1 but this is to check his work against theirs. Other students always go to boys in group 1 for help as they always appear to do well in tests and grasp difficult concepts quicker than anyone else in the class.

*B asks question of his own

11: 10

S back to seats and all quietly doing calculations from practical

T still going from table to table to check progress

11:20

*G stays back to ask questions about work

T jokingly tells her to go away. There are Year 10s to be taught as well.

C – Although T was right to ask her to leave as he had a Year 10 class to teach, this highlights part of the challenges both students and teachers face. This is a class of only 4 girls, some of which are reluctant to ask questions in class and may prefer to do this on a 1-2-1 basis. However, the teacher cannot afford to give up the time available for his next class to attend to her as well.

14 questions were asked in total, in the 1st half of the lesson. Of these, 11 were answered by boys and only 3 by girls. While this could be because there are more boys than girls, in previous lessons where a named person has been called, it was usually a named boy. Instances where girls were called to answer questions, it was because they had put their hand up.

<u>Discussion with Mr. Martins about questioning</u>

In chatting with Mr. Martins about my observation that more boys than girls appear to be called to answer questions compared to the girls in the class. He explained that the girls in the class were as capable as the boys in physics. However, he must be careful not to put the girls on the spot by calling on them as often as he would the boys because they are usually more reluctant to participate in lessons. Calling on them when they have not indicated a willingness to answer could alienate them and he is careful not to let that happen.

Appendix 12: Data reduction and initial coding – Year 8

Year 8: Example of Initial stage of data reduction and coding									
ID	Expn MstEnjyd	Expn LstEnjyd	BestPScLsn	ExplBPSL	ScAbRtg	ExpnJobRtg	JobInvlSc	SchHelp	
ABBEY	X	X	X	X	X	X	X	PRACTICALS	
ABBOTT	X	X	X	X	UNDERSTANDING	Career-driven	YES	YES	
ADDISON	OPPORTUNITY TO EXPERIMENT	NO OPPORTUNITY TO EXPRMT	SALT CRYSTALS	WATCHING IT GROW	LIKE SCI	ASTROPHYSICIST	YES	ACTIVITIES	
BETSY	ENJOYMENT	X	MAKING TOOTHPASTE	ACTIVE PART	UNDERSTANDING	VET RELATED	YES	ACTIVITIES	
BETTY	FUN	LEAST FAVOURITE	MODELLING THE DIGESTIVE SYSTEM	EXCITING	PERFORMANCE	LIKE SCI	YES	ACTIVITIES	TEACHER NOT GOOD AT EXPLAINING
BEVERLEY	DISCOVERY	DISAGREEMENT	SALT CRYSTALS	ACTIVE PART	ENJOYMENT	LACK OF ENCOURAGEMENT FROM TEACHER	NO	NO	TEACHER DOES NOT ASK HER QUESTIONS OFTEN
HALEY	ENJOYMENT	BORING	SALT CRYSTALS		LIKE SCI	LIKE SCI	YES	ACTIVITIES	TEACHER NOT GOOD AT EXPLAINING
HAPPY	X	X	FILTERED WATER	ACTIVE PART	PERFORMANCE	OTHER JOB	NO	ACTIVITIES	
ALARIC	FUN	LEARN NOTHING	X	X	PERFORMANCE	UNDECIDED	UNDECIDED	RESOURCES	
MADONNA	FUN	BORING	FILTERED WATER	FUN/INDEPENDENCE	PERFORMANCE	UNDECIDED	UNDECIDED	ACTIVITIES	
ALBAN	INNOVATIVE	X	X	X	UNDERSTANDING	STRONG INTEREST IN SCI	YES	ACTIVITIES	KNOWLEDGE OF THINGS NOT YET TAUGHT
EARTHA	x	x	x	X	ANXIETY	ANXIETY	NO	SCIENCE SCH	PANICS IN SCI

Appendix 13: Data reduction - Year 12

Student	Questions				
	Likelihood of same AS choice today as in September	**Memorable science lesson secondary school & explanation**	**Help from School (other than science teachers)**	**Best things from Secondary Science**	**Least liked things from Secondary Science**
Darren	Yes-Doing pretty good at it	EMS Catchy tune	Textbooks/Books in Lib	Lots of practical lessons	Practicals rarely worked
Dennis	Yes-I enjoy them. also fits with career choice	Screaming jelly babies It was fun & unexpected	Giving us external sources such as BBC bitesize	Practical lessons	Knowing what formula to use
Denzil	Yes-Finding Physics difficult. Still interesting and useful	Practical lessons The more enjoyable, I find a lesson, the more I learn	Curriculum days where people from university give lectures and activities related to science	Practical lessons	-
Dexter	Yes-I enjoy all of my choices	Astrophysics lesson I was very good at it	Information about events	Understanding the way, the universe works	Incredibly complicated at times
Dominic	Yes-Option block limited. Had to find balance between what I enjoyed & University requirements	-	-	-	-
Frances	Yes. Science subjects (including Russian, Further Maths & Maths)	Burning magnesium in chemistry. It was cool	Stem related activities during science week e.g. learning about space	How it is logical & explains the world we live in	Analysing errors in practicals
Drake	Yes-enjoying them	EM spectrum Cool song we had to learn	STEM clubs & events attended	Interesting and teachers were good	Difficult concepts
Duncan	Yes-enjoying them	-	After school clubs most weeks	Always interested in physics & chemistry. Always really enjoyed lessons	Wasn't too interested in biology
Talia	No-did well in history & chemistry. Chemistry would have improved chances for a STEM course at University	Osmosis practical using potatoes Opportunity to see how things happen in practice	Revision packs in the run up to exams. Regular practicals. Teachers provided environment to ask ques confidently	Applying theory to real life	Limitations in testing theories due to cost and impracticalities
Dustin	Yes-option block limited. Not able to do French, chemistry & politics. Will miss the discussions in politics, as I am very interested in politics. Chemistry is not needed for engineering/maths, but I recognise its importance especially in industry. Would have liked to do French.	-	-	-	-

Appendix 14: Excerpt from Departmental Handbook Word frequency search

Word	Length	Count	Weighted Percentage (%)	Similar Words
students	8	236	3.93	pupil, pupils, pupils', student, students, students'
learning	8	212	2.29	acquire, check, checked, checks, discovered, instructions, know, knowledge, knows, learn, learning, learning', letter, letters, read, reading, see, studies, study, take, takes, taking, teach, teaches, teaching
work	4	174	1.95	act, bring, employed, exercise, form, forms, going, influences, make, makes, making, play, process, processes, running, solving, studies, study, turned, work, working, works
science	7	81	1.23	science, sciences, skill, skills
set	3	120	1.2	arrange, arrangements, circumstances, context, contexts, correct, corrected, correction, corrections, fit, fix, fixed, limitations, limited, locate, located, mark, marked, marking, marking', marks, place, placed, positive, prepare, prepared, put, putting, ready, set, sets, setted, setting, situation
assessment	10	82	1.17	appraisal, assess, assessment, assessments, evaluate, evaluation, measurable, measuring, value, valued
lessons	7	59	0.92	example, examples, lesson, lessons, moral
school	6	58	0.87	education, educational, school, schools, train, training
planning	8	51	0.76	plan, planned, planning, plans, prepare, prepared, programme, programmes, provision
data	4	56	0.65	data, inform, informal, informally, information, informed
homework	8	41	0.64	homework, homeworks, prep, prepare, prepared
marking	7	104	0.63	check, checked, checks, cross, differentiated, differentiation, grade, grades, grading, mark, marked, marking, marking', marks, note, notes, notice, print, punctuation, score, scores, signed, target, targets
teacher	7	33	0.55	teacher, teachers, teachers'
monitoring	10	29	0.48	monitor, monitored, monitoring

Appendix 15: Excerpt of students' statements used for categorisation

	Student	S-E	Asp	STATEMENT
1	ADDISON1	10	10	I WOULD LIKE TO GET SCIENCE BASED JOB BECAUSE I WOULD LIKE TO HELP IMPROVE THE HUMAN RACE UNDERSTANDING OF IT
2	ALBAN1	8	9	I WOULD MOST LIKELY KEEP A STRONG INTEREST IN SCIENCE THROUGH KS4
3	HALEY1	6	10	I JOINED MY SCHOOL AND LEFT ALL MY FRIENDS FOR SCIENCE. I LOVE SCIENCE
4	BETTY1	6	9	I LOVE SCIENCE. I LEFT MY FRIENDS FOR SCIENCE
5	BAILEY1	9	7	I'M GOOD AT SCIENCE
6	BRENDA1	9	7	I LIKE SCIENCE BUT MY PARENTS WORK IN SCIENCE AND THEY DON'T LIKE THEIR JOBS
7	BAZ1	8.5	7	I LIKE MATHS AND SCIENCE AND WOULD LIKE TO CONTINUE THEM IN THE FUTURE
8	ARLENE1	8	8	I FIND SCIENCE FUN
9	FRANCES1	8	10	I HAVE ALWAYS ENJOYED PHYSICS AND I WOULD LIKE A CAREER IN IT
10	DEXTER1	8	8	BECAUSE I ENJOY IT
11	DRAKE1	8	9	I ENJOY PHYSICS AND WANT TO CONTINUE DOING IT
12	EBREL1	8	9	BECAUSE I WOULD LIKE TO BE A CHILDREN'S NURSE SO NEED TO KNOW A BIT BIOLOGY
13	DENNIS1	6	7	I WOULD LIKE TO DO AUTOMOTIVE ENGINEERING WHICH INVOLVES PHYSICS
14	DUNCAN1	9	8	I PLAN TO DO PHYSICS AT UNIVERSITY AND THEN A GET A PHYSICS BASED JOB
15	DARREN1	7	6	PHYSICS IS A LUCRATIVE JOB FIELD AND ITS HIGHLY LINKED TO ENGINEERING
16	DUSTIN1	8/9	7	I WOULD LIKE TO STUDY ENGINEERING AT UNIVERSITY BUT NOT GO INTO PHYSICS AFTER
17	DOMINIC1	8	6	PHYSICS BASED JOBS SUCH AS ENGINEERING ARE POPULAR AT THE MINUTE AND THERE IS A HIGH DEMAND FOR THEM. ALSO SOMEONE HAS TO ANSWER THE QUESTIONS OF THE UNIVERSE
18	ANGELA1	5	10	I WANT SOMETHING TO DO WITH CHEMICALS/MAKING MEDICINE
19	FAITH1	8.5	10	I WOULD LIKE TO GO INTO MEDICINE-BIOLOGY IS EXTREMELY HELPFUL FOR THIS
20	BENTLEY1	7	8	I WOULD LIKE TO BE A PILOT
21	BENNETT1	3	1	BECAUSE I AM MORE INTERESTED IN PE
22	DONALD1		5	I AM MORE LIKELY TO DO A SPORT SCIENCE DEGREE WHICH REQUIRE BIOLOGICAL KNOWLEDGE
23	BREWSTER1	6	4	I WOULD LIKE TO DO SOMETHING WITH TECHNOLOGY
24	AILEEN1	5	10	I WANT TO BE A MIDWIFE

Appendix 16: Questionnaire responses coded for SPSS

ID	Gender	YEAR	PriSch	SCIGROUP	VSITES	GAMES	GPLANTS	MENDG	DWFAMIL	ANMCARE	EKITS	ScTvPG	BestScLsn	ExplBSLsn	PPcvdScAl	ExpnScAb	ScJobRtg	ExpnJobRt	JobInvlSc	SchHelp	ScFamHist	PGSciJob
DARREN	MALE	2014	SWALE	RUBY	YES	YES	NO	NO	NO	NO	YES	YES	EM SPEC	CATCHY TU	7	GOOD AT	6	LUCRATIV	ENGINEER	RESOURCES	LOW	LOW
DENNIS	MALE	2014	RYE	RUBY	NO	YES	NO	YES	YES	YES	YES	YES	SCREAMIN	FUN	6	UNDERSTA	7	NEEDS SCI	AUTOMOT	RESOURCES	LOW	MEDIUM
DENZIL	MALE	2014	COQUET	RUBY	NO	NO	NO	YES	YES	YES	NO	YES	PRACTICA	ENJOYABL	4	UNDERSTA	3	FIND PHY	NO	WORKSHOPS	X	X
FAITH	FEMALE	2014	CALDER	RUBY	YES	NO	NO	NO	NO	YES	NO	YES	VAN DER (	ENJOYABL	9	UNDERSTA	10	MEDICINE	YES	RESOURCES	LOW	LOW
DEXTER	MALE	2014	TEES	RUBY	YES	YES	NO	YES	YES	NO	YES	YES	ASTROPHY	PERFORMA	8	UNDERSTA	8	ENJOY IT	YES	OPPORTUNITIES	LOW	MEDIUM
DOMINIC	MALE	2014	BREAMISH	RUBY	YES	NO	NO	NO	YES	NO	NO	YES	X	X	8	UNDERSTA	6	ENGINEER	YES	X	LOW	MEDIUM
DONALD	MALE	2014	WHARFE	RUBY	NO	NO	YES	NO	NO	YES	NO	YES	VAN DER (	INTRIGUIN	5	UNDERSTA	5	SPORTS SC	YES	EXTRA SUPPORT	LOW	LOW
FRANCES	FEMALE	2014	COQUET	RUBY	YES	NO	NO	NO	YES	NO	NO	YES	BURNING	COOL	8	UNDERSTA	10	ENJOY PHY	YES	ACTIVITIES	MEDIUM	HIGH
FRANCES	FEMALE	2015	COQUET	RUBY	YES	NO	NO	YES	YES	NO	NO	YES	CAN'T REM	X	8	UNDERSTA	7	UNDECIDE	YES	ACTIVITIES	MEDIUM	HIGH
DRAKE	MALE	2014	BAIN	RUBY	YES	NO	NO	NO	YES	NO	NO	YES	EM SPEC	COOL SON	8	UNDERSTA	9	ENJOY IT	YES	ACTIVITIES	LOW	LOW
DRAKE	MALE	2015	BAIN	RUBY	YES	YES	NO	NO	YES	NO	NO	YES	EM SPEC	CATCHY TU	9	UNDERSTA	8	LIKE PHY	YES	ACTIVITIES	LOW	LOW
DUNCAN	MALE	2014	TEES	RUBY	YES	YES	NO	NO	YES	NO	YES	YES	X	X	9	ENJOY IT	8	LIKE A SCI	YES	ACTIVITIES	LOW	MEDIUM
DUNCAN	MALE	2015	TEES	RUBY	YES	YES	NO	NO	YES	NO	NO	YES	RXN OF Na	EXPLOSIO	9	UNDERSTA	10	ENJOY IT	YES	ACTIVITIES	LOW	MEDIUM
FERN	FEMALE	2014	CALDER	RUBY	YES	NO	NO	NO	YES	NO	NO	YES	OSMOSIS	DISCOVER	8	UNDERSTA	6	OTHER JOI	NO	RESOURCES	MEDIUM	MEDIUM
FERN	FEMALE	2015	CALDER	RUBY	NO	NO	NO	NO	YES	NO	NO	YES	SCREAMIN	EXCITING	6	X	5	NOT INTEF	NO	ACTIVITIES	MEDIUM	MEDIUM
DUSTIN	MALE	2014	WHARFE	RUBY	YES	NO	YES	YES	YES	YES	NO	YES	X	X	9	UNDERSTA	7	ENGINEER	YES	YES	LOW	X
DUSTIN	MALE	2015	WHARFE	RUBY	NO	NO	YES	NO	YES	YES	NO	YES	X	X	7	X	5	X	X	X	LOW	MEDIUM

Appendix 17: Key Stage 3 SOW

Sections	Big ideas
Working Scientifically	• Scientific attitudes • Experimental skills and investigations • Analysis and evaluation • Measurement
Biology	• Structure and function of living organisms • Material cycles and energy • Interactions and interdependencies • Genetics and evolution
Chemistry	• Particulate nature of matter • Atoms, elements and compound • Pure and impure substances • Chemical reactions • Energetics • The Periodic Table • Materials • Earth and atmosphere
Physics	• Energy • Motion and Forces • Waves • Electricity and Magnetism • Matter • Space Physics

Appendix 18: Year 8 Programme of study for KS3 2014/15

Week commencing	Teaching block unit	Number of lessons Biology: 30 Chemistry: 28 Physics: 28	Discipline
	Term 1		
1st Sept		8	Biology
8th Sept	Health		
15th Sept	Health		
22nd Sept	Assessment: Health	3	
29th Sept	Periodic Table	5	Chemistry
6th Oct	Periodic Table		
13th Oct	Separations	6	
20th Oct	Separations		
27th Oct	Tests Periodic Table & Separations	3	

Half Term			
	Term 2		
10th Nov	Electricity	5	Physics
17th Nov	Electricity		
24th Nov	**Consolidation week**		
1st Dec	**Assessment week: Health, Periodic Table, Separations & Electricity**		
8th Dec	Magnetism	3	Physics
15th Dec	Assessment: Electricity & Magnetism	3	
Christmas			
Term 2			
5th Jan	Ecosystems	9	Biology
12th Jan	Ecosystems		
19th Jan	Ecosystems		
26th Jan	Adaptations	7	
2nd Feb	Adaptations		
9th Feb	Assessment: Ecosystems & Adaptations	3	
Half Term			
23rd Feb	Metals	5	Chemistry
2nd Mar	Metals		
9th Mar	**Consolidation week**		
16th Mar	**Assessment week: Magnetism, Ecosystems, Adaptations & Metals**		
23rd Mar	Ceramics, Composites, Polymers	2	Chemistry
1st Apr	Earth	2	
Easter			
	Term 3		
20th Apr	Earth	2	Chemistry
27th Apr	Assessment: Metals & Earth	3	
4th May	Energy	8	Physics
11th May	Energy		
18th May	Energy		
Half Term			
1st June	Motion and Pressure	6	Physics
8th June	Motion and Pressure		
15th June	Assessment: Energy, Motion and Pressure	3	
22nd June	**Consolidation week**		
29th June	**Exam week - all year's work**		
6th July			
13th July			

Year 12: AS Physics (Modules, Topics)

Term 1	Term 2	Term 3
Practical Skills Constituents of the atom Particles, antiparticles and photons The photoelectric effect Energy levels and photon emission Wave-Particle Duality Scalars and vectors Moments Motion along a straight line Projectile motion Momentum Work, energy and power Current–voltage characteristics Resistivity Potential divider Electromotive force and internal resistance **Resources**: CGP Textbook **Assessment**: Required practical: Determining g Required practical: Resistivity of a Wire Required practical: EMF Summative assessment: Particles and radiation Summative assessment: Quantum phenomena Summative assessment: mechanics (statics) test Summative assessment: mechanics (kinematics) test Summative assessment: Electricity test	Types of Wave Superposition Refraction, diffraction and interference Bulk properties of solids The Young modulus **Resources**: CGP Textbook **Assessment**: Required practical: Diffraction and Interference Required practical: Wave on a String Required practical: Young's Modulus Summative assessment: Waves test Summative assessment: Materials test	Periodic motion Thermal physics Molecular kinetic theory model Gravitational fields Orbits of planets and satellites **Resources**: CGP Textbook **Assessment**: Required practical: Pendulum and Mass on a Spring Required practical: Charles' Law Summative assessment: Circular Motion Test Summative assessment: SHM Test Summative assessment: Thermal Physics Test Summative assessment: Gravity Test

Appendix 20: Occupation of parents/Guardian

Category	Number of students	Parent/Guardian
Scientists	1	Physicist/Physicist
	2	Nurse/Police Officer
	3	Chemist/Physicist
	4	Nurse/Chem. Engineer
	5	Teacher/Unemployed
	6	Quality Manager/Full time carer
	7	Supply Teacher/Optician
	8	Nurse/Chef
	9	Bank Manager/Catering Manager
	10	Practice Manager/Photographer
	11	Nurse/Chef
	12	Design Engineer/Occupational Therapist
	13	Nurse/Gardener
	14	Paramedic/Accounts Team Leader
	15	Transport Manager/Hairdresser
	16	IT Specialist/Primary School Teacher
	17	Human Resources Manager/Children care worker
	18	Engineer/Accountant
	19	Accountant/Printer
	20	ICT project Manager/Teaching Assistant
	21	Firefighter/Secretary
	22	Lecturer/Lecturer
	23	Electronics Engineer/Civil Servant
	24	Headteacher (Primary School)/Civil Servant
	25	Police Officer/Social worker
	26	Occupational therapist/IT specialist
	27	Project Manager/Policeman
	28	Engineer/Works with disabled people
	29	Project Manager/Police Sergeant
	30	IT Manager/Accountant
	31	Nurse/ICT
	32	Prison Officer/Dog Handler
	33	Photographer/Not stated
	34	Student loan assessor/Not stated
	35	Oil Rig worker/Not stated
	36	Teaching Assistant/Quarry worker
	37	Not stated
The Ambivalent	1	Science Teacher/Primary School Teacher
	2	Nurse/land Surveyor
	3	Building Planner/Conservationist
	4	Chemist/Chemist
	5	Nurse/Proprietor of parachute centre
	6	Accountant/Clerk
	7	Police Officer/Teacher
	8	HSE Inspector/HR Company Director
	9	IT/Unemployed

	10	Engineer/School Secretary
	11	Teacher/Archaeologist
	12	Teacher/Photographer
	13	IT worker/Creche Worker
	14	PE Teacher/Plumber
	15	Officer worker/Not stated
	16	Teaching Assistant/Charity Worker
	17	Technician/Administrator
	18	Not stated
	19	Metal Worker/Bakery worker
	20	Coal miner/Chef
	21	Cleaner/Process operator
	22	Not stated
	23	Not stated
Arts/Humanities	1	Mental Health Nurse/Not stated
	2	Accountant/Electrician
	3	IT Specialist/Senior Sous-chef
	4	Engineer/IT Specialist
	5	Farmer/Call Handler
	6	Care Worker/Prison Worker
	7	Not stated
	8	Shop Assistant/Factory Worker
	9	Not stated
	10	Beautician/Barber
	11	Waste Manager/Plasterer
	12	Not stated
Resisters	1	IT/Prison Officer
	2	Physiotherapist/Physiotherapist
	3	Engineer/Care Worker
	4	Prison Officer/Secretary
	5	Teacher/Electrician
	6	Joiner/Not stated
	7	Mechanic/Clerk
	8	Traffic Warden/Administrator
	9	Town lighting/Administrator
	10	Prison Officer/Dinner Lady
	11	Not stated

If you just tell me your name please

So, my name is [redacted]

And what's your specialism?

Biology.

Biology and what's the highest qualification you have

I have a PGCE.

PGCE, okay.

I have a degree in medical microbiology, but...

Okay.

...my PGCE is in science.

Yes, okay. Alright, so I've been told that you work with primary schools, with feeder primary schools and your job is to get them, what I say, engaged in science before they come to Farne, so can you tell me - give me a general overview of what exactly it is you do.

Okay, so the project that we have currently is based on ten years of work with the feeder primary schools, where we work very closely with the primary teachers. Often many of them have specific responsibility for science in their school, so they come to regular meetings with us and we, we liaise about assessments and we liaise about how science is taught in their schools, but one of the most important things we do is we focus on students coming here for a particular day each year, working on their science skills, because skills are one of the, the key focuses of Key Stage 4, particularly, but also within Key Stage 3. The APP that was introduced about five years ago now, was very much driven along the scientific understanding and knowledge and evaluation, so all of those skills that students don't always get in a primary school. They maybe get them on a lose basis, but not a, a specific scientific basis, so we worked on these primary skills days for upwards of nine years now, where students come, and they do some experiments and they write about what they do, and they evaluate what they do. A lot of it is verbal, but this year particularly, we've looked at incorporating literacy into science.

Okay.

And they will write a passage about what they've experienced on that science skills day and then the teachers are coming with that work and we're really have a look at it and standardise and see where, in terms of a level in their scientific knowledge and understanding, they are in year five, so that when they come in year six or the end of year six, we maybe have a, a baseline. Because obviously they come with a Key Stage 2 teacher assess level. Key Stage 2 teachers aren't necessarily specialist. In fact, my experience is that they are not science specialists. A lot of science specialist will go into secondary or they'll go into business and industry, so unfortunately - but I mean, the one bonus we do have with primary teachers is they are so enthusiastic, they are so keen to develop the student's scientific skills, because they, they feel for their students that they don't always get a good deal.

Yes.

In terms of their science in primary school, especially in, in year six where literacy and numeracy is such a focus, so for the lead up to those SAT examinations in, in May, a lot of it is driven towards the literacy and numeracy, so we, we - what part of the reason we've kind of moved away from year six focus and, and moved down through the years to more year four, five, so that before they actually get to those year six literacy, numeracy tests, we're looking at their science skills and trying to develop them, them in those earlier years.

That's interesting....you guys have worked with the feeder primary schools.

Yes, I know locally we have a very close relationship with our feeder primary schools and beyond that now. I mean we have upwards of 27 primary schools feeding into Farne.

Okay.

So obviously it would be very difficult to maintain strong relationships with all 27 of those schools.

Bear in mind some of them are only feeding in one or two students a year. But to actually engage seven or eight primary schools, which is what we've got currently, is, is a good start.

Yes.

And like I say, we have such good links and we, we have such fantastic primary teachers who are enthusiastic for science. Even as non-science specialists, they see science as such an important and rich subject, which is really good.

Have you ever kind of like evaluated the impact of what you do? So maybe comparing students from schools that you've had no contacts with or the ones you - or the seven you work with, compared to the remaining 20 that you do not work with?

On a formal basis, no. But on a, a more casual basis, yes. We often will look - myself and [redacted] who is the ten to 14 transition...

Okay.

...person - will look at students that maybe come from the wider area, who aren't our feeder, direct feeders and we will maybe just put - more, more pass comment on the lack of science skills they have, compared to say students that come from [redacted] Primary, which is next door and they have good access to us here. Students that come from [redacted].and [redacted] and - oh, not [redacted], because that's the special school, although we do have very good links with [redacted] as well, but the schools very nearby, often students will have better science skills in year seven and we, we have passed comment on this, than schools that, that - them feeder primaries that come from further away and maybe have no links with their local secondary. I know there are local secondary schools that don't kind of outreach to primary schools at all.

The primary schools.

Or hardly at all. Except when they want their kids to be sent there.

Okay. This is quite impromptu, so what I'd ask for, at some point, would be when I say examples of the kind of things you do with them, like this project you've just mentioned. So that's on Wednesday at four.

Yes, that would be four o'clock, yes.

So, if we just, if it's possible, to get some kind of, I don't know - so that I can put it in context and have...?

Yes, I'll just show you on here.

Okay.

I know you can't see that on there, but I'll show you on the board.

Okay.

This is, so this is the, the thing that we did, the primary activity. So, we talked about the book and we talked about, in context, the solids, liquids and gases that will have gone into the medicine. Students are of varying ability, but, but very engaged in even this activity, which was quite a, like I would have said it was quite a boring activity.

Yes.

But because it's something - they do in year five now, the solids, liquids and gases, so they, they got quite involved in it and we talked about what makes a gas and a liquid and a solid and then we went into kind of changing state and we did some, just little mini experiments with the chocolate, to show that solid can become a liquid and a liquid can become a solid. Then we did our main experiments on gases and we tested carbon dioxide, oxygen and hydrogen and we did metal into acid and they did the test themselves, which they really really enjoyed and engaged with a lot and then the final bit was the, the wiz, bang bit, where we, we had a hydrogen and helium balloon and we popped them both. Obviously, the hydrogen balloon makes a big explosion, they love that and then we did carbon dioxide with dry ice.

Okay.

We did the dry ice and we did pH indicator with sodium hydroxide and it changes colour when you put the carbon dioxide in and it all - if you add some Fairy washing up liquid, it all bubbles out and the bubbles just disappear, because there's carbon dioxide in them and it just evaporates. It's brilliant, they love it, so that was kind of the, the basis of the day.

Okay.

Which they really enjoyed and there, there task was to write, using those key words, what they'd done across the morning or the afternoon and, like I say, the green work, the kind of your level two, three, the orange like fours and the reds are fives and sixes or maybe slightly higher than seven, sixes really, because sublimations are level seven.

Yes.

So, so that's something that you can - I can email to you.

Yes, please.

End of interview

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