A CRITICAL ANALYSIS OF APPROACHES TO INCREASING AND WIDENING PARTICIPATION IN HIGHER EDUCATION SCIENCE

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A thesis submitted in partial fulfilment of the requirements of the University of Sunderland for the degree of Professional Doctorate

April 2023

ABSTRACT

Levels of participation in STEM (Science, Technology, Engineering and Mathematics) education are an international, national and regional concern. Increasing and widening participation in STEM subjects is seen to matter in terms of economic development and social justice, and, in this context, there is a wide range of initiatives designed to encourage more people from more diverse backgrounds to study post-compulsory STEM subjects.

Centred on my own practice at a university in the North of England, this professional doctorate project sought to critically analyse approaches to increasing and widening participation in higher education science. Through an action research approach, the project specifically frames my professional practice through a critical review of the literature and, through three individual studies using questionnaires, investigates 1. the key influences on undergraduate students in their choice to study science at university; 2. the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students; and 3. the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital.

Findings from the study with undergraduate students, where the majority had mothers and fathers who had never attended university, highlight that a university offering the programme a student is interested in, having good links with industry and the sector, career opportunities, good university facilities, staff research interests and a good reputation of the degree programme are the most important factors in influencing a student's choice to study science there. Earlier in a young person's education, thinking that science would be useful for a future career and a good subject to have, as well as finding science interesting, exciting and enjoyable to learn were found to be key factors influencing choice to study post-compulsory science after GCSEs.

In positioning university-led science outreach, university staff felt strongly that it has an important part to play in securing a pipeline of future scientists needed for the UK economy and, also, although to a lesser extent, in contributing towards social justice. Staff described the primary purpose of science outreach activities as increasing

recruitment, raising awareness and raising aspirations, but felt that the goals could be more clearly defined and that there was not a coherent overarching view of what science outreach should be doing. All staff agreed that science outreach activities are effective in raising awareness of university science provision, however, the results revealed less confidence, particularly from professional services staff, that activities are effective in raising student aspirations and recruitment to the university.

Results from the third study show teachers, parents, volunteers and pupils perceived positive impacts on key dimensions of science capital through participation in a specific science outreach activity; most notably, increased scientific literacy, a greater awareness of the transferability and utility of science, and talking more about science with family, friends, neighbours and others in their community.

Contrasting with policy and practice that often promote a deficit model of ‘raising aspirations’, using science capital as a conceptual framework could provide the foundation for a more asset-based approach to increasing and widening participation in higher education science, recognising the structural constraints that frame access to higher education, whilst supporting the development of values, attitudes, expectations and behaviours in young people that promote attainment, engagement and participation in science.

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Acknowledgements

Many thanks to all those who have formed the wider teaching team at various points over the Professional Doctorate, but most particularly to my Director of Studies Dr Maddalena Taras and Co-Supervisors Dr Kim Gilligan and Professor Alastair Irons. Their challenge, guidance, support, and good humour have been invaluable.

Thank you to Ashleigh Hunt, Dr Elspeth Lees and Professor Heather Prince, who have given advice, encouragement and support throughout my journey.

I am grateful also to all the participants in this study who voluntarily gave up their time to share their thoughts and without whom the study would not have been possible.

Declaration

I declare that, except where explicit reference is made to the contribution of others, this thesis is the result of my own work and has not been submitted for any other degree at the University of Sunderland or any other institution.

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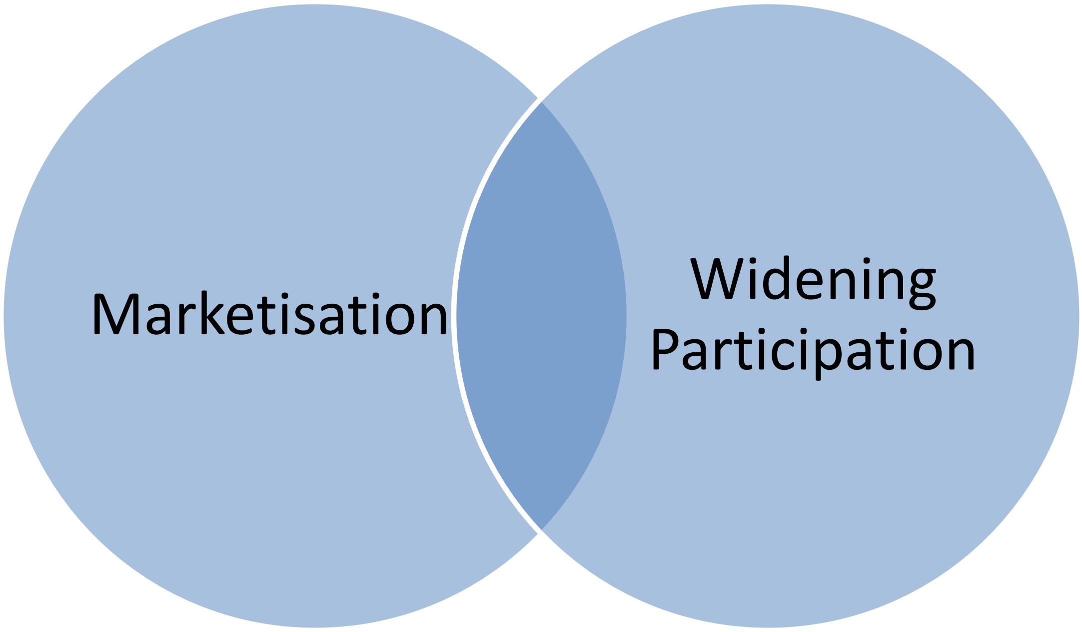
Operational Definitions

Capital	Economic, cultural and social resources that can generate the reproduction of social inequalities in society.
Field	A relatively autonomous domain of activity in which agents and their social positions are located.
Habitus	The habits developed within a particular context through an unconscious process, whereby social norms and tendencies guide thinking and behaviour in determinant ways, beyond those which individuals can control by will.
Higher Education	Tertiary education at universities or similar institutions leading to a level 4+ qualification.
Outreach	Initiatives designed to influence students' aspirations, expectations, skills and knowledge of both higher education and STEM subjects.
Science	The systematic study of the structure and behaviour of the physical and natural world.
Science Capital	A conceptual device for collating various types of economic, cultural and social capital that specifically relate to science.
STEM	Abbreviation for science, technology, engineering and mathematics, as subjects of study.
Widening Participation	Activity in education aimed at increasing the number of young people entering higher education and specifically the proportion from underrepresented groups.

Chapter 1: Introduction

1.1 Background to the Study



Levels of participation in STEM (Science, Technology, Engineering and Mathematics) education are, and have been for several years, an international (Smith and White, 2011; Australian Industry Group, 2013; Eilam *et al.,* 2016, U.S. Department of Education, 2016; OECD, 2019; Waite and McDonald, 2019; van den Hurk, Meelissen and van Langen, 2019), national (Hoyle, 2016; HM Government, 2017a) and regional concern (CECATS, 2017). Within the UK, reports from the government and employer groups frequently point out that the country faces a shortage in STEM skills. For example, the UK Government's green paper on building the industrial strategy, published in January 2017, acknowledges that the country has skills shortages in sectors that depend on STEM subjects (HM Government, 2017a). In a study by CBI/Pearson (2016), four out of ten employers in the United Kingdom reported challenges recruiting people with appropriate STEM skills. Griffiths (2012) also claimed that 100,000 STEM graduates are required annually within the UK economy and only 90,000 STEM students are graduating. Demand for people with higher skills in the science and engineering sectors was predicted to rise in the 5-year period up to

2021 (CBI/Pearson, 2016) and, indeed, the Royal Academy of Engineering forecast, in 2012, that the UK economy would require an additional 830,000 professional scientists, engineers and technologists before 2020 (Harrison, 2012). EngineeringUK (2018, p.5) claims that, nationally, “203,000 people with Level 3+ engineering skills are required per year” to meet expected demand through to 2024. Such forecasts are echoed by the SThree Group, a UK-based recruitment organisation focusing on STEM industries, which expects life sciences roles to grow by 121% in the next 10 years and engineering roles to grow by 115% (SThree, 2020). They go on to suggest that there is no evidence of increased numbers studying STEM subjects, a concern shared by Hoyle (2016), presenting doubts that the STEM skills gap will close soon.

Such figures reflect a prominent national policy discourse concerned with securing a pipeline of future scientists and engineers, where STEM industries are seen as critical to the future economic success of the country. National concerns are replicated at a regional level, where it is reported that there are not enough young people leaving school with the skills or aspiration to work in technology and science-based industries to meet the current demand from companies for employees with STEM related skills (CECATS, 2017). Nurturing talent and developing skills to meet the needs of such sectors are seen as a priority and, in this context, increasing participation in higher education science and engineering is seen to matter in terms of economic development regionally, nationally and globally.

A related strategic priority for UK governments is the widening participation agenda in higher education. Widening participation aims to address disparities between different socioeconomic groups in benefiting from higher education opportunities and, as Williams (2013) argues, brings about social justice through the possession of a degree. The exchange value of the degree in the labour market brings about the ‘justice’. This is particularly evident in the fields of science and engineering, where good levels of scientific literacy can benefit individuals, through science qualifications commanding strategic value in terms of enhancing educational and career options (Claussen and Osborne, 2013), and through average lifetime earnings being greater for science graduates than non-science graduates (de Vries, 2014). Increased science literacy also enables individuals to make more informed decisions about their health or critically evaluate proposed government policies. However, whilst there is some evidence of change (e.g., Institute of Physics, 2018; JCQ, 2019), over the last

20 years participation levels in science have remained relatively stable, as well as stubbornly patterned in terms of students' occupational background, ethnic group, age and gender (Smith, 2011; Smith and White, 2011; Johnson, 2011; Vignoles and Murray, 2016). Only a quarter of secondary school pupils in England study two or more STEM subjects at A level (A.T. Kearney, 2016) and the subsequent progression into STEM subjects in higher education (H.E.) is limited. STEM subjects also remain primarily the preserve of traditional-age, white students from higher socioeconomic classes, with other social groups excluded from the benefits.

These agendas around widening participation and securing the pipeline of future scientists and engineers frame my professional practice.

Employed at a university in the North of England and cutting my teeth as a teacher in the years following the publication of the Dearing Report (National Committee of Inquiry into Higher Education, 1997), widening participation has not only been a key influence on the development of my professional identity in the early stages of my career, but has also been a key focus of my recent roles. The way the university positions itself in relation to widening participation has shifted however over the years, in response to the effects of marketisation, impacting on my professional practice. Whilst the university markets its widening participation credentials in terms of accessibility and being student-friendly, a structural imperative to increase student numbers drives practice on the ground. This was strikingly evident in my recent role, where the objectives were explicit in their focus on widening participation, but the outcomes – or measures of success – included increasing the number of students on STEM courses at the university. Market-driven approaches undoubtedly have a part to play in increasing participation in STEM subjects, as well as lending themselves to evaluation through the number of students who attended, the number of outreach sessions delivered, how much participants enjoyed the activities, and ultimately how many people enrol on STEM courses. The data produced through such evaluation methods is easily digestible also by the funders and managers, who, it needs to be recognised, hold the power to close off projects. Such data however give little insight into increasing student aspirations and therefore offer limited value in influencing practice around widening participation. Viewing science through a social justice lens potentially offers greater value in finding approaches to make more equitable patterns of participation. My approach to the study is conflicted around the desire to influence meaningful change in practice around widening participation in higher education science and the need to present simpler 'performance data' around the achievement of marketing goals.

At a broad level, the focus of this study is the development of approaches to increasing and widening participation in higher education, framed by the agenda of widening participation, but also impacted by the marketisation of H.E. At this level there is cross-over with all subject areas, but I have specifically focused on science. I should therefore clarify why I think science is special. Although other occupations, such as care workers and ballet dancers, appear on the UK Shortage Occupation List (Home Office, 2022), the list is dominated by STEM-based occupations. The level of government and industry interest and investment in STEM participation to address the skills gap, I think, makes science (and engineering) distinctive. A focus on science aligns with my professional role as a science teacher, but it is important to note that I do not regard my subject as being intrinsically any more or less valuable than other subjects. I do, however, think the benefits to individuals show science and engineering to be distinctive in terms of redressing social inequality. The value in terms of social justice underpins the focus of this study on widening participation, whilst also recognising the drive to increase participation to supply the science 'pipeline' for future professionals needed by the economy.

1.2 Aim

Motivated by social justice and a desire to see more equitable access to higher education science (to widen participation), but mindful of both the need of the university to increase student recruitment and the need in the wider economy to increase the number of graduates with STEM-related skills, the aim of this research project is:

- To analyse critically approaches to increasing and widening participation in higher education science.

As such, the golden thread that permeates throughout this doctoral study is a concern for understanding ways to engage more people, from more diverse backgrounds, in higher education science, given the tension between widening participation and marketisation. Whilst much reference is made to STEM - science, technology, engineering and mathematics - in its totality, the scope of this study is limited to science as this captures the core activity in this field at the university and in my own professional practice.

1.3 Objectives

In seeking to develop a Professional Doctorate project that was tangible and feasible, and which provided valuable insights into the local context, as well as contributing substantially to the development of new ideas and approaches to increasing and widening participation in higher education science, the study addressed the following specific objectives:

1. To frame my professional practice through a critical review of the literature.
2. To investigate the key influences on undergraduate students in their choice to study science at university.
3. To investigate the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students.
4. To investigate the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital.
5. To contribute to professional practice and knowledge around increasing and widening participation in higher education science.

Objective 1 directs reflection on my experience to distil out what drives me as a professional, what my values are and how these values relate to professional issues. Contextualising the professional issues within the contemporary discourses on this area, through a critical review of the literature, promotes a deeper understanding of recent developments within my profession and current theoretical frameworks which have direct relevance to my professional context. Framing my professional practice in this way is important to enhance the research design and the validity of findings, as well as charting my development as a researching professional. Through the collection and analysis of empirical data, understanding the key influences on undergraduate students in their choice to study science at university (objective 2), the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students (objective 3) and the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach initiative on children's science capital (objective 4) are important to informing the development of approaches to engaging more people, from more diverse backgrounds, in higher education science. Objective 5 focuses on making a distinct contribution to my community of practice.

1.4 Structure of the Thesis

On embarking on the Professional Doctorate, the initial approach had been to create a report to accompany a portfolio of evidence drawn from my professional practice. This appealed to me as a way of developing 'on-the-ground' practice. As the study developed, along with my identity as a researcher, a more academic approach allowed me to engage more critically with the subject area. This is reflected here in the presentation of an academic thesis, with the following structure:

- **Chapter 1: Introduction**
  This chapter contextualises the research, explains the motivation behind the study and outlines the aims and objectives.
- **Chapter 2: Reflections around my Professional Identity**
  This chapter presents an autobiographical discussion, reflecting on the most important influences that have moulded my professional identity in relation to this doctoral study.
- **Chapter 3: Literature Review**
  This chapter presents a review of research articles and other published literature related to this area of professional practice; conducted to acquire an understanding of the topic, what the key issues are, theoretical frameworks which have direct relevance to my professional context, what has already been done on the topic and how it has been previously researched.
- **Chapter 4: Research Design and Methodology**
  This chapter presents and justifies the research design process adopted in this study.

- **Chapter 5: Results**

  This chapter presents the analysis of data obtained from three separate studies conducted with undergraduate science students, university staff involved in the delivery of science outreach and participants involved in a specific science outreach initiative. The individual studies seek to address objectives 2-4 but together they aim to inform a critical analysis of approaches to increasing and widening participation in higher education science.
- **Chapter 6: Discussion**

  This chapter considers the studies' findings in light of predicted results, current literature and current practice. The analysis explores the factors leading a student to study higher education science and practices around increasing and widening participation in higher education science.
- **Chapter 7: Conclusions and Contribution**

  This chapter brings together the findings from the professional doctorate project to address each of the objectives. It considers the contribution to my community of practice, both in terms of professional practice and knowledge, as well as reflecting on the research quality and proposing areas for future research. The chapter ends by reflecting on my journey as a researching professional in terms of personal and professional development.

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Chapter 2: Reflections around my Professional Identity

2.1 Introduction

As Fulton *et al.* (2013) explain, part of a doctoral journey is about exploring what drives me as a professional, what my values are and how these relate to professional issues within my project – essentially unpicking my professional identity. As defined by Slay and Smith (2011, p.85), professional identity is “one's self-concept based on attributes, beliefs, values, motives and experiences” within a professional role. The motivation for this study was grounded in my professional identity and so unpicking it was important. It was only through developing a deep understanding of my professional identity, and how it influences my behaviour, that I could make sense of my interactions within my community of practice and how I contribute to professional practice. It was important to also recognise that, as a teaching professional with over 20 years' experience, I may have been blinkered to alternative perspectives by the established norms, behaviour and culture of my community of practice, which Bain, Cooper and Sanders (2013, p.50) describe as “being deeply entrenched in a professional way of knowing”. Recognising how much I was influenced by the tacit understandings that shape my thoughts and feelings, as Bain, Cooper and Sanders (2013) encourage, enabled me to view my profession from fresh perspectives.

How I think, make judgements, and interact with other professionals in my current role is determined by my previous experiences – all the way back to childhood. Fulton *et al.* (2013) describe how one's professional identity is shaped by the values, beliefs and attitudes gained in childhood and which then develop over the years through personal and professional experiences. Reflecting on my career shows my personal and professional perspectives often intersect, often grounded in values and beliefs gained as a child. The aim of this chapter is to reflect on my journey leading to the conceptualisation of the research project and consider the most important influences that have moulded the development of my professional identity, and in turn this doctoral study. In so doing, it aims to bring into focus my values and the assumptions that are integral to my professional practice, and articulate how my background influences my positioning in relation to the topic. Reflections that were important initially in conceptualising my professional identity, but did not link directly to my golden thread, have subsequently been removed. Reflections on my journey as a researching professional in terms of personal and professional development can be found in chapter 7.

2.2 Route into Higher Education Science

To explore the area of participation in higher education science, it is useful to reflect on my pathway onto and experience of degree-level science.

At primary school I was studious and embraced all aspects of school life. Sport was important to me, and I was proud to represent the school at swimming and rugby. Academically, although not conscious of individual subject areas, I very much enjoyed investigations into nature and, on reflection, therefore had a keen interest in biology. It is interesting to note the writings of Cridge and Cridge (2015) here, when considering that much of my recent teaching has been around the subject of biology. Cridge and Cridge (2015, p.39) assert that "it is widely accepted that by around 10-12 years of age (late primary school) students have largely decided the general field of work that they want to be involved in" and that these early decisions are relatively stable - this seems to have played out to some extent in my own personal and professional development. This is explored further in section 3.10. On a similar note, Buzzanell, Berkelaar and Kisselburgh (2011) argue that by the age of 10 many children have made preliminary decisions about their career track. Whilst I can relate to this claim to some extent, my education and career has taken several twists, often unplanned and, by the age of 10, I certainly did not have any firm plans about my career.

During secondary school I realised my strengths lay primarily in the languages, followed closely by biology, although I did achieve consistently good O level grades across all subjects. I remember facing a dilemma when I needed to choose my options for A levels. I was keenly interested in studying languages to a higher level, but also had an interest in the sciences. It is interesting to locate this decision alongside the work of Eccles *et al.* (1983) around expectancy-value theory, Bandura (1991) around social cognitive theory and Lent, Brown and Hackett (1994) around social cognitive career theory, as well as the work, for example, of Wang (2013), Dutta *et al.* (2015) and Mau, Chen and Lin (2019) (see section 3.7), who advance that self-efficacy is an important factor in educational choices. To me, at the time, taking either the route of languages or science seemed like a viable option, as I had confidence from my O level results, in my ability to be successful in both subject areas. Through working with young people in a teaching career spanning over 20 years, it is abundantly clear that confidence levels vary dramatically between individuals, and this can impact significantly on a student's perception of their ability to be successful in a subject area.

Ultimately, my choice of A level subjects was swayed by the transferability of science qualifications. I recall rationalising that if I gained higher qualifications in science, I could learn languages at a later stage, but that the reverse would be more difficult. The value of science qualifications in the career market was undoubtedly an important influencing factor on my decision. My own decision-making mirrors the work of Osborne and Collins (2000), Cleaves (2005) and Butt *et al*. (2010) which has highlighted how the value a science education to a young person's university and/or career options can positively influence engagement in the subject. Understanding the extrinsic value and broad application of science qualifications is also a key dimension in science capital, which is explored further in section 3.10.

An important factor in shaping my decision to progress to university to study science was my family, particularly my parents, who were extremely supportive. Drawing on the work of Cleaves (2005), Smith (2007) and Harackiewicz *et al.* (2012), I can recognise that my parents nurtured my interest in science subjects, as they valued studying science for future success. However, progression to university proved challenging and Bourdieusian theory (explored further in section 3.8) provides a theoretical perspective on how my family may have lacked the social capital, as well as cultural and economic resources, that would have smoothed the pathway to university. I was the first from my extended family - which my father would have proudly referred to as working-class - to consider studying at university and progression to higher education represented a move to an unfamiliar field. I remember discounting elite universities completely from my deliberations because I did not feel that I would fit. Although I invested time and effort in researching and visiting different universities, my first choice was chosen because of its proximity to home. With reference to Bleazby (2015), I wonder now how this period in my life may have been different had my family been able to activate and deploy more capital to support my progression to university and my career aspirations.

Pertinent to this study also are the political and social conditions that existed when I was studying at university as an undergraduate student compared to the conditions today. As Berger and Luckman (1991) argue, what it means to be a student at any given point in time is a social construction, which changes with the prevailing political and social conditions. My experience of being an undergraduate student was different to the experiences of students today. Whilst I had invested time and effort in researching my first choice of degree and university, the choice of my final destination was much less considered. On reflection, there did not seem to be the same level of pressure to make the right choices that exists for today's students. In my teaching role, I have seen large numbers trawling open days, notably, with their parents (I recall attending any open days alone) in an attempt, it could be argued, to navigate their way through a higher education marketplace, within which universities are competing for students (explored further in section 3.2). As such, students are bombarded by marketing messages as universities attempt to distinguish their offer from that of competitors and increase student recruitment.

The structural imperative for universities to increase student numbers has arisen due to changes in the funding model for higher education, which, at an individual level, has made the financial situation for today's students very different to when I was an undergraduate student. For me, tuition was free and grants, as well as other benefits, were available to support with living costs. Nowadays, students in England are faced with tuition fees of over £9000 per year, with loans to support with living costs. My perception as an undergraduate student of the purpose of higher education will most likely be very different to that of current students. Whilst I did choose certain optional modules with a view to their value in the career market, as well as seek work experience during the vacations – and thus viewed higher education at least to some extent as an investment in self - the concept of individual employability was not particularly strong. My overriding identity was that of a 'student', in pursuit of knowledge, and in contrast to discourses in the current higher education context of students as recipients of a 'student experience' or consumers (explored further in section 3.2).

In the context of this study, aimed at critically analysing approaches to increasing and widening participation in higher education science, it must be acknowledged that the factors that influenced me to progress in post-compulsory science were in a different political and social context. It is important to understand the priorities of current students within the background context of shifting higher education policy.

2.3 Formative Years as a Science Teacher

After graduating with a science degree, I spent six years working in a variety of jobs before deciding to progress a professional career; a decision which prompted an in-depth analysis of my beliefs, values, motives, likes and dislikes. Wright (2013) espouses the importance of critical reflection for developing self-understanding and the power of reflection is evident through my own experience in that it provided the basis for entry into the educational profession, which despite its many challenges and frustrations, has ultimately proved immensely rewarding.

I joined the university to teach science in the year after the publication of the Dearing Report (National Committee of Inquiry into Higher Education, 1997). Government policy was committed to expanding the number of students entering both further and higher education and this period saw a proliferation of widening participation initiatives. The Government was equally committed to the retention of these students and David Blunkett, Secretary of State for Education and Employment at the time, highlighted the increased focus from Government on student ‘drop out’ in his guidance to the Higher Education Funding Council for England (HEFCE):

> “I expect to see the [funding] Council bear down on the rate of ‘drop out’”.
> (Blunkett, 2000, para. 11)

It should be noted that, at the time in the United Kingdom, education was increasingly being conceived by the Government as part of an audit culture, underpinned by two key assumptions. The first was that, given the high level of public expenditure on education, the service should provide ’value for money’, driving a focus on public accountability. UK governments were increasingly calling for both further and higher education to provide information about performance, requiring some measure of educational value and a spotlight on quality indicators of various kinds (Hodkinson and Bloomer, 2001; Loukkola, Peterbauer and Gover, 2020). The second assumption was that the twin policy objectives of greater social inclusion and enhanced economic competition should be met through continual improvement in the quality of education and learning. Again, it was assumed that outcome measures were needed and therefore, in this context, the focus on student completion rates intensified.

The policy priority of retention was driven through the funding bodies, with educational institutions being accountable to the funding bodies for quality measures on completion. Educational institutions, such as the university where I was employed, were, therefore, directly influenced at both a strategic and operational level by the funding bodies. Through the funding mechanisms, the university was directed to reduce ‘drop out’ rates. I felt that, for the university to respond effectively to this pressure and increase completion rates, it was necessary to understand the issues of non-completion at the institutional level. The reasons some students completed their course, whilst others left early were under-researched in the U.K. at the time (Longden, 2002). To contribute to a better understanding of these issues, through the framework of a Masters degree, I explored non-completion of full-time further and higher education courses at the university.

Whilst the study was aimed at understanding the issues around the non-completion of courses, some of the learning is applicable to this doctoral study, which is investigating approaches to increasing and widening participation in higher education science. Some of the theoretical underpinning for the study was based on the work of Tinto (1993), who suggests that initially students’ background characteristics influence commitment to a course, but this can be extrapolated to a commitment to a career in science and engineering. As explored in section 3.4, many of the studies into participation levels in science and engineering are seen through the lenses of race, gender, age and class. Another key influence was the work of Bean (1980), who presented a model which similarly considered the background characteristics of students and influences on a student’s beliefs, which he argued in turn shaped attitudes and behaviours. This resonates with the research of L. Archer *et al*. (2016) showing the influence of attitudes on progression in science (see section 3.10).

Dearing also facilitated the introduction of tuition fees, advancing that the costs of education should be met in part by graduates, and basing proposals for a new funding regime on the assumption that market regulation was necessary to achieve quality and efficiency (National Committee of Inquiry into Higher Education, 1997). Whilst Williams (2013) argues that other factors contribute to the construction of a consumer model of higher education, the introduction of tuition fees is commonly imagined as the birth of the student consumer. Particularly pertinent to this study, as Paricio (2017) argues, the construction of students as consumers within a H.E. marketplace shifts the paradigm in higher education. In contrast to a community of academics and students seeking universal knowledge, higher education. is conceived by students as a financial investment in the self. This has brought post-graduation employment prospects more central in the decision-making process of students and meant the university became increasingly concerned with marketing. The emerging employability agenda later became central to the development of my own professional identity, whilst the increasingly competitive market within higher education has created tensions in delivering the widening participation agenda.

2.4 Academic Identity

Having now taught higher education science for over 20 years, reflecting on my professional identity, as a university academic, illuminates the key influences on my decision to embark on doctoral study. The reflections also provide a starting point for charting my development as a researching professional (considered in section 7.7) and the conceptualisation of this research project.

Academic practice can be viewed as comprising three conventional elements - teaching, research and service (Macfarlane, 2011) - represented in figure 2.1.

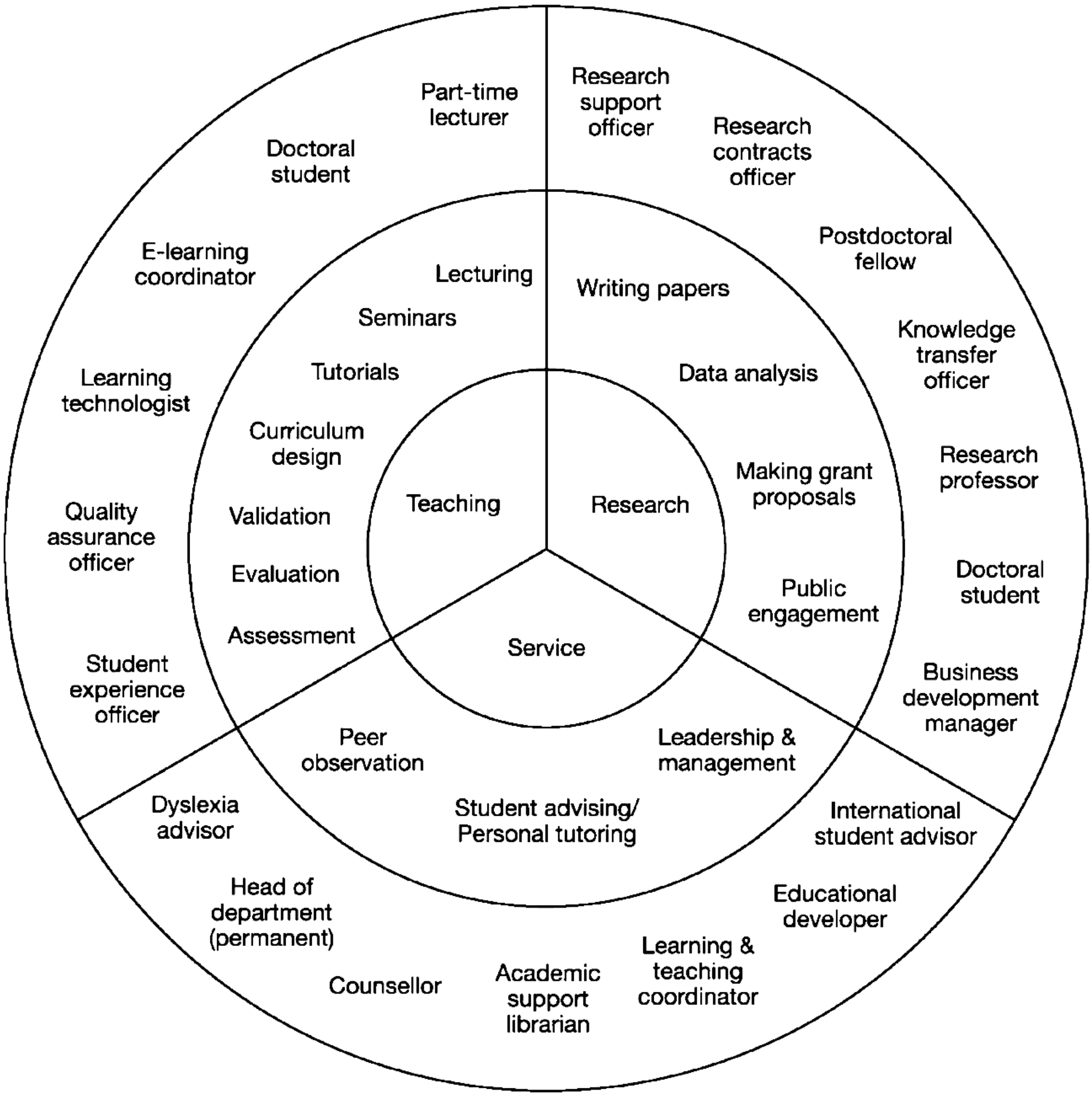

Figure 2.1 The disaggregation of academic practice (Macfarlane, 2011).

Identifying primarily as a science teacher, I always felt that teaching and learning support were the most important parts of my role and it is the area to which I undoubtedly dedicated the most time. Working directly with students to support their learning and development has always been a central focus of mine. Apart from reading academic papers to develop learning materials and apply the knowledge to teaching, research and scholarship did not feature greatly. This was partly due to time constraints, but also partly that I attached less priority to it. Whilst I was always aware that discipline research and scholarly activity was an academic requirement, my performance was never measured in this area and inevitably therefore less importance was given to it. It is notable how performance indicators have driven the focus of my academic practice in this way. Research however moved up the agenda within the university and a much stronger expectation developed that all staff would be engaged in research. This left me feeling exposed, but with more incentive to develop my research activity.

A large proportion of staff within the science area were/are research active, with numerous publications to their names, and comparisons between them and me were unavoidable. I felt that all the good work done in teaching and learning was undervalued and at the same time I felt daunted by a mammoth task of developing a meaningful research profile. This observation of 'value' fits in very much with the literature. Bourdieu (1986) describes a university's assets as academic and scientific capital, with scientific capital being traditionally of higher value than academic. Hughes (2005, p.11) speaks of 'myths' in research / teaching relationships and one such myth being "the superiority of the lecturer as researcher". Sikes (2006) points out that status and resources tend to be attached to those deemed research active, whilst Macfarlane (2011, p.71) also talks about teaching being a “Cinderella activity [compared to research] despite institutional rhetoric”.

The balance of research and teaching within academic practice and academic identity is debated (e.g., Lapoule and Lynch, 2018; Berbegal-Mirabent, Mas-Machuca and Marimon, 2018), but, at the time, I felt that a good teacher needs to show evidence that, at the very least, they are aware of up-to-date knowledge and have a broad understanding of their field. Whilst I appreciated that one way of being able to do this was through research and doctoral study, I did not subscribe to the view that a doctorate would necessarily improve the quality of my teaching or the quality of the learning experience I provided to the students. Given that I had to engage with a wide range of subjects and students (often first years), who needed a lot more support than knowledge of the subject or the research process that a narrowly focused PhD would provide, I felt my efforts to increase my teaching knowledge and skills were equally valid.

Nevertheless, based on the conventional view presented by Macfarlane (2011), my own academic practice was not fulfilling the holistic nature of academic identity. Data published by the Higher Education Statistics Agency (HESA) (2010) suggest that my academic practice at the time was perhaps in line with most of the academic community. This suggestion is further supported by Macfarlane’s (2011, p.64) claim that “the low proportion of staff returned in successive research assessment exercises by a large number of UK universities indicates that many ‘academics’ are principally teachers rather than all-round academics”. However, I accepted that research is important to fulfil the holistic nature of academic identity, providing the initial trigger for embarking on the professional doctorate programme.

Pedagogical research held more interest for me than subject discipline research and over the subsequent years I took steps to become more research active. This chapter of my career is set in the period following the Browne Review (explored further in section 3.2.4). Whilst tuition fees were introduced in 1998 in response to the findings of The Dearing Report, following the Browne Review (Department for Business, Innovation and Skills, 2010) a new model of university finances was introduced in 2010, based primarily on student fees as opposed to government grants.   This new finance model fundamentally changed how universities work. Whereas in the past, universities received grant-based funding from the government, they now depended more heavily on income from tuition fees. This created a structural imperative to rapidly increase student numbers to bring in more income and created an environment where universities compete for resources and status in a market-driven system.

With rising tuition fees and an increasingly competitive graduate marketplace, employability development in higher education became increasingly important and provided the context for entry to the professional doctorate programme. I was interested in understanding how students’ understanding of their employability could be enhanced, how best to support students in recognising the value of their employability and how students’ ability to articulate their employability to employers could be increased. These interests formed the basis for my original research proposal. I viewed employability as important in supporting individuals to secure graduate-level employment in STEM-related fields and enjoy the benefits that a good level of scientific literacy can bring, and thus felt it dovetailed with my values on social justice. This, I felt, complimented the value I place on widening participation. My practice was geared, however, towards increasing the percentage of science graduates who were in study or employment, reported in the Destination of Leavers from Higher Education (DLH.E.) survey, and uncritically towards the supply of future STEM professionals required by the economy (explored further in section 3.3), rather than any concern with social justice. On reflection, this approach does not sit comfortably with my core values, but, under pressure to ‘get the job done’, I had not considered how employability overlooks how structures such as social class, gender and race can frame opportunities for individuals. The process of framing my professional practice within relevant contemporary discourses and engaging with theoretical frameworks led to the recognition that structural factors constrain access to higher education, as well as employment, and to a shift in the focus of this doctoral study. The work done around employability now sits outside its scope but will form the basis of future research outputs.

Theorisations of capital, and in particular its refinement to science capital, provided a lens for viewing approaches around access to higher education science to address an issue I encountered in my own professional practice. In terms of employability the emphasis of my professional practice centred on undergraduate students, but I was also involved, as part of my academic role, in delivering outreach activities aimed at 'inspiring the next generation of scientists'. These activities were organised as marketing or widening participation initiatives (see section 3.6), in liaison with schools and colleges, and, whilst I enjoyed working with younger students, the activities became a source of increasing frustration. Some activities were unashamedly focused on recruitment to science programmes, adopting a pure marketing approach to increase participation in higher education science. Others were couched in terms of widening participation, but whilst the target audiences may have differed, there was little other differentiation in terms of the design and delivery of the scientific content. The evaluation of all science outreach activities was limited to the use of ‘happy sheets’, where participants were asked to rate their enjoyment of a session or how interesting they found the session. Undoubtedly in my case, and I suspect in the case of my science colleagues also, this focus limited the design and delivery of activities to meet the marketing needs of the university, with little consideration given to the wider factors that influence young people’s participation in post-compulsory science education. With the measures of success limited to the number of students who attended, the number of outreach sessions delivered and how much participants enjoyed the activities, the data could be used to confirm whether marketing targets had been met, but often had minimal value in understanding the impact on student aspirations. Given my years of teaching experience, I knew that I could deliver an interesting, engaging, and enjoyable session. What I did not know was whether my efforts had had any effect on raising aspirations or progression to higher education science. Theoretical models provide a lens for viewing my experience of progressing into higher education science (see sections 2.2 and 3.7) and they also provide a lens for understanding ways to support the development of values, attitudes, expectations and behaviours in young people that promote participation in science, given the tension between widening participation and marketisation. Drawing on such theories, this doctoral study provided a framework for critically analysing approaches to increasing and widening participation in higher education science, with a view to contributing to professional practice and knowledge in this area.

2.5 Summary

Reflective practice, as a process in which practitioners reflect and learn from their own teaching experience to develop their pedagogic skills and professional practice, is espoused within the teaching profession (H.E.A, 2015). However, as Bain, Cooper and Sanders (2013) explain, experienced professionals have very limited time for reflection. Instead, to meet the numerous deadlines, reliance is placed on the tacit professional knowledge, with reflection only at a surface-level as to how teaching methods can be improved. In-depth, critical reflection had facilitated my entry into the teaching profession and yet 20 years later I was undoubtedly relying on my tacit knowledge to operate within my professional environment. Through this autobiographical account I have explored the key past influences that have shaped my professional development and, in considering my values and beliefs, have developed a deeper level of thinking about my current professional practice.

My professional identity is underpinned by a concern for social justice, which, within the higher education context, is framed by agendas around widening participation, marketisation and employability. As the first from my extended family to go to university, I have first-hand experience of the benefits that higher education can bring. Entering the teaching profession just after the publication of the Dearing Report (1997), the widening participation (WP) agenda was highly influential in my formative years as a teacher and a concern for providing equitable access to education has remained a thread throughout my career. Through subsequent policy reforms, in more recent years, the employability agenda has increased in prominence in higher education, becoming another key influence on my professional identity, whilst marketisation has generated a structural imperative to increase student numbers, creating a tension in my professional practice around engaging more young people, from more diverse backgrounds, in higher education science.

Through this reflective journey, my focus has shifted from an unquestioning embrace of the employability agenda to a critical analysis of approaches to increasing and widening participation in higher education science. This shift circumscribes the scope of the study, which can be viewed in terms of a young person's journey up to the point of entering higher education, rather than progressing from a degree into graduate-level employment.

The chapter brings to the fore what drives me as a professional, what my values are and how these relate to professional issues within my project. Developing an explicit understanding of my values and assumptions frames who I am within my role as a researching professional, thus bringing greater validity to the findings of this doctoral study. The next chapter considers the literature which relates to the professional issues to contextualise my study within the contemporary discourses on this area.

Chapter 3: Literature Review

3.1 Introduction

> "Research is greatly strengthened by placing your new information in the context of what is already known about the issue" (Laws, Harper and Marcus, 2003, p.213).

A systematic literature review is important within research to understand what the key issues are, what others have written on the topic and how it has been researched (Hart and Bond, 1998; Byrne, 2017). This chapter reviews the literature relating to this study. The focus of this study is on participation in higher education STEM (science, technology, engineering and mathematics) subjects (most specifically the science subjects) and is framed by the widening participation agenda in higher education and the marketisation of higher education. Within this context, this chapter draws upon the theory and empirical studies relating to post-compulsory participation in STEM subjects. As a professional doctorate student, I am particularly interested in the application of knowledge to advance professional practice and hence the chapter also draws on professional reports and studies into professional practice. Figure 3.1 shows the main sections of the literature review chapter (in brown boxes) and the key concepts presented in each (in green boxes). The chapter starts with a review of key policy reforms in higher education (section 3.2), which illustrates the development of agendas in higher education that frame my professional practice and this study. This section is presented alongside all other sections in figure 3.1 to represent the nature of the reforms in providing the background context for my professional practice and the study. The next section explores the literature around concern for increasing and widening participation in STEM subjects (section 3.3), highlighting a very important distinction between economic and social justice perspectives. Section 3.4 considers the stratification of participation levels in STEM subjects and section 3.5 examines the reasons for the disparities. Broader considerations around participation in higher education are placed alongside considerations around participation in science more specifically. Strategies for widening participation in higher education science are considered in section 3.6, focusing on university-led outreach and contextualised admissions. Section 3.7 presents the theoretical influences on this study, leading to

Bourdieu’s theory of social reproduction (section 3.8), as a theoretical explanation of patterns of inequality in which the interplay between agency and structure is foregrounded. Section 3.9 explores how the conceptual lens of capital helps with understanding how young people construct their identities, alongside wider structural factors that impact on their life chances. The final section of the literature review (section 3.10) looks at the refinement of the conceptual lens to science capital to explore participation in higher education science, which leads into data collection for this study.

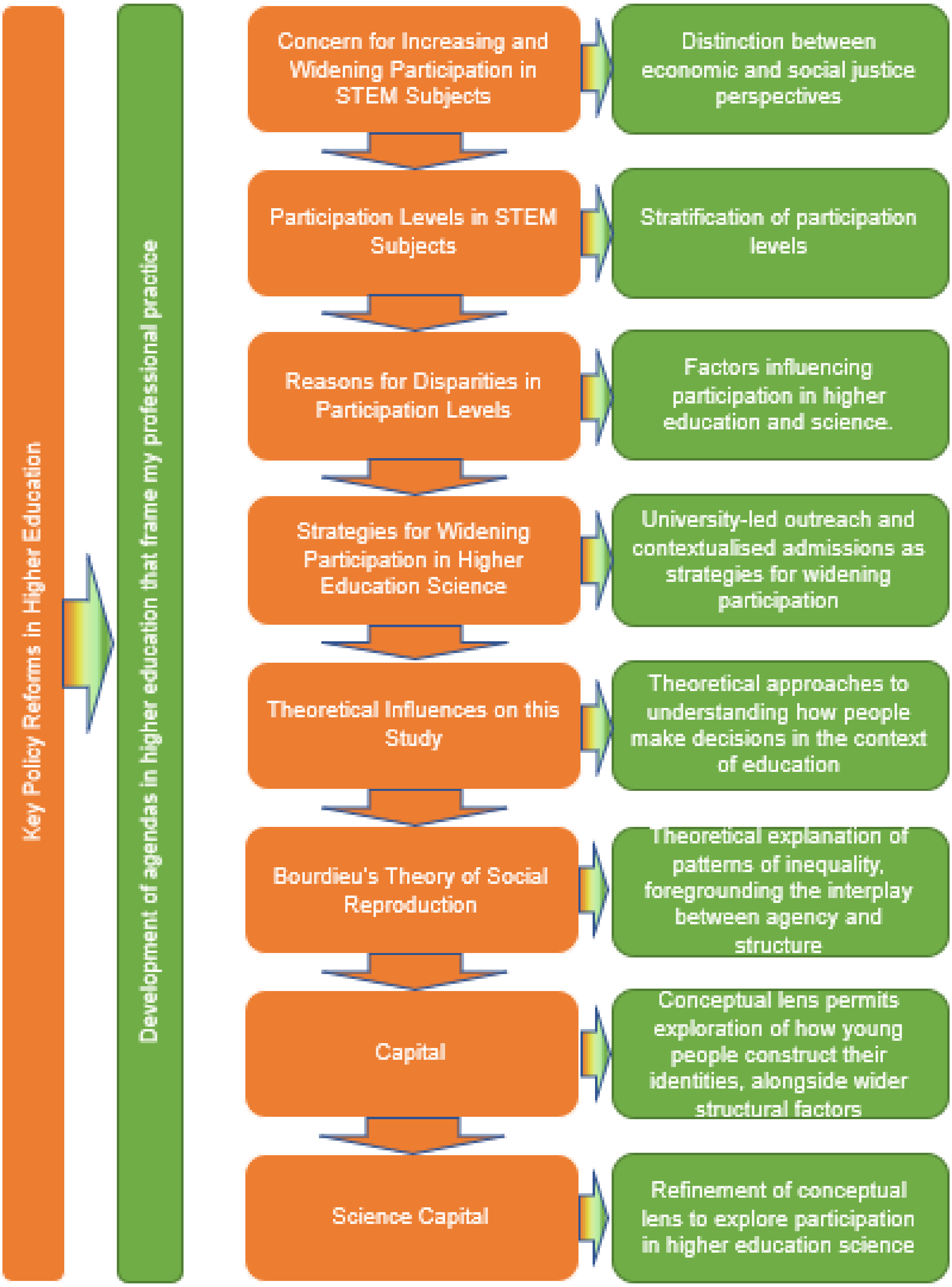

Figure 3.1 Diagram showing the main sections of the literature review chapter and the key concepts presented in each.

3.2 Key Policy Reforms in Higher Education

3.2.1 Overview

In a sense, to understand the context of this study it is necessary to fundamentally question the purpose of higher education. Wilhelm von Humboldt, a German diplomat and philosopher, considered this in 1810 and argued the importance of a common search for knowledge of a general nature, beyond vocational education, by the whole community of academics and students (cited in Swain, 2011). Newman deliberated over the purpose of higher education again in 1852 and concluded a university was about teaching universal knowledge (Newman and Turner, 1996). The purpose of higher education has changed over more recent years. In response to the social and political context, universities are no longer singularly concerned with educational purposes and the transmission of knowledge to the next generation of citizens. Now they are more often expected to serve non-educational purposes relating to widening participation and individual employability, within an increasingly marketised landscape. This shift – often painted in the literature as a change from the perception of knowledge as a public good to a private good – has resulted in trends of consumerism permeating all aspects higher education practices (Holmwood, 2016), to the point where some warn that universities should not be viewed as "intellectual vending machines" (Sacks, 2020, p.7). This transformation from the image of a university as a community collectively engaged in the collaborative pursuit of truth to one increasingly driven by the values of the market, where studying for a degree is conceptualised as "an individualised self-investment" (Johnson *et al.*, 2019, p.470), provides the background context for this study. Understanding the forces shaping decision-making in higher education in general, and in particular the current focus on its contribution to human capital and instrumental economic goals, is important for understanding the positioning of approaches to increasing and widening participation in higher education science. Four key policy reforms that have been particularly influential in shaping the higher education context are shown in figure 3.2 and discussed below. These are the Robbins Report, the Dearing Report (formally known as the reports of the National Committee of Inquiry into Higher Education), the Browne Review and the most recent review chaired by Philip Augar. Each will be discussed in turn.

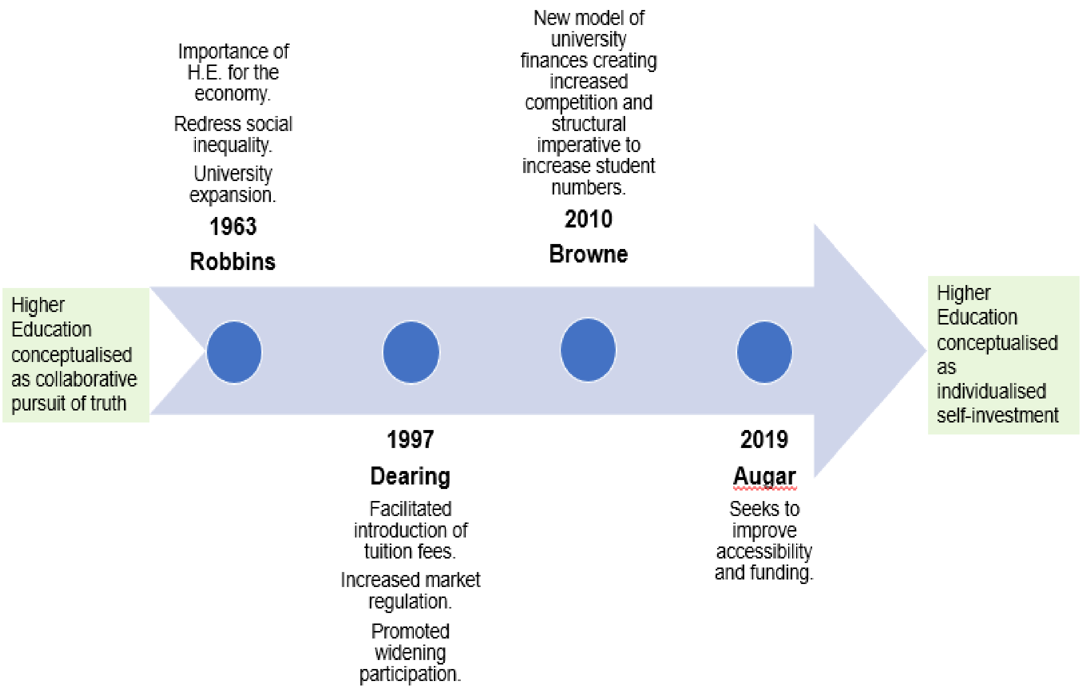

Figure 3.2 A timeline of key policy reforms and their significance to higher education science.

3.2.2 Robbins Report

In 1963, Lord Robbins, in his report to the government on the future of higher education, identified four functions of universities: "instruction in skills" (para.25), "promotion of the general powers of the mind" (para.26), "advancement of learning" (para.27) and "the transmission of a common culture and common standards of citizenship" (para.28) (Committee on Higher Education, 1963). Whilst recognising that higher education should extend beyond teaching solely what will be of some practical use, it is notable that Robbins placed 'instruction in skills' first to foreground the importance of higher education for the economy, and his report went on to consider that most would participate in higher education to enhance their employment prospects. It is also notable that the Robbins Report spoke of "the transmission of a common culture and common standards of citizenship" (Committee on Higher Education, 1963, p.7) in terms of equality of opportunity, tasking universities to provide places for students from all classes and create atmospheres in institutions that "in some measure compensate for any inequalities of home background" (Committee on Higher Education, 1963, p.7). In doing so, the Robbins Report introduced an objective of higher education to redress social inequality.

The importance of higher education for the economy and a focus on social inequality are pertinent to this study, but the most notable legacy of Robbins is that of university expansion. As an undergraduate student during this era of university expansion, my experience as a student of higher education is described in section 2.2.

3.2.3 Dearing Report

The Dearing Report (National Committee of Inquiry into Higher Education, 1997) was commissioned to try find policy solutions to Robbin's legacy of university expansion. Higher education in the UK had expanded from a participation rate within 18-21-year-olds of 8.4% in 1970 to 32% in 1995 (Bill, 1998); a very significant increase in student numbers that had taken place at the same time as core funding had reduced. Against this backdrop, the Dearing Inquiry Committee was tasked with making long-term recommendations on the purposes, shape, structure, size and funding of higher education. More precisely, it was instructed to have regard to the following principles:

- students should be able to choose between a diverse range of courses, institutions, modes, and locations of study
- there should be maximum participation in initial higher education
- learning should be increasingly responsive to employment needs and include the development of general skills widely valued in employment
- that the effectiveness of teaching and learning should be enhanced
- standards of qualifications should be at least maintained and assured
- value for money and cost-effectiveness should be obtained in the use of resources.

(National Committee of Inquiry into Higher Education, 1997, p.3)

The Committee was also instructed to take into account the context, where, amongst other considerations, it was recognised that students were entering higher education from a wider range of backgrounds, that higher education has an important role in the implementation of government policies and meeting the research and postgraduate training needs of science and engineering industries, and that higher education should continue to enable personal development for not only the benefit of individuals, but also wider society (National Committee of Inquiry into Higher Education, 1997, p.4).

The Inquiry made a total of 93, wide-ranging recommendations, to funding bodies, student unions, employers, research councils and the Government (49 recommendations were addressed to the government). Of particular significance to this project are the recommendations around the funding of higher education. The Dearing Report established the principle that “students should enter into an obligation to make contributions to the cost of their higher education once they are in work” (National Committee of Inquiry into Higher Education, 1997, p.2) and, as such, facilitated the government to introduce tuition fees. More widely, in grounding proposals for a new funding regime in the philosophy that quality and efficiency could be most effectively achieved through market regulation, the Report endorsed a growing perception of higher education as a private rather than a social good.

The Dearing Report also promoted widening participation and offered recommendations on how patterns of underrepresentation from some socioeconomic groups might be addressed (National Committee of Inquiry into Higher Education, 1997). The Report recommended a range of measures, such as prioritising funding to those organisations that can prove a commitment to widening participation through having a strategy and a mechanism for monitoring progress in place; directing funding through pilot projects to institutions who recruit students from disadvantaged areas; and funding initiatives aimed at addressing low expectations and achievement to increase the take-up of higher education opportunities.

Significantly also, the Dearing Report provided the foundation for a unitary higher education system, proposing greater consistency between the pre- and post-1992 institutions around strategy development and governance, and steering universities towards common purposes. In changing the remit of the Quality Assurance Agency (QAA), which brought greater audit, regulation and managerialism, the impact was heightened public accountability of universities, operating under increased governmental influence.

The Dearing Report has been described as quickly becoming shelf ware (Birch, 2017), however, it had an important part to play in shaping the foundation for the current higher education system. It also had a very important part to play in shaping my professional identity (see section 2.3).

3.2.4 Browne Review

Whilst tuition fees were introduced in 1998 in response to the findings of The Dearing Report (National Committee of Inquiry into Higher Education, 1997), a new model of university finances was introduced in 2010, following the Browne Review (Department for Business, Innovation and Skills, 2010), based primarily on student fees as opposed to government grants. This new finance model fundamentally changed how universities work. Whereas in the past, universities received grant-based funding from the government, they now depended more heavily on income from tuition fees. This created a structural imperative to rapidly increase student numbers to bring in more income and has created an environment where universities compete for resources and status in a market-driven system. The Higher Education and Research Act 2017, enacted into law in 2017, created a new regulatory framework for higher education, intended to increase competition further.

The Higher Education and Research Act 2017 creates significant tensions when we look at universities fulfilling the purposes of higher education. For example, whilst the Act states "the need to promote equality of opportunity in connection with access to and participation in higher education" (House of Lords and House of Commons, 2017, p.2), high tuition fees limit the opportunities for those from lower-income families and tacitly endorse the view that higher education is only for the privileged; for those who can afford it. When universities are defined primarily by their capacity to meet market criteria, university practice is necessarily skewed towards meeting those market criteria. So, whilst widening participation may be seen as a laudable aim at institutional-level, practice is in fact primarily aimed at increasing participation i.e., increasing student numbers. Market-driven approaches to increasing participation are not necessarily effective in widening participation, which, as a review of the literature suggests (see section 3.8-3.10), requires more value-based approaches.

3.2.5 Augar Review

The Augar Review was set up to focus on accessibility and funding of higher education that met student and taxpayers' needs, with the following terms of reference:

- ensure choice and competition across a joined-up post-18 education and training sector

• create a system that is accessible to all
• deliver the skills the country needs
• deliver value for money for graduates and taxpayers.
(Department for Education, 2018, p.2)

The panel concludes that the higher education sector in England broadly fulfils these objectives, and that the expansion of England's university sector has "brought benefits to graduates, employers, and society at large" (Post-18 Education and Funding Review Panel, 2019, p.65). It reflects that the establishment of a market in H.E. has delivered many of these benefits but cautions that shortcomings exist at both institutional and system-wide levels. For example, price competition has developed differently to original expectations. With price being taken as a sign of quality, there is little differentiation between the tuition fees charged by different universities, resulting in the emergence of alternative forms of market competition, such as enhancements in teaching, pastoral support and campus facilities. This has had positive impacts in improving the student experience and raising levels of student satisfaction but has also meant universities have directed increasing levels of resources at influencing the decisions taken by applicants. The report describes how universities have increased and professionalised their marketing, citing a case of "one university spending over £3 million a year on marketing" (Post-18 Education and Funding Review Panel, 2019, p.78). Whilst the report refers to "over-enthusiastic marketing" (p.78), when a primary focus of recent government policy has been the development of a more active market environment within higher education, it is inevitable that universities would respond with changes in behaviour towards a more market-focused perspective and an increased focus on marketing strategies.

The Augar Review also concludes that "the current method of university funding has resulted in an accidental over-investment in some subjects and an under-investment in others that is at odds with the government's Industrial Strategy and with taxpayers' interests" (Post-18 Education and Funding Review Panel, 2019, p.84). Of particular significance to this project, the report describes how replacing most of the teaching grant by tuition fees in 2012 has precipitated some degree courses being over-funded relative to their reasonable cost of provision, and other degrees in STEM subjects, which as explained in section 1.1 are central to the government's Industrial Strategy, being under-funded. The Review advocates that universities should be encouraged to offer these subjects and not be financially penalised for providing them, as is currently the case.

With 53 recommendations seeking to improve the accessibility and funding of higher education, the Review has the potential to significantly influence the development of the sector in future. However, the report was commissioned by Theresa May, who resigned just a week before it was published in May 2019, and it is unclear if the current government will seek to implement these recommendations.

3.3 Concern for Increasing and Widening Participation in STEM Subjects

Within the literature, there are different rationales given for increasing and widening participation in STEM subjects. Forming a very important distinction, broadly speaking, some reports are focused on the supply of future STEM professionals required by the economy, whereas others are concerned with social justice.

3.3.1 Economic Perspective

The motivation to increase and widen post-compulsory levels of STEM participation comes in different guises, with several reports concerned with securing a pipeline of future scientists and engineers. The economic pipeline rationale is most prominent in the national policy discourse, where STEM industries are seen as critical to the future economic success of the country. The Industrial Strategy White Paper (HM Government, 2017b) is highly significant with its aim of boosting productivity and the earning power of individuals through investment in skills; specifically mentioning investment to address shortages of STEM skills. The White Paper recognises that the UK “does not have enough people skilled in science, technology, engineering and maths” (HM Government, 2017b, p.94), and identifies policies to ameliorate the current situation. Narrowing the disparities between communities in skills and education, as well as removing barriers faced by workers from under-represented groups, are seen in the White Paper as important in helping workers realise their potential but are clearly actions that will also increase and widen participation in STEM subjects. Similarly, a report by the Social Market Foundation (2017, p.5) stresses “the vital role that science, technology, research and engineering jobs play in the UK economy”. Its findings suggest that growth in STEM jobs was expected to double the rate of other occupations between the publication date and 2023, with science-focused industries expected to account for 28% of job openings (over 2.8 million jobs) by 2023. The report attributes some of the growth to the Government's commitment to investment, as detailed in the Industrial Strategy White Paper. Again, the Social Market Foundation report acknowledges the STEM skills gap, citing that the number of graduates will fall short of the number of people needed to fill the roles (Social Market Foundation, 2017, p.4). In terms of widening participation, the Foundation emphasises the need for more girls to study science subjects at school, and in further and higher education. The figure that only one in five STEM jobs is undertaken by a woman is concerning and shows the lack of gender parity – whilst also suggesting one approach to addressing the STEM skills gap could be to widen participation in terms of gender. The CBI Education and Skills Survey *Inspiring Growth,* published in 2015, also paints a disquieting picture in terms of a STEM skills gap. The findings show that there were already widespread difficulties in recruiting staff with relevant STEM skills at every level and suggest over half of businesses (52%) see a shortfall in experienced STEM-skilled staff (CBI, 2015). With the UK Commission for Employment and Skills (UKCES 2012) predicting that there would be a 13% expansion in the demand for science, engineering and technology professionals in the UK by 2020, meeting this skills gap is seen as essential to securing the future prosperity of the country. With a national focus, these reports are pre-dated by other reports highlighting similar themes. A report by the UK Council for Industry and Higher Education states that:

> the workforce of the future will increasingly require higher-level skills as structural adjustments in the economy force businesses to move up the value chain. These jobs of the future will increasingly require people with the capabilities that a STEM qualification provides (Herrmann, 2009, p.1).

The Science and Innovation Investment Framework published in 2006 (HM Treasury, 2006) identifies a need to harness scientific developments in Britain to improve the country's economic future and an earlier CBI Education and Skills Survey, *Taking Stock*, warned of skills shortages for scientists, particularly at graduate level, a decade ago (CBI, 2008).

As well as nationally, this concern is particularly pertinent to the regional context, where it is reported that there are not enough young people leaving school with the skills or aspiration to work in technology and science-based industries to meet the current demand from companies for employees with STEM related skills (CECATS, 2017).

From an economic perspective, the intersection of STEM and NEET is also a particular concern in the regional context. The NEET category of 'not in education, employment or training' refers to young people who are unemployed or economically inactive, or have not received any form of education or training, for four weeks (Maguire, 2015; Eurostat, 2019; Ralston *et al.,* 2022). Whilst the NEET rate for 16-24-year-olds in England appears to be falling, from 16.9% in 2008 to 11.2% in 2018 (Powell, 2018) and to 10.5% in 2021 (Richmond and Regan, 2022), there are still significant regional differences. The NEET rate in the North-East of England in 2021 was highest of all the regions at 11.7%, compared to, for example, 9.7% in the North-West and 9.6% in the South-East (Gov.UK, 2022).

With a focus on reducing the number of young people not in employment, education or training, STEM features prominently within the NEET agenda. Strategies to enhance employment opportunities include encouraging the development of STEM skills that are in high demand (Allen, 2014), with teachers directed to link curriculum learning with careers and especially highlight the relevance of STEM subjects for a wide range of future career paths (Richmond and Regan, 2022). Further measures to improve careers guidance, detailed in the Government's careers strategy published in 2017, intend that schools should offer every young person seven encounters with employers, including STEM employers (Powell, 2018). In creating further opportunities to enhance teaching and learning through the provision of real-life contexts and illuminating direct lines through education to employment, STEM enrichment activities are also seen as a way of reducing the likelihood of a young person becoming NEET (Morgan and Kirby, 2016) and supporting more into employment.

The literature proposes that increasing and widening participation in science matters in terms of the economic development of the country and the region. There is a national and regional drive to encourage more young people, from more diverse backgrounds, to participate in STEM subjects in response to the STEM skills gap and the rate of young people not in employment, education, or training. This level of government and industry interest, and investment in STEM participation, makes science education distinctive and the university where I work has positioned itself very purposely to meet the current and future needs of the county and the wider region. Whilst the report by the National Audit Office (2018) acknowledges some positive results from government efforts to produce more people with the right STEM skills, the long-standing nature of the skills gap and the slow rate of improvement in the national and regional NEET figures does, however, draw into question the effectiveness of previous initiatives and suggests new approaches are needed.

3.3.2 Social Justice Perspective

Increasing and widening participation in STEM subjects is more than simply about national and regional economic growth. Within other strands of the literature participation in STEM subjects is seen to matter in terms of social justice, as low levels of participation mean that individuals are excluded from the benefits that good levels of scientific literacy can bring. From this perspective, widening and increasing STEM participation is needed for reasons of social equity; that is, every individual has a right to benefit from the outcomes of society based on fairness and according to need (Stuart and Bunting, 2019).

Osborne is prominent in arguing that high levels of scientific literacy contribute to an equitable society (e.g., Osborne 2007; Osborne and Dillon 2010). Under this umbrella of science being a public good, the literature can be divided into two complementary strands.

Van den Hurk, Meelissen and van Langen (2019) argue that knowledge and skills in STEM subjects could provide a secure future for individuals; an argument supported by Claussen and Osborne (2013), in their analysis of the intrinsic value of scientific knowledge and its extrinsic value for future employment, who claim that science qualifications command strategic value in terms of enhancing educational and career options. This is further supported by de Vries (2014), who shows that average lifetime earnings are greater for science graduates than non-science graduates, as well as by research conducted by the Korn Ferry Hay Group (2016; 2017; 2022) that shows how graduates with a science qualification can earn nearly 20% more than their peers. These figures compare to the claim by EngineeringUK (2018) that graduates in technology and engineering subjects earn 18% more than the mean for all graduates in the six months after completing their courses, whilst Carnevale, Cheah and Hanson (2015) report a 34% higher starting wage for STEM graduates against other graduates, and 95% more than those who did not study in higher education. The CBI Education and Skills Survey 2015 also highlights how STEM-qualified graduates are at a real advantage in the jobs market (CBI 2015). Interestingly, Claussen and Osborne (2013) do argue that formal science education does not represent well the value of an education in science and suggest that emphasis is often on areas that do not hold any value to young people. In contrast, it can be argued that initiatives aimed at increasing participation in STEM subjects ultimately bring less benefit to individuals. Macilwain, for example, writing in *Nature* (2013), argues that such initiatives distort the labour markets and depress wages.

As well as strategic value in terms of educational and career options, science provides general knowledge underpinning everyday life (NFER, 2011). As Fischhoff (2013) and Hartmann (2013) both argue, whether employed within a STEM-related field or not, increased science literacy benefits individuals throughout their lives by allowing them to make sound choices about complicated issues. Individuals, for example, are more able to make informed decisions about their health or critically evaluate proposed government policies. This is exemplified in a study by Osborne and Collins (2000) where women were concerned that their children should be able to use a knowledge and understanding of science to see through the use of science in advertising to influence behaviour.

Besides being the right thing to do from a moral viewpoint, encouraging more people from more diverse backgrounds to engage with science will enhance the mix of perspectives involved in scientific research. This in turn should lead to better scientific research. A more representative mix of people involved in science is more likely to pursue the problems and questions relevant to the whole of society. This point is highlighted well by Rich (2022) in reference to automatic hand dryers and soap dispensers that do not react to dark skin. In a similar vein, increased diversity will lead to a more innovative scientific sector. Better decisions should flow from the wider range of perspectives brought by more diverse teams.

3.4 Participation Levels in STEM Subjects

Whether from an economic growth perspective or a social justice standpoint, there is a widely accepted need to increase and widen participation in STEM subjects. The widening participation (WP) agenda in UK higher education has in fact been driven by government policy since 1997, when The Dearing Report (1997) asserted that, "it should be an objective of policy to see that those groups who are currently under-represented in higher education come to be properly represented: as participation increases so it must widen" (National Committee of Inquiry into Higher Education, 1997, para.7.21).

However, the concentrated focus of national policy is inconsistent with the gradual rate of change in widening participation in the United Kingdom, particularly in the most selective universities (Boliver, 2015) and in STEM subjects (Kandiko Howson, Cohen and Viola, 2022). Whilst some widening participation initiatives have had some impact on increasing the diversity of the student population (Barkat, 2019), the findings of several studies evidence the inequalities that still exist in levels of participation in science, with considerable variation in terms of gender, ethnicity and social class.

Smith (2010) found that initiatives to increase recruitment to science subjects have made little long-term difference to levels of participation in higher education. Smith and White (2011) analysed data on applications and acceptances to university to investigate the effect of widening participation (WP) policies on the breakdown of students studying science degrees in the United Kingdom in terms of their social backgrounds. They concluded that the patterns of participation in science subjects have not changed over the last 20 years, in relation to ethnic group, age and socio-economic classification.

In another study, Smith (2011) investigated gendered participation in H.E. STEM subjects and concludes that widening participation (WP) initiatives have not impacted on female participation in physics and engineering. Miller and Wai (2015) similarly describe unequal patterns of participation in STEM fields based on gender. Other statistics also reveal that women are under-represented in physics, engineering and mathematics. With relative stability over 25 years, statistics show that females make up only 5% of registered engineers in the United Kingdom and only 20% of enrolments for A-level Physics (Women's Engineering Society 2017). The representation of women however is more balanced in other scientific fields (Yang and Barth 2015), such as the biological and medical fields, where currently, 46% (n=137,587) of registered doctors in the United Kingdom are female and women constitute the majority of trainee doctors (General Medical Council 2018).

Johnson (2011) also examines underrepresentation in STEM subjects due to issues of gender, as well as ethnicity. Participation levels in terms of ethnicity described in the literature are similarly patterned. Studies by Jones and Elias (2005) and Elias, Jones and McWhinnie (2006) found low levels of representation in physics undergraduate degrees from British students with Pakistani, Bangladeshi, Black Caribbean and Black African backgrounds. Van den Hurk, Meelissen and van Langen (2019) also report that young people from minority backgrounds are less likely to progress in STEM education.

Vignoles and Murray (2016) show that participation in H.E. continues to vary dramatically according to family background. Gorard and See (2009), in their analysis of large-scale official data sets, also show that participation and attainment in science are stratified by socio-economic status. Their findings show that young people from less affluent families are less likely to study post-compulsory science than many other subjects and, in those who do, lower attainment levels are likely to discourage further study of the subject. Similarly, Wang and Degol (2013), in their review of pathways to STEM career choices, conclude that young people with higher socioeconomic status are more likely to progress in STEM education.

The patterns of unequal participation have led to a number of studies aimed at understanding the reasons and a number of attempts to widen participation in higher education.

3.5 Reasons for Disparities in Participation Levels

The reasons put forward in the literature for the disparities in participation levels are complex and, as Blickenstaff (2005) describes, the interplay of several factors with the social context must be considered. Broader considerations around participation in higher education must also be placed alongside considerations around participation in science more specifically.

Literature often foregrounds how policies to increase and widen participation are framed. In the specific context of NEET, Pemberton (2008), for example, argues that providing young people with alternative choices can encourage greater participation in education. This suggests the need for policies framed in the logic of individual deficit, but these are criticised by others (e.g., Serracant, 2014; André and Crosby, 2022) for ignoring systematic and structural factors that affect the pathways of young people. As the social and economic contexts in which young people live and learn are determinants of educational disadvantage, Kvieskienė *et al.* (2021) argue that access to resources is a critical reason for disparities in participation. Some young people must overcome significant obstacles to progress to higher education or to the next stage of their career. For example, young people with disabilities may experience an increased administrative burden to secure the study support needed to access higher education or a lack of financial resources may impede a young person from accessing careers guidance and enrichment activities. Similarly, young people from less privileged backgrounds may lack the 'social capital' needed to engage with careers services or may have access to less information about higher status occupations (Richmond and Regan, 2022).

Deficits in social capital and a lack of familiarity with the culture of higher education can also lead to many young people feeling that they do not belong at university. As Coombs (2022) asserts, "universities can seem like bastions of privilege, with unspoken academic norms and social rules" (p.11). Whilst young people from privileged backgrounds have had opportunities to learn dispositions to fit the university context, Crozier *et al.* (2008) argue that those from less privileged backgrounds have not. Social identities, such as gender, class, age, and ethnicity, can therefore influence whether a young person feels they fit in or feels like an outsider. Feeling like outsiders, because of the cultural mismatch between the backgrounds of less advantaged young people and middle-class institutions, can mean many experience insecurity about entering a new environment (Spengen, 2013). For those that overcome the barriers to attend university, the cultural mismatch can also place additional demands on some groups of students as they attempt to reconcile the tension between their sense of belonging in higher education and their homes (Reay, Crozier and Clayton, 2010), and navigate "inhospitable waters" (Crozier, Reay and Clayton, 2019; p.934).

With friendships and networks providing support in navigating systems and a sense of belonging (Stuart, 2006), recognising that these are influenced by gender, class, age and ethnicity (Read, Burke and Crozier, 2020) highlights the importance of diversity in helping young people feel that they fit in to university life. Data from recent HEPI / Advance HE Student Academic Experience Surveys, each collecting the views of over 10000 full-time undergraduate students, show the influence of diversity in relation to identity and a young person's sense of belonging (Neves and Hewitt, 2021; Neves and Hewitt, 2022). Over one in three students from the total sample in the 2022 survey felt that having a diverse student population was important to their sense of belonging, rising from one in five in 2021. Considered in terms of ethnicity, both Black and Asian students reported a diverse student population to be more important than White students for fostering their sense of belonging. Vytniorgu (2022) also reports that diversity is important to students, emphasising the need to bring people with different backgrounds together and thus suggesting, in contrast, an absence of diversity could be seen as a barrier to participation in higher education.

Data from the recent HEPI / Advance HE Student Academic Experience Surveys also shows that, from all the factors surveyed, approachable and accessible academic staff ranked foremost in students' perception of their own belonging (Neves and Hewitt, 2021; Neves and Hewitt, 2022). Being able to connect and interact with academic staff is important in supporting young people to navigate unfamiliar higher education systems; increasingly so if this support is not available from parents. Whilst for many young people (e.g., second-generation students), parental support can imbue a privileged knowledge of university life, many young people are disadvantaged by their lack of support.

As parents' beliefs, values and associated everyday practices can play an influential role in a young person's educational environment (Kewalramani, Phillipson and Belford, 2022), growing up in an environment where not much value is placed on higher education can also limit a young person's aspirations. The importance of parents in supporting progression to university is highlighted by Schoon, Burger and Cook (2021) in their study drawing on data from the Longitudinal Study of Young People in England (LSYPE). Whilst recognising that several forms of support are needed for young people from disadvantaged backgrounds to succeed academically, they concluded that parental aspirations facilitated a pathway towards participation in higher education. Although examining perceived parental expectations rather than aspirations, the findings of Chen *et al.* (2022) also highlight the critical role of parental aspirations in shaping the aspirations of young people (specifically in the field of STEM). Differences in parental aspirations across lines of class and ethnicity may therefore lead to disparities in participation levels in higher education. Through semi-structured interviews, Wheeler (2018) discovered considerable differences between the aspirations of working-class and middle-class parents. The findings show that working-class parents were “present-centred” (p.767), focused on a day-by-day basis, whereas middle-class parents pushed their children towards a particular end goal, often higher education. Studies also show that parental aspirations for their children’s educational attainment differ in relation to ethnicity. Spera, Wentzel and Matto (2009) found that, at similar low levels of parental education, White parents had significantly lower aspirations for their children’s educational attainment than did parents of other ethnicities. Similarly, Strand (2011; 2014), in his analyses of data from over 14000 students from the nationally representative longitudinal study of young people in England, found lower parental aspirations resulted in lower educational attainment in White students compared to minority ethnic groups at low socioeconomic status. Strand (2014) presents this phenomenon as a “minority ethnic advantage” (p.131) at low socioeconomic status, facilitating progression to higher education, but it must be acknowledged that, despite a greater proportion of young people from ethnic minorities progressing into higher education in general compared to their White counterparts, the former are underrepresented in highly selective universities (Boliver, 2016).

Young people from disadvantaged backgrounds generally are less likely to access highly selective universities and they are also less likely to study for high-status subjects (Henderson, Shure and Adamecz-Völgyi, 2020). Smith and White (2011) suggest in their paper that entrants from traditional backgrounds are more likely (and hence, by inference, entrants from nontraditional backgrounds are less likely) to study science because of the perceived prestige associated with these subjects. This is linked to Bourdieusian notions of social reproduction considered later (see section 3.8). Smith (2011) and Cheryan *et al.* (2017) advance that science is seen as a masculine pursuit, which acts as a barrier to female entrants. On its own, this suggests that a critical number of females is needed to overcome the barrier but the work of

Johnson (2011) highlights how the reasons are more nuanced. Johnson (2011) talks of a 'double bind for women of colour' - that is, identities in terms of gender and race are interwoven to hinder or facilitate participation. The work of L. Archer, Dewitt and Willis (2014) adds a further dimension, suggesting that science is not just for boys, but for middle-class boys – the findings highlight how identities in terms of gender and social class interact to impact on participation. Different authors also view the influence of social class in different ways. L. Archer, Dewitt and Willis (2014, p.21) propose science participation is mediated by identity and that a science career is "unthinkable" for many working-class boys. Vignoles and Murray (2016), on the other hand, consider the effect of disadvantaged backgrounds on achievement levels, which acts then as a barrier to progression.

As Thompson (2011) argues, the systemic and structural factors that exist within education need to be considered when trying to understand the progression of young people into higher education science and the reasons for disparities in participation levels.

3.6 Strategies for Widening Participation in Higher Education Science

3.6.1 University-Led STEM Outreach

A key strategy for widening participation in higher education has been university-led outreach and there is a wide range of initiatives designed to influence students' aspirations, expectations, skills and knowledge of both higher education and STEM subjects (Clark *et al.*, 2016; CECATS, 2017; Millar *et al.*, 2019), with the ultimate aim of increasing participation in H.E. STEM subjects. Whereas previously such university-led outreach may have been conceptualised as a civic duty for a public good, it is now also moulded by increasing institutional concern for research impact, graduate employability, recruitment, and widening participation (Johnson *et al.*, 2019).

With the Research Excellence Framework (REF) and research councils increasingly concerned with the benefit of studies beyond academia (Johnson *et al.,* 2019; REF, 2021), outreach activities provide opportunities for individual academics to tie the impact agenda into their work. Increasing pressure for universities to meet the expectations of all stakeholders, including students, parents, employers, government bodies and professional organisations (AdvanceH.E., 2020) means the employability agenda also drives much outreach practice. Delivering outreach activities can provide CV-enhancing experience for students – an important consideration in light of the Teaching Excellence Framework (TEF), which uses the employability of graduates in part to assess the quality of teaching. Although the measures used by TEF to judge employability are questioned (e.g. EngineeringUK, 2018), such measures are included to steer practice towards preparing graduates to be 'work ready' and thus contribute to addressing skills shortages, particularly in STEM areas requiring high-level skills.

Most commonly though, outreach activities are grouped with marketing or widening participation initiatives. All are instrumentally grounded in student recruitment. Banerjee (2017), for example, offers that the most common aim of STEM outreach programmes is to increase the participation of young people in STEM subjects, with further goals identified by Laursen *et al*., (2007) and Scull and Cuthill (2010) of addressing underrepresentation from groups such as those from low socioeconomic backgrounds and females. Similarly, Sadler *et al.* (2018) found that most participants in their study described a key goal of university-led STEM outreach was to recruit future students to university and STEM careers. Given the highly competitive environment within which universities operate, marketing initiatives are designed in response to the increasingly consumerist approach that students are adopting in their H.E. decision-making. Research into the factors that influence choice in school-leavers suggests that students conform to a marketing model (Cridge and Cridge, 2015), prioritising the reputation of the programme and price (including distance from home and living costs) (Maringe, 2006).

Whilst marketing initiatives are aimed at influencing students at a macro level, widening participation programmes tend to be more focused on target groups and individualistic in their nature. The widening participation (WP) agenda in UK higher education has been driven by government policy since 1997, when The Dearing Report (1997) asserted that:

> It should be an objective of policy to see that those groups who are currently under-represented in higher education come to be properly represented: as participation increases so it must widen. (National Committee of Inquiry into Higher Education, 1997, paragraph 7.21)

Over the last 20 years widening participation initiatives have aimed at increasing participation in higher education in general and, in particular, from social groups who traditionally have been less likely to participate – specifically targeting the characteristics of students' occupational background, ethnic group, age and sex.

As a key strategy for widening participation in higher education, university-led outreach initiatives are often aimed at raising aspirations to encourage more applications from disadvantaged groups. Research shows, however, that many young people from disadvantaged backgrounds aspire to study at university, implying that limited aspirations have only a minor role in creating the socioeconomic disparities seen in levels of participation (Gorard, See, and Davies, 2011; Kintrea, St Clair, and Houston, 2011). Policy definitions have also been criticised for framing aspiration in narrow economic terms, despite its complexity, and overlooking the structural issues which restrict a young person's ability to realise their potential (Rainford, 2021). In predicating the 'raising aspirations' discourses on becoming middle-class to succeed (Boliver, 2017), policy has often promoted a deficit model, whereby individuals with innate potential to succeed are seen to be limited by low aspirations rather than structural barriers that hinder their ability to realise their aspirations. Whilst Rainford (2021) reports that practitioners often eschew the deficit model of aspiration in favour of "helping individuals *realise* aspirations or raise their *expectations"* (Rainford, 2021; p.2), never-the-less 'raising aspirations' still endures in both national and institutional policy.

Within this context, the literature describes a range of university-led STEM outreach initiatives, from large, centrally funded programmes to those with an informal and *ad hoc* nature (Eilam *et al.*, 2016; Vennix, den Brok and Taconis, 2018; Sadler *et al.*, 2018). The latter (as personally experienced) often arise through direct contact from schools or community groups with academics through personal networks. Such requests tend to be worked around busy schedules and in an era of performativity there is a tendency to 'get the job done' without explicit consideration of the overarching purposes or a strategic vision. The outcome from a university perspective is that there is not a clear picture of the activities being offered to schools, nor is there a coherent overarching view of the role of the different outreach activities and how they fit within a wider strategy. Like previous studies that have highlighted the problem (e.g., Miranda and Hermann 2010; Varner 2014), the broad goals of raising young people's aspirations and increasing participation in higher education science are not refined into impactful objectives for specific activities. As Fear *et al*. (2001, p.26) note, the emphasis is on "delivering the goods and little consideration is given to which outreach activities to deliver, why and to whom". Research that clarifies the nature or the broad effects of outreach initiatives on increasing and widening young peoples' post-compulsory participation in STEM education is scarce (Sadler *et al*., 2018). The few studies that exist mainly describe shortcomings around evaluation (Knox, 2001) or a lack of university-wide strategic support (Beck *et al.,* 2006; Greaney *et al.*, 2014). Beck *et al.* (2006) did conclude that outreach was a viable way to increase scientific knowledge, but the study did not explore the impact on post-compulsory participation in STEM subjects. Greaney *et al.* (2014) report increases in STEM participation through outreach activity involving school-university partnerships, but stress the need for early intervention, viewing post-14 as too late. As Eilam *et al.* (2016, p.445) assert, "universities' contribution to enhancing STEM literacy and recruitment of students to STEM is yet mostly unknown", thus calling for further investigation. Evaluating STEM outreach initiatives to get a feel for what works and what does not could be a useful first step.

As argued by Scull and Cuthill (2010), the broader patterns of science participation outlined earlier call into question the effectiveness of university-led STEM outreach initiatives and a greater understanding of the impact of these initiatives is needed (Fear *et al*., 2001). Few initiatives offer robust evaluations of their impact on increasing and widening participation (Bogue *et al.,* 2013), compromised, the literature suggests, by an absence of clearly defined goals (Carleton-Hug and Hug, 2010; Miranda and Hermann 2010; Varner 2014) and a focus on using short-term measures (Felix *et al.,* 2004). A clear alignment between aims, objectives and outcomes is often absent (Reed-Rhoads, 2011; Bogue *et al.*, 2013; Banarjee, 2017), making it difficult to assess whether participation in the outreach activities results in increased participation in post-compulsory science education.

In terms of measuring impacts on student aspirations, evaluation is often based on meeting the marketing needs of universities. Sadler *et al.* (2018) found that the majority of evaluation methods used by institutions centred on gathering feedback from pupils and teachers at the end of outreach activities. Only a small minority of universities in the study by Sadler *et al.* (2018) used longitudinal studies and enrolment data to evaluate the efficacy of outreach programmes in increasing participation in H.E. STEM subjects. Tracking attendance at outreach activities and future participation in post-compulsory STEM subjects would assess the attainment of outreach goals, as opposed to outreach delivery. Such evaluation is possible through the Higher Education Access Tracker (H.E.AT), which aims to provide robust evidence of outreach impact through longitudinal tracking. Often therefore evaluation actually assesses the delivery of the outreach activities rather than the impact on young people's aspirations and one accusation is that initiatives take therefore an approach that is singularly focused on 'attitudes to science' (Osborne, Simon, and Collins, 2003). When, as is often the case, the evaluation of science outreach activities is limited to the use of 'happy sheets', where participants are asked to rate their enjoyment of a session or how interesting they found the session, this focus drives the design and delivery of activities. Little consideration is given to the wider factors that influence young people's participation in post-compulsory STEM education, such as an awareness of scientific principles, perceived transferability and utility of science and family influences (as considered in section 3.10). The problem here is that, although some studies (e.g. Reiss, 2004; Barmby, Kind and Jones, 2008) show a decline in attitudes towards science through secondary school, there is considerable research that shows that young people are generally interested in science (e.g. L. Archer *et al.*, 2013; Butt *et al.*, 2010; Dewitt and Archer, 2015; NFER, 2011) and that this interest is not necessarily translated into post-compulsory science participation (DeWitt, Archer and Mau, 2016; Millar *et al.*, 2019). As L. Archer *et al.* (2012) assert, although young people may enjoy 'doing' science, it does not mean that they want to 'be' a scientist. Research also shows that young people who typically attend STEM outreach already have an interest in science, as well as intentions to enrol in future science courses (Gibson and Chase, 2002; Markowitz 2004; Miranda and Hermann 2010; Essex and Haxton, 2018).

Admittedly, as recognised in participant responses in the study by Sadler *et al.* (2018), it is difficult to assess the impact of a short-term STEM outreach initiatives on young people's awareness or aspirations. There are many factors affecting young people's attitudes and decisions that make it difficult to distill out the influence of a specific outreach activity. A particular student, for example, might participate in an activity with the university once in their secondary school career and the bigger picture, such as the family's financial situation and the local or national job market, will most likely have a more significant influence on their decision-making about careers than enjoying themselves participating in a particular science activity. Data that can be easily collected around the time of an event does not necessarily provide valuable insights into the broader conceptions of awareness and aspirations. The types of data collected are often limited to the number of students who attended, the number of outreach sessions delivered and how much participants enjoyed the activities. At best the data is useful in identifying whether marketing goals have been achieved (Husher, 2010) but contributes little to understanding the effects on student aspirations. A more feasible approach may be to explore the influences on undergraduate students STEM aspirations and the factors that led them to participating in H.E. STEM subjects; a greater understanding of which could inform outreach practice.

The literature suggests that there is an essential need to consider a different approach and look at whether university-led outreach is meeting the specific goal of raising young people's aspirations for STEM careers (Fear *et al.,* 2001; Sadler *et al.,* 2018). As Sadler *et al.* (2018, p.590) assert, "frameworks, and ways to discuss and categorise STEM outreach initiatives, as well as evaluation approaches, are needed". Without a conceptual framework for evaluating the effectiveness of STEM outreach activities, there will continue to be a reliance from practitioners on using short-term methods to evaluate the quality of delivery. Eilam *et al.* (2016) have made one step towards meeting this need. Using the Theory of Legitimacy, they developed a conceptual framework to evaluate STEM outreach positioning within universities' operations. The framework does not appear particularly useful however in evaluating individual outreach activities and, as the authors suggest, further research is needed regarding the impact of outreach programmes. Beyond using the science capital concept as a framework for the design of intervention activities, frameworks are otherwise mainly absent from the literature. Assessing whether participants in STEM outreach activities demonstrate gains in the dimensions of science capital offers a framework for evaluation, like the approach taken by Rawlinson *et al.* (2021) in investigating the impact of a campus-based university science event. Exploring how practitioners operationalise the concept in the design and delivery of STEM outreach activities may also provide insights into how such activities could be made more effective.

A myriad of factors impacts on the processes that lead a student to commit to a career in STEM. University-led outreach programmes seek to influence the decision-making process and whilst some evaluations indicate that programmes can be effective (Ghazzawi and Jagannathan, 2011; Henriksen, Jensen and Sjaastad, 2015; Vennix, den Brok and Taconis, 2018), many scientists consider outreach as a "bleak prospect with limited room for improvement" (Ecklund *et al.*, 2012, p.3). Indeed, Ecklund *et al.* (2012) reported that less than half of those interviewed had concrete ideas for how science outreach could be improved. Certainly, questions remain about how these outreach initiatives could be made more effective (Addi-Raccah and Israelashvili, 2014; Varner, 2014; Vignoles and Murray, 2016; CECATS, 2017; van den Hurk, Meelissen and van Langen, 2019). By exploring the factors influencing the participation of young people in H.E. STEM subjects and exploring approaches to increasing the effectiveness of outreach activities, this research is seeking to develop a more nuanced understanding of how outreach programmes could be made more effective in influencing students to participate in STEM subjects in H.E. and ultimately pursue a STEM career.

3.6.2 Contextualised Admissions

A recent shift towards the use of contextualised admissions practices seeks to consider the impact of socioeconomic factors on previous attainment (Boliver *et al.*, 2020). Currently, approximately a third of UK universities consider the socioeconomic circumstances (or related background characteristics) of applicants' attainment as part of the admissions process (Moore, Mountford-Zimdars and Wiggans, 2013). Given that young people from disadvantaged backgrounds must expend additional effort and resources to overcome contextual challenges not encountered by others, the use of contextual indicators is considered a promising way of creating a fairer admissions system and addressing the issue of lower levels of participation in higher education of young people from less advantaged backgrounds (Boliver, Gorard and Siddiqui, 2015). Applicants are normally identified as 'widening participation' using indicators of disadvantage, such as receipt of free school meals, low household income, parents not in professional occupations, has spent time in care or is a refugee (Boliver *et al.,* 2017). However, the trustworthiness of indicators is called into question (Boliver, Gorard and Siddiqui, 2015), with Gorard *et al.* (2019) also reporting that 28 different categories of contextual indicators showed up in a systematic literature review; the use in practice of many limited by their availability and accuracy. Furthermore, the process of selection on contextual indicators is heavily influenced by the professional judgment of academics. With a lack of clarity around the definition of 'widening participation', blending individual, institutional and area level factors, means those responsible for making admissions decisions are likely to draw on personal values to define and address the problem (Stevenson, Clegg, and Lefever, 2010). Especially in selective science settings, where admissions staff often perceive formal grades as both evidence of prior attainment and indicators of an applicant's potential to succeed on the course (Boliver and Powell, 2021), the conservative ethos of academics creates a less flexible entry route through A-level study (Kandiko Howson, Cohen and Viola, 2022). As such, despite the aims of national and institutional policy to address stratified patterns of participation in higher education science, the nature of decision-making around university admissions pits social justice against opposing discourses of social reproduction.

3.7 Theoretical Influences on this Study

The complexities of real-life problems cannot be captured in any one theory and the literature describes different theoretical approaches to understanding how people make decisions in the context of education. Costa, McCrae and Holland (1984) and Head and Ramsden (1990), for example, have related educational choices to individual personality types, grounding their theoretical approach in psychology. Other perspectives centre on academic motivation, such as expectancy-value theory (Eccles *et al.*, 1983), which models the motivation for an educational choice based on expectancies for success and the value the person attributes to the option. With the assumption that beliefs about ability influence the value a person places on an option, expectancy-value theory links educational decision-making to achievement and is constructed in part on self-efficacy. The inclusion of self-efficacy overlaps with other theories, such as Bandura's social cognitive theory (Bandura, 1991) and its refinement to the social cognitive career theory. Social cognitive career theory (SCCT) models the inter-relationship between personal, contextual and behavioural factors that underpin a person's academic (and career) choices and how these factors can impact self-efficacy, expected outcomes and goal mechanisms (Lent, Brown and Hackett, 1994). It has been used as a theoretical lens to investigate choice to progress in STEM subjects (e.g. Wang, 2013; Dutta *et al.,* 2015; Mau, Chen and Lin*,* 2019) and suggests that individuals aspire to progress in STEM education if they have high self-efficacy in relation to STEM subjects and hold beliefs that pursuing STEM will produce valued outcomes. As explained by Lent and Brown (2019, p.1), 25 years after the development of SCCT, the theory "was invested in understanding how certain aspects of persons (e.g., gender, culture) and their socioeconomic locations become constructed in ways that make choice options more or less available to particular individuals". Whilst SCCT acknowledges the importance of personal characteristics such as ethnicity, gender and socioeconomic status in influencing the link between self-efficacy, outcome expectations and goals, sociological theories foreground these factors more in terms of their effect on educational and vocational behaviour. As such, the sociology of education provides one possible avenue for developing a deeper understanding of the disparities in participation in H.E. STEM subjects and a conceptual framework within which to locate university-led science outreach activities. Indeed, much research around widening participation is conceptualised within sociological discourses focusing on structural factors, habitus, and capital (e.g., Ball *et al.*, 2002; Ball, 2006; Reay, 1998; Reay, David and Ball, 2005; Reay, Crozier and Clayton, 2010). Such sociological theories explain how H.E. decisions and choices are unequal and socially patterned, but, as Baker (2019) describes, policy assumes that students make these as individuals in a decontextualised manner. Little consideration is given to structural factors impacting on individual lives in a perspective of decision-making that focuses on economic instrumental goals (L. Archer, 2007; Hart, 2013). This tension between social justice and marketisation outlooks is evident in this study and, in recognising that structural constraints can impede a young person's available options, it draws heavily on sociological theory and specifically on Bourdieu's theory of social reproduction. The conceptual lens of capital and its refinement to science capital permits exploration of how young people construct their science identities, alongside wider structural factors that impact on their life chances.

3.8 Bourdieu's Theory of Social Reproduction

As Apple (2013) considers, the study of how education is affected by public institutions and individual experiences has contributed significantly to understanding the production of inequalities and, within this field, Bourdieu has been highly influential. Bourdieu's theory of social reproduction attempts to explain patterns of inequality, however, as noted by L. Archer *et al.* (2012), Bourdieusian theory has not been used extensively in science education, despite it offering both an explanation of the stubbornly patterned participation levels in post-compulsory science and potential to address these disparities.

Bourdieu's theory of social reproduction was developed on the back of existentialism and structuralism. Existentialism theorises an individual person as having free will and control over their decisions and actions. Structuralism, in opposition, theorises the influence of a broader, overarching system of structure on elements of human culture. Centred on the interplay between agency and structure, Bourdieu's theory looks at the mechanisms of domination that exist within society and the processes that conserve these mechanisms (Bourdieu, 1984, 2010). Sharing some commonality with Bernstein's work emphasising the importance of class differences in linguistic codes (Bernstein, 1962a; Bernstein, 1962b; Bernstein & Henderson, 1969), Bourdieu's theory illuminates the activities and structures that perpetuate social inequality from one generation to the next and attempts to explain why some individuals may feel marginalised by scientific and academic culture. In encompassing structural constraints, the theory provides recognition that H.E. choices are shaped by access to financial resources, social networks and cultural capital. Financial constraints, for example, can restrict choices in terms of travel and living costs (Reay, David and Ball, 2005). It must be noted that this is in contrast with current policy discourse that conceptualises students as "rational and instrumental consumers" (Baker, 2019, p.2), with agency, and ignores the effect of structural constraints in their decision-making. In ignoring context, such individualistic approaches promote a deficit model, exemplified by approaches to widening participation around raising aspirations, whereas, as explored in section 3.10, Bourdieusian theory can provide the conceptual foundation for a more asset-based approach.

Bourdieu (1984, 1986, 2010) sees power as being culturally and symbolically created and considers relations of privilege and domination to be constructed through the interplay of habitus (internal dispositions, produced through socialisation, which guide behaviour) with field (social contexts) and capital (cultural, social and economic assets).

3.8.1 Habitus

Essentially habitus encapsulates the habits developed within a particular context and describes how the accumulation of experiences that individuals gain throughout their lifetime become the impetus for new choices in life (Gravesen, 2019). It is created through an unconscious process, whereby social norms and tendencies guide thinking and behaviour in determinant ways, beyond those which individuals can control by will. Bourdieu's habitus is often criticised as too deterministic (e.g., Jenkins, 2002; King, 2000; King, 2004; Pula, 2020), meaning an individual is fully determined by society, with no autonomous process and agency. M. Archer (2007, 2012) also questions whether, in the contemporary context, habitus can in fact be formed due to the high level of structural instability. She questions how young people can be prepared for unpredictable circumstances through socialisation and argues that a greater level of mediation is needed between objective structural opportunities and again individual agency, through reflexive deliberation.

However, in including a level of agency, making it possible to act against determined roles, and arguing that habitus is both constructed through socialisation into the world through family, culture and education, but also has the potential to influence a person's construct of the social world, Bourdieu's theory can be used to explain engagement with science. In this context, habitus goes beyond consciously identifying with science, such as enjoying science lessons, and encompasses values and everyday practices. For example, in their study investigating how families shape children's engagement with science, L. Archer *et al.* (2012) report that, although some children enjoyed 'doing' science, this did not lead to an aspiration to 'be' a scientist. Even though a young person may like, and consciously identify with science, the family context may mean they do not see a future career in science as possible for themselves, explaining how parental beliefs and behaviour can both support and impede a young person's progression in science education (Kelly, 2016; Wang and Degol, 2013). Whilst L. Archer *et al.* (2012) go on to argue that habitus is not necessarily deterministic, as their analysis shows some children displaying agency and proactively choosing a science career despite the family context, it does provide a powerful structuring context.

In constraining thoughts and actions, as proposed by Bourdieu (2010), habitus results in the reproduction of existing societal (and university) power structures. Bourdieu's theory highlights the risk of simply perpetuating existing structures and inequalities unless a conscious effort is made to challenge and reframe them. With outreach activities, for example, there is an inherent risk that the activities do not 'fit' with the target groups. Without reflecting on diversity, in terms of occupational background, ethnic group, age and gender, there is a risk that the status quo remains – which is borne out by the unchanging patterns of participation. As Matthews (2017) argues by drawing on Bourdieu, partnerships engaging participants with differing habitus, who engage in reflectivity, are needed to disrupt traditional hierarchies in higher education structures.

3.8.2 Fields

A second concept central to Bourdieu’s theory is that of ‘fields’. Conceptualised as a relatively autonomous domain of activity in which agents and their social positions are located, a field has specific rules and defines the relations among the agents (Bourdieu, 2010). As such, science and education are seen by Bourdieu as separate fields, as also are home, school and university. The interplay between habitus and field creates a refraction effect – essentially a boundary - around different fields. If a young person's habitus and dispositions fit with the different fields, then the boundaries are porous, and movement is easy e.g., progression from school to university. Where a young person's habitus and dispositions do not fit with the next field, the boundary is less porous, and progression is blocked. In this respect progression to H.E. science subjects involves moving through two boundaries – one around the science field and one around the university field. Varner (2014, p.335) describes how such “boundaries are further reinforced when scientific knowledge is branded as specialized”. The effect of the boundaries/refraction is evident also in UCAS data that indicates BTEC students are less likely to progress to selecting universities and more likely to withdraw from university in general in comparison to those on a traditional academic pathway (H.E.FCE, 2017). This is significant in a widening participation context when young people from disadvantaged backgrounds are three times more likely to hold only BTEC qualifications than those from more advantaged backgrounds (Cope, 2022). From a Bourdieusian perspective, it can be argued that the habitus of this category of students does not fit with the dominant field of university. This is further highlighted in the report by Reay *et al.* (2001, p.858) which examines the class differences in universities, showing that the more prestigious universities “remain overwhelmingly white and middle class” and the findings of Moote *et al. (*2021) that show access to high status post-compulsory science courses is less likely for students from less advantaged social backgrounds.

As Bateson *et al.* (2018) argue, often widening participation initiatives focus on the shortcomings of young people and do not address structural issues. This is exemplified within initiatives seeking to raise the aspirations of young people, focusing on individuals rather than collective circumstances and thus giving little consideration to H.E. practices and government policies that may act as barriers to participation in H.E. science. From a Bourdieusian perspective, disrupting dominant power relations and structures within science and H.E. offers the potential to reduce the refraction effect by changing the field (Barton, Tan and Rivet, 2008). As the accumulated experience of science as being ‘for me’ or not will be shaped by the relationship between field and a student’s habitus (L. Archer *et al*., 2012), this could create more inclusive possibilities for young people in science. At the very least, for science outreach activities to be successful, it is necessary for young people to be given the support to negotiate the boundaries between school and university (Wilk, Spindler and Scherer, 2016).

3.9 Capital

Bourdieu also introduces the idea of ‘capital’, which is conceptualized as the economic, cultural, social and symbolic resources that can generate the reproduction of social inequalities in society. He proposes three fundamental types of capital - economic capital (income and wealth), cultural capital (shared outlook, knowledge, beliefs and skills) which is institutionalised in the form of educational qualifications, and social capital (membership of a group and the connections of a social network). The conversion of cultural and social capital to economic capital is possible in certain conditions. This can play out, for example, in the use of what Ball and Vincent (1998, p.380) describe as “cold and hot knowledge”. Cold knowledge is explained as that disseminated directly from universities, such as websites and prospectuses, whereas hot knowledge is that gained through informal social networks based on direct experience. With hot knowledge being more trusted and valued in decision-making about educational pathways (Slack *et al.*, 2014), young people with more extensive social networks (and therefore more social capital) have an advantage in their H.E choices and subsequent potential for increased income.

The different types of capital are synonymous with different types of power (Bourdieu, 1986) and capital is whatever is taken as significant for ‘social agents’ within an arena. Thus, the value of a young person’s capital is determined by the social context, or field. This is emphasised by Gonsalves *et al.* (2021) in their argument that the doxa of scientific fields may differ across institutions and programmes, meaning, for example, that what is valued as capital at one university may be different to the capital that is valued at another university. Equally, a young person’s capital may be valued and legitimized at secondary school, but less valued at university, thus reinforcing the boundary effect and inhibiting progression to higher education science.

Several studies have examined the development of capital to promote academic achievement and progression, with the concept being refined, in terms of ‘science capital’ to explain how a student’s existing resources can inform their post-compulsory education and career choices with regards to science.

3.9.1 Studies on Cultural Capital

Cultural products such as language, values, judgements and activities of everyday life essentially lead to ‘a sense of one’s place’. So, for example, H.E. science faculties place a lot a value on level 3, and to a lesser extent, level 2 science qualifications. Where families place a similar value, then progression is facilitated. This is borne out by the ‘concerted cultivation’ practiced in some families (notably middle-class) (Lareau, 2003) where children are actively nurtured towards academic achievement. If the content of the level 2 and level 3 science qualifications is seen as irrelevant to the everyday lives of families, then less capital is developed. Bourdieu (1986, p.48) argues that “the educational system contributes to the reproduction of the social structure by sanctioning the hereditary transmission of cultural capital” and that investment of cultural capital, and time, produces ability. Studies by Israel, Beaulieu and Hartless (2001) and Dika and Singh (2002) show, for example, how middle-class families often use extra-curricular activities to develop capital with the aim of producing academic achievement and promoting progression to university-level study. By developing cultural capital to meet the demands of the scholastic market the children of middle-class families feel that they belong in post-compulsory education and progression is seamless. On the contrary, as described by Gravesen (2019), the children of lesser-privileged homes often find it harder to engage in formal education because of lower transmission of cultural capital.

3.10 Science Capital

3.10.1 Science Capital Concept

Drawing on Bourdieu's theory of social reproduction, the concept of 'science capital' has been developed to explain how a student's existing resources can inform their post-compulsory education and career choices. Much of this work has stemmed from the ASPIRES project at King's College London, led by Professor Louise Archer. Drawing on data collected from young people aged 10-14 and their families, over a period of 5 years, ASPIRES discovered that the amount of science related resources in families influenced children's engagement with the subject. For example, children who had parents who worked in scientific professions or had scientific hobbies were more likely to want to progress in science beyond compulsory education. Science capital was further developed conceptually and empirically through the ASPIRES 2 and the Enterprising Science project, extending the concept of science capital beyond homes and into museums and schools, where it was subsequently used to design teaching strategies. The research is recognised for its impact in addressing educational inequalities in science participation.

Conceptually, L. Archer *et al*. (2015) and DeWitt, Archer and Mau (2016) advance an argument that Bourdieusian notions of capital – which essentially is an art-based conceptualisation - can be further refined to understand patterns of aspiration and participation in science education. The concept of 'science capital' they propose captures a range of science-related resources, legitimises a wider range of scientific knowledge and offers a new lens for understanding disparities in science participation.

Science capital has been shown to be more closely related than cultural capital to science aspirations and it is explained as:

> a conceptual device for collating various types of economic, social and cultural capital that specifically relate to science – notably those which have the potential to generate use or exchange value for individuals or groups to support or enhance their attainment, engagement and/or participation in science (L. Archer *et al*., 2015, p.928).

Covering what science a young person knows, how they think about science (their attitudes and dispositions), who they know and what sort of everyday engagement they have with science, as detailed in L. Archer *et al.* (2016), the concept has been developed using empirical data collected from 3658 secondary students. Science capital can be distinguished into eight dimensions, which are considered in the light of other literature below.

1. **'Scientific literacy: scientific knowledge, skills and understanding about how science works, including confidence in the ability to use and apply these capabilities.** Linking with the work of Bandura around social cognitive theory (Bandura, 1991), this also very much fits with the model proposed by Chemers *et al*. (2011) who put forward science self-efficacy as an important factor influencing young people's commitment to a science career. Similarly, Syed *et al*. (2019) also cite self-efficacy in STEM and an awareness of scientific principles as an important determinant in choosing a science career. It is concerning then that girls' perceptions of their STEM competencies are frequently lower than boys' (Wang and Degol, 2013), with lower self-efficacy in STEM influencing progression choices in post-compulsory STEM education (Eddy and Brownell, 2016). Enjoyment of science, which is frequently associated with ability, was also discovered to be a significant factor influencing the decision to study post-compulsory science across ethnic-minority students in the study by Springate *et al.* (2008).
2. **Science-related attitudes, values and aspirations: this relates to the extent to which a young person sees science relevant to everyday life.** Often young people find it difficult to recognise the links between the science taught in schools and their day-to-day existences (Osborne and Collins, 2000; Butt *et al.,* 2010; NFER, 2011), and young people in several studies have explained their

disengagement from science by the lack of relevance and applicability of the curriculum (Osborne and Collins, 2000; Williams *et al*., 2003; Cleaves, 2005; Barmby, Kind and Jones, 2008; Springate *et al*., 2008). Indeed, young people in a student-led review of the science curriculum recommended that science subjects would be more popular if they "connected more with real-life situations" (Murray and Reiss, 2005, p.92) and Gaspard *et al.* (2015) reported positive impacts on the value beliefs of young people, influencing progression and career choices in science, through a focus on the relevance of STEM in lessons. Of direct relevance to outreach activities are the findings of the National Foundation for Educational Research (NFER, 2011) which suggest that contextualising science in real-life situations and making it more applicable to the everyday lives of young people would encourage greater participation.

3. **Symbolic knowledge about the transferability of science: understanding the extrinsic value and broad application of science qualifications.** Although only a minority of the students in the study by Springate *et al*. (2008) had decided to progress to higher education science because they were aware that studying for a scientific degree would help them develop skills sought by employers, several other studies, such as Osborne and Collins (2000), Cleaves (2005) and Butt *et al*. (2010), have highlighted how the value of a science education to a young person's career options can positively influence engagement in the subject. This is further supported by the findings of the National Foundation for Educational Research (NFER, 2011), reporting that a key element underlying engagement in science was perceptions of its applicability and transferability to higher education and employment opportunities. Interestingly, the findings of their study suggest that such value is seldom made explicit enough to young people and, as King *et al.* (2015) advise care around this dimension as some teachers see it as beyond their remit and that careers advice falls to other professionals, there is scope in this dimension for outreach activities to have an impact by communicating how science links to a variety of career pathways. Foregrounding the extrinsic value of science qualifications for future employment would go some way to addressing the calls from Adamuti-Tranche and Andres (2008) and Lyons and Quinn (2010) for more to be done in this area.
4. **Science media consumption.** For young people, often there is little cross-over between studying science at school and leisure activities. NFER (2011) found

that young people did not frequently use television, the internet or newspapers to expand their scientific knowledge. This finding is supported by the survey work of L. Archer *et al*. (2012, p.888) who reported that “over a third of young people never read a book or magazine about science (36.6%) and never looked at science-related websites (33.8%)”. Almost a fifth of the sample of 9000 students reported that they do not watch a science-related programmes on television. Given its accessibility, the internet could be a useful way forward for reaching young people and encouraging greater interest in science (Varner, 2014) because, as the findings of Dou *et al*. (2019) show, consuming science media fosters the development of students’ STEM identities.

5. **Participation in out of school science learning contexts: how often a young person participates in informal science learning contexts, such as science museums, science clubs, fairs etc.** Studies show that young people with opportunities to frequently engage with science in both formal and informal environments are more likely to progress to post-compulsory science education (Sadler *et al.*, 2012; Sahin, 2013). However, whilst Butt *et al. (*2010, p.7) reported that “more than half of young people interviewed had visited a place of scientific interest in the last year”, visitors to science museums tend to come from white and middle-class backgrounds (Ipsos MORI, 2011; Dewitt*,* Archer and Mau, 2016; Dawson, 2019). Similarly, recent research shows science festivals are mainly frequented by people with higher socioeconomic status (Kennedy, Jensen and Verbeke*,* 2018; Nielsen, Gathings and Peterman*,* 2019; Gathings and Peterman, 2021), whilst the findings of an American study show that other informal science sites, such as zoos and natural history museums, are more likely to be visited by those with more years of formal education, as well as those in higher income brackets (NSB, 2018). The middle class are particularly adept at harnessing free time to develop cultural capital (Bourdieu, 1986). L. Archer *et al.* (2012, p.888) also found that “just under a quarter (23.4%) of children said that they ‘‘never’’ do any science-related activities outside of school”, which inevitably will restrict their picture of the implications of STEM (Vennix, den Brok and Taconis, 2018) and so creating opportunities to participate in informal science learning contexts offers potential to support more young people from more diverse backgrounds to progress within science education and careers.

6. **Family scientific knowledge, skills and qualifications.** These equate to cultural resources, from which students from lower socioeconomic backgrounds are often excluded (Bleazby, 2015). L. Archer *et al. (*2012) assert that social class has a key part in nurturing or inhibiting young people's science aspirations and identifications; arguing that these are facilitated within middle-class families through the activation and deployment of capital and that these resources are absent within working-class families. According to Hargreaves (1975), whilst teachers and friends may grow in influence later in a child's life, the primary influence throughout childhood on their beliefs and values is the parents, who determine the culture to the child through their interactions (Hendry *et al*., 1992). As Aschbacher, Li and Roth (2010) suggest, parental knowledge, skills and qualifications creates a 'micro-climate' within which young people form their perceptions about science and develop their science identities. Levels of parental education tend to correlate with ambitions towards university (Roksa and Potter, 2011; Schuette, Ponton and Charlton, 2012) and the children of parents with strong scientific social capital, as well as cultural and economic resources to support achievement, are more likely to be higher achievers in science (Aschbacher, Li and Roth*,* 2010). Conversely, if the parents do not view the study of science as valuable for future success, then any initial interest and enthusiasm for STEM from a young person can easily be extinguished (Smith, 2007). On a related note, family influences have also been connected to differences in STEM participation between genders, with, for example, Tenenbaum and Leaper (2003) finding that science is more commonly perceived by parents as difficult for their daughters than for their sons. Developing outreach work to increase the access of families to science-related knowledge, resources, and social capital offers scope for influencing young people's STEM aspirations
7. **Knowing people that work in science-related roles.** Knowing people that work in science-related roles can enhance motivation and attitude towards STEM careers by providing role models (Stout *et al.,* 2011; Stoeger *et al.*, 2016), but networks also provide support and opportunity for (scientific) community involvement and the development of 'science social capital' (Stahl *et al.,* 2021). This dimension is in line with the findings of the NFER (2011) that highlight that students can be helped to engage with science education through belonging to a STEM network. With place mediating access to networks (Stahl *et al.,* 2021), in

the local context, this is particularly pertinent to isolated areas of the region where some young people will have limited opportunities to meet people that work in science-related roles. Whilst it is not possible for outreach activities to influence whether or not a young person has family members who work in a science-related job, there is scope for initiatives to facilitate the development of their 'science social capital'.

8. **Talking about science in everyday life: how often a young person talks about science out of school with key people in their lives (e.g., friends, siblings, parents, neighbours, community members) and the extent to which a young person is encouraged to continue with science by key people in their lives.** Although situated in different cultural contexts to the UK, the findings of Buzzanell, Berkelaar and Kisselburgh (2011) show the significant influence parents have on children's perceptions of careers. Similarly, participants in the study by Oritz *et al.* (2019) reflected how parents were instrumental in fostering their engagement with STEM subjects. The influence of parental interest on children's engagement with science subjects was also highlighted by Butt *et al.* (2010), reporting that parents' level of interest in science often overlapped with a young person's level of interest. Further support for the influence of parents comes from the results from Harackiewicz *et al.* (2012), who, in taking a randomised, experimental approach, found that a three-part intervention designed to highlight the usefulness of STEM education to parents led to increased participation in STEM courses from young people whose parents were in the experimental group compared to the control group. They conclude that "parents are an untapped resource for increasing STEM motivation in adolescents" (Harackiewicz *et al.*, 2012, p.905), with relatively simple interventions targeted at parents producing significant changes in the academic choices of young people, but this claim must be qualified by the findings of Rosek *et al.* (2015) who found that the effect was moderated to some extent by gender and prior levels of achievement.

   In considering other key people in the lives of young people, Butt *et al.* (2010) did find that the influence of friends was much less than either family members or teachers, but as Aschbacher, Li and Roth (2010, p.578) reason, "students who find solid support for science in multiple communities were more likely to consolidate their science identities and persist in their STEM aspirations than young people with less breadth and depth of support". They go on to assert that the young people are buoyed by perceived strong and aligned support for their science identities from multiple sources; an assertion supported by the findings of Burt and Johnson (2018) in their study of the origins of early STEM interest for Black male engineering students.

Science capital is useful in illuminating all the influences that lead to students choosing STEM subjects or not. Supported by the findings of Nomikou, Archer and King (2017) and Moote *et al.* (2021), focusing on these 8 dimensions may produce values, attitudes, expectations and behaviours in young people that promote post-compulsory participation in science education.

3.10.2 Further Consideration of Science Capital

Although it can be claimed that an equally good argument can be made for, say, 'sports capital' and concerns exist that the level of refinement removes the focus from systemic factors (Moote *et al*., 2020), empirical research shows that young people with high levels of science capital are much more likely to choose science subjects in post-compulsory education than those with low levels of science capital (L. Archer *et al.*, 2015). As a young person accumulates greater amounts of science capital, the more they will feel that they understand the 'rules of the game' and the more porous the field boundary will be. One criticism that can be levelled at these findings however is that the researchers used future science affinity as a proxy for actual participation – essentially, they looked at anticipated participation rather than actual participation. Future intention to enrol in STEM courses is not always matched by actual enrolments (Husher, 2010).

The age of the young people also needs to be taken into consideration. Much of the work around science capital has focused on secondary age, and yet Cridge and Cridge (2015, p.39) assert that "it is widely accepted that by around 10-12 years of age (late primary school) students have largely decided the general field of work that they want to be involved in" and that these early decisions are relatively stable. Admittedly, Cridge and Cridge's claims are drawn primarily from experience, but these are supported by Buzzanell, Berkelaar and Kisselburgh (2011) who argue that by the age of 10 many children have made preliminary decisions about their career track. Such arguments are particularly concerning when considered alongside the findings of Chambers *et al.* (2018), who, in a survey of children aged 7-11 years-old, found nearly twice as many boys as girls wanted to become scientists. Such evidence draws into question the impact of any efforts to increase the science capital of young people above primary age, but other evidence does point to interests in science not being solidified until age 14 (Ormerod & Duckworth, 1976; Tai, *et al*., 2006). Tai *et al.* (2006) suggest the critical period to influence career aspirations is 10-14 years old. Certainly, it appears that efforts to increase the science capital of secondary school students should be targeted at those below the age of 14 and, as interest in scientific careers is significantly influenced by experiences and attitudes students develop before secondary school (Sadler *et al.,* 2012), there is also a potential role for university-led outreach in developing science capital at primary level.

What is also not explicit in this concept is the effect of teaching on post-compulsory science participation. School science issues are acknowledged by DeWitt, Archer and Mau (2016) as part of the field that mediates capital, but it must be recognised that teaching quality is a key determinant of engagement (Osborne, Simon and Collins, 2003; Springate *et al*., 2008; Bennett and Hogarth, 2009; Butt *et al*., 2010). Butt *et al*. (2010) discovered that 52% children in their survey considered a good teacher was important to them wanting to learn science, whilst 47% reported being discouraged from learning science by a bad teacher. In the same vein, studies have shown that interventions focusing on improving STEM pedagogy positively influenced the intentions of young people to pursue a STEM career (Gaspard *et al*., 2015; Kara and Yesilyurt, 2008). In refining the focus to the operationalisation of science capital into a pedagogical approach, King *et al.* (2016) and King and Nomikou (2017) report on studies that suggest the concept offers the potential to enhance science teaching practice with a view to enhancing student engagement. It is not a massive jump to assume that the operationalisation of science capital into an approach for science outreach activities would similarly offer the potential to enhance the engagement of young people. As such, science capital forms a key part of the induction training for the STEM Ambassador programme, which is a national scheme drawing on the expertise of STEM professionals in a voluntary capacity to support learning and increase engagement in STEM subjects (STEM Learning, 2022), but could also provide a framework for enhancing STEM outreach at a local level.

3.10.3 Pragmatising Science Capital

As a step towards considering Fear et al.'s (2001) provocation that there is an essential need to re-examine university-led STEM outreach in terms of purposes and impacts, science capital can provide a conceptual framework for increasing and widening participation in H.E. STEM subjects. Without a clear view of the purpose, assessing the success of outreach initiatives is difficult beyond making short-term judgements about participant enjoyment and interest levels (Sadler *et al*., 2018). Given the findings of Moote *et al.* (2021, p.15), which showed that 17/18-year-old "students with high science capital were significantly more likely to report intentions to pursue university enrolment", as a conceptual framework science capital can provide a clarity of purpose to outreach activities, making more explicit the role of university-led outreach in fostering the engagement of young people with science subjects, as well as encouraging progression to higher level study and STEM careers in the future. As such it could permit university-led STEM outreach initiatives to advance from the use of superficial measures of success (such as 'happy sheets' discussed in section 2.4) towards the development of an overarching vision.

The concept can be pragmatized through a reflective framework for the design of intervention activities (Science Museum Group, 2015). Whilst also allowing for science-related resources to be more equitably distributed, understanding the dimensions that influence the development of science capital allows for targeted intervention. DeWitt, Archer and Mau (2016) suggest that the dimensions most related to anticipated future participation and identity in science are, in descending order:

- scientific literacy
- perceived transferability and utility of science
- family influences.

As a general approach, targeting these three dimensions should in theory provide the greatest impacts. As DeWitt, Archer and Mau (2016) suggest, some elements of science capital will provide greater scope for intervention, such the understanding of parents about the value of science qualifications in the jobs market. The evidence suggests that designing outreach activities to be commensurate with the dimensions of science capital – for example, to develop young people's scientific literacy/knowledge and understanding, promote the transferability of science in the labour market and include parents so conversations can carry on at home – has potential to positively influence young people's attitudes towards and progression within STEM education. Whilst science capital is useful as a reflective framework in the design of such initiatives, the value of the concept to evaluate the impact of outreach initiatives is less straightforward. The complex nature of the concept does not facilitate quick or easy measurement, but the 'Science Capital Made Clear' pack (L. Archer, *et al.,* 2016) suggests surveys might offer a pragmatic way to assess whether an intervention impacts on levels of science capital. Surveying fourteen items, each weighted appropriately, provides a measure of science capital and permits a science capital score or index to be calculated. Short and relatively quick to administer, a science capital survey would lend itself to a quantitative approach to data collection from many respondents. From the literature it appears that surveys might be useful for capturing the impact of sustained and long-term interventions. King *et al.* (2015) show statistically significant gains in science capital as a result of a targeted intervention, but this was working with teachers over a year. Given the complexity of the concept, it is hard to see how a survey would capture changes in science capital resulting a single intervention. It is doubtful that a one-off intervention will impact significantly on a young person's science capital – at least to an extent that will be evident in the index. An index might be useful for measuring baselines, and would permit, for example, obtaining an overview of the distribution of science capital among a wide range of individuals. This would permit the mapping of science capital across a region and might identify a useful starting point for future interventions – possibly nuanced at school level. The findings of such a mapping exercise would be of potential interest to schools and outreach practitioners, and through dissemination could influence approaches to engaging more young people with STEM subjects.

Just because the index is not able to measure any impacts related to science capital does not mean none have occurred. An intervention could have an impact without affecting an individual's score on the index. More in-depth, qualitative methods may allow changes to be captured. Whilst a key principle of science capital approach is that it should be comprehensive, in that it should recognise and aim to address all eight dimensions, is it not useful to target a specific sub-set of dimensions? If an intervention targets, say, the development of science literacy, if it is not working against the other dimensions, surely a young person's science capital would be increased in some way. For a large-scale intervention, a survey might be an appropriate method for capturing impact in relation to a specific dimension e.g., did the intervention increase the perception of science as interesting? Also, though, more in-depth interviews and focus groups might be an appropriate tool for collecting rich data and illuminate how the science capital of individuals has changed as a result of an intervention.

L. Archer *et al.* (2017) discuss an attempt at using a pedagogical approach, grounded in the science capital concept, in a secondary school setting. The research attempted to marry theory and practice “to improve things on the ground” (L. Archer *et al.,* 2017, p.13), which resonates with the action research approach of this project. The authors cite the teachers involved as explicitly valuing the opportunity of investigating theory in practice. Again though, data were collected from a long-term development project (9 months in duration) rather than from a single intervention. The project was framed as a small-scale, exploratory study and, whilst providing some useful insights in terms of the perceptions and experiences of teachers and young people, the scalability of the intervention is limited by its extended nature. The necessary relationships are not in place to adopt a similar study design with science teachers locally, but seeking to understand how teachers (or PGCE students) perceive the science capital approach could impact upon young people’s engagement in science and their possible career choices, and would be of value to initiatives aimed at increasing and widening participation in higher education science; particularly teachers’ perceptions of how this might be included in university-led outreach to increase the impact.

There is also value in asking those delivering university-led STEM outreach (academics and outreach practitioners) to outline the specific aims and objectives of their outreach activities, and about the impacts they perceived their activities to have, with a view to considering these in light of a science capital framework.

3.11 Summary

This chapter provides a synthesis of key literature relevant to this study. In considering key policy reforms it charts the transformation of universities as a public good to a private good, where studying for a degree is conceptualised as an investment in self and practices in H.E. are driven by market values. An overarching focus on instrumental economic goals blurs distinctions between increasing and widening participation and overlooks structural constraints, which theory suggests should be considered to understand the disparities in participation levels. The refinement of Bourdieusian notions of capital to the concept of science capital provides a framework for exploring further approaches to increasing and widening participation with a view to increasing the effectiveness of university-led science outreach and engaging more young people from more diverse backgrounds in higher education science. The methodology for this investigation is described in the next chapter.

Chapter 4: Research Design and Methodology

4.1 Introduction

The research design process involves numerous steps and at each step the researcher must take some key decisions (Byrne, 2016). At a philosophical level, these decisions will be heavily influenced by the assumptions a researcher holds about how the world is perceived and the best ways to understand it. At a more operational level, there are, for example, many possible research methods available and, whilst it is essential that the tools must address the research questions, it is unlikely that there will only be one way to achieve this. Each method will have benefits and limitations in terms of data collection. It is essential then that the overall research design is congruent with the methods used, is an effective one for the job and is justifiable in terms of the research questions (Vogt, Gardner and Haeffele, 2012). This chapter presents and justifies the research design process adopted in this study.

4.2 Philosophical Basis

4.2.1 Research Paradigm

Assumptions about the nature of reality and knowledge, along with the researcher's value systems and ethical principles feed into the paradigm position for research. As Haigh *et al*. (2019) explain a paradigm constitutes a set of perceptual orientations and assumptions that determine how phenomena are viewed and the methods that should be used to study those phenomena. They elaborate on the four interwoven perspectives that provide fundamental underpinning for conceptions of knowledge and knowing: *ontology* –philosophical assumptions about the nature of reality in terms of what actually exists, what it looks like, what units make it up and how they interact with each other; *epistemology* – assumptions about the nature and scope of knowledge; *methodology* – the approach to the creation of knowledge; and *axiology* – consideration of how value judgements influence the process of knowledge construction. Aligning views in relation to these considerations in a coherent fashion constitutes a paradigm position and is illustrated in figure 4.1.

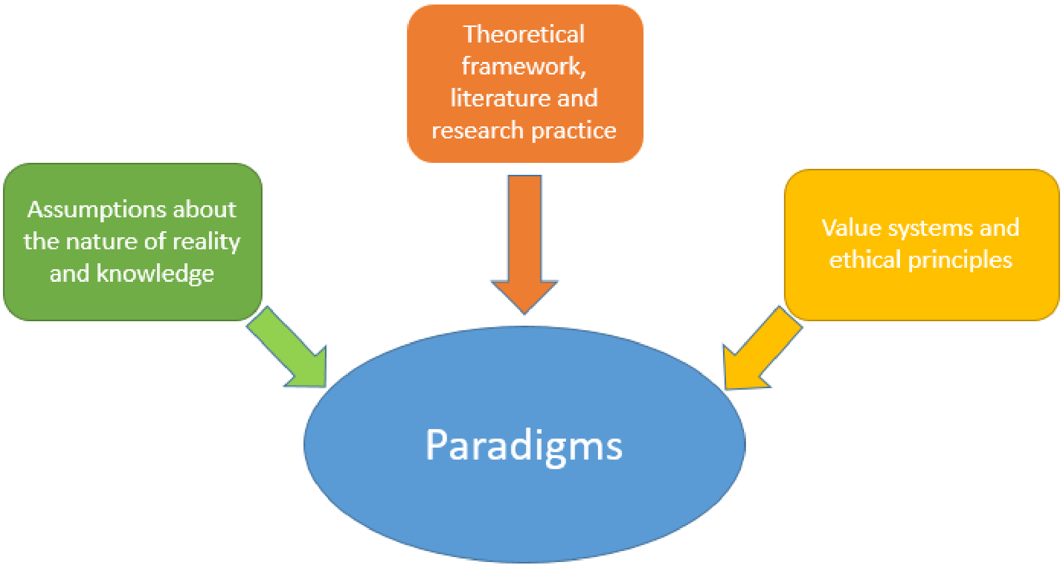

Figure 4.1 Factors influencing the choice of a paradigm (Kawulich, 2012).

As Fulton *et al.* (2013) explain, there is no clear agreement on the paradigms available to be applied to a research study. However, whilst there is some blurring, the two main research paradigms are viewed as constructivist and positivist. A constructivist approach sees knowledge as subjective and personal, and typically aligns with qualitative methodologies. Qualitative research is principally concerned with understanding how individuals create, modify and interpret the world (Cohen, Manion and Morrison, 2007). In contrast, a positivist approach views knowledge as concrete and objective, and typically aligns to quantitative methodologies. Through the systematic observation of changes in the phenomena of interest whilst altering what are thought to be causal influences, quantitative research takes a controlled and rigorous approach to the discovery of scientific 'truths' (Walsh, 2001). Table 4.1 gives a summary of these two paradigms for comparison, along with the related methodologies and data collection techniques.

Table 4.1 Summary of selected paradigms (adapted from Mertens (2007) and Kawulich (2012)).

	Positivist **Post-Positivist**	**Constructivism** **Interpretive**
Purpose of the research	To discover general laws that govern the universe	To discover perceptions and describe human nature
Philosophical underpinnings	Informed mainly by idealism, realism and critical realism	Informed by hermeneutics and phenomenology
Ontological assumptions	There is a single autonomous reality	There are multiple realities as constructs of human mind
Epistemological assumptions	Knowledge is objective	Knowledge is subjective
Axiological assumptions	Values only have a place in the choice of research topic and the research process should be value free	Study of social life is value-laden
Methodology	Quantitative approaches based on precise observation and measurement, such as experiments, quasi-experiments, and surveys	Qualitative approaches that see truth as context-dependent, such as phenomenology and ethnography
Data collection methods	Typically use structured questionnaires, official statistics, observations, and tests	Typically emphasise participant observation, interviews, pictures, photographs, journals, and documents

Some researchers believe that, because the assumptions underlying each approach are so vastly different, qualitative and quantitative methodologies cannot be combined. This is not universally the case, and some researchers advocate combining methodologies. Frost (2011), for example, suggests that the primary concern should be to address the research questions rather than the underlying ontology and epistemology of the approaches used to do this. Similarly, Easterby-Smith, Thorpe and Lowe (1991), Tashakkori and Teddlie (1998), Bishop *et al*. (2011) and Fisher and Stenner (2011) put the research question at the centre of the research process and advocate combining methodologies to address the research question with any method available. Juxtaposing different paradigms in this way is seen to provide more perspectives on the phenomena being investigated and enable weaknesses to be cancelled out. Potential bias and sterility of a single-method approach can be overcome by combining data collection methods and, as Fisher and Stenner (2011) highlight, can yield rich and meaningful data through a qualitatively meaningful and quantitatively precise measurement framework, leading many researchers to position their research within a pragmatic paradigm.

A further paradigm position, representing an amalgam of perspectives that contrast with those aligned with positivist and constructivist positions is critical realism (Danermark *et al.*, 2002). Joining ontological realism with epistemological constructivism, critical realism is a philosophical position most closely associated with the work of Roy Bhaskar (Cruickshank, 2003) and, as Houston (2014) describes, is one that is attracting increasing interest in academic and professional fields. As Shipway (2013), M. Archer *et al.* (2016) and Haigh *et al.* (2019) explain, critical realism is defined by the following key features:

- a reality exists that operates independently of our perceptions, theories and constructions
- knowledge is transitive and is dependent on the context, concept and activity
- a concern with the nature of causation, relations, and the complex and continuous interaction of structure and agency.

Critical realism attempts to reconcile the opposition that exists between positivist and constructivist perspectives about reality and how it can be known. Whilst social reality is viewed as operating within an open system, whereby laws and constants cannot explain social action, it is also viewed as being more than simply a social construct

(Bordogna, 2020). In seeking the causes of events and suggesting that the social world is framed by relationships between unobservable structures and agents acting in the world (Scott, 2010), the paradigm position offers a framework to approach complex educational problems. Believing that both can yield relevant insight, critical realism accepts quantitative and qualitative approaches to data collection.

Crucially, no single paradigmatic framework is ‘correct’. The researcher must determine their own paradigmatic view and consider how that informs their research design to best answer the question under study. As Kawulich (2012) explains, a researcher’s ontological and epistemological perspectives, along with their value system, the theoretical perspectives on the topic under study and the literature that exists on the subject combine to influence the choice of paradigm and methodology most appropriate for the study.

4.2.2 Ontological and Epistemological Perspective in this Research

> “All research is based on assumptions about how the world is perceived and how we can best come to understand it.” (Trochim, 2006, p.1).

The purpose of research is to further knowledge. It is concerned with understanding the world. How I interpret the world and what I deem valuable will influence how knowledge is constructed and impact on this understanding. As Kincheloe and Berry (2004) highlight, I therefore need to be conscious of the way I perceive phenomena, as these perceptions are underpinned by philosophical assumptions which will impact on the outcome of the research.

At the outset, therefore, it is imperative that I make explicit my beliefs and values; and recognise and acknowledge ‘where I am coming from’ in terms of my philosophical assumptions (Opie, 2005). By clarifying my underpinning philosophy, the rigour of my research will be enhanced, leading to more credible research outcomes.

As a university lecturer working with colleagues to increase and widen the participation of young people in science subjects, a focus on outreach activities has led me to consider the development of science capital. The research has arisen from me valuing the quality of learning experiences for young people and believing that an important part of my role is to support and create opportunities for individuals to develop personally. I also believe in the concept of social justice where opportunities and privileges within society are distributed fairly. The research is based on an assumption that young people's perception of science can potentially affect their engagement with the subject, as well as a desire to enact change and generate actionable knowledge.

In clarifying my positionality, it is imperative to consider my ontological and epistemological stances. As explained earlier, ontology and epistemology are two of the most central concepts in the philosophy of science and social research. Raising questions about the essence of the phenomena being investigated (Cohen, Manion and Morrison, 2011), ontology is used to distinguish between different positions towards the underlying nature of reality (Nicholas and Hathcoat, 2014). The nature of the relationship between the subject and the object is informed by the ontological position and how these relationships are conceived therefore influences the approach taken to research.

Realism is one ontological position which argues that an objective truth exists independent of the human mind. From an ontological realism position, science can be considered as a body of knowledge, ascertained as truth and proved by earlier scientists – a set of procedures and rules that can be employed to resolve problems.

Relativism is an opposing ontological position which posits that truth is a subjective construction invented in the human mind. In this view, entities in the world are mind-dependent and relative to particular contexts (Nicholas and Hathcoat, 2014). From this ontological position, science can be viewed as a human conceptualisation of the phenomena that individuals observe in the world around them.

From an ontological perspective, I believe that some entities are extra-discursive and exist independently of their identification; that there is a single reality (Fleetwood, 2013). I have an ontological realism.

Leading on from ontology, epistemology is the branch of philosophy that studies the nature and scope of knowledge. Essentially epistemology is concerned with the construction of knowledge and, in terms of education, is interested with what counts as educational knowledge, how it is obtained and how it is structured (Sharp, 2012). As Houston (2014) argues, any research should be considered at an epistemological level to define its dimensions and borders, and improve its applicability.

Critical realism provides a philosophical tool for identifying causal mechanisms within a particular field of activity and subscribes to the notion that, as well as understanding the social world, the researcher should also seek to change it to further human well-being. This is consonant with the aims of this research, which, from an epistemological perspective, is seeking practical knowledge to address issues encountered in my own professional practice so that emancipatory action can be taken. Essentially practical rather than idealistic, the approach used here sees the world as integrated and messy (Denscombe, 2008), but supports a methodology for change and development.

In seeking to understand and change the social world, Bhaskar (1989) argues that we must identify the structures at work. In doing so he addresses a major concern in sociology around how human agency engages with social structure. Different theories have emphasised one of the two polarities in their attempt to explain social life (Coghlan and Brydon-Miller, 2014). As reviewed in section 3.8, Bourdieu, for example, emphasises how the structural mechanisms that exists in society guide thinking and behaviour in determinant ways. In contrast, Giddens (1984), in his concept of structuration, posits that individuals are thoughtful, creative, and always have some form of agency to transform a situation. The philosophical position of critical realism recognises that social conditions have real impacts but that individuals both are impacted by these conditions and generate them, thus shaping their social world (Bhaskar, 1989; Fleetwood and Ackroyd, 2004).

Recognising the inter-relationship between the two, critical realism requires the researcher to look for causal explanation and interpretative understanding (Fleetwood and Ackroyd, 2004), accepting that social science is transformative. Both individual agency and context are important in this respect, with both being causal factors which, although inter-related, can be analysed separately. In relation to this study, both the young person as agent and their external context within which they learn, are important to understanding the participation of young people in science subjects and adopting a critical realist perspective has methodological implications.

4.3 Methodological Approach to this Research – Action Research

Within a paradigmatic framework of critical realism, action research provides a popular approach among professionals, particularly in education, seeking to use research to improve practice (Denscombe, 2010). It is regarded as a powerful form of educational research in being a methodology for development and change (Gray, 2004; McNiff, 2013). Action research provides a robust framework for understanding complex situations (Reason and Bradbury, 2008) and sits comfortably within a foundation of critical realism, which, as a philosophical perspective, enables researchers to gain a thorough understanding of the social world and the nature of the problems which they seek to resolve, thus enriching action research with analytical depth. The cyclical and reflective nature of action research allows the exploration of events within the causal levels of reality (Houston, 2014), with a view to acquiring insights which can potentially lead to the amelioration of practical situations

Each methodology has advantages and disadvantages, but ultimately the choice of methodology is dependent on identifying the best one for the specific research project (Denscombe, 2010). With the aim of understanding ways to engage more people, from more diverse backgrounds, in higher education science, given the tension between widening participation and marketisation, this research is focused on developing practice in this area. It is focused on solving a problem, is future-oriented and involves me, as the researcher, working with collaborative partners. Action research therefore is an appropriate methodology and one that reflects the iterative processes used by professionals in assessing needs, responding to them and evaluating progress (Hart and Bond, 1995). As Kemmis *et al.* (1982), cited in Hart and Bond (1995, p.31), argue:

> The major aim of action research is the establishment of conditions under which self-reflection is genuinely possible: conditions under which aims and claims can be tested, under which practice can be regarded strategically and 'experimentally', and under which practitioners can organise as a critical community committed to the improvement of their work and their understanding of it.

It is useful here to consider some other definitions of action research:

- "Action research is the study of a social situation with a view to improving the quality of action within it" (Elliot, 1991, p.69).
- "Action research is a way to promote knowledge generation that is intrinsically capable of producing public goods through concrete and practical problem-solving and of shaping deeper reflection processes through broad disciplinary

and stakeholder participation in research-based discourses" (Levin and Greenwood, 2008, p.211).

- "Action research is action disciplined by inquiry; a personal attempt at understanding whilst engaged in a process of improvement and reform" (Hopkins, 2014, p.58).
- "Action research is a systematic approach to investigation that enables people to find effective solutions to problems they confront in their everyday lives" (Stringer, 2014, p.1).

From these definitions can be drawn four defining characteristics of action research. First is a practical orientation, coupled with, secondly, being geared to changing matters. Research is utilised to generate a deeper understanding of issues arising in practice, but also sets out to improve the situation (Denscombe, 2010). Findings are fed into concrete situations, as part of the research process rather than tagging this step on afterwards, with the validation of theories generated through action research being done through practice (Elliot, 1991; Denscombe, 2010). Alluded to earlier, the cyclical nature of action research is a third defining characteristic and fourthly is participation, whereby people who are impacted by the research are involved at all stages of the research process. Thus, working *with* people will bring about greater change.

In relation to participation, it is important to note that, at the outset, the aim had been to develop a participatory action research project. It was felt that, with the researcher and participants working together, this would permit a deeper understanding of the situation and effect change for the better. Due to competing organisational demands, as well as ambiguity and fluidity in job roles, it was difficult to secure the anticipated levels of participation. If this dimension of action research is viewed on a continuum, from participatory on the left to researcher-led on the right, the study slid right during its duration. In their article on participatory action research methodology, Mackenzie *et al.* (2012) conclude that the success of the approach relies on clear demarcation of roles between researcher and participants and considerable effort spent building and maintaining relationships. The changing organisational context did not support these factors and the move towards a more researcher-led approach was necessary to ensure that the overall success of the project was not jeopardized. Action research can similarly be conceived on a continuum between being fixed/pre-designed at one end and flexible at the other; the approach here was emergent. Whilst at times it felt that some of the time invested in developing dead-end relationships was wasted, the discussion was important in shaping how I perceived, defined and approached the problem, ensuring the findings were as valuable as possible.

In its most basic form, the cyclical nature and steps involved in action research can be represented in the model shown in figure 4.2, developed originally by Kurt Lewin.

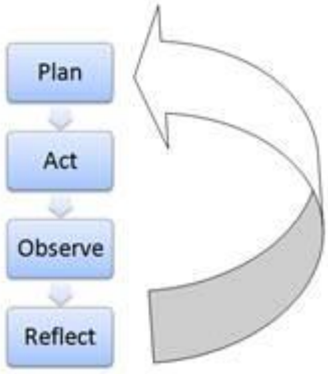

Figure 4.2 Lewin's basic action research model (taken from Costello (2011)).

The model proposes the need to plan activities or interventions (aimed at solving a problem), implementing those activities, observing the outcomes, reflecting on what has happened and then planning further action as necessary. Recognised as a model for change, it is worth noting that Lewin's initial development of action research methodology did not include any critique of wider society and did not consider issues of power (Hart and Bond, 1995).

Many other authors offer diagrammatic representations of action research, at the core of which are cycles of action and reflection. As the name suggests, action is key to this methodology, but, as McNiff (2013) suggests, critical self-reflection is also central. Building in opportunity for evaluation and reflection is essential. McNiff (2013) presents a rather messy approach to action research, shown in figure 4.3, arguing that traditional models do not accurately represent the tumultuous nature of professional practice.

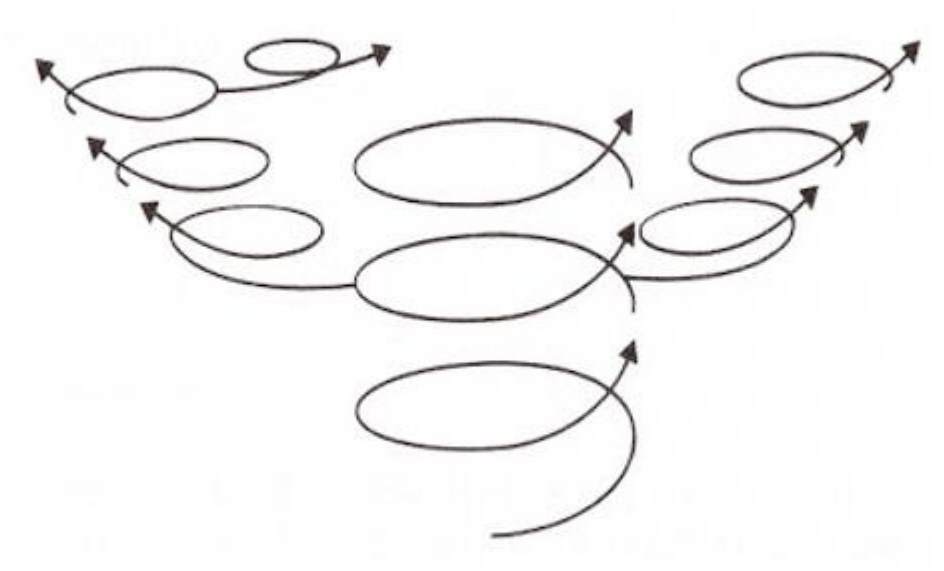

Figure 4.3 Messiness of action research (taken from McNiff (2013))

However, whilst prescriptive models could potentially be restrictive to the research process, and perhaps do not accurately capture the nature of professional practice, the frameworks do provide structure and, as such, enhance the rigour of the research. Following a particular model would enhance the rigour of my research and hence improve the robustness of my findings. Elliott's model has merit for this project, shown in figure 4.4.

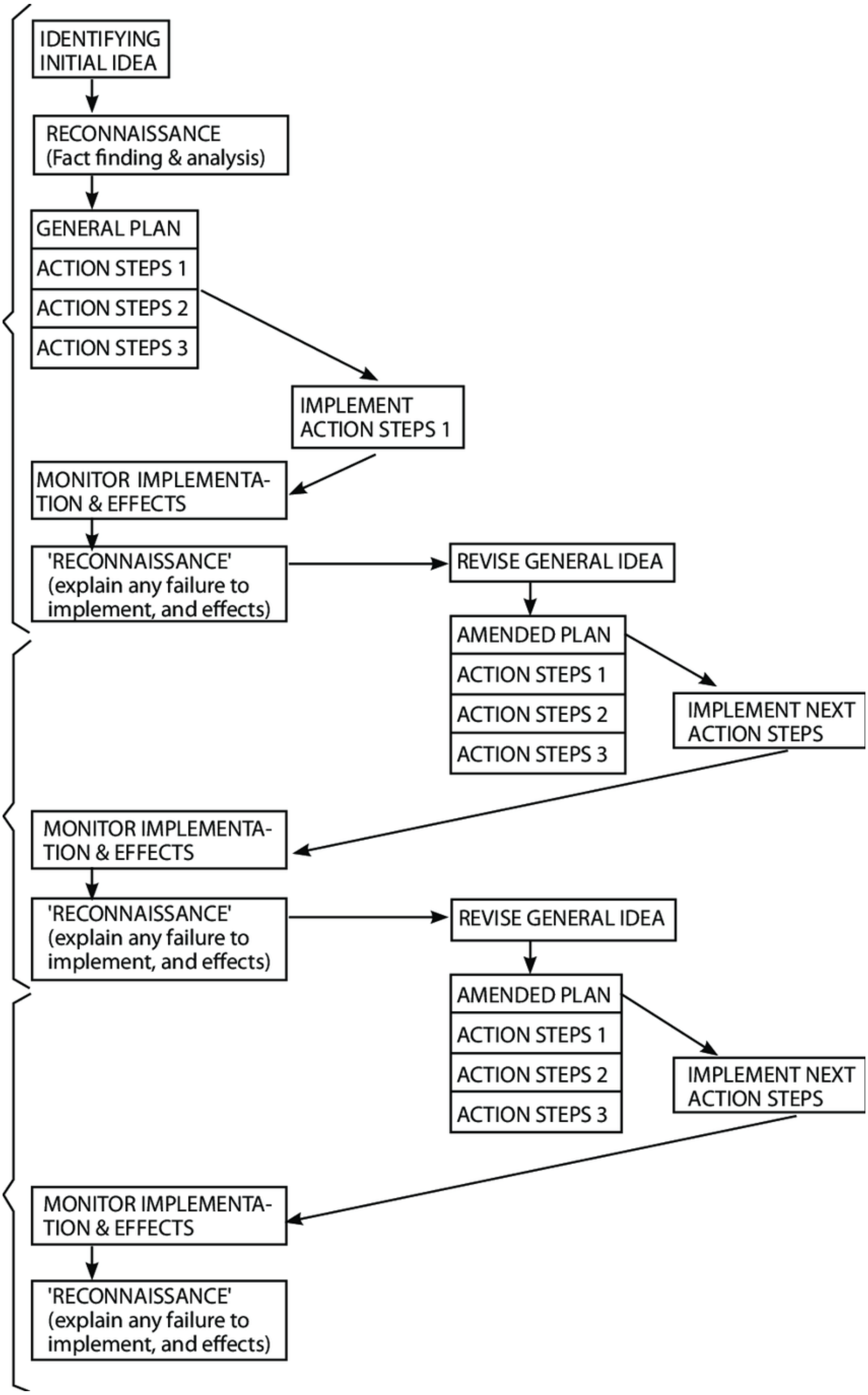

Figure 4.4 Elliott's action research model (taken from Elliott, 1991).

The model clearly identifies the need for 'reconnaissance' (fact finding and analysis) early in the project. Whilst review of the literature may suggest several avenues for investigation, if the research is to make a meaningful contribution to practice, there is a need to develop a full and clear picture of what is already being done. In this project, this involved establishing a baseline of what science outreach has previously taken place, soliciting the views and perceptions of stakeholders through individual and group discussions, as well as online surveys, and interrogation of data on participation in science in compulsory education within the region.

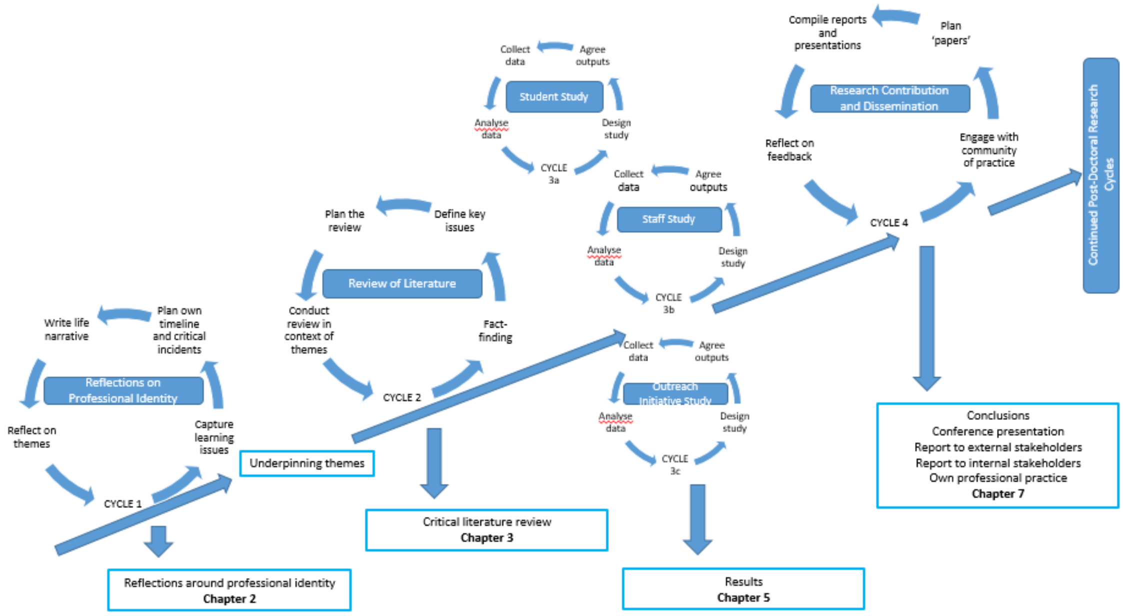

Figure 4.5 Doctoral research map (adapted from Muir (2007)).

Adopting an action research methodology, figure 4.5 maps the actual approach taken in this study. Cycle 1 centred on reflection around my professional identity. Spanning both the taught element of the Professional Doctorate programme and the start of my individual study, this involved me exploring what drives me as a professional, what my values are and how these relate to professional issues within my project – essentially unpicking my professional identity. With the motivation for this study grounded in my professional identity, this allowed me to develop a deep understanding of my professional identity and how it influences my behaviour, so that I could make sense of my interactions within my community of practice and how I contribute to professional practice. The output of cycle 1 is captured in chapter 2 of the report and the underpinning themes guided the parameters for cycle 2 – a review of the literature.

Cycle 2 centred on a review of the literature. Framed by key influences on the development of my professional identity, this cycle allowed me to acquire a deeper understanding of the research topic, of what has already been done on it, how it has been researched and what the key issues were. Drawing on theory, empirical studies and professional reports, the literature review allowed me to define key issues, which are captured in chapter 3 of the report, and inform cycle 3 – three individual studies centred around data collection.

Cycle 3 in effect comprised three smaller cycles – student study, staff study and outreach initiative study. The data collection and analysis in cycle 3 is expanded on further below in section 4.8, but it is worth recognising the importance of cycle 4 at this point. Ebbutt (1985, p.157) asserts that, "if action research is to be considered legitimately as research, then participants in it must be prepared to produce written reports of their activities". He adds that public critique of these reports is important. To enhance the rigour of my research, a cycle of research contribution and dissemination was included in the methodology, in which reports and conference presentations were subject to critical review by members of my community of practice.

4.4 Defining my Community of Practice

Drawing on the work of Waterman *et al.* (2001) and relating to the defining characteristics of action research, Reason and Bradbury (2008) allude to ways in which the quality of the research can be enhanced. These include clearly describing and justifying the participants and stakeholders, and considering the relationship between researcher and participants. In their toolkit, Hart and Bond (1995) advise identifying the players (stakeholders) and mapping their position in terms of their influence. For this action research project, the stakeholders were identified across categories of management, sponsors, users, interest groups and practitioners. This permitted consideration of who were invested in the project and their influence on the project, particularly in terms of whether they shared my views or not. Hart and Bond (1995) also advise listing the stakeholders in rank order according to the power they hold. This exercise not only identified the most powerful, but also the nature of the power. Some stakeholders, for example, held power over resources, people, permission, time and places, some held the power to marginalise/centralise and close off/open up, some stakeholders held power over funding and others held power to disrupt/support or to cooperate/say no.

Importantly, this process allowed me to define my community of practice, in recognising who could benefit from my research. This was primarily outreach practitioners (including all members of university staff involved in student recruitment, marketing and widening participation activities, as well as members of professional associations and charities involved in promoting engagement in science) who can bring about change in practice and managers who can influence policy decisions. The themes of my research were developed through reflecting on my professional identity (cycle 1) and interrogation of the literature (cycle 2) (see section 4.3), but dialogue with members of my community of practice was important to ensure the findings would lead to a contribution to practice rather than serving to simply satisfy intellectual curiosity. Outcomes were agreed to increase the impact of the research, such as using the findings to inform the development of student recruitment and outreach plans and reports to external organisations working in collaboration. In seeking the development of research-informed practice to promote social justice for young people the research aligned with the strategic focus of a research centre within the university, and it was recognised that the findings would also have value to the wider academic community interested in the participation of young people in higher education science, with outcomes agreed around the delivery of conference presentations.

4.5 Choice of Research Methods

As explained in section 4.3, this doctoral project adopted an action research methodology, within which cycle 3 comprised three smaller cycles of data collection and analysis. These individual studies were designed to contribute to the overall aim of critically analysing approaches to increasing and widening participation in higher education science through investigating the key influences on undergraduate students in their choice to study science at university (student study), investigating the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students (staff study) and investigating the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital (outreach initiative study).

It was recognised that there are many methods of data collection and analysis, each with strengths and weaknesses, and that the methodological approach adopted has a key role in determining which are the most suitable methods for addressing the research aim. Researcher reflections are an essential component of action research and can be considered as one of the research methods (Fulton *et al*., 2013), but, as a methodology, action research does not specify any other constraints on the means for data collection and analysis. Indeed, Herr and Anderson (2005, p.70) state that, “action research must begin with a clear direction but with the anticipation that as data gathering and analysis proceed, the questions, methods, design and participants may all shift somewhat”. As such, both quantitative and qualitative research methods were considered (expanded upon further in sections 4.5.1 and 4.5.2), with the final choice, as justified by Ahmed, Opoku and Aziz (2016), heavily influenced by the type of data, time and other resources available in the specific professional context.

4.5.1 Choice of Data Collection Methods

Congruent with the philosophical underpinning and methodological approach of this doctoral project, the key influences on undergraduate students in their choice to study science at university, the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students and the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children’s science capital could theoretically have been investigated through the collection of either quantitative or qualitative data.

Quantitative methods offered a structured data collection process with numerical data output, allowing perceptions and attitudes of target participants to be quantified. The reliance on concrete numbers was seen as beneficial in helping to remove subjectivity and bias from the research, with another benefit being the relative ease of gathering data from a large sample size.

Alternatively, offering richness and insight, qualitative methods provided a means of gathering data to gain insight into people’s experiences and to explore complex topics. For example, using interviews to explore the topic directly with the person experiencing the phenomenon under study would have provided different perspectives, and through studying the natural language used by participants or non-verbal cues the data could be enriched further (Manns, 2017). It must be noted that the quality of the data generated will be determined, in large part, by the skills of the researcher (Patton,

2002) and very little meaningful data will be collected from, for example, an ill-prepared, rushed and unrecorded interview (Preece, 1998). To ensure that meaningful data is obtained, the time involved in the preparation of interviews, conduct of interviews and subsequent transcription can be significant (and prohibitive when time and resource availability were considered). A lack of standardisation and reliability were also seen as a disadvantage of qualitative research methods. Whilst a rigorous and structured approach to data analysis provide some mitigation (Manns, 2017), potential bias could exist in terms of the responses elicited from questions and in the subjective interpretation of responses. Qualitative research methods did however have the advantage of requiring a relatively small number of research participants.

Combining quantitative and qualitative methods of research, mixed methods offered an alternative to mono methods to provide valuable insights into social phenomena (Brannen and Moss, 2012). In recognising the benefits and limitations of quantitative and qualitative methods at the same time, data collection tools such as questionnaires offered a route to both exploring perspectives and generating quantifiable data (Rubin and Babbie, 2008). The reliability of findings could be enhanced through rigorous questionnaire design, administrative control and clerical accuracy, whilst the inclusion of open-ended questions could create a more complete and detailed description of phenomena. Deemed most appropriate for addressing the aim of the research in my specific professional context, on balance of the benefits and limitations, and time and resource availability, mixed methods were used in cycle 3 of this doctoral project. Questionnaires were used as tools to collect both quantitative data, through for example the use of rating scales, and qualitative data, by giving participants the opportunity to write in their own words. More specific details about the questionnaires used in the three individual studies comprising cycle 3 of the doctoral project are given in section 4.8, explaining, for example, how themes derived from the literature guided their design, but more general considerations around the benefits and limitations of questionnaires as data collection tools are given here.

As data collection tools, questionnaires (online or paper) are reasonably inexpensive and relatively easy to administer. They do have certain disadvantages, however, such as uncertainty around whether responses have been provided by the target person and without consultation with others. Low response rates of less than 10% are also common (Denscombe, 2003; Collis and Hussey 2014). Confidence that the right person has responded can be increased by administering questionnaires at the beginning or end of a taught session, which would also potentially enhance the return rate. Indeed, Bean (1980) suggests that response rates of 66% can be achieved by using teaching staff to administer questionnaires. Further weaknesses remain though with written questionnaires because of differences in how questions are interpreted between participants (Preece, 1998) and only literate individuals being able to respond (Gill, Johnson and Clark, 2010). This is particularly pertinent to this study where language used in an academic setting may be unfamiliar or have different meaning within student and parent populations. Sample bias may also be an issue because of responses coming from those with heightened interest in the topic and therefore not providing a true representation of the whole population. It must be acknowledged that responses may be missed from 'hard to reach' sub-groups within a larger population that are difficult to access due to a "social or physical location, vulnerability, or otherwise hidden nature" (Ellard-Gray *et al*., 2015; p.1).

4.5.2 Choice of Data Analysis Methods

As explained above in section 4.5.1, questionnaires were used to collect both quantitative and qualitative data.

Quantitative data lend themselves to statistical analysis, which allows for large sources of information to be summarised and facilitates comparisons across categories and over time (Kruger, 2003). In selecting the method of statistical analysis though it is important to consider the type of data to be interrogated, which, in the use of Likert scales within questionnaires, introduces a long-running debate (Carifio and Perla, 2008). Likert scales produce ordinal data, where respondents rate factors, but the distance between responses is not measurable. The difference between 'major influence', 'strong influence', 'some influence' and 'none' or 'strongly agree', 'agree', 'disagree' and 'strongly disagree' are not necessarily equal. This contrasts with interval data where the difference between responses can be measured (Sullivan and Artino, 2013).

Jamieson (2004) asserts that because Likert scales produce ordinal data then they must be analysed using non-parametric statistics. That is, it is not appropriate to convert ordinal data to numbers and calculate means and standard deviations that depend on data that are normally distributed and have unclear meanings when applied to Likert scale responses. The meaning of the mean of 'major influence' and 'strong influence', for example, is unclear. Similarly, if responses are clustered at the extremes, the mean may give a central response which is not truly characteristic of the data.

Non-parametric tests do not assume a normal distribution (Sullivan and Artino, 2013) and are valid with small sample sizes and non-normal data. Therefore, there is an argument that non-parametric tests such as frequencies, the Kruskal-Wallis test and the Mann-Whitney *U* test should be used for analysis instead of parametric tests. Similarly, as the point that separates the upper and lower halves of the data when arranged from smallest to largest, the median is a better measure of central tendency for Likert scale data. This can be calculated by allocating a number to individual points on the Likert scale, for example, '1 = strongly agree', '2 = agree', '3 = disagree' and '4 = strongly disagree'. The numbers are then arranged in an order from smallest to largest to find the middle number. In the same vein, the median function in Microsoft® Excel will return the number in the middle of a data set.

However, non-parametric tests are less sensitive and less powerful than parametric tests (Carifio and Perla, 2008) and are therefore less likely to detect an effect that truly exists. There is much support in the literature therefore for using parametric tests to analyse Likert scale data. Jamieson (2004), for example, argues that if the data are nearly normally distributed and there is an adequate sample size (given as 5-10 observations per group), then parametric tests can be used with Likert scale ordinal data. This is supported by Norman (2010), who provides evidence, using real and simulated data, that concerns around using parametric tests with ordinal data are unfounded. He argues that parametric tests are robust enough to give unbiased answers with data from Likert scales, even when the underlying assumption that the data is normally distributed is violated, and can be used with "no fear of coming to the wrong conclusion" (Norman, 2010, p.631). The findings from a study by de Winter and Dodou (2010), who conducted a simulation to assess the capabilities of the two-sample t-test (parametric) and Mann-Whitney (non-parametric) test to analyse Likert scale data, lend further support. The two-sample t-test and Mann-Whitney test differences between pairings and the findings show that both types of analyses generate error rates close to the target value (significance level), with only very small differences in statistical power. They conclude that, across group sizes of 10, 30 and 200, it does not matter which of the two tests are used to analyse Likert data.

The debate within the literature around whether to use non-parametric or parametric tests with Likert data continues. The decision is influenced by whether the median or mean is the best measure of central tendency for the distribution of the data. For this study, to describe the data, means were of limited value and a frequency distribution of responses was more helpful. It is appropriate though to use either non-parametric and parametric tests to analyse Likert scale responses and therefore, to increase the likelihood of detecting an effect that truly exists, both the Kruskal-Wallis test and its parametric equivalent, the ANOVA test, have been used to test if there was a significant difference between samples. Acknowledging that sample sizes available in this doctoral study limit the extent to which results can be generalised to wider populations, numbers were never-the-less adequate in the outreach initiative study to test if any differences between groups were so large that they were unlikely to have occurred by chance.

If an ANOVA test yielded significant results, then it was followed up with *post hoc* t-tests to determine which means were different between two groups. At that stage, it was important to consider sample sizes and variances within samples. Better statistical power is provided by the unequal variances' version of the two-sample t-test if the data have unequal variances and unequal sample sizes.

If a Kruskal-Wallis test gave significant results, then it was followed up with a *post hoc* Mann-Whitney tests to compare two sample groups.

For the analysis of qualitative data, possibly the two most common approaches are content analysis and grounded theory methods (Gray, 2004; Barbour, 2014). Content analysis involves locating categories or classes within the data, which are usually derived from theoretical models. Grounded theory, in contrast, uses a process of open and selective coding to develop categories and theories inductively from the data (Frey, 2018). Other methods of analysis exist, such as narrative analysis, conversation analysis and discourse analysis (Check and Schutt, 2012; Barbour, 2014), but, as the research epistemology guides what can be said about the data and informs how meaning is theorised, it is imperative that the method of analysis matches the conceptual framework. Thematic analysis is described as “a method for identifying, analysing, and reporting patterns (themes) within data” (Braun and Clarke, 2006, p.79), but is without any inherent philosophical underpinning. It is essential therefore for any researcher to clarify the philosophical assumptions that underpin their work, as articulated in section 4.2.2. As such, the use of thematic analysis in this study fits with a critical realist perspective in that, according to Braun and Clarke (2006, p.81), the method of analysis recognises “the ways individuals make meaning of their experience and, in turn, the ways the broader social context impinges on those meanings, while retaining focus on the material and other limits of ‘reality’”. With broad application, thematic analysis can also be used with a wide range of data sets, varying in type and size, and can be applied usefully to a wide range of research questions (Allen, 2017; King and Brooks, 2018). Reliability, and indeed its relevance, should be considered as different researchers may have different ideas about what constitutes a theme or which themes are important (Fugard and Potts, 2019). From a constructionist perspective, it should not be assumed that two researchers will identify the same themes or indeed whether this should be viewed as a strength of the analysis. From a critical realist perspective however, reliability assumes greater relevance as, with themes existing in the data, it should be assumed that different researchers will find the same themes if following the same method. Mills, Durepos and Wiebe (2010) do however observe that the method of thematic analysis is rarely explained clearly enough by researchers for accurate replication. As an analytic method, it is important also to consider the source of the data which may introduce bias, but this is mitigated by controlling the questions asked in the collection of data.

Whilst thematic analysis is often considered a basic method for identifying and analysing patterns in qualitative data (King and Brooks, 2018), it does provide a robust description and understanding of data (Allen, 2017). Braun and Clarke (2006) also assert that researchers unfamiliar with qualitative methods of analysis should start with thematic analysis, as it is more accessible and easier to use than other approaches. As a science lecturer most familiar with quantitative data analysis, thematic analysis provided an appropriate method of analysis.

4.6 Validity/Trustworthiness/Authenticity

Within action research, the construction of meaning requires a process where series of arguments can be tested. The Habermasian ideal speech situation, described in Somekh (2006), characterises a process where all participants have equal rights to speak and are involved in the construction of meaning exchange arguments without coercion. In this idealised situation, each participant earnestly judges the arguments put forward and gives the best judgement they can make. The process will arrive at a legitimate truth when no further arguments are able to overturn those already stated. As a continuous process, where new findings and experiences challenge existing knowledge, the ideal speech situation provides a logical and rational process for making meaning. However, this process neglects the influence of emotions, power and inequality and, in interpreting Gadamer's work, Greenwood and Levin (2007, p.68) advocate a "more complex combination of dialogue, mutual interpretation and eventual (but never final) 'fusion of horizons'". At the heart of these processes is the relationality among researchers and participants and the validity of action research rests on these collaborative relationships (Reason and Bradbury, 2008) - in essence providing 'ecological validity'. Inevitably though, findings will carry a large degree of context specificity, but meanings in one context can be assessed for their transferability to a different context by reflecting on similarities and differences between background characteristics (Greenwood and Levin, 2007).

4.7 Ethics

> "Ethical tensions are part of the everyday practice of doing research" (Guillemin and Gillam, 2004, p.261).

As a discipline, ethics is traditionally divided into three major areas:

- meta-ethics – which asks questions about the possibility, nature and significance of distinctively ethical truths
- normative ethics – which seeks to justify the content of ethical prescriptions
- applied ethics – which seeks to answer real questions that are ethically controversial.

Research ethics falls within the sphere of applied ethics with its primary concern being the practical decision-making of the researcher. Moral theories and meta-ethics however provide a grounding to clarify reasons for arriving at decisions, and, drawing on a bioethics approach in particular, such decision-making is commonly underpinned by four principles:

- beneficence – an obligation to promote well-being
- autonomy – respect the right of self-determination
- non-maleficence – an obligation to avoid doing harm
- justice – an obligation to treat everyone equally, fairly and impartially.

(Beauchamp and Childress, 2001).

These overarching principles have been further refined by the British Educational Research Association, which provides definitive guidelines for conducting educational research. In line with these guidelines, this research was conducted within an ethic of respect for the person, knowledge, democratic values, the quality of educational research and academic freedom (British Educational Research Association, 2018). Adhering to these principles and in agreement with the Chair of the Ethics Group at the University of Sunderland, ethical clearance was sought from the research ethics panel at my home institution for specific studies that developed through the action research approach. Any issues identified through ethical review were actioned and data collection only took place after approval had been granted. My Director of Studies and co-supervisors were kept informed of the outcomes from ethical review and confirmation of approval for each of the studies was emailed to the University of Sunderland Ethics Group.

Given the methodology, there was a particular responsibility to participants in the research. It was important to remember that participants may have been either active or passive subjects in the research processes, and, engaged in action research, my own reflective research may have impinged on others, such as students and colleagues. The main ethical issues arising in this study related to dignity, anonymity and confidentiality.

Particularly with students and other young people, in relation to dignity, recognising that the participants may have considered me as someone in authority was important, and, as such, may have felt an obligation to take part in the research. Assurances were given to everyone contacted that they were not obliged to participate, and withdrawal was possible at any point.

Maintaining anonymity throughout data gathering and analysis was important in safeguarding the rights of participants, as well as potentially making them more forthcoming (Sieber and Tolich, 2013). Confidentiality is when responses are known only to the researcher and could be assured using password protected computers and locked filing cabinets. It was important to remember that assuring both anonymity and confidentiality goes beyond preventing the disclosure of sensitive information to considering all aspects of the data that may permit individuals to be identified.

In line with good practice for ethical research, Participant Information Sheets were developed for specific studies. These provided information on:

- purpose of the research
- why that participant has been selected
- what would happen if recruited
- possible risks and benefits of participation
- the fact that participation is voluntary and rights to withdraw
- how will data be kept confidential
- what will happen at the end of the study
- how will results be disseminated
- how to complain.

Informed consent was also sought, and participants were asked to sign and date a consent form.

The above steps provided assurance of the integrity of the research at a procedural level, but it was anticipated that, in practice, there would undoubtedly be everyday ethical issues that arose in carrying out the research (Guillemin and Gillam, 2004). Issues may have arisen, for example, through a participant expressing discomfort with an answer or revealing vulnerability. Such unexpected situations required immediate decisions of ethical concern. Guillemin and Gillam (2004) highlight the role of reflexivity in these moments, where reflexivity is defined as a “deeply questioning enquiry into professionals’ actions, thoughts, feelings, beliefs, values and identity in a professional context” (Bolton, 2006, p.203). Whilst a lack of time and expectations of constant business act as impediments, it is argued that reflexivity is essential for responsible and ethical practice (Guillemin and Gillam, 2004). A continuous process of critical scrutiny facilitated principle-based decision-making around the interactions between myself, as researcher, and participants that respected the autonomy, dignity and privacy of all.

The approach outlined above assured the ethical integrity of the research overall, but two areas – the ethics of research with children (see section 4.7.1) and the ethics of insider research (see section 4.7.2) - warranted further consideration.

4.7.1 Ethical Considerations for Research with Children

Including children in the research (within the outreach initiative study) meant additional procedures needed to be in place to maintain ethical standards. Article 1 of the United Nations Convention on the Rights of the Child defines a child as "every human being below the age of 18 years unless under the law applicable to the child, majority is attained earlier". Seeking responses from 9–16-year-olds involved in the FIRST® LEGO® League therefore meant researching the perceptions of children and required further consideration to be given to ethical issues.

In conducting research with children, the ethics principles are the same as those applicable to adults, such as informed consent, transparency, and the right to withdraw. The Economic and Social Research Council however give further conditions specific to research involving children:

- children's competencies, perceptions and frameworks of reference, which may differ according to factors including – but not only – their age, may differ from those of adults
- children's potential vulnerability to exploitation in interaction with adults, and adults' specific responsibilities towards children
- the differential power relationships between adult researcher and child participant
- the role of adult gatekeepers in mediating access to children, with concomitant ethical implications in relation to informed consent.

(ESRC, 2012).

These were addressed as follows:

- It was recognised that, in comparison to adults, children may have a limited vocabulary and a different understanding and/or use of words, and may have a shorter attention span (Punch, 2002). The data collection tool (questionnaire) was kept short, with a view to the shorter attention span of children. Clarity of language was needed, alongside an awareness that children may have limitations of language or articulation, whilst possibly also using words that adults do not understand. The questionnaire format treated the children in the same way as adult participants and allowed them to display their competencies without being patronised. Pre-testing the questionnaire provided a check that these points had been addressed.

- Consideration was given to risk, benefits and safeguarding children during the research, in line with BERA (2018) guidelines. As the principal researcher there was a duty to ensure that the method was appropriate and would not cause participants any physical or psychological harm (Alderson and Morrow, 2011). It was recognised that a potential source of harm was misunderstanding, which could cause confusion or anxiety. Again, pre-testing the questionnaire and all associated information was important in this respect. There was a need to reassure children that there are no right and wrong answers. DBS clearance and attendance at a suitable training course on safeguarding gave greater confidence in recognising issues defined as child protection issues. Anonymity and confidentiality could not be guaranteed when working with children because of safeguarding requirements, as it may have been necessary to disclose a child protection issue, and questionnaires were screened as soon as possible after completion. Any identifying marks were then removed.
- In seeking consent, it was recognised that there was a need to view the children as autonomous individuals. However, the law states that children are not legally competent to provide consent. Therefore, it was necessary to seek consent from gatekeepers to seek consent from the children. In deciding the approach to seeking consent, the following considerations were important:
    - Age. The young people involved ranged in age between 9 and 16 years old. With younger ages the issue of assent is more contentious, but with older children passive consent is appropriate. This tended to passive consent.
    - Nature of research. The research was not exploring particularly sensitive topics or using a particularly intrusive method.

- Location of research. The research was conducted in a school or university setting where consent was sought from teachers as additional gatekeepers.

As Punch (2002) advises, to gain children's consent and involvement in research, it is necessary to go via adult gatekeepers who control access to the children. Therefore, to maintain appropriate ethical standards and facilitate the highest possible return rate, active consent was sought from teachers (to research children), passive consent from parents (return slip if they do not want their child to participate in the research; slip not returned taken as consent) and consent from individual children. Competence was assumed but the methods for seeking consent were adjusted to the level of understanding.

4.7.2 Insider Researcher

As a researching professional conducting an action research project within my own institution, I can be classed as an i*nsider researcher* (Given, 2008). Undertaking research as an insider brings many advantages, such as having my own insider cultural tacit knowledge, easy access to people and the opportunity to make positive change in my own setting (Costley, Elliot and Gibbs, 2010; Atlins and Wallace, 2012; Teusner, 2019). However, conducting the project from an insider perspective also raised ethical and methodological challenges. As Fleming (2018) advises, normal, everyday relationships and activities may acquire different perspectives when part of a formalised research process. Tensions around the duality of my role, as *researcher* and as *professional*, existed throughout, requiring an awareness and management of the inherent risks associated with any power relationships. For example, less experienced colleagues, students and other young people may have perceived a power imbalance, necessitating particular care around the recruitment of participants to avoid the perception of implicit coercion.

It must be recognised that the research is value laden in that I will have brought my values from my professional identity to the way the research is framed and conducted (Fernie and Smith, 2010). As Atkins and Wallace (2012) explain, this makes it difficult to maintain impartiality, as, as an insider, I will be naturally subjective about the university and the focus of study. To guard against bias and improve the validity of findings, I have distilled out my beliefs and values through reflection (see chapter 2) and made explicit my underpinning philosophical assumptions (see section 4.2.2). This has been important in enhancing the quality of data collection and interpretation of findings. It has also been important in maintaining ethical commitments. Recognising that my own biography, responsibilities and relationships frame the lens through which I view the world and interact with others in the university (Costley, Elliott and Gibbs, 2010), I have had to be self-aware about interactions between myself and others. A continuous process of reflexivity has been important in maintaining sensitivity to influences on me from outside the work setting and awareness of power dynamics. Identifying, limiting, and controlling any potential harm has been critical to avoiding relationships with individuals and different groups within the university being compromised and important for maintaining the trust and respect needed to continue working constructively with colleagues after the project ended. This ethical commitment extends beyond the end of the project. Whilst, in research carried out by an outsider, ethical concerns may diminish once the research is published (Floyd and Arthur, 2012), as an insider researcher I needed/need to be mindful of how information shared by colleagues and students may impact on future relationships and activities.

4.8 Action Research Cycle 3

Cycle 3 of the doctoral project in effect comprised three smaller cycles – student study, staff study and outreach initiative study – and further specific detail on data collection and data analysis in each of these studies is given in this section.

4.8.1 Student Study

Using a questionnaire, data was collected from all new starters on undergraduate science degrees at the university in relation to the following research objective:

- To investigate the key influences on undergraduate students in their choice to study science at university.

4.8.1.1 Data Collection (Student Study)

The use of a questionnaire offered the advantages of standardized questions, anonymity and efficient use of time for the student participants and hence an extensive literature review was conducted to inform the development of the data collection tool. The questionnaire was designed around 65 questions, drawn primarily from the studies of Woolnough *et al.* (1997), Veloutsou, Lewis and Paton (2004), Rodeiro (2007), Porter (2011), Robertson (2012), Carnasciali and Thompson (2013), Munisamy *et al.* (2014), L. Archer *et al.* (2015), Cridge and Cridge (2015), King *et al.* (2015) and DeWitt, Archer and Moote (2019). Some questions were designed specifically to understand the local context.

Informed consent was sought from participants, who were provided with a Participant Information Sheet. The Participant Information Sheet was based on university good practice and gave information about the research to allow participants to make an informed decision about whether or not to participate. Participants were asked to complete and sign a consent form, again based on university good practice.

Section A solicited demographic information, following guidance published by Kirklees Council (2019). This section asked participants to provide some basic information about themselves. Questions were only included which provided data that would be used i.e., when there was a clear reason for asking for the personal information to comply with the Data Protection Act. In terms of gender, it was recognised that responsibility lay with me as the researcher to ensure that all participants had the opportunity to describe and categorise themselves as they wish. The questionnaire did not ask for a response based on a binary divide of male or female, but instead allowed respondents to self-define by asking 'what is your gender?' and providing a free text box for the response. Participants were asked for their age on their last birthday. This allowed for answers to this question to be grouped into relevant age bands. The question relating to ethnicity drew upon the categories that were used in the 2001 census. It is noted that the set of ethnic categories used in the 2011 census was more comprehensive, but space available on the questionnaire limited use of the full set. Socioeconomic status is a composite measure of a family's or an individual's economic and social standing (Levesque, 2011) and is a complex assessment based on income, education, and occupation. Frequently however only one of the variables is used, such as parents' highest qualification. In this study socioeconomic status was simplified to whether or not parents attended university. The reasoning behind this decision drew on the work of De Witt, Archer and Moote (2019), who used parental education (e.g., university attendance) to determine cultural capital and their consideration of cultural capital as a conceptual basis for participation in post-compulsory physics.

Section B contained mainly items on a rating scale. Participants were asked to identify the extent to which different factors influenced their choice of a science degree. Participants rated each factor on a 4-point scale ranging across ‘no influence’, ‘some influence’, ‘strong influence’ and ‘major influence’. As Krosnick and Presser (2010) explain from their review of methodological literature, there is not an accepted standard for how many points should be used on a rating scale, with practice varying greatly. They do however stipulate conditions that should be met for a rating scale to work effectively and the four points were chosen with these conditions in mind; that is, they covered the full measurement range, without any gaps, and the meanings of adjacent points did not overlap. A single open-ended question invited participants to give any other factors, not already included, that had influenced their choice of degree at the university.

Section C adopted a similar format, comprising mainly items on a rating scale. The items focused however on factors that influenced participants’ choice to study post-compulsory science. Two further questions asked participants to give the age by which they had decided they wanted to continue studying or working in science after school and by what age they had decided they wanted to study specifically for a degree in science.

Drawing on the concept of science capital and the work of Woolnough *et al.* (1997), in section D participants were asked to indicate the extent to which they agreed with statements or to indicate the frequency with which they engaged in certain activities pertaining to the time before participants completed their GCSE’s or equivalent.

The questionnaire design is summarised in table 4.2.

Table 4.2 Summary of student questionnaire design

Sections	Reason	Key Influences
A	To understand demographic characteristics of student population.	De Witt, Archer and Moote (2019) Kirklees Council (2019) Robertson (2000)
B	To understand the key factors that influenced participants' choice of a science degree.	Cridge and Cridge (2015) Munisamy *et al*. (2014) Carnasciali and Thompson (2013) Rodeiro (2007) Veloutsou, Lewis and Paton (2004) Woolnough *et al.* (1997) Some questions were also designed specifically to understand the local context.
C	To understand the key factors that influenced participants' choice to study post-compulsory science.	DeWitt, Archer and Moote (2019) Carnasciali and Thompson (2013) Rodeiro (2007) Robertson (2000)
D	To understand participants' behaviour, attitudes, and influences in relation to the key dimension of science capital prior to completing GCSEs.	L. Archer *et al.* (2016) L. Archer *et al.* (2015) Woolnough *et al.* (1997)

It was expected that the potential physical and/or psychological harm or distress would be the same as any experienced in everyday life. The questionnaire had been designed to take approximately 10-15 mins to complete to minimise inconvenience. It was recognised however that some of the students may not have gained their first-choice course or university and thus feel some distress. A debrief paragraph at the end of the questionnaire directed participants to support within the university if they had concerns about any of their academic studies.

Ethical approval was sought from the research ethics panel at my home institution. In line with the ethics procedure at the university, my supervisors were asked to review the application prior to submission and were informed of the outcome. Confirmation of approval is included in Appendix 9.1, and this was also emailed to the University of Sunderland Ethics Group.

A draft questionnaire was pre-tested prior to distribution. Whilst not identical to the target sample group, five students already enrolled on science undergraduate courses at the university were asked to complete the questionnaire to help identify ambiguous questions or issues that might introduce bias in responses. They were asked to consider if there were any questions they did not understand, if there were any questions that made them feel uncomfortable, if the instructions were clear, if all the options needed were available and if the formatting was clear. This approach mitigated to some extent the concerns expressed in section 4.5.1 around differences between me and students in the use of and meaning attached to language. It was also noted how long the questionnaire took to complete.

As a result of critical comments and student responses, the questionnaire was modified before being deployed in hard copy. For example, the draft questionnaire included questions referring to GCSE's, which a student educated in Scotland was unsure how to answer. This was modified to 'GCSE's or equivalent'. Based on feedback from the students, consideration was also given to expanding the reference to parents in the questionnaire to 'parents and carers'. However, section 576 of the Education Act 1996 defines "parent" as:

> all natural (biological) parents, whether they are married or not;
> any person who, although not a natural parent, has parental responsibility for a child or young person;

any person who, although not a natural parent, has care of a child or young person.

The decision was taken therefore to not make the amendment.

It was agreed with academic staff at the university that the questionnaire could be distributed in hard copy within scheduled sessions to ensure a high return rate. The questionnaire was administered to 80 students in total over two sessions, which captured all new starters on undergraduate science degrees at the university.

Participants were recruited at the end of a timetabled session. Information about the research was given verbally, where it was stressed that participation was entirely voluntary, and participants were under no obligation to complete the questionnaire. As new students at the university, participants may have felt undue pressure to participate and therefore particular care was taken to stress that participation was entirely voluntary to maintain ethical standards. The questionnaire was completed by 69 students, giving a response rate of 86.25%. One participant completed the questionnaire but did not give permission for their anonymous responses to be analysed and quoted, and therefore the responses of this participant were discounted from the study.

The raw data (hard copy questionnaires) were stored in a sole-occupancy, locked office, and was destroyed on completion of the study. Digitalised data was stored in a password protected file on the university OneDrive system that stores data at a level of encryption that complies with both the DPA and new GDPR.

4.8.1.2 Data Analysis (Student Study)

In line with the considerations outlined in section 4.5.2, the data were analysed using frequency distributions of responses and median values as a measure of central tendency for the distribution of the data. The results are presented in section 5.2.

4.8.2 Staff Study

Using a questionnaire, data was collected from academic and professional services staff at the university in relation to the following research objective:

- To investigate the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students.

4.8.2.1 Data Collection (Staff Study)

Similar to the approach taken within the student study (see section 4.8.1.1), using a questionnaire offered the advantages of standardized questions, anonymity and efficient use of time for the staff participants. An extensive literature review informed the development of the tool used to investigate the perceptions of university staff. Studies by Ecklund *et al. (*2012), Eilam (2016) and Sadler *et al*. (2018) were particularly influential in the design of the 38 questions that made up the questionnaire.

The accompanying Participant Information Sheet was based on university good practice and provided information about the research to allow participants to make an informed decision about whether or not to participate. In completing and signing a consent form, again based on university good practice, all participants gave informed consent to their taking part in the study.

The first question asked participants to identify whether they were academic of professional services staff. Current outreach practice often relies on the two groups of staff working together on the organisation and delivery, but differing demands on their time and differing priorities could be expected to generate different approaches and perceptions between the groups. Testing whether the two groups of participants result in significantly different responses to questions and perceive the purpose and impacts of outreach activities differently may facilitate debate around which activities should be delivered, why and to whom.

In completing sections A and B, participants were asked to consider all outreach activities they delivered to science students. They were also requested to answer each question in order and not to return to any questions after answering subsequent ones. This was done to reduce the extent to which Likert type items might influence responses.

Section A comprised questions around the purposes, evaluation and impacts of outreach activities, requiring mainly free-text responses.

Section B contained mainly items on a rating scale. Participants were asked to identify their level of agreement with different statements. Participants rated each item on a 4-point scale ranging across ‘strongly disagree’, ‘disagree’, ‘agree’ and ‘strongly agree’. In choosing the length of the scale, consideration was given to the ease by which respondents could map their attitudes onto the alternatives. The scale provided opportunities for accurate mapping for individuals who wanted to report moderate or extreme attitudes. Whilst it is recognised that adding more points to the rating scale would have permitted respondents to make more fine-grained distinctions, it was felt that this would have compromised the clarity of the scale point meanings. As Krosnick and Presser (2010) explain, ambiguity in the meaning of the scale points would impact negatively on the reliability and validity of measurement. Many authors (e.g., Weijters, Cabooter and Schillewaert (2010) and Revilla *et al.* (2014)) however recommend using at least a 5-point scale with the offer of a midpoint and justification is therefore needed as to why this was not done in this case. Offering a midpoint would have allowed those respondents with a truly neutral stance to indicate their neutrality and not be forced to choose a polar option. However, particularly when the motivation to provide accurate reports is low (which could have been the case here), offering a midpoint may encourage satisficing (Krosnick and Presser, 2010) - that is, where respondents settle for satisfactory answers without diligently attempting the most accurate responses. Following this line of reasoning, it was felt that not offering a midpoint would increase data quality.

The design of the staff questionnaire is summarised in table 4.3.

Table 4.3 Summary of staff questionnaire design

Sections	Reason	Key Influences
A	To understand participants' perceptions of the purposes, evaluation and impacts of outreach activities, through mainly free-text responses.	Sadler *et al*. (2018) Eilam (2016) Ecklund *et al. (*2012)
B	To understand participants' perceptions of the purposes, evaluation and impacts of outreach activities, through rating scales.	Sadler *et al*. (2018)

It was expected that the potential physical and/or psychological harm or distress would be the same as any experienced in everyday life. The questionnaire had been designed to take approximately 20 mins to complete to minimise inconvenience. A debrief paragraph at the end of the questionnaire thanked participants for their time and reminded them of the purposes of the study.

Ethical approval was sought from the research ethics panel at my home institution. In line with the ethics procedure at the university, my supervisors were asked to review the application prior to submission and were informed of the outcome. Confirmation of approval is included in Appendix 9.2, and this was also emailed to the University of Sunderland Ethics Group.

A draft questionnaire was pre-tested before circulation. A group of university staff were asked to complete the questionnaire to help identify ambiguous questions or issues that might introduce bias in responses. The time needed for completion was noted.

As a result of critical comments and staff responses, the questionnaire was modified before being deployed in hard copy. For example, reference to 'science students' in the instructions and the participant information sheet was changed to 'young people studying science'. It was noted that due to formatting there was a tendency to list all the aims in the question 'How would you describe the key purpose of the outreach activities with which you are involved?', before turning the page to the secondary purposes box, having already covered these. Reformatting presented an unsatisfactory solution and therefore ‘key purpose’ was highlighted in bold to stress that the question was just seeking one aim.

To facilitate a higher response rate, where possible participants were recruited through face-to-face contact. Information about the research was given verbally, where it was stressed that participation was entirely voluntary and participants were under no obligation to complete the questionnaire. Although no direct line management responsibility, less experienced colleagues may have felt undue pressure to participate, and so particular care was taken in this area to ensure appropriate ethical standards. Where face-to-face contact was not possible, participants were recruited via email with information and paper questionnaires sent through the internal post.

The questionnaire was administered to 17 members of academic staff and 7 members of professional services staff involved in delivering outreach activities to young people studying science. It was requested that completed questionnaires were returned by a specific date. Six questionnaires were completed and returned by this date. Many members of staff had indicated verbally that they would complete the questionnaire, so a further email prompt was sent and followed up by face-to-face conversations with colleagues. In all interactions it was stressed that there was no obligation to participate in the research study, in line with the ethics framework, but the support of colleagues would be greatly appreciated. A further 6 completed questionnaires were received, meaning the questionnaire was completed by 12 members of staff in total, giving a response rate of 50%.

The raw data (hard copy questionnaires) were stored in a sole-occupancy, locked office, and was destroyed on completion of the study. Digitalised data were stored in a password protected file on the university OneDrive system that stores data at a level of encryption that complies with both the DPA and new GDPR.

4.8.2.2 Data Analysis (Staff Study)

The questionnaire generated both qualitative and quantitative data.

Data from section A were analysed using thematic analysis. Whilst thematic analysis allows a large degree of flexibility in interpreting the data, the risk of missing nuances in the data was recognised. Because analysis relies on the researcher’s judgement, care had to be taken around my choices and interpretations, to not impose any pre-conceived ideas and obscure true meanings.

The first step was familiarisation with the data. To get a thorough overview of all the data before starting to analyse individual items, all data on paper questionnaires were transcribed to a central (electronic) location. This also permitted data to be anonymised and stored in accordance with GDPR regulations.

The next step was coding the data. This involved highlighting sections of the text and assigning shorthand labels or 'codes' to describe the content. The data were then collated into groups identified by code, which gave a condensed overview of the main points and common meanings that recurred throughout the data. Themes were then generated by identifying patterns among the codes. At this stage, some of the codes became themes in their own right (e.g., 'recruitment'), whilst others were incorporated into a broader classification. Some of the codes were also discarded because they did not appear often in the data and so were deemed not relevant. Thematic analysis relies on the researcher's judgement, particularly in making choices around codes and themes, and so a crucial next step was returning to the data to make sure the themes were useful and accurate representations of the data.

This approach allowed me as the researcher to find out more about staff views, opinions and values from a set of qualitative data. Because of the flexibility in interpreting the data and the inherent subjectivity in this method, the potential risk of personal bias cannot be ignored. As such, to add objectivity and cross-validate the findings, reanalysing the data using the qualitative analysis software *Quirkos* was considered. Whilst potentially making the data more visually engaging, fundamentally the tool relies on researcher judgement and therefore, given the timescales of this project, it was decided that the potential benefits were not great enough to justify the time needed for reanalysis.

Data from section B were quantitative in nature and were described using frequencies and medians as a measure of central tendency. F-tests were conducted to establish whether the variances in the responses from professional services staff and academic staff were equal or not. In conducting the F-tests, a check was carried out to ensure the variance of variable 1 was higher than that of variable 2, to ensure that Excel would calculate the correct F value. Where this was not the case, the inputted variables were swapped to ensure accuracy in the F calculation. The results from the F-tests informed the t-test conducted on the data to explore whether the two groups of participants resulted in significantly different responses to questions.

The results are presented in section 5.3.

4.8.3 Outreach Initiative Study

The outreach initiative study centred on the development of the FIRST® LEGO® League in the local area, which is a STEM challenge for 9–16-year-olds. It aims to encourage interest in real world themes and develop skills that are crucial for future careers, which resonates with the aims of courses at the university. The competition encourages innovation and communication with marks awarded to teams of school children for a robot game, project and core values. The competition has a global reach, with teams from 98 different countries competing in the league. Within the UK, the FIRST® LEGO® League is relatively well established in other parts of the country but until 2015 did not have a presence in the county. The competition was introduced to 6 schools as a pilot and, through the support of two organisations in particular has grown significantly since the initial pilot, with the county having the largest number of teams in the competition in 2018-19 (67 teams in total). This growth has however been limited in geographical spread to specific areas of the county.

In 2019-20, the university supported partner organisations to develop the FIRST® LEGO® League across those parts of the county with limited activity to date. This was seen as an opportunity to primarily excite and engage more young people in science and technology with a view to increasing participation in STEM subjects, whilst presenting indirect marketing benefits (and opportunities to enhance the employability of students at the university).

Teachers from the 10 new schools, which were supported by the university, initially visited the campus to receive training and equipment for the scheme. Within their schools, over a period of four months, the teachers worked with teams of 10 pupils to complete the robotic challenge and project. This sustained 'intervention', over a period of time, viewed from a science capital perspective, is important, in a way similar to King *et al.* (2015), who show statistically significant gains in science capital as a result of a targeted intervention over a period of a year. The teams were supported in their endeavours by volunteers, who gave their time, enthusiasm and experience to encourage and inspire young people to progress further in STEM subjects. Within the university, undergraduate science students were encouraged to participate alongside other volunteers drawn from industry.

The 10 new schools then came together in a finals event in January 2020 where they were judged on their robot design, a robotic challenge, their project and core values. The event involved other volunteers in supporting roles:

- robot design judges x 3 per day
- core values judges x 4 per day
- project judges x 4 per day
- robot game judges x 6 per day
- timekeepers x 2 per day
- scorers x 2 per day
- practice table assistants x 2 per day
- additional activities monitors x 3 per day.

Across the county there were a further four finals events taking place, involving teams from other parts of the county.

To develop the competition in this way drew on significant financial and in-kind support from a range of organisations, including the university. This is multiplied several times to operate the league across the county. To operate successfully requires the involvement of teachers, parents, volunteers, sponsors and of course children.

Anecdotally, teachers comment how the competition facilitates the development of a broad set of skills, impacting across the whole school curriculum, as well as being fun, exciting and enthralling for pupils. The buy-in from a significant number of schools and a range of other organisations suggests at some level the competition is meeting the aims of enthusing and engaging young people in science and technology. This is further supported by the findings from evaluations completed in previous years. It was felt by the researcher and members of my community of practice however that more robust research was needed to understand the impacts of participation in the FIRST® LEGO® League, certainly in the local context. The findings of such research were deemed valuable in informing the university's support for the league in future years, wider university practice around STEM outreach activities and the development of the league in the county more generally. The design of the challenge is commensurate with the dimensions of science capital - to develop young people's scientific literacy/knowledge and understanding, but also promote the application of science in the real world and promote conversations about science with significant others in a young person's life. The concept of science capital provides a framework for such research and the specific research objective related to this individual study was:

- To investigate the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital.

4.8.3.1 Data Collection (Outreach Initiative Study)

The complex nature of the science capital concept does not facilitate quick or easy measurement, however, as discussed in section 3.10.3, L. Archer *et al. (*2016) suggests surveys (using questionnaires as data collection tools) might offer a pragmatic way to assess whether an intervention impacts on levels of science capital. Short and relatively quick to administer, a science capital questionnaire lends itself to a quantitative approach to data collection from a large number of respondents. King *et al.* (2015), for example, show that questionnaires can be useful for capturing the impact, in terms of gains in science capital, of sustained and long-term interventions. A consideration in this case is that data was collected from research participants at the end of the intervention and no comparison, in terms of a quantitative measurement of science capital, was possible with the starting measurement. The questionnaires sought participants' perceptions on the impact on the dimensions of science capital, which contribute to gains in science capital, but did not seek to determine an actual quantitative science capital index. In making the science capital of young people participating in the FIRST® LEGO® League the central focus of the research, and seeking the views of young people directly, the study design accommodated the criticism of Millar *et al.* (2019, p.2584) that the majority of research on outreach projects have "concentrated on the experiences of teachers and teachers' reports of student engagement with and attitudes towards science". Nevertheless, teachers, parents and volunteers were also included within the study to understand the perspectives of all participants in the outreach initiative.

Informed consent was sought from all participants. For adults, the Participant Information Sheet was based on university good practice and provided information about the research to allow participants to make an informed decision about whether or not to participate. Participants were asked to complete and sign a consent form, based on university good practice (or indicate consent online). For children, it was recognised that there is a need to view the children as autonomous individuals, however, the law states that children are not legally competent to provide consent. Consent was therefore sought from the gatekeepers to seek consent from the children. Given the nature of the research, which was not exploring particularly sensitive topics or using a particularly intrusive method, the steps included:

1. seeking active consent from teachers (to research children)
2. seeking passive consent from parents - i.e., return slip if they did not want their child to participate in the research (slip not returned was taken as consent)
3. seeking consent from individual children (competence was assumed but the information and method was adjusted to the level of understanding).

Further ethical considerations for research with children are covered in section 4.7.1.

The first question for volunteers asked participants to identify their involvement in the FIRST® LEGO® League – as a coach, judge or other. Coaches would have had more involvement with school teams and better placed to consider impacts in terms of science capital because of their longer-term involvement.

Having potentially a major influence on children's engagement with science (see section 3.10.1), section A for teachers, parents and volunteers solicited their perceptions of STEM subjects in terms of social justice and the economic pipeline. The children were not asked these questions.

The other sections contained Likert-type items. Participants were asked to identify their level of agreement with different statements, rating each item on a 4-point Likert scale ranging from 'strongly disagree' to 'strongly agree'. Similar considerations to those described with the student questionnaire informed the choice of scale (see section 4.8.1.1) so that the four points covered the entire measurement continuum, leaving out no regions, and the meanings of adjacent points did not overlap. The statements in section B for teachers, parents and volunteers, and section A for children were based on the dimensions of science capital and focused on the impact on the children. With parents' level of interest in science often overlapping with a young person's level of interest (Cleaves, 2005; Butt *et al.,* 2010) (see section 3.10.1), section B for the children and section C for the parents focused on potential impacts on the parents.

The design of the outreach initiative questionnaires, used with children, teachers, parents and volunteers, is summarised in tables 4.4 and 4.5.

Table 4.4 Summary of the design of outreach initiative questionnaires (children and teachers)

Questionnaire	**Sections**	**Reason**	**Key Influences**
Children	A	To understand participants' perceptions on the impact of the outreach activity on the dimensions of science capital (focused on the impact on the children).	Millar *et al.* (2019) L. Archer *et al.* (2016) L. Archer *et al.* (2015) King *et al.* (2015)
	B	To understand potential impacts on the parents.	Buzzanell, Berkelaar and Kisselburgh (2011) Butt *et al.* (2010) Cleaves (2005)
Teachers	A	To understand participants' perceptions of STEM subjects in terms of social justice and economic pipeline.	van den Hurk, Meelissen and van Langen (2019) Butt *et al.* (2010)
	B	To understand participants' perceptions on the impact of the outreach activity on the dimensions of science capital (focused on the impact on the children).	Millar *et al.* (2019) L. Archer *et al.* (2016) L. Archer *et al.* (2015) King *et al.* (2015)

Table 4.5 Summary of the design of outreach initiative questionnaires (parents and volunteers)

Questionnaire	Sections	Reason	Key Influences
Parents	A	To understand participants' perceptions of STEM subjects in terms of social justice and economic pipeline.	Kelly (2016) Smith (2007) Tenenbaum and Leaper (2003)
	B	To understand participants' perceptions on the impact of the outreach activity on the dimensions of science capital (focused on the impact on the children).	Millar *et al.* (2019) L. Archer *et al.* (2016) L. Archer *et al.* (2015) King *et al.* (2015)
	C	To understand potential impacts on the parents.	Buzzanell, Berkelaar and Kisselburgh (2011) Butt *et al.* (2010) Cleaves (2005)
Volunteers	A	To understand participants' perceptions of STEM subjects in terms of social justice and economic pipeline.	van den Hurk, Meelissen and van Langen (2019) Butt *et al.* (2010)
	B	To understand participants' perceptions on the impact of the outreach activity on the dimensions of science capital (focused on the impact on the children).	Millar *et al.* (2019) L. Archer *et al.* (2016) L. Archer *et al.* (2015) King *et al.* (2015)

For adults, it was expected that the potential physical and/or psychological harm or distress would be the same as any experienced in everyday life. The questionnaire had been designed to take approximately 10 minutes to complete to minimise inconvenience. A debrief paragraph at the end of the questionnaire thanked participants for their time and reminded them of the purpose of the study.

It was recognised that, in comparison to adults, children may have a limited vocabulary and a different understanding and/or use of words, as well as potentially a shorter attention span. Misunderstanding could have caused confusion and anxiety and be a potential source of harm. The questionnaire was therefore kept short, and children were reassured that there were no right or wrong answers. A questionnaire format was adopted for the children also to treat them in the same way as adult participants, thus allowing them to display their competencies without being patronised.

Ethical approval was sought from the research ethics panel at my home institution. In line with the ethics procedure at the university, my supervisors were asked to review the application prior to submission and were informed of the outcome. Confirmation of approval is included in Appendix 9.3, and this was also emailed to the University of Sunderland Ethics Group.

All draft questionnaires were pre-tested before circulation. This was an important step for all questionnaires, as with the student and staff studies, to check that questions were not ambiguous, and to assure that the language used was clear and did not cause confusion. For children, teachers and volunteers, it was possible to pre-test the questionnaires with a range of individuals who were representative of the target groups. Thus, pre-testing provided a reasonable level of mitigation against the concerns considered in section 4.5.1 around differences in the use and meaning attached to language. With parents, there was less confidence that pre-testing included a range of people who were fully representative of the target group, potentially missing 'hard to reach' sub-groups. As a data collection tool, therefore, the format and language of the parent questionnaire may have hindered access by some parents, thus creating sample bias by not providing a true representation of the whole population. The time taken to complete the questionnaires was noted.

As a result of critical comments, the questionnaires were modified before being deployed.

Initially also the intention had been to ask all participants - children, teachers, parents and volunteers – to identify the type of school. The concept of science capital was developed empirically through research with school children of secondary age and so differences in responses may be evident in a comparison between the two age groups. This question was however removed as this would have allowed identification of participant responses.

On the teacher questionnaire, a question worded as 'Made explicit the extrinsic value and broad application of science qualifications' was changed to 'Made explicit that a science qualification can help get many different types of job'. One tester queried the wording around the first question - 'life chances' - suggesting it could be misinterpreted as 'life expectancy'. This term is used frequently in the associated literature, but as a result of this feedback the term was changed to 'life opportunities'.

Through this pre-testing, it was recognised also that not all supporters – judges and coaches – would be formally registered as STEM Ambassadors. Given that all were volunteering their time to support STEM learning, they were effectively acting in this role. The perceptions of all supporters were deemed relevant and valuable, so care was taken with the use of the terminology 'STEM Ambassador' so that no volunteers felt excluded and unable to participate in the study. In section B, a column was added for 'Don't Know' because, whereas coaches should be able to comment, judges may not be able to.

The parent questionnaire was distributed online. Pre-testing therefore involved checking that the online questionnaire was accessible via mobile devices. Responses were tested in the Analyse tab in the JISC online survey platform to ensure that the questionnaire had generated the kind of data expected. Other modifications as a result of pre-testing included:

- The use of 'etc.' was removed and to increase accessibility 'e.g.' was changed to 'for example', as it is often read as 'egg'.
- The question 'Has learnt how science is a part of their inside- and outside-of-school life' was changed to 'has learnt how science is a part of their life inside and outside of school'.
- 'Has a greater understanding of the value of science education to their university and/or career options' was changed to '... future study and/or career options'.
- In the final question, which was worded 'I think more that science is useful for my child's future', 'more' was deleted. Consideration was given to adding a further question - 'I now feel more strongly that science is useful for my child's future than before s/he participated in the LEGO League', to try to capture a change in parents' perceptions about science as a result of their child participating in LEGO League, but all options seemed an unsatisfactory way of wording.

Because ethical clearance was received only shortly before event, time pressures meant that the parent questionnaire was piloted after the teacher and volunteer questionnaires had been distributed. Some of these changes may have also improved the earlier two questionnaires but the opportunity was not there.

The following changes were made to the pupil questionnaire as a result of pre-testing:

- ‘Indicate’ was changed to ‘tick’.
- ‘Participating’ was changed to ‘taking part’.
- The dash was removed after ‘I’ at end of statement in section A.
- The instruction and corresponding statement were separated on different lines.
- ‘Principles’ was changed to ‘ideas’.
- ‘Have a greater understanding of the value of science education to my future study and/or career options’ was changed to ‘…of how science learning could be useful for my future career options’.
- ‘Members of my community’ was changed to ‘people in my community’.
- ‘Planetarium’ was removed altogether as it was not relevant to the FIRST® LEGO® League challenge.
- ‘Through me participating’ was changed to ‘because I took part in…’.
- The first statement in section B was removed altogether – ‘my parents think science is more interesting’ – as children struggled to make that judgement.

Research participants were recruited from the school children participating in the FIRST® LEGO® League in the local area, their teachers and their parents, plus volunteers involved in the league. The questionnaires were administered in two phases.

In the first phase, paper questionnaires were distributed to teachers and volunteers at an event at the university in January. Information about the research was given again verbally, where it was stressed that participation was entirely voluntary, and participants were under no obligation to complete the questionnaire.

The teacher questionnaire sought consent for their team to be invited to participate in the study. Where consent was indicated (8 out of 10 teams), information about the research was then emailed to the headteacher of the school in their role as primary gatekeeper. If the headteacher gave consent, a signed covering letter, teacher information sheet, teacher consent form and the questionnaires were sent to the teachers, along with a return addressed envelope. Information for children was in an age-appropriate manner and worded carefully so that children felt no undue pressure to participate. Further consent was sought from the children themselves, in an age-appropriate manner, in line with ethical clearance. Further information for parents was emailed to schools, for dissemination via school systems. This information included a link to the JISC online parent questionnaire.

Questionnaires were distributed to 20 teachers and 22 volunteers.

Parent and children questionnaires were sent to 8 schools, where the teachers had indicated that the invite to participate in the research could be extended to their team and parents. Information on how many teachers forwarded the invite, and link to the online questionnaire, to parents or how many arranged for children to complete the questionnaire in school is not available, but potentially the questionnaire could have been distributed to 80 children and 160 parents.

Only 6 children questionnaires were returned initially. Following a polite reminder/request emailed to schools asking for the return of any completed questionnaires, a further 21 were returned, giving a total of 27. Administration of the children's questionnaire involved a time lag due to seeking the various levels of consent. As such, it is important to consider the impact on their recall of participation in FIRST® LEGO® League as the children may move on and forget. Gaining consent for children to participate in the study presented complexities in other ways also. Each school seemed to take a different approach. Approval was given by the research ethics panel for parents to indicate if they did NOT consent, with the plan that questionnaires would remain in school and teachers administer with the whole group. It was felt that this would meet ethical standards and give the highest return rate. Some schools obviously then sought active consent from parents, which would have created some confusion between the message from school and my information sheet. Some schools also sent the questionnaires out to parents for children to complete at home. This was exemplified by one school that returned one completed questionnaire and two forms from parents indicating that they did not consent. With the other 7 questionnaires sent to the school not accounted for, it must be concluded that the plans designed to avoid non-completion, but no active consent/no consent have been ineffective to some extent.

The raw data (hard copy questionnaires) were stored in a sole-occupancy, locked office, and were destroyed on completion of the study. Digitalised data was stored in a password protected file on the university OneDrive system that stores data at a level of encryption that complies with both the DPA and new GDPR. The online questionnaire used was also GDPR compliant.

4.8.3.2 Data Analysis (Outreach Initiative Study)

As outlined in section 4.5.2, the best approach for analysing Likert data, whether to use non-parametric or parametric tests, is debated. Whether the median or mean is the best measure of central tendency for the distribution of the data is a key influence in this decision. For this study, to describe the data, means were of limited value and a frequency distribution of responses was more helpful, with median values as a measure of central tendency. Given that it is appropriate to use both non-parametric and parametric tests to analyse Likert scale responses, this approach was taken in this study. Both the ANOVA test and its non-parametric equivalent, the Kruskal-Wallis test, were used to test if there was a significant difference between samples at the 0.05 significance level. This increased the likelihood of detecting an effect that truly exists.

If an ANOVA test yielded significant results, then it was followed up with *post hoc* t-tests to determine which means were different between two groups. As better statistical power is provided by the unequal variances' version of the two-sample t-test if the data have unequal variances and unequal sample sizes, at that stage, it was important to consider sample sizes and variances within samples to inform the best choice of t-test.

If a Kruskal-Wallis test gave significant results, then it was followed up with *post hoc* Mann-Whitney tests to compare two sample groups.

The results are presented in section 5.4.

4.9 Summary

The aims, approaches and outcomes of research are inevitably influenced by the researcher's views about the nature of knowledge and how it is constructed. In attending to these views, I have positioned the research in a paradigm of critical realism and developed an action research methodology. The cyclical approach centred firstly on reflection around my professional identity, exploring what drives me as a professional, what my values are and how these relate to professional issues within my project, and then on a review of the literature. A critical review of theoretical, empirical and professional literature informed the third cycle, which comprised three individual studies centred on data collection. Questionnaires, generating primarily quantitative data but some qualitative data, were used as the method of data collection in each of the individual studies, with participants recruited from undergraduate science students, university staff involved in the delivery of science outreach and participants involved in a specific science outreach initiative. The results from these studies are presented in the next chapter, whilst the final cycle, within the scope of this professional doctorate project, focused on research contribution and dissemination.

Chapter 5: Results

5.1 Introduction

The purpose of this full project, as discussed in chapter 1, is to analyse critically approaches to increasing and widening participation in higher education science. Specifically, the research aims to address the following objectives:

1. To frame my professional practice through a critical review of the literature.
2. To investigate the key influences on undergraduate students in their choice to study science at university.
3. To investigate the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students.
4. To investigate the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital.
5. To contribute to professional practice and knowledge around increasing and widening participation in higher education science.

This chapter presents the analysis of data obtained from three separate studies conducted with undergraduate science students (section 5.2), university staff involved in the delivery of science outreach (section 5.3) and participants involved in a specific science outreach initiative (section 5.4). Each sub-section begins with a description of the participant group to provide context, followed by presentation of and commentary on the data. Individual studies seek to address specific research objectives but together they aim to inform a critical analysis of approaches to increasing and widening participation in higher education science.

5.2 Student Study

5.2.1 Participants

New starters on undergraduate science degrees at the university were investigated in relation to the following research question:

- What were the key influences on current undergraduate students in their choice to study science at university?

The questionnaire was administered to 80 students, who had recently enrolled on an undergraduate science degree at the university, at the start of semester 1 in the 2019/20 academic year. 69 qualified participants, representing students studying animal conservation science, marine and freshwater conservation, conservation biology, zoology, biomedical science and forensic science voluntarily completed the questionnaire, giving a response rate of 86.25%. One participant completed the questionnaire, however, did not give permission for their anonymous responses to be analysed and quoted, and therefore the responses of this participant were discounted from the study.

Analysis of the student data has been conducted at the group level to understand the key influences on undergraduate student in their choice to study science at university. It was felt that this would provide insights to best inform practice around increasing participation in undergraduate science programmes – a key concern in the current higher education context. There is the possibility of analysing the data in relation to the background of students to understand if the influences on the choice to study science at university differ across gender, parents' educational background and ethnicity. This would provide more nuanced insights that may allow for the development of more targeted interventions at a future stage.

5.2.2 Demographic Characteristics

To understand how student enrolments on science courses at the university are patterned by demographic characteristics, the following items were analysed: gender, age, ethnicity and parental education.

5.2.2.1 Gender

The majority of study participants were female. Of the 68 respondents, 65% (n= 44) identified themselves as female and 35% (n = 24) identified themselves as male.

Table 5.1 illustrates the gender breakdown by degree. 'Animal Conservation Science', 'Marine and Fresh Water Conservation' and 'Conservation Biology' have all been grouped as ‘Conservation’ to give a more robust picture with the larger group size. Only three respondents indicated that they were studying forensic science and therefore the results may not reflect an accurate picture of the gender breakdown on that degree course.

Table 5.1 Gender profile by degree area

	Female		**Male**	
	n	**%**	**n**	**%**
Conservation	19	56	15	44
Zoology	14	70	6	30
Biomedical Science	9	82	2	18
Forensic Science	2	67	1	33

The majority of respondents who are studying degrees in zoology, biomedical science and forensic science are female. There is a more equal balance of gender in the conservation group.

5.2.2.2 Age

Table 5.2 shows the age profile of students enrolled on science courses. The majority (n = 48, 71%) are a standard age (i.e., 17-20 years old), but a significant percentage are a non-standard age (i.e., ‘mature students’) (n = 20, 29%). The question of age was asked because students who are older than 20 years old may have delayed pursuing a science career because they delayed pursuing a degree generally, studied another subject first and are now studying a second degree or pursued a non-degree career and are now returning to education in pursuit of a first-time degree. These different circumstances may lead to those aged 20 years or older to have different reasons for studying a science degree and often these are characterized as ‘career changers’ and/or ‘returners to H.E’ and are targeted through different marketing approaches to standard age entrants.

Table 5.2 Age profile of students enrolled on science courses

Age	n	%
Standard (17-20 years old)	48	71
Non-Standard (older than 20 years old)	20	29

5.2.2.3 Ethnicity

Participants were given the option of selecting one of five ethnicity classifications. The classifications included: (a) Asian or Asian British, (b) Black or Black British, (c) White, (d) Mixed, (e) Other. Table 5.3 illustrates the ethnicity breakdown of the total sample population.

Table 5.3 Ethnicity of students enrolled on science courses

Ethnicity	n	%
Asian or Asian British	8	12
Black or Black British	0	0
Mixed	3	4
White	57	84
Other	0	0

The majority identified as ‘White’ (n= 57, 84%), with 12% (n = 8) identifying as ‘Asian or Asian British’. 4% (n = 3) identified as ‘mixed. No respondents indicated their ethnicity as ‘Black or Black British’ or ‘Other’.

5.2.2.4 Parental Education

Students were asked to indicate the educational background of their parents. The results are shown in table 5.4.

One respondent did not answer this question. Of 67 respondents, 38 (57%) indicated that their mother or father had never attended university. 24% (n = 16) of respondents indicated that one of their parents had attended university, whilst 15% (n = 10) of respondents indicated that both parents are graduates. 4% (n = 3) of respondents indicated that both parents had attended university but had not graduated.

Table 5.4 Parents' educational background of students enrolled on science courses

Parental Education	n	%
Parents have never attended university	38	57
One parent is a university graduate	16	24
Both parents are university graduates	10	15
Both parents attended university but never graduated	3	4

5.2.3 Factors Influencing Choice of Current Science Degree

In section B of the questionnaire participants were asked to identify the extent to which different factors positively influenced the choice of their current science degree. These are presented in groups – those factors which relate to people, marketing, employment, the university and the locality.

5.2.3.1 People Factors

Participants were asked to rate the level of influence on their choice to study science at university of parents, siblings, friends, teachers, speakers from universities, speakers from employment, graduates from the university and having a good science teacher. The results are shown in table 5.5.

Whilst some individual participants reported these factors as having a strong or major influence on their choice to study science at university, the data show overall that participants did not indicate a significant influence of people factors on their choice to study science at university. The median values show each of these people factors as either having some or no influence.

Table 5.5 Influence of people factors on the choice to study science at university

Level of Influence	Factor															
	Parents		Siblings		Friends		Teachers		Speakers from universities		Speakers from employment		Graduates from the university		Having a good science teacher	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Major	7	10	3	4	2	3	7	10	2	3	1	1	2	3	10	15
Strong	19	28	12	18	15	22	13	19	12	18	7	10	8	12	22	32
Some	25	37	13	19	18	26	22	32	26	38	19	28	12	18	14	21
None	17	25	40	59	33	49	25	37	25	37	38	56	43	63	20	29
	Median															
	Some		None		Some		Some		Some		None		None		Some	

5.2.3.2 Marketing Factors

Participants were asked to rate the level of influence on their choice to study science at university of open day/careers events, websites and prospectuses. The results are shown in table 5.6.

Similar to people factors, whilst some individual participants reported these marketing factors as having a strong or major influence on their choice to study science at university, the data show overall that participants did not indicate a significant influence on their choice to study science at university. The median values show each of these marketing factors as having some influence. It is worthy of note however that, whilst the median for websites is ‘some’, 41% of participants did report this factor as having a strong influence on their choice.

Table 5.6 Influence of marketing factors on the choice to study science at university

Level of Influence	Factor					
	Open day/Careers events		Websites		Prospectuses	
	n	%	n	%	n	%
Major	10	15	4	6	3	4
Strong	19	28	28	41	20	29
Some	24	35	28	41	18	26
None	12	18	6	9	23	34
	Median					
	Some		Some		Some	

5.2.3.3 Employment Factors

Participants were asked to rate the level of influence on their choice to study science at university of good job prospects, career opportunities, high level of pay within this field, high employability of graduates from this university and personal employment opportunities whilst at university. The results are shown in table 5.7.

The median indicates that career opportunities was a strong influence on participants' choice to study science at university (38% reported a strong influence and 15% reported a major influence). 37% of participants also indicated that the high employability of graduates from this university was a strong influence, but, with only 6% indicating a major influence, the median value for this factor shows 'some' influence overall. Both good job prospects and personal employment opportunities whilst at university had some influence. The majority of participants (56%) indicated that the high level of pay within this field had no influence and this is reflected in the median for this factor.

Table 5.7 Influence of employment factors on the choice to study science at university

Level of Influence	Factor									
	Good job prospects		Career opportunities		High level of pay within this field		High employability of graduates from this university		Personal employment opportunities whilst at university	
	n	%	n	%	n	%	n	%	n	%
Major	11	16	10	15	1	1	4	6	5	7
Strong	14	21	26	38	4	6	25	37	12	18
Some	32	47	27	40	23	34	18	26	24	35
None	9	13	3	4	38	56	18	26	25	37
	Median									
	Some		Strong		None		Some		Some	

5.2.3.4 University Factors

Grouped as university factors, participants were asked to rate the level of influence on their choice to study science at university of the following factors:

- the degree seemed easy
- the degree seemed challenging
- good reputation of the university
- good reputation of the degree programme
- university ranking in major league tables
- the university offers the programme I am interested in
- the university has good links with industry and the sector
- the cost of studying at this university (including distance from home and living costs)
- good university facilities

- student to staff ratio
- university staff research interests
- social life at the university.

The results are shown in tables 5.8 and 5.9. The university factors are split across two tables for clarity of presentation.

Table 5.8 Influence of university factors on the choice to study science at university

Level of Influence	**Factor**											
	Degree seemed easy		**Degree seemed challenging**		**Good reputation of the university**		**Good reputation of the degree programme**		**University ranking in major league tables**		**University offers the programme I am interested in**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Major	0	0	4	6	5	6	5	7	1	1	28	41
Strong	0	0	15	22	25	37	29	43	3	4	28	41
Some	8	12	25	37	20	29	20	29	19	28	6	9
None	57	84	22	32	16	24	12	18	42	62	4	6
	Median											
	None		Some		Some		Strong		None		Strong	

Median values for five factors show a strong influence on the choice to study science at university; that is, the good reputation of the degree programme, the university offers the programme I am interested in, the university has good links with industry and the sector, good university facilities and university staff research interests. The data show other university factors to have some influence, except the degree seemed easy and the university ranking in major league tables that had no influence.

Table 5.9 Influence of university factors on the choice to study science at university

Level of Influence	Factor											
	University has good links with industry and sector		Cost of studying at this university		Good university facilities		Student to staff ratio		University staff research interests		Social life at the university	
	n	%	n	%	n	%	n	%	n	%	n	%
Major	19	28	6	9	10	15	21	31	15	22	2	3
Strong	21	31	14	21	25	37	10	15	20	29	10	15
Some	16	24	17	25	24	35	13	19	14	21	26	38
None	9	13	28	41	6	9	21	31	17	25	28	41
	Median											
	Strong		Some		Strong		Some		Strong		Some	

5.2.3.5 Locality Factors

Participants were asked to rate the level of influence on their choice to study science at university of the university being close to home, the local social life and the local infrastructure. The results are shown in table 5.10.

The majority of participants indicated that the factors of being close to home (59%) and the local social life (51%) had no influence on their choice to study science at university. Median values for these two factors also show no influence. Whilst 44% of participants indicated that the local infrastructure also had no influence on their choice, the median value for this factor indicates some influence for the group as a whole.

Table 5.10 Influence of locality factors on the choice to study science at university

Level of Influence	**Factor**					
	Close to home		**Local social life**		**Local infrastructure**	
	n	**%**	**n**	**%**	**n**	**%**
Major	9	13	3	4	5	7
Strong	4	6	10	15	10	15
Some	12	18	17	25	20	29
None	40	59	35	51	30	44
	Median					
	None		None		Some	

5.2.3.6 Ranking of Factors

Table 5.11 shows all the factors ordered in descending order with respect to the number and percentage of respondents who indicated the factor as either a major or strong influence in their decision to study science at university.

Table 5.11 Ranking of factors where respondents indicated a major or strong influence.

Factor	**n**	**%**
University offers the programme I am interested in	56	82
University has good links with industry and sector	40	59
Career opportunities	36	53
Good university facilities	35	51
University staff research interests	35	51
Good reputation of the degree programme	34	50
Websites	32	47

Factor	n	%
Having a good science teacher	32	47
Student to staff ratio	31	46
Open day/careers events	29	43
Good reputation of the university	29	43
High employability of graduates from this university	29	43
Parents	26	38
Good job prospects	25	37
Prospectuses	23	34
Teachers	20	29
Cost of studying at this university	20	29
Degree seemed challenging	19	28
Friends	17	25
Personal employment opportunities whilst at university	17	25
Siblings	15	22
Local infrastructure	15	22
Speakers from universities	14	21
Close to home	13	19
Local social life	13	19
Social life at the university	12	18
Graduates from the university	10	15
Speakers from employment	8	12
High level of pay within this field	5	7
University ranking in major league tables	4	6
Degree seemed easy	0	0

5.2.4 Factors Influencing the Choice to Study Science after GCSEs

In section C of the questionnaire participants were asked to identify the extent to which nine factors positively influenced their choice to continue studying science after their GCSEs. The results are presented in tables 5.12 and 5.13. The factors are split across two tables for clarity of presentation.

Table 5.12 Influence of factors on the choice to study science after GCSEs

Level of Influence	**Factor**									
	I was good at science at school		**I thought I would do well at science**		**I thought science was interesting**		**I thought science would be useful for my future career**		**I found science exciting**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Major	5	8	3	4	24	36	15	22	22	32
Strong	23	35	20	30	34	51	34	51	31	46
Some	27	41	32	48	7	10	13	19	14	21
None	11	17	12	18	2	3	5	7	1	1
	Median									
	Some		Some		Strong		Strong		Strong	

Median values for five factors show a strong influence on the choice to study science after GCSEs:

- I thought science was interesting
- I thought science would be useful for my future career
- I found science exciting
- I thought this was a good subject to have
- I enjoyed learning science.

Table 5.13 Influence of factors on the choice to study science after GCSEs

Level of Influence	**Factor**							
	I was advised to take science		**I thought this was a good subject to have**		**I enjoyed learning science**		**I thought having science qualifications would lead to good employment prospects**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Major	4	6	11	17	17	25	11	17
Strong	4	6	26	39	37	54	17	26
Some	16	24	21	32	13	19	27	41
None	42	64	8	12	1	1	11	17
	Median							
	None		Strong		Strong		Some	

'I thought science was interesting' particularly stands out, with 87% of participants indicating this had either a major or strong influence on their decision. The percentage of participants who indicated a major or strong influence for 'I found science exciting' and 'I enjoyed learning science' was 78% and 79% respectively. Whilst the median values still show a strong influence, a lower percentage of participants indicated that the more rationale/strategic factors – 'I thought science would be useful for my future career' and 'I thought this was a good subject to have' – had a major or strong influence. The remaining factors had some influence except 'I was advised to take science', which the median value indicated had no influence.

5.2.5 Age at Decision

In section C of the questionnaire, participants were asked by what age they had decided that they wanted to continue studying or working in science after school. As a continuous data set, mean is an appropriate measure of central tendency. The mean age that participants decided they wanted to continue studying or working in science after school was 17.4 years (S.D. = 4.15). Ages given ranged from 10 to 29 years old.

Participants were also asked by what age they had decided that they wanted to study specifically for a degree in science. The mean age given was 18.5 years (S.D. = 4.58), with a range of 9-35 years old. There does appear to be some anomaly here with one participant suggesting they had decided specifically to study for a degree in science at an earlier age than they had decided they wanted to continue studying or working in science after school.

5.2.6 Pre-GCSEs or Equivalent

In section D of the questionnaire participants were asked to think back to before they completed their GCSEs and identify their level of agreement with seven statements. The statements were based on the dimensions of science capital. The results are presented in tables 5.14 and 5.15. The statements are split across two tables for clarity of presentation.

Four statements gave a median response of agree:

- I thought a science qualification can help you get many types of job.
- I knew how to use scientific evidence to make an argument.
- Teachers explained science is useful for my future.
- I felt it was useful to know about science in my daily life.

It is notable that 86% of participants either agreed or strongly agreed with the statement 'I thought a science qualification can help you get many types of job'. 71% of participants agreed or strongly agreed with the statement 'I felt it was useful to know about science in my daily life'.

Table 5.14 Level of agreement with statements pertaining to the time before participants completed their GCSEs or equivalent

Level of Agreement	Statement							
	I thought a science qualification can help you get many types of job		Parents thought science is very interesting		Parents explained to me that science is useful for my future		I knew how to use scientific evidence to make an argument	
	n	%	n	%	n	%	n	%
Strongly Disagree	5	8	11	17	17	26	10	15
Disagree	4	6	22	33	22	33	12	18
Agree	45	69	25	38	22	33	34	52
Strongly Agree	11	17	8	12	5	8	9	14
	Median							
	Agree		Disagree/ Agree		Disagree		Agree	

The statements 'parents explained to me that science is useful for my future' and 'teachers encouraged me to continue with science after GCSEs' gave a median response of disagree.

Equal proportions of participants agreed and disagreed with the statement 'parents thought science is very interesting'.

Table 5.15 Level of agreement with statements pertaining to the time before participants completed their GCSEs or equivalent

Level of Agreement	**Statement**					
	Teachers encouraged me to continue with science after GCSEs		**Teachers explained science is useful for my future**		**I felt it was useful to know about science in my daily life**	
	n	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	19	29	13	20	8	12
Disagree	22	34	19	29	11	16
Agree	21	32	28	43	39	58
Strongly Agree	3	5	5	8	9	13
	Median					
	Disagree		Agree		Agree	

Also thinking back to before they completed their GCSEs or equivalent, participants were asked if they knew someone who worked in science. 62% of participants (n=42) indicated they did not know someone who worked in science and 38% (n=26) indicated they did. Of the 26 participants who indicated they knew someone who worked in science, 11 gave a family member, 8 gave a friend or family friend and 4 replied with teacher or lecturer.

Again, drawing on the concept of science capital and the work of Woolnough *et al.* (1997), in section D participants were asked to indicate the frequency with which they engaged in certain activities pertaining to the time before they completed their GCSE's or equivalent. The results are shown in table 5.16.

Table 5.16 Frequency of engagement in activities pertaining to the time before participants completed their GCSEs or equivalent.

Frequency	Activity					
	Attend lunchtime or afterschool science club		Visit science centre, museum, or planetarium		Visit zoo or aquarium	
	n	%	n	%	n	%
Never	43	65	10	15	6	9
Less than once a year	6	9	25	37	16	24
At least once a year	3	5	25	37	29	43
At least once a term	3	5	6	9	11	16
At least once a month	11	17	1	1	6	9
	Median					
	Never		Less than once a year		At least once a year	

Participants were also asked, when not in school, how often they read books or magazines about science. The results are shown in table 5.17.

Table 5.17 Frequency of reading books or magazines about science when not in school.

Frequency	n	%
Never or rarely	13	19
Occasionally	17	25
Sometimes	22	32
Regularly	12	18
Always	4	6

The median value is ‘sometimes’.

Participants were asked, when not in school, how often they talked about science with other people. The results are shown in table 5.18.

Table 5.18 Frequency of talking about science with other people when not in school.

Frequency	n	%
Never	11	17
A few times a year	13	20
Once a month	14	22
Once a week	15	23
Almost every day	12	18

The median is ‘once a month’, but there is a relatively equal spread across all categories.

The final question on the questionnaire asked participants with whom they talked about science prior to completing their GCSEs. This question solicited open responses and a tally is given in table 5.19. Some participants did not identify anyone, some identified only one person, and some identified several categories of people. The categories shown in table 5.19 are taken directly from participant responses. It is recognised that there may be an overlap of meaning between categories. For example, some participants identified parents and family separately; others only specified family but this may have been meant to include parents also. Friends were cited most frequently with 41 responses in total. Family was the second most frequent category with 19 responses in total. If all categories that could be interpreted as 'family' are added together, then the total remains less than friends.

Table 5.19 Responses to the question 'Who did you talk with about science?'

Category	Number of Responses
People who would listen	2
Grandparent	1
Friends	41
Parents	12
Siblings	4
Family	19
Partner	1
Teacher	5

5.3 Staff Study

5.3.1 Participants

Academic and professional services staff at the university were investigated in relation to the following research question:

- How do academics and professional services staff perceive the purposes and impacts of university-led science outreach?

The questionnaire was administered to 17 members of academic staff and 7 members of professional services staff involved in delivering outreach activities to young people studying science. 12 qualified participants (5 members of academic staff and 7 members of professional staff) voluntarily completed the questionnaire, giving an overall response rate of 50%.

5.3.2 Free-Text Responses on Perceptions of the Purposes, Evaluation, and Impacts of Outreach Activities

Section A comprised questions around the purposes, evaluation and impacts of outreach activities, requiring mainly free-text responses. Data were analysed using thematic analysis, whereby responses were examined to identify common themes, such as repeated topics and ideas. Whilst thematic analysis allows a large degree of flexibility in interpreting the data, the risk of missing nuances in the data was recognised. Because analysis relies on the researcher's judgement, care had to be taken around my choices and interpretations, to not impose any pre-conceived ideas and obscure true meanings.

The key themes identified, relating to each question, are given in table 5.20.

Table 5.20 Perceptions of the Purposes, Evaluation, and Impacts of Outreach Activities (Free-Text Responses)

Question Focus	Key Themes
Key purpose of the outreach activities	Raising awareness: subject and H.E. options Raising aspirations Recruitment
Secondary purposes of the outreach activities	Recruitment Marketing Develop knowledge, skills, and confidence
Specific objectives of the outreach activities	Develop scientific literacy: scientific knowledge, skills and understanding, including confidence (academics) Develop H.E. literacy: knowledge and understanding of H.E., including confidence Engage students in fun activities Widen participation

Question Focus	Key Themes
Methods used to evaluate the effectiveness of activities in achieving the aims	Immediate post-survey/evaluation sheet (10) Pre-survey (6) Longitudinal survey (6) Interview about activity (4) Mid-activity tracking (4) Observation during delivery (2) None (2)
What the evaluation is designed to assess	Impact: on confidence, knowledge, understanding, application numbers (professional services) Uncertainty (academics)
Perceived issues associated with evaluation	Limitations of data collection method
Findings that arise from the evaluations	Student experience (by clear majority): enjoyment; positive and negative Otherwise, a range of ideas with no clear themes.
Perceived impacts of the outreach activities	Increased knowledge: of university offer, H.E. options, science Increased recruitment
Outreach activities felt to be the most effective in increasing recruitment to the university	Interactive Market the university Summer universities

Question Focus	Key Themes
Outreach activities felt to be the most effective in enhancing science literacy	Interactive Masterclasses
Outreach activities felt to be the most effective in increasing participation in science subjects	Masterclasses Summer universities Active participation Early intervention/long-term
Outreach activities felt to be the most effective in widening participation in science subjects	Target nontraditional learners Projects
How to improve science outreach at the university	Improved marketing Targeted Staffing support Projects Planned journey

5.3.3 Rating Scales Responses on Perceptions of the Purposes, Evaluation and Impacts of Outreach Activities

Participants were asked to identify their level of agreement with 23 statements. The results are presented in table 5.21.

Table 5.21 Perceptions of the Purposes, Evaluation, and Impacts of Outreach Activities (Rating Scale Responses)

Statement		Level of Agreement				Median
		Strongly Disagree	Disagree	Agree	Strongly Agree	
The goals could be more clearly defined.	n	0	1	8	3	Agree
	%	0	8	67	25	
I am confident that the activities are successful in achieving their goals.	n	0	3	9	0	Agree
	%	0	25	75	0	
I feel that the activities change students' attitudes positively towards the university.	n	0	2	8	1	Agree
	%	0	17	67	8	
I feel that the activities change students' attitudes positively towards science.	n	0	4	7	1	Agree
	%	0	33	58	8	
I feel that the outreach activities are targeted at the correct age	n	0	3	7	0	Agree

group to raise awareness of science provision at the university.	**%**	0	25	58	0	
I feel that the outreach activities are targeted at the correct age group to raise aspirations.	**n**	0	4	6	0	Agree
	%	0	33	50	0	
From a university perspective I feel there is a coherent overarching view of what science outreach activities should be doing.	**n**	4	5	2	0	Disagree
	%	33	42	17	0	
I feel that senior management value my work around outreach activities.	**n**	1	4	2	4	Agree
	%	8	33	17	33	
I feel that the objectives of science outreach activities and what is actually measured in the evaluation are aligned.	**n**	1	2	5	0	Agree
	%	8	17	42	0	
I feel the activities are effective in raising student aspirations.	**n**	0	4	7	0	Agree
	%	0	33	58	0	
I feel the activities are effective in raising awareness of university science provision.	**n**	0	0	9	1	Agree
	%	0	0	75	8	

I feel the activities are effective in recruiting students to the university.	**n**	0	2	8	0	Agree
	%	0	17	67	0	
Outreach activities are heavily influenced by the needs of marketing.	**n**	4	2	2	3	Disagree
	%	33	17	17	25	
Outreach activities are heavily influenced by the needs of widening participation.	**n**	0	6	5	1	Disagree / Agree
	%	0	50	42	8	
Outreach activities are heavily influenced by the needs of the school curriculum.	**n**	0	4	5	0	Agree
	%	0	33	42	0	
Outreach activities are heavily influenced by a personal interest.	**n**	1	5	5	0	Disagree
	%	8	42	42	0	
Outreach activities are heavily influenced by my personal contacts.	**n**	1	2	9	0	Agree
	%	8	17	75	0	
	n	0	5	1	1	Disagree

Outreach activities are heavily influenced by the employability agenda	**%**	0	42	8	8	
The specific goal of raising student aspirations for science careers is being met by university-led outreach.	**n**	0	4	5	1	Agree
	%	0	33	42	8	
University-led science outreach has an important part to play in contributing to the research agenda.	**n**	0	2	4	5	Agree
	%	0	17	33	42	
University-led science outreach has an important part to play in contributing to the employability agenda.	**n**	0	1	6	5	Agree
	%	0	8	50	42	
University-led science outreach has an important part to play in securing a pipeline of future scientists needed for the UK economy.	**n**	0	0	3	7	Strongly Agree
	%	0	0	25	58	
University-led science outreach has an important part to play in contributing towards social justice.	**n**	0	0	5	5	Agree/ Strongly Agree
	%	0	0	42	42	

Not all participants gave a response to all questions. Although the option was not available on the rating scale, some participants also indicated 'don't know' or 'neutral' on the questionnaire. The following statements received 'don't know' or 'neutral' responses:

- I feel that the activities change students' attitudes positively towards the university (x1 academic).
- I feel that the outreach activities are targeted at the correct age group to raise awareness of science provision at the university (x2 academic).
- I feel that the outreach activities are targeted at the correct age group to raise aspirations (x2 academic).
- From a university perspective I feel there is a coherent overarching view of what science outreach activities should be doing (x1 academic).
- I feel that senior management value my work around outreach activities (x1 academic).
- I feel that the objectives of science outreach activities and what is actually measured in the evaluation are aligned (x1 professional services and x3 academic).
- I feel the activities are effective in raising student aspirations (x1 academic).
- I feel the activities are effective in raising awareness of university science provision (x2 academic).
- I feel the activities are effective in recruiting students to the university (x2 academic).
- Outreach activities are heavily influenced by the needs of marketing (x1 academic).
- Outreach activities are heavily influenced by the needs of the school curriculum (x3 academic).
- Outreach activities are heavily influenced by a personal interest (x1 academic).
- Outreach activities are heavily influenced by the employability agenda (x4 professional services and x1 academic).
- The specific goal of raising student aspirations for science careers is being met by university-led outreach (x1 professional services and x2 academic).
- University-led science outreach has an important part to play in contributing to the research agenda (x1 academic).
- University-led science outreach has an important part to play in securing a pipeline of future scientists needed for the UK economy (x2 academic).
- University-led science outreach has an important part to play in contributing towards social justice (x2 academic).

It is noteworthy that the majority of ‘don’t know’ responses were given by academic staff. Outreach activities are driven by professional services staff and this is perhaps indicative that key messages are not being received by academic staff who feel unable to make a judgement based on the evidence available.

Percentages were calculated based on the number of participants who completed the questionnaire (12) rather than the number of responses to each statement and therefore do not necessarily total 100% in the table.

All respondents (83% of participants) either agreed or strongly agreed with the statement that university-led science outreach has an important part to play in securing a pipeline of future scientists needed for the UK. The median for this statement was ‘strongly agree’. Similarly, all respondents either agreed or strongly agreed with the statement that university-led science outreach has an important part to play in contributing towards social justice. However, because equal proportions of participants indicated both categories the median value is split as ‘strongly agree/agree’. All respondents (83% of participants) also either agreed or strongly agreed with the statement ‘I feel the activities are effective in raising awareness of university science provision’; the median value showed ‘agree’.

Other statements where over 75% of participants either agree or strongly agree are:

- The goals could be more clearly defined (92%).
- I am confident that the activities are successful in achieving their goals (75%).
- I feel that the activities change students' attitudes positively towards the university (75%).
- Outreach activities are heavily influenced by my personal contacts (75%).
- University-led science outreach has an important part to play in contributing to the research agenda (75%).
- University-led science outreach has an important part to play in contributing to the employability agenda (92%).

Statements where over 75% of participants either disagree or strongly disagree are:

- From a university perspective I feel there is a coherent overarching view of what science outreach activities should be doing (75%).

- (Although a somewhat arbitrary figure, it was agreed with my supervisors that 75% of participants would indicate a significant level of agreement).

5.4 Outreach Initiative Study

5.4.1 Participants

The aim of this study was to investigate the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital.

In phase 1, research participants were recruited from teachers and volunteers participating in the FIRST® LEGO® League in the local area. To facilitate a higher response rate, participants were recruited through face-to-face contact at an event at the university, where they were asked to complete paper questionnaires. Twelve teachers and 21 volunteers completed the questionnaire.

At the event, agreement from the teachers was sought to extend the invite to participate in the research study to members of the school team (children) and their parents. Where agreement was indicated in writing, agreement was subsequently sought from the Headteacher also (if different) and schools were then asked to disseminate information about the research to parents (which also included a link to the parent JISC online questionnaire). With appropriate consent in place, teachers were asked to arrange for the children to complete the questionnaire in school. This allowed appropriate support to be in place for any participants who may have had specific learning needs. Ten parents and 27 children voluntarily completed the questionnaire.

5.4.2 Perspectives on STEM Subjects

The first four items on the questionnaires used with teachers, volunteers and parents sought their perspectives on STEM subjects in terms of social justice and the economic pipeline. The results are presented in graphical and tabular format. For each of the four questionnaire items, ANOVA and Kruskal-Wallis tests were conducted on the data to explore whether the groups of participants resulted in significantly different responses to the questions. If a significant difference was evident, further t-tests were conducted to explore between which group pairs there was a significant difference in responses. The full set of calculations can be found in the appendix and summary results are given here to show whether or not there is a significant difference between the means (or medians) of teachers, parents and volunteers.

5.4.2.1 STEM subjects offer the potential to increase the life opportunities for young people

The first item on the questionnaires completed by teachers, volunteers and parents asked participants to indicate their level of agreement with the statement ‘STEM subjects offer the potential to increase the life opportunities for young people’. The results are presented in table 5.22.

The results from teachers, volunteers and parents as a collective group show a high level of agreement from all adult participants that STEM subjects offer the potential to increase the life opportunities for young people. From all the teachers, volunteers and parents, 81% (n=35) strongly agreed with the statement and 16% (n=7) agreed. Only 2% (n=1) disagreed.

The data were then analysed on a group basis. The results from teachers show 100% (n=12) strongly agreed with the statement that STEM subjects offer the potential to increase life opportunities for young people.

A total of 21 volunteers indicated their level of agreement with the statement ‘STEM subjects offer the potential to increase the life opportunities of young people’. No volunteers disagreed with the statement, with 29% agreeing and a majority of 71% strongly agreeing.

Focusing on the level of agreement of parents with the statement ‘STEM subjects offer the potential to increase the life opportunities of young people’, table 5.22 shows 90% (n= 9) in agreement or strong agreement. Only one parent (10%) strongly disagreed.

Table 5.22 Level of agreement with the statement 'STEM subjects offer the potential to increase the life opportunities for young people'

Level of Agreement	**Group**							
	Teachers		**Volunteers**		**Parents**		**All Adult Participants**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	0	0	0	0	1	10	1	2
Disagree	0	0	0	0	0	0	0	0
Agree	0	0	6	29	1	10	7	16
Strongly Agree	12	100	15	71	8	80	35	81

In conducting an ANOVA test on data from teacher, volunteer and parent groups in relation to the statement 'STEM subjects offer the potential to increase the life opportunities for young people', the calculated F-value is less than the F-critical value (shown in table 5.23). The null hypothesis is therefore accepted, indicating that there is no significant difference between the groups. Similarly, the p-value is greater than alpha-value selected (0.05) and therefore the null hypothesis is accepted.

Table 5.23 Summary results from ANOVA test on data from teacher, volunteer and parent groups in relation to the statement 'STEM subjects offer the potential to increase the life opportunities for young people'

ANOVA: Single Factor						
Groups	**Count**		**Source of Variation**	**F**	**P-value**	**F Critical**
Teachers	12		Between Groups	1.558768	0.222906	3.231727
Parents	10					
Volunteers	21					

5.4.2.2 Participation levels in STEM subjects matter in terms of social justice

The second item on the questionnaires completed by teachers, volunteers and parents asked participants to indicate their level of agreement with the statement 'participation levels in STEM subjects matter in terms of social justice'. The results are presented in table 5.24.

Table 5.24 Level of agreement of all adult participants with the statement 'participation levels in STEM subjects matter in terms of social justice'

Level of Agreement	**Group**							
	Teachers		**Volunteers**		**Parents**		**All Adult Participants**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	0	0	1	5	1	10	2	5
Disagree	0	0	2	10	0	0	2	5
Agree	3	25	10	48	5	50	18	42
Strongly Agree	9	75	8	38	4	40	21	49

The results from teachers, volunteers and parents, presented as a collective group, show a high level of agreement from all adult participants that participation levels in STEM subjects matter in terms of social justice. From all the teachers, volunteers and parents, 91% (n=39) either strongly agreed or agreed with the statement. It is worth noting that the strength of agreement is less than the previous statement, with 49% strongly agreeing. 10% (n=4) either disagreed or strongly disagreed.

When the data are split on a group basis, 75% teachers (n= 9) strongly agreed with the statement that participation in STEM subjects matters in terms of social justice. A further 25% (n=3) teachers agreed with the statement and no teachers indicated their disagreement.

The results from volunteers when asked about their level of agreement with the statement ‘participation levels in STEM subjects matter in terms of social justice’ show a total of 86% (n=18) either agreed or strongly agreed with the statement. 15% (n=3) did not agree. Percentage figures do not total 100% due to rounding.

All parents except one either agreed or strongly agreed with the statement ‘participation levels in STEM subjects matter in terms of social justice’. Only one parent (10%) strongly disagreed.

Table 5.25 Summary results from ANOVA test on data from teacher, volunteer and parent groups in relation to the statement ‘participation levels in STEM subjects matter in terms of social justice'

ANOVA: Single Factor						
Groups	**Count**		**Source of Variation**	**F**	**P-value**	**F critical**
Teachers	12		Between Groups	2.320977	0.111259	3.231727
Parents	10					
Volunteers	21					

Table 5.25 shows the summary results from an ANOVA test to ascertain whether there is a significant difference between the responses of teachers, volunteers and parents. The calculated F-value is less than the F-critical value and therefore the null

hypothesis is accepted, indicating that there is no significant difference between the groups. Similarly, the p-value is greater than alpha-value selected (0.05) and therefore the null hypothesis is accepted.

5.4.2.3 The UK urgently needs employees with STEM skills

The third item on the questionnaires completed by teachers, volunteers and parents asked participants to indicate their level of agreement with the statement 'the UK urgently needs employees with STEM skills'. The results are presented in table 5.26.

Table 5.26 Level of agreement with the statement 'the UK urgently needs employees with STEM skills'

Level of Agreement	Group							
	Teachers		Volunteers		Parents		All Adult Participants	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	0	0	1	10	1	2
Disagree	0	0	1	5	0	0	1	2
Agree	0	0	9	43	6	60	15	35
Strongly Agree	12	100	11	52	3	30	26	60

The results of the collective group of all adult participants in relation to their level of agreement with the statement 'the UK urgently needs employees with STEM skills' show only 4% (n=2) indicated a level of disagreement. 95% (n=41) indicated a level of agreement and 60% (n=26) of adult participants in fact strongly agreed with the statement.

Results from teachers show 100% (n=12) strongly agreed with the statement that the UK urgently needs employees with STEM skills.

Whilst only one volunteer (5%) indicated disagreement with the statement that the UK urgently needs more employees with STEM skills (and therefore 95% (n=20) indicated a level of agreement), the strength of agreement was less than teachers. 52% (n=11) volunteers strongly agreed with the statement and 43% (n=9) agreed.

Ten parents in total indicated their level of agreement with the statement 'the UK urgently needs employees with STEM skills'. Of these respondents, 30% (n=3) strongly agreed, 60% (n=6) agreed and 10% (n=1) parents strongly disagreed.

Table 5.27 Summary results from ANOVA test on data from teacher, volunteer and parent groups in relation to the statement 'the UK urgently needs employees with STEM skills'

ANOVA: Single Factor						
Groups	**Count**		**Source of Variation**	**F**	**P-value**	**F critical**
Teachers	12		Between Groups	6.450061	0.003733	3.231727
Parents	10					
Volunteers	21					

As shown in table 5.27, the calculated F-value, from conducting an ANOVA test on data from teacher, volunteer and parent groups in relation to the statement 'the UK urgently needs employees with STEM skills', is greater than the F-critical value for the alpha level selected (0.05). Therefore, there is evidence to reject the null hypothesis and say that at least one of the three groups has a significantly different mean. Another measure for ANOVA is the p-value - as the p-value is less than the alpha level selected (0.05), the null hypothesis is rejected, suggesting again that at least one of the three groups has a significantly different mean.

Similarly, Kruskal-Wallis test showed that at least one of the groups has a significantly different median.

As shown in table 5.28, a two-sample t-test comparing the means of teacher and parent responses gave a p two-tail value of 0.00991. This is less than the alpha level selected (0.05) and indicates a significant difference between the responses of teachers and parents.

Table 5.28 Results from two-sample t-tests conducted on pairs of groups.

t-Test: Two-Sample Assuming Unequal Variances			
	Teachers Parents	**Teachers Volunteers**	**Parents Volunteers**
P(T<=t) two-tail	0.009991	0.00072	0.241344
p two-tail less than 0.05 = sig. difference	Sig. difference	Sig. difference	No sig. difference

In comparing the responses of teachers and volunteers the resultant p two-tail value was 0.00072, which again is less than the selected alpha level and indicates a significant difference in the responses of teachers and volunteers.

A comparison of responses between parents and volunteers gave a p two-tail value of 0.241344, which is greater than the alpha level selected and suggests there is no significant difference between the two groups.

5.4.2.4 STEM represents this country's economic future

The fourth item on the questionnaires completed by teachers, volunteers and parents asked participants to indicate their level of agreement with the statement 'STEM represents this country's economic future'. The results are presented in table 5.29.

The results from teachers, volunteers and parents as a collective group on their level of agreement with the statement 'STEM represents this country's economic future' show a total of 95% (n=41) indicated that they either agreed (42%) or strongly agreed (53%) with the statement. Two participants (4%) indicated a level of disagreement.

All teachers (100%, n= 12) strongly agreed with the statement 'STEM represents this country's economic future'.

Of the volunteers indicating their level of agreement with the statement 'STEM represents this country's economic future' 33% (n=7) strongly agreed and 62% (n=13) agreed. 5% (n=1) volunteers disagreed with the statement.

Table 5.29 Level of agreement with the statement 'STEM represents this country's economic future'

Level of Agreement	Group							
	Teachers		Volunteers		Parents		All Adult Participants	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	0	0	1	10	1	2
Disagree	0	0	1	5	0	0	1	2
Agree	0	0	13	62	5	50	18	42
Strongly Agree	12	100	7	33	4	40	23	53

From the group of 10 parents, 90% respondents agreed (50%) or strongly agreed (40%) with the statement 'STEM represents this country's economic future'.

Table 5.30 Summary results from ANOVA test on data from teacher, volunteer and parent groups in relation to the statement 'STEM represents this country's economic future'.

ANOVA: Single Factor						
Groups	**Count**		**Source of Variation**	**F**	**P-value**	**F critical**
Teachers	12		Between Groups	6.930807	0.002604	3.231727
Parents	10					
Volunteers	21					

In conducting an ANOVA test on data from teacher, volunteer and parent groups in relation to the statement 'STEM represents this country's economic future', the calculated F-value (6.930807) is greater than the F-critical value (3.231727) for the alpha level selected (0.05) (shown in table 5.30). Therefore, there is evidence to reject the null hypothesis and say that at least one of the three groups has a significantly different mean. Another measure for ANOVA is the p-value - as the p-value (0.002604) is less than the alpha level selected (0.05), the null hypothesis is rejected, suggesting again that at least one of the three groups has a significantly different mean.

Similarly, Kruskal-Wallis test showed that at least one of the groups has a significantly different median.

As table 5.31 shows, a two-sample t-test comparing the means of teacher and parent responses gave a p two-tail value of 0.022367. This is less than the alpha level selected (0.05) and indicates a significant difference between the responses of teachers and parents.

Table 5.31 Results from two-sample t-tests conducted on pairs of groups in relation to the statement 'STEM represents this country's economic future'

t-Test: Two-Sample Assuming Unequal Variances			
	Teachers Parents	**Teachers Volunteers**	**Parents Volunteers**
P(T<=t) two-tail	0.022367	1.03E-05	0.790354
p two-tail less than 0.05 = sig. difference	Sig. difference	Sig. difference	No sig. difference

In comparing the responses of teachers and volunteers the resultant p two-tail value was 1.03E-05, which again is less than the selected alpha level and indicates a significant difference in the responses of teachers and volunteers.

A comparison of responses between parents and volunteers gave a p two-tail value of 0.790354, which is greater than the alpha level selected and suggests there is no significant difference between the two groups.

5.4.3 Impact on the Dimensions of Science Capital

The statements in section B for teachers, parents and volunteers, and section A for children were based on the dimensions of science capital and focused on the impact on the children of participation in the FIRST® LEGO® League. Section B for the children and section C for the parents focused on potential impacts on the parents. Participants were asked to indicate their level of agreement with a range of statements. The results are presented in tables 5.32 – 5.50.

5.4.3.1 Learn about the world outside of school

Table 5.32 Level of agreement that participating in the LEGO League has supported pupils to learn about the world outside of school

Level of Agreement	Group							
	Teachers		Volunteers		Parents		Pupils	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	0	0	0	0	1	4
Disagree	0	0	1	5	0	0	1	4
Agree	5	42	7	32	7	70	18	67
Strongly Agree	7	58	13	59	3	30	7	26

The data in table 5.32 shows that all teachers either agreed (42%, n= 5) or strongly agreed (58%, n= 7) with the statement 'participating in the LEGO League has supported pupils to learn about the world outside of school'.

When asked to indicate their level of agreement with the same statement, 32% volunteers (n=7) agreed, and 59% volunteers (n=13) strongly agreed. One volunteer disagreed with the statement, and one indicated that they did not know.

All parents either agreed (70%, n=7) or strongly agreed (30%, n= 3) with the statement ‘through participating in the LEGO League my child has learnt about the world outside of school’.

From those pupils who participated in the LEGO League and who completed the questionnaire, 67% (n= 18) agreed and 26% (n=7) strongly agreed that they had learnt about the world outside of school. Two pupils did indicate a level of disagreement with this statement.

5.4.3.2 Learn how science is a part of their inside- and outside-of-school lives

Table 5.33 Level of agreement that participating in the LEGO League has supported pupils to learn how science is a part of their inside- and outside-of-school lives

Level of Agreement	Group							
	Teachers		Volunteers		Parents		Pupils	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	0	0	0	0	0	0
Disagree	0	0	2	9	1	10	1	4
Agree	3	25	5	23	4	40	9	35
Strongly Agree	9	75	14	64	5	50	16	62

The results in table 5.33 show that all teachers agreed that participating in the LEGO League had supported pupils to learn how science is a part of their inside- and outside-of-school lives. Three quarters of the teachers strongly agreed with the statement.

Whilst 9% (n=2) volunteers disagreed with the statement ‘participating in the LEGO League has supported pupils to learn how science is a part of their inside- and outside-of-school lives’, the majority indicated a level of agreement (23% agree and 64% strongly agree).

One parent indicated their disagreement with this statement, whilst 40% (n=4) agreed and 50% (n=5) strongly agreed.

Most pupils who completed the questionnaire felt that they had learnt how science is a part of their life inside and outside of school (35% (n=9) agreed and 62% (n=16) strongly agreed). One pupil indicated that they disagreed.

5.4.3.3 Learn interesting things about the world inside and outside of school

Table 5.34 Level of agreement that participating in the LEGO League has supported pupils to learn interesting things about the world inside and outside of school

Level of Agreement	**Group**							
	Teachers		**Volunteers**		**Parents**		**Pupils**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	0	0	0	0	0	0	1	4
Disagree	0	0	1	5	0	0	3	11
Agree	3	24	5	23	5	50	11	41
Strongly Agree	9	75	15	68	5	50	12	44

When responding to the statement ‘participating in the LEGO League has supported pupils to learn interesting things about the world inside and outside of school’, table 5.34 shows that all teachers agreed (25% (n=3) agreed and 75% (n=9) strongly agreed).

When responding to the same statement, one volunteer (representing 5%) indicated disagreement. One volunteer indicated that they did not know. All others either agreed (23%, n=5) or strongly agreed (68%, n=15).

All parents agreed with the statement ‘through participating in the LEGO League my child has learnt interesting things about the world inside and outside of school’. The distribution was split evenly, with 50% (n=5) agreeing and 50% (n=5) strongly agreeing).

The results from pupils show a higher level of disagreement in relation to this statement, with 11% (n=3) indicating they disagreed and 4% (n=1) indicating they strongly disagreed. A total of 85% (n=23) either agreed or strongly agreed with the statement.

5.4.3.4 Develop a greater awareness of scientific principles

Table 5.35 Level of agreement that participating in the LEGO League has supported pupils to develop a greater awareness of scientific principles

Level of Agreement	**Group**							
	Teachers		**Volunteers**		**Parents**		**Pupils**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	0	0	0	0	0	0	0	0
Disagree	0	0	1	5	1	10	1	4
Agree	7	58	9	41	3	30	12	44
Strongly Agree	5	42	12	55	6	60	14	52

In relation to the impact on the dimensions of science capital, the fourth statement considered whether participation in the LEGO League had supported pupils to develop a greater awareness of scientific principles. Table 5.35 shows that all teachers agreed (58%, n=7) or strongly agreed (42%, n=5).

In responding to the statement 'participating in the LEGO League has supported pupils to develop a greater awareness of scientific principles', one volunteer (5%) disagreed. All other volunteers indicated a level of agreement (41% (n=9) agree and 55% (n=12) strongly agree).

Parents were asked to consider whether their child had developed a greater awareness of scientific principles through participating in the LEGO League. One parent felt not (10% disagree), whilst 30% (n=3) agreed and 60% (n=6) strongly agreed with the statement.

Results from pupils show a similar pattern to those from parents and volunteers. Again, one pupil (4%) disagreed with the statement ‘through participating in the LEGO League, I have developed a greater awareness of scientific ideas’, whilst 44% (n=12) and 52% (n=14) strongly agreed with the statement.

5.4.3.5 Made science more enjoyable

Table 5.36 Level of agreement that participating in the LEGO League has made science more enjoyable

Level of Agreement	Group							
	Teachers		Volunteers		Parents		Pupils	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	0	0	0	0	0	0
Disagree	0	0	1	5	1	10	0	0
Agree	3	25	6	27	4	40	15	56
Strongly Agree	9	75	15	68	5	50	12	44

As shown in table 5.36, teachers were in strong agreement overall with the statement ‘participating in the LEGO League has made science more enjoyable’. Nine teachers (75%) indicated they strongly agreed with the statement and 3 teachers (25%) agreed. No teachers responded with a level of disagreement.

The results from volunteers reflected a similar pattern to teachers, in that volunteers were in strong agreement overall with the statement ‘participating in the LEGO League has made science more enjoyable' (27% (n=6) agree and 68% (n=15) strongly agree), but one respondent (5%) indicated that they disagreed with the statement.

Parents were asked to indicate their level of agreement with the statement 'through participating in the LEGO League my child thinks that science is more enjoyable'. 50% (n=5) strongly agreed, 40% (n=4) agreed and 10% (n=1) disagreed.

All pupils agreed with the statement 'through participating in the LEGO League I think that science is more enjoyable' (56% (n=15) agree and 44% (n=12) strongly agree). No pupils disagreed with the statement.

5.4.3.6 Develop scientific knowledge, skills and understanding

Table 5.37 Level of agreement that participating in the LEGO League has supported pupils to develop scientific knowledge, skills and understanding

Level of Agreement	**Group**							
	Teachers		**Volunteers**		**Parents**		**Pupils**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	0	0	0	0	0	0	1	4
Disagree	0	0	0	0	0	0	2	7
Agree	2	17	8	36	4	40	11	41
Strongly Agree	10	83	14	64	6	60	13	48

As table 5.37 shows, there was strong agreement from teachers that participating in the LEGO League had supported pupils to develop scientific knowledge, skills and understanding. 83% teachers (n=10) strongly agreed with this particular statement and 17% (n=2) agreed.

Responses from volunteers showed a similar outcome as teachers, with all respondents indicating a level of agreement. 64% volunteers (n=14) strongly agreed that participating in the LEGO League had supported pupils to develop scientific knowledge, skills and understanding, and 36% (n=8) agreed.

Whilst the strength of agreement was less overall, all parents similarly indicated a level of agreement with the statement ‘through participating in the LEGO League my child has developed scientific knowledge, skills and understanding’. 60% parents (n=6) strongly agreed and 40% (n=4) agreed.

Pupils were the only group that indicated some level of disagreement in relation to developing scientific knowledge, skills and understanding. 11% pupils (n=3) in total either disagreed or strongly disagreed. The remaining 89% pupils either agreed (41%, n=11) or strongly agreed (48%, n= 13).

5.4.3.7 Made science relevant to everyday life

Table 5.38 Level of agreement that participating in the LEGO League has made science relevant to everyday life

Level of Agreement	**Group**							
	Teachers		**Volunteers**		**Parents**		**Pupils**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	0	0	0	0	0	0	0	0
Disagree	0	0	2	9	0	0	0	0
Agree	4	33	7	32	6	60	16	59
Strongly Agree	8	67	13	59	4	40	11	41

As shown in table 5.38, all teachers indicated a level of agreement with the statement ‘participating in the LEGO League has made science relevant to everyday life’. The strength of agreement from teachers was highest from all the groups, with 67% (n=8) strongly agreeing with the statement.

Table 5.38 shows that 91% volunteers (n=20) either agreed (32%) or strongly agreed (59%) with the statement. Two volunteers did however disagree, representing 9% of respondents.

In a similar vein to teachers above and pupils below, all parents agreed with the statement 'through participating in the LEGO League my child thinks science is relevant to everyday life'. 60% (n=6) parents agreed and 40% (n=4) strongly agreed.

All pupils felt that they think science is relevant to everyday life through participating in the LEGO League. This was split 59% (n=16) agree and 41% (n=11) strongly agree.

5.4.3.8 Made explicit that a science qualification can help get many different types of job

Table 5.39 Level of agreement that participating in the LEGO League has made explicit that a science qualification can help get many different types of job

Level of Agreement	Group							
	Teachers		Volunteers		Parents		Pupils	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	1	5	0	0	0	0
Disagree	1	8	2	9	0	0	1	4
Agree	2	17	9	41	6	60	6	22
Strongly Agree	9	75	8	36	4	40	20	74

'Participating in the LEGO League has made explicit that a science qualification can help get many different types of job' was the first statement to elicit disagreement from teachers, as shown in table 5.39. One teacher (8%) disagreed with the statement. 17% teachers (n=2) agreed and 75% (n=9) strongly agreed.

From a total of 22 volunteers, 36% (n=8) strongly agreed the statement 'participating in the LEGO League has made explicit that a science qualification can help get many different types of job' and a further 41% (n=9) agreed. 14% volunteers (n=3) either disagreed or strongly disagreed, whilst 5% (n=2) felt they did not know.

All parents (n=10) felt that their child had developed a greater understanding that a science qualification can help get many different types of job through participating in the LEGO League. This was split 60% agree and 40% strongly agree.

Results from pupils in relation to making explicit that a science qualification can help get many different types of job show a similar pattern to those from teachers. 74% pupils (n=20) strongly agreed with the statement, 22% (n=6) agreed and 4% (n=1) disagreed.

5.4.3.9 Highlighted the value of science education to pupils' university and/or career options

Table 5.40 Level of agreement that participating in the LEGO League has highlighted the value of science education to pupils' university and/or career options

Level of Agreement	Group							
	Teachers		Volunteers		Parents		Pupils	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	1	5	0	0	0	0
Disagree	1	8	1	5	0	0	1	4
Agree	4	33	9	41	7	70	12	44
Strongly Agree	7	58	8	36	3	30	14	52

From a total of 12 teachers who responded to the questionnaire, as shown in table 5.40, 58% (n=7) strongly agreed and 33% (n=4) agreed with the statement ‘participating in the LEGO League has highlighted the value of science education to pupils’ university and/or career options’. One teacher (8%) disagreed.

Twenty-two volunteers responded to the questionnaire item ‘participating in the LEGO League has highlighted the value of science education to pupils’ university and/or career options’. Of these, 36% (n=8) strongly agreed and 41% (n=9) agreed. One volunteer (5%) indicated that they disagreed, and another volunteer indicated that they strongly disagreed. Three volunteers indicated that they did not know whether or not participating in the LEGO League had highlighted the value of science education to pupils’ university and/or career options.

All parents felt that their child had a greater understanding of the value of science education to their future study and/or career options through participating in the LEGO League. This was split 30% (n=3) strongly agree and 70% (n=7) agree.

With 96% (n=26) either agreeing or strongly agreeing with this item, the results show that pupils felt that they had a greater understanding of how learning science could be useful for their future career options through participating in the LEGO League. One pupil (4%) disagreed with the statement.

5.4.3.10 Encouraged greater science media consumption

As shown in table 5.41, all teachers felt that participating in the LEGO League had encouraged greater science media consumption, with 33% (n=4) agreeing and 67% (n=8) strongly agreeing with the statement.

Whilst one volunteer (5%) disagreed with the statement that participating in the LEGO League had encouraged greater science media consumption, 77% (n=17) either agreed or strongly agreed. Four volunteers responded that they did not know.

A total of 90% parents (n=9) either agreed or strongly agreed that through participating in the LEGO League their child had used television, the internet, or newspapers to expand their scientific knowledge. One parent (10%) disagreed.

Although a total of 81% pupils (n=21) either agreed or strongly agreed with this item, the results from pupils are notable in their level of disagreement, which is higher than teachers, volunteers, and parents. Four pupils (15%) strongly disagreed, and one pupil (4%) disagreed that they had used television, websites or newspapers to find out about science as part of the LEGO League.

Table 5.41 Level of agreement that participating in the LEGO League has encouraged greater science media consumption - using television, the internet or newspapers to expand pupils' scientific knowledge

Level of Agreement	**Group**							
	Teachers		**Volunteers**		**Parents**		**Pupils**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	0	0	0	0	0	0	4	15
Disagree	0	0	1	5	1	10	1	4
Agree	4	33	11	50	6	60	13	50
Strongly Agree	8	67	6	27	3	30	8	31

Related to the field of media consumption, but focusing on different media, pupils were asked to indicate their level of agreement with the statement 'through participating in the LEGO League I have read books and magazines to find out about science'. The results are shown in table 5.42 and give the lowest level of agreement from any items in this section, with 63% pupils (n=17) agreeing or strongly agreeing. Five pupils (19%) disagreed with the statement and a further five strongly disagreed.

Table 5.42 Level of agreement of pupils with the statement 'through participating in the LEGO League I have read books and magazines to find out about science'

Level of Agreement	Pupils	
	n	%
Strongly Disagree	5	19
Disagree	5	19
Agree	13	48
Strongly Agree	4	15

5.4.3.11 Participate more in informal science learning contexts, such as science museums, science clubs, fairs etc.

Table 5.43 Level of agreement that participating in the LEGO League has encouraged pupils to participate more in informal science learning contexts, such as science museums, science clubs, fairs etc

Level of Agreement	Group							
	Teachers		Volunteers		Parents		Pupils	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	0	0	0	0	3	11
Disagree	1	8	2	9	4	40	4	15
Agree	3	25	6	27	3	30	7	26
Strongly Agree	8	67	12	55	3	30	13	48

As shown in table 5.43, the majority (92%, n= 11) of teachers felt that participating in the LEGO League had encouraged pupils to participate more in informal science learning contexts, such as science museums, science clubs, fairs etc. One teacher (8%) disagreed.

The majority (82%, n= 18) of volunteers felt that participating in the LEGO League had encouraged pupils to participate more in informal science learning contexts, such as science museums, science clubs, fairs etc. Two volunteers (9%) disagreed, and two volunteers indicated that they did not know.

The level of agreement with this statement was less with parents than the preceding two groups, with 30% (n=3) agreeing and 30% (n=3) strongly agreeing. Four parents (40%) disagreed that through participating in the LEGO League their child had participated more in informal science learning contexts, such as science museums, science clubs and fairs.

Considering pupil responses, ‘strongly agree’ elicited the highest level of response, with 48% pupils (n=13) falling into this category. A further 26% pupils (n=7) indicated that they agreed with the statement. Seven pupils overall (26%) either disagreed or strongly disagreed that through participating in the LEGO League they had gone to a science centre or science museum outside of school.

5.4.3.12 Opportunities for pupils to talk about science out of school with key people in their lives (e.g. friends, siblings, parents, neighbours, community members)

The results in table 5.44 show that teachers felt strongly that participating in the LEGO League has created opportunities for pupils to talk about science out of school with key people in their lives, with 92% (n=11) strongly agreeing and 8% (n=1) agreeing. No teachers disagreed with this statement.

The strength of feeling was less from volunteers than teachers, with 50% (n=11) strongly agreeing and 36% (n=8) agreeing, nut no volunteers disagreed with the statement. Three volunteers did indicate that they did not know.

The majority of parents indicated some level of agreement with the statement ‘through participating in the LEGO League my child has talked more about science out of school with key people in their lives', with 60% (n=6) agreeing and 30% (n=3) strongly agreeing. One parent (10%) disagreed.

Table 5.44 Level of agreement that participating in the LEGO League has created opportunities for pupils to talk about science out of school with key people in their lives (e.g., friends, siblings, parents, neighbours, community members)

Level of Agreement	Group							
	Teachers		Volunteers		Parents		Pupils	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	0	0	0	0	1	4
Disagree	0	0	0	0	1	10	1	4
Agree	1	8	8	36	6	60	12	44
Strongly Agree	11	92	11	50	3	30	13	48

One pupil disagreed and one pupil strongly disagreed that they had talked more about science out of school with friends, siblings, parents, neighbours and other people in their community through participating in the LEGO League. The majority (92% (n=25) either agreed or strongly agreed.

5.4.3.13 Opportunities for pupils to talk about science with people outside their normal networks

Similar to the preceding statement, the results in table 5.45 show that teachers felt strongly that participating in the LEGO League had created opportunities for pupils to talk about science with people outside their normal networks. 83% teachers (n=10) strongly agreed with the statement and 17% (n=2) agreed. No teachers disagreed.

Table 5.45 Level of agreement that participating in the LEGO League has created opportunities for pupils to talk about science with people outside their normal networks

Level of Agreement	**Group**							
	Teachers		**Volunteers**		**Parents**		**Pupils**	
	n	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Strongly Disagree	0	0	0	0	0	0	0	0
Disagree	0	0	0	0	2	20	3	11
Agree	2	17	9	43	7	70	9	33
Strongly Agree	10	83	12	57	1	10	15	56

In a similar vein to teachers, all volunteers felt that participating in the LEGO League had created opportunities for pupils to talk about science with people outside their normal networks, with 43% (n=9) agreeing and 57% (n=12) strongly agreeing.

The results show that the strength of agreement from parents with this statement was least out of the four groups. Whilst 70% (n=7) agreed with the statement, only 10% (n=1) strongly agreed and 20% (n=2) disagreed.

When considering the statement 'through participating in the LEGO League I have met more people who work in science', the results show that 56% pupils (n=15) strongly agreed and 33% (n=9) agreed. 11% pupils (n=3) indicated that they disagreed with the statement.

5.4.3.14 STEM identity

As shown in table 5.46, all teachers felt that participating in the LEGO League had built STEM identity by challenging stereotypes about STEM careers, with 75% (n=9) strongly agreeing with the statement and 25% (n=3) agreeing.

Table 5.46 Level of agreement that participating in the LEGO League has built STEM identity by challenging stereotypes about STEM careers

Level of Agreement	Group							
	Teachers		Volunteers		Parents		Pupils	
	n	%	n	%	n	%	n	%
Strongly Disagree	0	0	0	0	0	0	0	0
Disagree	0	0	2	9	0	0	1	4
Agree	3	25	10	45	6	60	7	26
Strongly Agree	9	75	7	32	4	40	19	70

When considering the statement ‘participating in the LEGO League has built STEM identity by challenging stereotypes about STEM careers’, 9% volunteers (n=2) disagreed, 45% (n=10) agreed and 32% (n=7) strongly agreed. Three volunteers indicated that they did not know.

The statement was phrased differently for parents and pupils, but still focused on the development of STEM identity. As shown in table 5.46, all parents felt that through participating in the LEGO League their child thought that science is for everyone regardless of background, with 40% (n=4) strongly agreeing with the statement and 60% (n=6) agreeing.

Overall, pupils were in strong agreement that they thought science was for everyone regardless of background, with 70% (n=19) strongly agreeing with the statement. A further 26% (n=7) agreed, whilst 4 5 (n=1) disagreed.

5.4.3.15 Further Items for Pupils

Two items in the questionnaires were only presented to pupils. The responses are shown in tables 5.47 and 5.48.

Table 5.47 Level of agreement of pupils with the statement ‘through me participating in the LEGO League my parents have explained to me that science is useful for my future‘

Level of Agreement	**Pupils**	
	n	**%**
Strongly Disagree	1	4
Disagree	0	0
Agree	19	73
Strongly Agree	6	23

When asked to consider the statement ‘through me participating in the LEGO League my parents have explained to me that science is useful for my future‘, as shown in table 5.47, 96% pupils (n=25) indicated some level of agreement (73% agree and 23% strongly agree). 4% pupils (n=1) strongly disagreed with the statement.

Table 5.48 Level of agreement of pupils with the statement ‘through me participating in the LEGO League my teachers have explained to me that science is useful for my future‘

Level of Agreement	**Pupils**	
	n	**%**
Strongly Disagree	0	0
Disagree	0	0
Agree	7	27
Strongly Agree	19	73

When pupils were asked to consider if teachers, rather than parents, had explained to them that science is useful for their future, 27% (n=7) agreed and 73% (n=19) strongly agreed (shown in table 5.48).

5.4.3.16 Further Items for Parents

Two items in the questionnaires were designed to try capture any impact on parents from their child participating in the LEGO League. The results are shown in tables 5.49 and 5.50.

Table 5.49 Level of agreement of parents with the statement 'through my child participating in the LEGO League I think science is more interesting'

Level of Agreement	**Parents**	
	n	**%**
Strongly Disagree	0	0
Disagree	0	0
Agree	5	50
Strongly Agree	5	50

As shown in table 5.49, all parents (n=10) felt that they thought science was more interesting through their child participating in the LEGO League. This was split evenly – 50% agreeing and 50% strongly agreeing.

Generating the strongest level of agreement from parents from all items in section 5.4.3, as shown in table 5.50, 80% parents (n=8) strongly agreed with the statement 'through my child participating in the LEGO League I think that science is useful for my child's future'. A further 20% parents (n=2) agreed.

Table 5.50 Level of agreement of parents with the statement 'through my child participating in the LEGO League I think that science is useful for my child's future'

Level of Agreement	Parents	
	n	%
Strongly Disagree	0	0
Disagree	0	0
Agree	2	20
Strongly Agree	8	80

5.5 Summary

This chapter presents the results from three individual studies comprising cycle 3 of the overarching action research methodology adopted within this Professional Doctorate project. An analysis of questionnaire data collected from undergraduate science students in relation to demographic characteristics, as well as factors that influenced the choice of their current science degree and the choice to continue studying science after their GCSEs contributes to an understanding of the key influences on their decision to study science at university. Such insights are valuable in informing practice around widening and increasing participation in undergraduate science programmes, such as outreach activities, whilst an analysis of questionnaire data from university staff sheds light on their perceptions of the purposes, evaluation and impacts of current outreach activities delivered to science students. The results of the final study show the perspectives of teachers, volunteers, and parents on STEM subjects in terms of social justice and the economic pipeline, as well as the perspectives of the same participants, plus children, on the impact of participation in a specific science outreach activity on children's science capital.

Whilst the individual studies sought to address specific research objectives, together they aimed to inform a critical analysis of approaches to increasing and widening participation in higher education science and the findings are examined further within the Discussion chapter, in light of current knowledge on the topic, with a view to evaluating the meaning, importance and relevance of these results.

Chapter 6: Discussion

6.1 Introduction

The aim of this study, as discussed in chapter 1, was to analyse critically approaches to increasing and widening participation in higher education science. In so doing, the research sought to specifically address the following objectives:

1. To frame my professional practice through a critical review of the literature.
2. To investigate the key influences on undergraduate students in their choice to study science at university.
3. To investigate the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students.
4. To investigate the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital.
5. To contribute to professional practice and knowledge around increasing and widening participation in higher education science.

My professional identity was considered in chapter 2 and chapter 3 presented a critical review of the literature. Chapter 4 presented and justified the research design process adopted in this study. This chapter is a discussion of the results, presented in chapter 5, from three individual studies, which investigated 1. the key factors influencing the choice of first year undergraduate students to study science at university, 2. the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students and 3. the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific outreach activity on children's science capital. These findings, addressing objectives 2-4, are considered in light of academic and professional literature and informed by the conceptual model of science capital presented in chapter 3. Thus, the analysis explores the factors leading a student to study higher education science and practices around increasing and widening participation in higher education science.

6.2 Student Study

To understand why young people do or do not progress into post-compulsory science the development of students' attitudes, behaviours and aspirations towards science are often related to interest and persistence in science education (Wang and Degol, 2013; van den Hurk, Meelissen and van Langen, 2019). An understanding of the factors that influence interest and persistence in science education can inform routes to increase and widen participation in science subjects. Data were collected from new starters on undergraduate science degrees at the university through a questionnaire with the objective of investigating the key influences in their choice to study science at university. This was done to provide insights to inform practice around increasing participation in undergraduate science programmes, which, as highlighted in chapters 1 and 3, is a key concern in the current higher education context.

The results, presented in section 5.2, are discussed here. These cover the demographic characteristics of undergraduate students currently studying science at the university, the factors influencing their choice of current science degree, factors influencing the choice to study science after GCSEs and influences on their engagement with science pre-GCSEs.

It is important to note that, in seeking to investigate influences in students' choices around studying science, participants were asked to make judgements about earlier stages in their lives and, as such, the potential exists for their recollections to be reworked in their minds. Asking participants to recall past attitudes and behaviours can lead to validity and reliability issues (Schwarz and Oyserman 2001; Schwarz 2007). The factors have been considered in reverse chronological order (current degree - post-GCSE - pre-GCSE), reflecting declining confidence in the accuracy of recollections. This consideration and a relevant literature base (see chapter 3) were used to inform the interpretation of the findings.

The specific research objective was:

- To investigate the key influences on undergraduate students in their choice to study science at university.

6.2.1 Demographic Characteristics

To understand how student enrolments on science courses at the university are patterned by demographic characteristics, the data were analysed in relation to the social identities of gender, age, ethnicity, and parental education (as a measure of socioeconomic status). Whilst the context-specific nature of the research, conducted at a single institution at a single point in time, limits the extent to which the results are generalisable to other settings and other points in time, they do however permit description of the demographic characteristics of the specific group, comparison with levels of participation reported in the literature and consideration of how the social identities may influence progression to higher education science. Tables of the demographic characteristics of undergraduate students currently studying a science degree at the university are presented in section 5.2.2.

Proportionally more female than male students completed the questionnaire (65% and 35% respectively overall). Biomedical science (82% female) and zoology (70% female) stand out in terms of their gender balance. Whilst these figures represent the proportions of students completing the questionnaire, rather than actual proportions within the population of science students at the university, they are a reasonable estimation given the response rate of 89%. These figures are in stark contrast to some figures that are reported around the participation of females in post-compulsory science education (e.g. only 20% of students taking Physics A-level are female (Women's Engineering Society 2017)). However, it is commonly accepted that gendered levels of participation in science are more nuanced. Fewer females tend to participate in science subjects associated with technology and engineering courses, whereas those science subjects that emphasise the application or social context, or present opportunities to give back, attract more (Martin Fisher-Ari, 2021; Rosenthal, 2021). Never-the-less, when considered also at a more nuanced level of biological sciences, the results of this study differ from the findings of Yang and Barth (2015), who reported equal representation of women and men. Taking science participation to be mediated by identity (L. Archer, Dewitt and Willis, 2014), the findings suggest that a science career was "thinkable" for females in the group, despite science being often perceived as a masculine pursuit (Tenenbaum and Leaper, 2003; Smith, 2011; Cheryan *et al.*, 2017; Martin Fisher-Ari, 2021). Understanding the factors that influenced their educational decision-making that led to the study of degree-level science provides insights into how to engage more women in higher education science more generally. As a future development, understanding more fully how the science courses at this university are perceived by female students could further inform marketing messages for the specific courses at the university.

The findings also show that the majority (71%) of respondents were standard age (i.e. 17-20 years old). A significant percentage however were non-standard age (i.e., ‘mature students’) (n = 20, 29%). Such students are often characterised as ‘career changers’ and/or ‘returners to H.E’ and are targeted through different marketing approaches to standard age entrants.

The majority of respondents identified as ‘White’ (n= 57, 84%), with 12% (n = 8) identifying as ‘Asian or Asian British’. 4% (n = 3) identified as ‘mixed. No respondents indicated their ethnicity as ‘Black or Black British’ or ‘Other’. The ethnic backgrounds of the questionnaire respondents reflect the findings of Jones and Elias (2005) and Elias, Jones and McWhinnie (2006) who found low levels of representation in science undergraduate degrees from British students with Pakistani, Bangladeshi, Black Caribbean and Black African backgrounds. As diversity has an important influence in relation to identity and a young person’s sense of belonging (Neves and Hewitt, 2021; Neves and Hewitt, 2022; Vytniorgu, 2022)), an absence of diversity could be seen as a barrier to participation in higher education. With Black and Asian students reporting a diverse student population to be more important than White students for fostering their sense of belonging, the current ethnicity pattern may limit the impact of future initiatives to increase and widen participation, without conscious efforts to bring people with different backgrounds together. Given the small number of participants in this study, however, the results have limited value in illuminating the factors that support the science identities of young people from ethnic minority backgrounds and hence how to bring greater diversity to higher education science. Through a Bourdieusian lens, more needs to be done to understand the systematic barriers that hinder participation or, in the language of Asai (2020), why young people from ethnic minority backgrounds are excluded from higher education science.

The findings of several studies show a correlation between parents’ socioeconomic status and a child’s choice of AS/A level subjects (e.g., Robertson, 2000). Similarly, Vignoles and Murray (2016) show that participation in higher education varies dramatically according to family background. The children of the more advantaged social classes have been shown to be oriented towards science and more academic subjects (Gorard and See, 2009). This suggests that, in a sample of students studying only science degrees, the proportions would be skewed towards the higher social classes. Similarly, in this study, where parental education was used as a measure of socioeconomic status, it could be expected that higher proportions will have parents who have attended university. In fact, the majority (56%) of students indicated that their mother or father had never attended university. This finding does not align with some sections of the literature which suggest that a greater proportion would have at least one, if not both, parents who have attended university. It must however be considered in the wider context of social mobility. When English universities are ranked on their contribution to social mobility, the least selective post-1992 universities come out on top, enrolling the majority of low socioeconomic status students who attend university (The Sutton Trust, 2021). Falling into the bracket of a less selective post-1992 university, it is not unexpected that a high proportion of students at this institution would indicate their mother or father had never attended university. The proportion may have been much lower at a highly selective university (Boliver, 2015; Kandiko Howson, Cohen and Viola, 2022). Never-the-less, resonating with my personal values, supporting people from less advantaged backgrounds to study science at university matters from a social justice perspective, as such people are much less likely to progress to higher education in the first place (Britton, Drayton and van der Erve, 2021). As the social and economic contexts in which young people live and learn are determinants of educational disadvantage (Kvieskienė *et al.*, 2021), some of these people will probably have overcome significant obstacles to progress to higher education. These may have been a lack of financial resources that impeded access to enrichment activities or a lack of opportunities to learn dispositions to fit the university context (Crozier *et al.,* 2008; Spengen, 2013). In successfully overcoming the obstacles, understanding the factors that led participants to study science at university provides insights into ways to engage more people from less advantaged backgrounds in higher education science.

After considering gender, age, ethnicity and socioeconomic status separately, it is important to remember that identity is multifaceted and that social identities will intersect to uniquely shape an individual's educational decision-making (Johnson, 2011; L. Archer, Dewitt and Willis, 2014) and therefore their engagement with higher education science.

6.2.2 Factors Influencing Choice of Current Science Degree

6.2.2.1 People Factors

The conclusions of Aschbacher, Li and Roth (2010, p.578) support the view that young people who receive robust support for science from several sources are "more likely to consolidate their science identities and persist in their S(T)EM aspirations … than students with less breadth and depth of support". These sources could include parents, siblings, teachers and friends. In considering sources of advice and information about AS/A level choices, Rodeiro (2007) found that parents were the most sought source of advice, followed by other family members, such as brothers and sisters. In the study teachers were also a very influential source of advice. Butt *et al.* (2010) showed a significant influence of parents on young people's willingness to engage in science education, echoed by Buzzanell, Berkelaar and Kisselburgh (2011) who found parents were a major influence on the perception of work and career,

Given these findings of previous studies, although section B of this questionnaire considered the choice of degree rather than AS/A levels, it is logical to expect that parents, siblings and teachers would be highly influential. Whilst some individual participants reported these factors as having a strong or major influence on their choice to study science at university (parents 38%, friends 25%, teachers 29%), the data show overall that participants did not indicate a significant influence of people factors on their choice to study science at university. The median values show all the people factors as only having some or no influence.

These findings may reflect an intersection of ethnicity and socioeconomic status. Responses around demographic characteristics indicated the majority of participants were White and with low socioeconomic status. The work of Wheeler (2018) showed that parents of low socioeconomic status were less likely to push their children towards higher education and Spera, Wentzel and Matto (2009) showed that, at similarly low levels of parental education, White parents had significantly lower aspirations for their children's educational attainment than did parents of other ethnicities. Whilst students may simply have not acknowledged any advice or guidance towards a science degree, the low influence of parents on students' choice to study science at university may be indicative of lower parental aspirations. With parental aspirations playing a critical role in shaping the aspirations of young people in the field of STEM (Chen *et al.,* 2022) and family habitus providing a powerful structuring context (L. Archer *et al.*, 2012; Kewalramani, Phillipson and Belford, 2022), in choosing to study higher education science without significant influence from parents, siblings and teachers, the results suggest a level of agency.

The percentage figure for major or strong influence for one people factor is notable however – having a good science teacher (47%). 'Having a good science teacher' stands out because it introduces questions around whether science outreach should target teachers. This approach may increase participation of young people into science, but it does not fit neatly with a marketing perspective, relying on the development of relationships and soft knowledge, and with inherent difficulties in measuring impact. Several studies (e.g., Aslam, Adefila and Bagiya, 2018; Luehmann and Markowitz, 2007) suggest an association between the professional identity of science teachers and the influence of teachers on the development of young people's identities, suggesting that outreach practice that supports the science identity of teachers could impact on the science identity of students, and subsequently their participation in higher education science. Teachers' perspectives on STEM subjects will be an important consideration in the development of science identity and are discussed in section 6.4.1.

Also notable in the light of current practice is that the medians for speakers from universities and graduates from the university shows no influence.

6.2.2.2 Marketing Factors

Like people factors, whilst some individual participants reported the marketing factors (open day/careers events, websites and prospectuses) as having a strong or major influence, the data show overall that participants did not indicate a significant influence on their choice to study science at university. The median values show each of these marketing factors as having some influence. It is worthy of note however that, whilst the median for websites is 'some', 47% of participants did report this factor as having a strong influence on their choice. Participants will have had to navigate university admissions processes and consider admission requirements, so it was expected that website information would have been influential in their decision-making and this finding is surprisingly low. A great deal of time and effort goes into open days and talks from the university and so it is interesting to see that 43% participants perceive open days as having a strong influence and 21% participants perceived talks from the university as having a strong influence.

6.2.2.3 Employment Factors

The findings show that career opportunities were a strong influence on participants' choice to study science at university (38% reported a strong influence and 15% reported a major influence). Whilst the median value for high employability of graduates from this university shows 'some' influence overall, 37% of participants did indicate that the factor was a strong influence and 6% indicating a major influence. The employability of graduates at this university is promoted heavily, but also at most other universities and so it was anticipated that this would be drowned out in the noise of similar claims. Both good job prospects and personal employment opportunities whilst at university had some influence. The majority of participants (56%) indicated that the high level of pay within this field had no influence and this is reflected in the median for this factor.

These findings are congruent with those of Munisamy *et al.* (2014), who investigated the reasons for pursuing higher education. They found 'to get a good job' and 'next step in career path' as two of five reasons that stood out for being rated extremely important. The ability to find a job easily after the graduation was important in the research by Veloutsou, Lewis and Paton (2004). Several other studies, e.g., Osborne and Collins, 2000; Cleaves, 2005; Butt *et al*., 2010, have also highlighted how the value a science education to a young person's career options can positively influence engagement in the subject, and the National Foundation for Educational Research (NFER) (2011) found that the strongest influence on young people's engagement with science education was the benefits for future career pathways.

The findings of this study around employment factors, situated with similar findings in the literature, suggest that embedding an awareness of careers from science into outreach activities could have an influence on leading young people into higher education science. In so doing, this would respond to the call from Adamuti-Tranche and Andres (2008), as well as Lyons and Quinn (2010), for more to be done to make explicit the value of science qualifications for future employment.

With employment factors appearing to play a significant role in leading young people to higher education science, in the widening participation context, it is important to ensure that graduates, irrespective of their gender, ethnicity or social backgrounds, can benefit from higher education in their transition from their degree into employment. However, despite employability being a complex construct (Nazar and Van Der Heijden, 2012; Bargsted, 2017), the employability agenda within higher education is underpinned by the notion of a student as an enterprising and constantly strategising self (Smith, 2010; Heaney, 2015), and often simply reduces the concept to a set of knowledge and skills which translate into employment. In assuming equality between individuals, within the contemporary employability discourse little consideration is given to how opportunities for students are framed by socioeconomic background, ethnicity and gender (Moreau and Leathwood, 2006; Eyre, 2011; Rooney and Rawlinson, 2016; Hammond, 2017; Keaney, 2018). This is despite employment outcomes showing that those from Black, Asian and Mixed backgrounds and lower socioeconomic backgrounds are less likely to secure a highly skilled job after graduation (Office for Students, 2019). Other evidence also shows the existence of barriers for young people from less privileged backgrounds in entering the elite professions (Ashley *et al*., 2015), and for women and those from ethnic minority backgrounds in accessing highly skilled science jobs (Funk and Parker, 2018). A Bourdieusian perspective suggests that structural factors may inhibit an individual's ability to develop the necessary economic, social and cultural capital, thus placing them at a disadvantage in the job market and limiting the opportunities available to them. If concerns around disparities in science participation are to be addressed, then the interplay of social identities with the labour market must be considered. In addition to seeking ways to engage more young people from more diverse backgrounds in higher education science, it should be incumbent on universities to support disadvantaged students in overcoming the barriers that hinder their transition into the workplace.

6.2.2.4 University Factors

In the same research by Munisamy *et al.* (2014) the reputation of the university and the reputation of the programme were two further reasons that stood out for being rated extremely important. Similarly, Veloutsou, Lewis and Paton (2004) found, when choosing a university, students identified the department's reputation and the university's reputation as key factors. The department's reputation was perceived by the participants as more important than the university's reputation.

In this study it was felt that students would identify with their programme rather than the department, but otherwise the ranking of these two university factors is reflected in the results of this study. 50% participants identified the reputation of the programme as having a strong or major influence on their choice to study science at the university and 43% identified the reputation of the university. It is worth noting that, when median values are considered, the good reputation of the degree programme shows as a strong influence, whereas the good reputation of the university had only some influence.

Other factors that had a strong influence were good university facilities, university staff research interests, the university has good links with industry and sector and the university offers the programme I am interested in. The final factor is not as obvious as it might seem, as anecdotal evidence suggests school sixth form students choose a university based on the availability of a particular degree programme whereas college students choose the course based on availability at the preferred university.

The university has a good level of control on presenting facilities, research interests and links with industry. The question these results generate for practice is how to grow the reputation of both the programmes and the university. Reputation is often linked to ranking in major league tables, but as a factor this was shown to have no influence in participants' choice to study science at the university. From where, therefore, do students gain their perception of the university's and programme's reputation? Considering how people make sense of information and the trust placed in different types of information may suggest ways to influence the perceived reputations, thus potentially increasing the effectiveness of science outreach and participation levels (Fischhoff and Scheufele, 2013; Varner, 2014). In considering information, Ball and Vincent (1998) make a distinction between 'cold knowledge' and 'hot knowledge'. They describe cold knowledge as "official knowledge that is normally constructed specifically for public dissemination" (Ball and Vincent, 1998, p.380); materials produced by an institution, such as websites, prospectuses and newsletters. Information provided by a university ('cold knowledge') is often distrusted and, as discussed above, it is notable that these factors did not have a significant influence on participants' choice to study science at university. Alternatively, hot knowledge is knowledge based on direct experience and personal recommendation, embedded within social networks, which is more trusted and valued in making decisions about educational pathways (Slack *et al.,* 2014). Nurturing such networks could potentially improve the effectiveness of science outreach and increase participation in science, but it must be recognised that, because 'hot knowledge' is rooted in social networks, there will be an unequal distribution across socioeconomic groups. Overlapping with Bourdieusian notion of 'social capital', those students with more extensive social networks have an advantage in their educational decision-making and these differences need to be considered from a widening participation perspective.

The findings show that the reputation of the programme and university are important to recruiting students to science courses, but the link to the employability of graduates also should not be overlooked. The exchange value of employability skills, and degree certificate itself, is socially constructed (Gracia, 2009). The perceived reputation of the university from which an individual graduates influences how employers value a graduate's skills and knowledge.

Before conducting the study, I felt that both the cost of studying at this university and the student: staff ratio would have a strong influence on participants' choice to study science at the university. The results in fact show that both had only some influence.

6.2.2.5 Locality Factors

In considering locality factors, the local infrastructure had some influence, whereas the local social life and being close to home had no influence.

6.2.2.6 Key Findings on Factors Influencing Choice of Current Science Degree

The results show the following factors are the most important in participants' choice to study science at university – university offers the programme I am interested in, university has good links with industry and sector, career opportunities, good university facilities, university staff research interests, good reputation of the degree programme. It could be argued therefore that, to increase participation in H.E science, these should form the core basis of marketing messages and be incorporated into outreach activities where the key purpose is the recruitment of students.

Being ranked second, 'the university has good links with industry and sector' is an important influence. It can be considered also alongside 'good job prospects', where 37% participants indicated a strong or major influence. This suggests employability is a key influence and justifies heavy promotion in marketing.

These factors may be useful in influencing decisions to study science at a particular institution, but do not shed much light on young people's choice to study post-compulsory science after GCSEs. The following section of the questionnaire gave more insight.

6.2.3 Factors Influencing the Choice to Study Science after GCSEs

Several studies in the literature have investigated the factors influencing the choice to study post-compulsory science (e.g. Stables and Wikeley (1997), Carnasciali and Thompson (2013), Rodeiro (2007) and DeWitt, Archer and Moote (2019)) and, similarly, section C of the student questionnaire asked participants to consider the factors influencing their choice to study science after GCSEs. Whereas previous studies have investigated similar factors, they are not always agreed on the relative weightings of these influences. Rodeiro (2007), for example, reports that 'I thought it would be an interesting subject' was the most popular choice whereas DeWitt, Archer and Moote (2019) found 'how useful the subject is for my future job or career' was the most popular choice. In this study, both these factors had a strong influence on the choice of participants to study science after GCSEs, along with three others. The five factors where medians showed a strong influence were:

- I thought science was interesting.
- I thought science would be useful for my future career.
- I found science exciting.
- I thought this was a good subject to have.
- I enjoyed learning science.

In line with DeWitt, Archer and Moote (2019), the expectation was that 'I thought science would be useful for my future career' would be the most popular choice. Whilst 73% participants indicated that this factor was a major or strong influence, it was not the most popular. The most popular was in fact 'I thought science was interesting', with 87% participants indicating a major or strong influence. The facto***r*** 'I enjoyed learning science' was also shown to have a strong influence (79% participants indicating a major or strong influence). Surprisingly, 'I found science exciting' was also a very popular choice, with 78% participants indicating a major or strong influence. This was the least popular reason in Rodeiro's study.

In line with expectations, future employment considerations, enjoyment and usefulness dominate the responses. It is interesting to note however that those factors that could be considered within the affective domain (enjoyed learning science, found science interesting/exciting) rank more highly than the more rational/strategic factors (I thought science would be a good subject to have/would be useful for my future career). Whilst the strategic factors link with the employability factors in section B of the questionnaire, the findings suggest that presenting science as interesting, exciting and enjoyable could have an impact on increasing and widening participation in science. As Ballantyne and Packer (2005) suggest, emotion is a strong motivational force that promotes learning, positive changes in attitudes and values, and engagement. They caution however that the duration of the impact of emotional engagement is unclear and, similarly, Adelman, Falk and James (2000) warn that enthusiasm wanes without reinforcement after an informal science intervention, whereas factual knowledge may persist, highlighting the need to cater to both areas in any outreach activity.

At the opposite end of the scale, 'I was advised to take science' is notable as the only factor where the median value shows no influence (only 12% participants indicated this was a major or strong influence). The lack of agency inherent in the statement may be a reason. This finding does counteract an argument for working with teachers.

Participants were also asked 'by what age had you decided that you wanted to continue studying or working in science after school?'. Buzzanell, Berkelaar and Kisselburgh (2011) argue that by the age of 10 many children have made preliminary decisions about their career track. Other evidence points to interests in science not being solidified until age 14 (Ormerod & Duckworth, 1976; Tai, et al., 2006). Tai et al.

(2006) suggest the critical period to influence career aspirations is 10-14 years old. On this evidence it was expected that most participants would report an age less than 14. In fact, the mean age that participants decided they wanted to continue studying or working in science after school was 17.4 years. This figure is older than expected and the literature suggests. The finding suggests that outreach activities targeting 16–18-year-olds will have potential to influence participation in science after school. Ages given ranged from 10 to 29 years old.

A further question asked participants by what age they had decided that they wanted to study specifically for a degree in science. Because this decision will be influenced more by the marketing approaches of universities, it was expected that the age would be later than the previous question, which was indeed the case. The mean age given was 18.5 years. This figure did range however from 9 years old to 35 years old.

6.2.4 Pre-GCSEs or Equivalent

The items considered in section D were drawn from measures that underpin the concept of science capital. As explored in section 3.10, science capital is a refinement of Bourdieusian notions of capital to explain how a young person's existing resources, specifically related to science, can support engagement and participation in science (L. Archer *et al.,* 2015). Children with more science capital have been shown to be more likely to want to pursue science in post-compulsory education or as a career. Given the participants in this study have chosen to pursue science in post-compulsory education, by inference they can be considered to have higher levels of science capital and therefore it was expected that participants would either agree with the items or engage frequently in the activities.

In fact, four statements gave a median response of agree:

- I thought a science qualification can help you get many types of job (86% participants agreed or strongly agreed).
- I felt it was useful to know about science in my daily life (71% participants agreed or strongly agreed).
- I knew how to use scientific evidence to make an argument (66% participants agreed or strongly agreed).

- Teachers explained science is useful for my future (51% participants agreed or strongly agreed).

Equal proportions of participants agreed and disagreed with the statement ‘parents thought science is very interesting’.

The statements ‘parents explained to me that science is useful for my future’ and ‘teachers encouraged me to continue with science after GCSEs’ gave a median response of disagree.

It is worthy of note that the highest proportion of participants agreed or strongly agreed with the factor related to employability. Whilst the actual ranking is slightly different to the previous section, the perception that a science qualification can help get many types of job is a persistent theme. A clear understanding of the relevance of science to daily life is also important and resonates with the science capital approach to teaching (L. Archer *et al.*, 2016). Both factors present opportunities in the design of outreach sessions. The findings suggest that highlighting the relevance of science to everyday life and career opportunities may have some influence on participation in post-compulsory science. Interestingly, teachers and parents do not appear to have been an influence, except in teachers explaining that science is useful for future careers. This infers students then used the information to make an individual decision, displaying agency in their choice of educational pathway. However, whilst not explicitly recognised by participants, as explained in section 3.8.1, the role of parents and teachers in influencing thinking and behaviour through the unconscious construction of habitus should not be overlooked.

Surprising from a science capital perspective, only 38% students indicated they knew someone who worked in science. Family member was the most frequent response.

Similarly surprising from a science capital perspective is the frequency of engagement in activities. 65% students had never attended a lunchtime or afterschool science club (median = never). Visiting a zoo or aquarium was the most frequent activity, which, given the breakdown of subject disciplines in the sample, is not unsurprising, but it is surprising that even this activity was not frequent with the median showing only at least once a year. Most students had visited a science centre, museum or planetarium less than once a year, which does not align with the idea of science capital.

The results show that the majority of students read books and magazines ‘sometimes’, but there was a relatively even distribution across all frequencies and therefore the findings do not shed much light on the importance of reading books about science as an influence in choosing to study post-compulsory science. Similarly, there was a relatively equal spread across all categories in terms of the frequency of talking about science with other people when not in school. The median shows ‘once a month’, but the value of this finding is questionable. The participants were being asked to make a judgement about not particularly memorable activities that took place several years in the past, which may undermine the value of these findings.

The results show that, pre-GCSE, participants talked about science mostly with their friends. This supports the importance of peer groups, as found by Millar *et al*. (2019), in establishing social bonds that influence how a young person relates to science. Outreach activities that create opportunities to discuss science with friends may support the development of science identity. Despite this, results from section A showed that friends were not a key influence on decision to study science at university.

6.3 Staff Study

There is a wide range of initiatives designed to influence students’ aspirations, expectations, skills and knowledge of both higher education and science subjects (CECATS, 2017), with the aims of sparking an interest in science, sustaining an interest in science and ultimately converting interest into increased participation in post-compulsory science education (Cridge and Cridge, 2015) Universities are key stakeholders in this endeavour and through university-led STEM outreach are important players in the efforts to increase and widen participation. Several studies (Fear *et al.,* 2001; Eilam *et al.,* 2016; Millar *et al.,* 2019; Sadler *et al.,* 2018) (see section 3.6.1) question whether university-led outreach is effective in meeting the goal of raising young people’s aspirations for science careers. To explore this further, academic and professional services staff at the university were investigated in relation to the following research question:

- How do academics and professional services staff perceive the purposes and impacts of outreach activities delivered to science students?

The specific research objective was:

- To investigate the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students.

The results, presented in section 5.3, are discussed here.

6.3.1 Perspectives on University-Led Science Outreach

The types and scales of science outreach activities offered by universities vary considerably (Eilam *et al.,* 2016; Sadler *et al*., 2018; Vennix, den Brok and Taconis, 2018). As Eilam *et al.* (2016) elaborate, outreach activities may include public lectures, teachers' professional development programmes, out-of-school enrichment activities, the direct teaching of students and attendance at science fairs, as well as many more.

With reference to section 3.3 within the literature, there are different rationales given for increasing and widening participation in STEM subjects. Forming a very important distinction, broadly speaking, some reports are focused on the supply of future STEM professionals required by the economy, whereas others are concerned with social justice. In positioning university-led science outreach, participants in this study strongly agreed that it has an important part to play in securing a pipeline of future scientists needed for the UK economy. In subscribing to the economic perspective, university-led science outreach could also be seen as contributing to the NEET agenda and reducing the likelihood of a young person becoming 'not in employment, education or training' (Morgan and Kirby, 2016). Although the strength of agreement was less (median value was agree/strongly agree), participants also felt that university-led science outreach has an important part to play in contributing towards social justice. It is assumed that participants recognised the value of university-led science outreach in supporting every individual to profit from the benefits that good levels of scientific literacy can bring based on fairness and according to need. This duality of perspectives may, as is often the case with contextualised admissions also, reflect a lack of clarity around the definition of 'widening participation'. In drawing on personal values to define and address the problem (Stevenson, Clegg, and Lefever, 2010), the design of outreach initiatives will be heavily influenced by the professional judgment of academics and professional services staff. Where it is assumed that students make higher education choices in an individualised and context-free manner, in line with prominent higher education policies (Baker, 2019), it is logical to assume that both increasing and widening participation in higher education science can be achieved through the same approach to science outreach, with little regard to structural constraints. A lack of clarity around the role suggests, despite the aims of national and institutional policy to address stratified patterns of participation in higher education science, university-led science outreach is compromised by the tension between social justice and opposing discourses of social reproduction.

6.3.2 Purposes of University-Led Science Outreach

When asked to describe the key purpose of the outreach activities to science students, it was expected that recruitment to university science courses would be the most common goal. This indeed appears as a common response, but alongside raising awareness and raising aspirations, which had been expected to be cited as a secondary purpose. Secondary purposes were in fact given as recruitment, marketing and developing knowledge, skills and confidence.

The findings of this study are congruent with those of Sadler *et al.* (2018), who found that most participants in their study described a key goal of university-led STEM outreach was to recruit future students to university and STEM careers, as well as Husher (2010, p.158) who found that the most common reason for conducting STEM outreach was to "encourage the pursuit of science studies and/or careers". Participants in the study by Sadler *et al.* (2018) also outlined another key goal of their outreach programmes as raising awareness and a passion for STEM, which aligns with the findings of this study.

Whilst Laursen *et al*. (2007) and Scull and Cuthill (2010) identified further goals of increasing the participation of under-represented groups, such as those from low socioeconomic backgrounds and females, in this study the goals of raising awareness and aspirations have been elevated to a higher level than expected from the literature. Widening participation is a key part of the university's identity, but in an increasingly marketised environment, where universities are defined primarily by their capacity to meet market criteria and there is a structural imperative to increase student numbers (see section 3.2), pressures exist that may relegate widening participation to a less prominent level. The perceptions of both academic and professional services staff suggest that in fact this is not the case, and both groups of staff recognise the importance of university-led outreach initiatives in supporting the progression of under-represented groups into higher education science. In citing ‘raising aspirations’, however, the finding suggests that outreach initiatives are based on a deficit model, predicated on becoming middle-class to succeed (Boliver, 2017). Such a model sees individuals with innate potential to succeed to be limited by low aspirations. It ignores that many young people from disadvantaged backgrounds aspire to study at university (Gorard, See, and Davies, 2011; Kintrea, St Clair, and Houston, 2011) and are hindered in their ability to realise their aspirations by structural barriers. That staff perceive a key purpose of university-led science outreach is ‘raising aspirations’ is understandable, given that dominant policy definitions frame aspiration in narrow economic terms, despite its complexity, but the finding does call into question the ability of university-led outreach to impact on the disparities seen in levels of participation in higher education science. As reported by Rainford (2021), it is hoped that practitioners eschew the deficit model of aspiration in favour of “helping individuals *realise* aspirations or raise their *expectations”* (Rainford, 2021; p.2).

It is interesting also that recruitment appears both as a key and secondary purpose. This raises the question as to whether the aim of activities could be more explicit, as this could reflect some confusion around the purpose of sessions, evident from section B of the questionnaire, where participants agreed that the goals of science outreach could be more clearly defined. Whilst this finding fits with that of Carleton-Hug and Hug (2010), who found that the majority of science outreach lacked an explicit definition of goals, and a goal in planning may be translated in different ways by practitioners, the lack of clearly defined goals never-the-less diminishes the effectiveness of outreach activities and hampers the assessment of how well an activity meets its intended purpose (Miranda and Herman, 2010; Varner, 2014).

6.3.3 Objectives of University-Led Science Outreach

When asked to outline the specific objectives of the outreach activities, it was expected that participants would have difficulty identifying these. Both Varner (2014) and Sadler *et al.* (2018) found little progression from the overarching purposes of university-led STEM outreach to specific objectives and view a lack of specific objectives as an inhibitor for evaluating the effectiveness of activities and impacts on student aspirations.

Although different in focus, both academic and professional services staff in this study did in fact identify concrete and measurable objectives. Responses from academic staff themed around the development of scientific literacy, such as developing scientific knowledge, skills and understanding, including confidence. Responses from professional services staff gave specific objectives around the development of H.E. literacy, such as knowledge and understanding of H.E., and again including confidence. These objectives could be seen to build the science capital of students and, as such, are aligned with the broader aims of supporting progression into post-compulsory science subjects. As Banerjee (2017, p.202) cautions though, evidence is needed that “engagement in these activities is manifested in terms of increasing or widening science participation”, as often there are discrepancies between objectives and outcomes (Reed-Rhoads, 2011; Bogue *et al.,* 2013; Banerjee, 2017), and the influence of agency and structural constraints should not be overlooked.

‘Engage students in fun activities’ was also cited as a specific objective. L. Archer *at al*. (2016) suggest that just because students find science fun they do not necessarily identify as a scientist. It is questionable therefore whether engaging students in fun activities is a worthwhile objective. The need to present science as interesting, enjoyable and exciting is not in question, particularly given the findings from the student study, but this could be viewed as a delivery mechanism for the achievement of other objectives, rather than an objective in itself. Alternatively, Rawlinson *et al.* (2021) do argue that having fun in a university setting can have a subtle impact of reducing barriers to access and moving towards a sense of belonging in higher education.

6.3.4 Evaluation of University-Led Science Outreach

To evaluate the effectiveness of activities in achieving the aims, immediate post-survey/evaluation sheet was the most frequent response. This finding is congruent with that of Husher (2010) who reported that the most common approach to evaluating science outreach was through survey tools distributed at the end of a programme. Other studies similarly show most evaluations of outreach activities limited to the use of short-term measures (DeGrazia *et al.,* 2001; Gall, Vollbrecht and Tobias*,* 2020; Lott, 2003; Luehmann and Markowitz, 2007; Mountain & Wells, 2002; Shanahan *et al*., 2011; Thomas, 2012). Immediate post-surveys/evaluation sheets are useful in measuring the level of enjoyment of a session or how interesting participants found the session and have therefore a value in informing the development and refinement of activities. In line with the findings of Sadler *et al.* (2018), it was expected that the evaluation would focus on student satisfaction and the quality of delivery, and therefore provide formative data for the development of outreach activities rather than attainment of goals. In fact, professional services staff indicated that evaluation is designed to assess impact on confidence, knowledge, understanding and application numbers, and is therefore more aligned to the achievement of objectives rather than session delivery. In evaluating the impact on application numbers, there is clearly some assessment of marketing objectives, similar to those of Husher (2010), even though respondents in this study do not perceive that outreach activities are heavily influenced by the needs of marketing.

Overall, respondents did feel that the objectives of science outreach activities and the outcomes measured in the evaluation are aligned, contrasting with the findings of Husher (2010) who reported a mismatch between objectives and the outcomes measured in the evaluation. This conviction however was not fully shared by academic staff who demonstrated some uncertainty about what the evaluation was designed to assess. As outreach is steered by professional services this suggests a need for greater communication around the purposes of evaluation and the findings themselves.

As Bottomley and Parry (2002) warn however, immediate post-surveys/evaluation sheets are unreliable in indicating long-term effects on attitudes of young people towards science or their intentions to progress to science degrees. Felix *et al.* (2004) also attribute a lack of understanding about the impacts of outreach activities on an emphasis on assessing short-term impacts and immediate post-surveys/evaluation sheets therefore should be viewed as having limited value in evaluating long-term impacts of outreach on participation levels in higher education science.

Within the literature, longitudinal evaluation of the long-term impacts of outreach on interest and progression is sparse. Some studies (e.g., Laursen et al., 2007 and Markowitz, 2004) have used post-participation surveys and interviews to report on long-term effects of outreach activity, and Bogue *et al.* (2013) has tracked the university course enrolments of outreach participants. Results from this study show that longitudinal surveys are used in practice, which will permit more robust evaluation of the effectiveness of outreach activities in supporting progression to higher education science. Van den Hurk, Meelissen and van Langen (2019) do provide a note of caution in that studies with an experimental design are needed to provide confidence that any effects are caused by an intervention. Whilst pre-, post- and longitudinal surveys have practical advantages, the absence of a control group inhibits causal inference.

In this vein, limitations of the data collection method were perceived as an issue associated with evaluation. As Sadler *et al.* (2018) suggest, it is difficult to measure aspiration and data that can be easily collected around the time of an event does not necessarily provide valuable insights into the broader conceptions of awareness and aspirations.

A range of perceptions were put forward in relation to the findings that arise from the evaluations. A clear majority focused however on the student experience. This matched expectations, but some respondents indicated evaluations show students are dissatisfied.

6.3.5 Impact and Effectiveness of University-Led Science Outreach

In relation to the perceived impacts of the outreach activities, informed by the findings of Sadler *et al.* (2018), it was expected that the outreach activities would be perceived as placing university science courses in a good light and as changing attitudes towards a university. The findings show that outreach activities are perceived as having a positive impact on recruitment. This is in line with expectations to a large degree but is in fact more specific and measurable. Caution was noted around tracking impact with longitudinal surveys, which is a relatively recent development and still in its infancy. Staff also perceived that outreach activities increased the knowledge of participants – of the university offer, but also H.E. options and science as a subject area.

Participants were asked which outreach activities they felt are most effective in increasing recruitment to the university. Only one specific outreach activity came through in the findings – summer universities. Otherwise, staff wrote in more general terms about activities that market the university and interactive ones. In highlighting interactivity, this could suggest a focus on delivery rather than the achievement of specific objectives. However, through experiencing science rather than being told about it, students will have more opportunity to develop knowledge and skills, therefore building science capital, which, in theory, will support progression in science subjects. The power of active engagement to enhance learning and generate enthusiasm should not be overlooked (Michael, 2006). Cooper, Dann and Harrison (2010) and MacLeish *et al.* (2012) have reported that hands-on activities led to the success of outreach activities, however, they did not explore the connection between the outreach activities and attitudes towards science subjects. Vennix, den Brok and Taconis (2018) however do argue that hands-on activities can contribute towards positive perceptions of outreach activities and in turn influence positive attitudes towards science subjects.

Interactivity again came through as a theme when participants were asked which outreach activities they felt are most effective in enhancing science literacy. This time however masterclasses were noted as a specific outreach activity. It is difficult to see why masterclasses are perceived as enhancing science literacy and not summer universities and, conversely, why summer universities are perceived as increasing recruitment to the university and not masterclasses. Summer universities take place over 3 days, whereas masterclasses are 1-2 hours in duration. Despite the much shorter duration, from my own professional experience, it is felt that masterclasses would be more effective than summer universities at increasing recruitment, as the format facilitates more effective engagement with more young people, particularly when the advertising around masterclasses, opportunities for lead generation and actual delivery are considered.

Given responses to previous questions, it was to be expected that masterclasses and summer universities were identified as outreach activities that participants feel are most effective in increasing participation in STEM subjects. ‘Active participation’ was mentioned, which is synonymous with ‘interactive’. Early and long-term interventions were also identified, which would allow building knowledge and skills, developing understanding, and removing barriers over the long-term to facilitate progression.

In relation to which outreach activities are most effective in widening participation in STEM subjects, those that target non-traditional learners were suggested. This reflects the current approach where certain activities are designated 'WP' (widening participation) and are designed and focused to increase progression from groups who do not traditionally enter H.E. e.g., white, working-class boys. This places the focus on individuals when systemic differences are needed. It is argued that the approach should be reframed from encouraging more working-class boys to take STEM subjects to removing barriers to subject choice for all.

6.3.6 Ways to Improve University-Led Science Outreach

In contrast with Ecklund *et al*. (2012, p.3), who found that less than half of those interviewed suggested meaningful ways to improve science outreach, and that science outreach was a "bleak prospect with limited room for improvement", several suggestions were put forward by both professional services and academic staff. These themed as:

- improved marketing
- targeted
- staffing support
- projects
- planned journey.

Improved marketing, staffing support and planned journey can be viewed from a management perspective. Within the literature there are few studies that specifically investigate the management of outreach programmes. Those that have done so report a paucity of management oversight. Beck *et al.* (2006) and Greany *et al.* (2014) found a lack of strategic planning across the university and Krasny (2005) reported limited communication around STEM outreach between different levels of university structure. Ecklund *at al.* (2012) also reported a lack of outreach programme infrastructure. The findings of this study show that participants feel that, from a university perspective, there is not a coherent overarching view of what science outreach activities should be doing. As the findings of Sadler *et al.* (2018) warn, the lack of institutional ownership can result in fragile and start-stop outreach.

Eilam *et al.* (2016) argue that a lack of strategic planning impacts the initiation and development of outreach activities, manifesting in many interventions being based on individual relationships. This is reflected in the findings of this study, where participants agreed that outreach activities are heavily influenced by their personal contacts.

Despite the perception of a lack of a coherent overarching view, participants in this study did feel that senior management value their work around outreach activities. This contrasts with the findings of Kim and Forther (2008) and Shanley and Lopez (2009) who reported a lack of encouragement at the institutional level, which acted as an impediment to staff involvement in the delivery of science outreach. Similarly, Ecklund *et al.* (2012) concluded that science outreach activities did not receive institutional support, with priority given to more academic pursuits, such as research. Senior management support is undoubtedly influential in developing effective science outreach, but it is important to avoid the findings of Sadler *et al.* (2018) who reported that support was given on the basis of 'conviction' that it was valuable rather than evidence. Critical senior management oversight is needed to strengthen evaluation and seek evidence of impact.

A planned journey could come from the perspective of sustained intervention, as well as projects. A targeted approach would lead to effective use of resources.

Surprisingly, despite the complexities described by the literature and the free-text responses of respondents around the definition of explicit goals (and the recognition by participants that outreach goals could be more clearly defined), the translation of goals into specific objectives and the limitations of evaluation methods impeding effective evaluation of science outreach, there were no suggestions of improvements around these areas. Participants in this study reported confidence that the activities are successful in achieving their goals. They agreed that the activities change students' attitudes positively towards the university, change students' attitudes positively towards science, are effective in raising student aspirations, are effective in raising awareness of university science provision and are effective in recruiting students to the university. There was also agreement that the specific goal of raising student aspirations for science careers is being met by university-led outreach. Mindful of the claim of Bogue *et al.* (2013), that few STEM outreach programmes offer robust evaluations of their effectiveness, beyond anecdotal claims, further exploration is needed around the basis of these perceptions and whether there is evidence to support the perceptions. Whether these perceptions are supported by evidence is not clear from this study.

Participants in the study did not agree that outreach activities are heavily influenced by either a personal interest or by the employability agenda. They did feel however that outreach activities are heavily influenced by the needs of the school curriculum. Eilam *et al.* (2016) reported universities, in the context of science outreach, being influenced by school needs, but in so doing, highlighted that the needs of students may be compromised. Young people in several studies have explained their disengagement from science by the lack of relevance and applicability of the curriculum (Osborne and Collins, 2000; Williams *et al*., 2003; Cleaves, 2005; Barmby, Kind and Jones, 2008; Springate *et al*., 2008). Reeds-Rhoads (2011) and Bogue *et al*. (2013) caution that designing outreach activities to meet the curriculum needs of schools may create a gap between the overarching purpose of outreach activities and what is being achieved in practice, thus limiting impacts on widening participation. Bell (2009) also concurs that the effectiveness of outreach can be limited by designing activities to meet school needs. Explicit consideration should be given to the design of outreach activities to ensure their relevance to young people from all backgrounds.

Participants in the study by Sadler *et al.* (2018) raised concerns that, in targeting older secondary school students, the outreach activities were too late to achieve the goal of increasing recruitment to and participation in H.E. science courses. They reflected that students had already established which degree subjects they wished to pursue. Participants in this study felt that the outreach activities are targeted at the correct age group to raise awareness of science provision at the university. Findings from the student study, discussed in section 6.2, validate these perceptions and thus suggest there is little scope in adjusting the target age to improve recruitment to university science courses. However, participants felt that the outreach activities are targeted at the correct age group also to raise aspirations and this finding contrasts with studies by Markowitz (2004), Husher (2010) and Miranda and Hermann (2010) that reveal students typically already had intentions to enrol on future science courses, Such preformed intentions present challenges for outreach where the aim is to raise aspirations and further consideration is needed regarding the target age for widening participation initiatives, alongside wider criticisms of the deficit model of ‘raising aspirations’.

6.4 Outreach Initiative Study

The perceptions of children, teachers, parents and volunteers were sought on the impact of participation in a specific science outreach activity – namely the FIRST® LEGO® League - on children's science capital. Anecdotally, teachers comment how the competition facilitates the development of a broad set of skills, impacting across the whole school curriculum, as well as being fun, exciting, and enthralling for pupils. The buy-in from a significant number of schools and a range of other organisations suggests the competition is meeting the aims of enthusing and engaging young people in science and technology. This is further supported by the findings from evaluations completed in previous years. This study explored beyond whether pupils find the FIRST® LEGO® League exciting and fun, to understanding the potential impacts on future engagement with science subjects.

The design of the challenge is commensurate with the dimensions of science capital (see section 3.) - to develop young people's scientific literacy/knowledge and understanding, but also promote the application of science in the real world and promote conversations about science with significant others in a young person's life. It was felt therefore that the concept of science capital would provide a robust framework for this research and the data would give an insight into whether this specific science outreach activity is a practical way of building young people's science capital and, as such, developing values, attitudes, expectations and behaviours in young people that promote attainment, engagement and participation in STEM education.

The study also solicited the perspectives of adult participants on STEM subjects in relation to the economic pipeline and social justice.

The specific research objectives was:

- To investigate the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital.

The results, presented in section 5.4, are discussed here.

6.4.1 Perspectives on STEM Subjects

The beliefs and behaviour of parents can both encourage and discourage the progression of young people into post-compulsory science (Kelly, 2016; Smith, 2007; Tenenbaum and Leaper, 2003). Similarly, teachers and the school climate can have a significant influence on attitudes to science (van den Hurk, Meelissen and van Langen, 2019; Butt *et al.,* 2010). Responses were sought from parents and teachers of the children participating in the outreach activity, as well as volunteers supporting the activity, to gain an understanding of their perspectives in relation to the economic pipeline and social justice.

In taking the results from teachers, volunteers and parents as a collective group, there was a high level of agreement from all adult participants that STEM subjects offer the potential to increase the life chances for young people. From all the teacher, volunteer and parent participants, 81% (n=35) strongly agreed with the statement and 16% (n=7) agreed. Only 2% (n=1) disagreed. In conducting an ANOVA test on data from teacher, volunteer and parent groups in relation to the statement 'STEM subjects offer the potential to increase the life opportunities for young people', the calculated F-value indicated that there is no significant difference between the groups. It is however notable that 100% teachers strongly agreed with this perspective.

As a collective group, the results from teachers, volunteers and parents show a high level of agreement that participation levels in STEM subjects matter in terms of social justice. From all the teacher, volunteer and parent participants, 91% (n=39) either strongly agreed or agreed with the statement. It is worth noting that the strength of agreement is less than the previous statement, with 49% strongly agreeing. 10% (n=4) either disagreed or strongly disagreed. This could potentially be due to the term 'social justice' being less recognizable than 'life chances'. Again, no significant difference was found between the responses of teachers, volunteers and parents in relation to STEM subjects matter in terms of social justice.

In seeking perspectives around the economic pipeline, parents, teachers and volunteers were questioned in relation to their level of agreement with the statement 'the UK urgently needs employees with STEM skills'. Only 4% (n=2) indicated a level of disagreement, with 95% (n=41) indicating a level of agreement. 60% (n=26) of adult participants in fact strongly agreed with the statement. Whilst the overall level of agreement is similar to 'increase the life chances of young people' (95% v 97%), a lower percentage strongly agree (60% v 81%). A significant difference was shown to exist between teachers and volunteers/parents, with 100% teachers strongly agreeing with the statement.

The statement ‘STEM represents this country’s economic future’ generated similar levels of agreement from teachers, volunteers and parents. A total of 95% (n=41) indicated that they either agreed (42%) or strongly agreed (53%) with the statement. Only two participants (4%) indicated a level of disagreement. Again, there was a significant difference between teachers and volunteers/parents, with 100% teachers strongly agreeing with the statement.

Recall section 3.3, where it was discussed that the motivation to increase and widen post-compulsory levels of STEM participation comes in different guises. The economic pipeline rationale is most prominent in the national policy discourse, where STEM industries are seen as critical to the future economic success of the country, but participation in STEM subjects is seen to matter also in terms of social justice as low levels of participation mean that individuals are excluded from the benefits that good levels of scientific literacy can bring (e.g., Osborne 2007; Osborne and Dillon 2010). In this study, the results show that teachers, parents and volunteers all subscribe to both perspectives. The value of STEM subjects in increasing the life chances of young people generated the highest level of agreement. For parents, it is easy to see why benefits to an individual child take higher priority than more abstract benefits to the wider economy. The difference between the perspectives of parents (and volunteers) and teachers could be argued reflects the prominence of the economic pipeline discourse in educational settings, driven by government policies. With teachers directed to link curriculum learning with careers and especially highlight the relevance of STEM subjects for a wide range of future career paths (Richmond and Regan, 2022), the development of STEM skills that are in high demand will assume a prominent position in school settings (Allen, 2014). The economic pipeline perspective however often solidifies current inequitable structures (Bullock, 2017), raising the concern that outreach activities grounded in this approach will do little to reduce the disparities in participation levels in higher education science. It is welcome then that teachers also identified the importance of the social justice perspective.

6.4.2 Perceptions on the Impact on the Dimensions of Science Capital

In response to the concern with participation rates in science, there is a wide range of outreach programmes that aim to both spark an interest within young people and sustain that interest in science. Often studies of outreach programmes have sought the perspectives of only a few stakeholders in the programme (Millar *et al.,* 2019). This study investigated the perspectives of school pupils, teachers, parents and volunteers in one science outreach programme with the aim of better understanding the impact on the dimensions of science capital and thus the development of science identity. In so doing, the study sought to explore whether the science outreach programme has the potential to influence young people's participation in post-compulsory science.

Questionnaires were distributed to 20 teachers and were completed by 12 teachers, giving a response rate of 60%. With volunteers there was a 100% response rate, with questionnaires administered to and completed by 22 participants. Questionnaires were completed by 10 parents and 27 pupils in total from schools where the teachers had indicated that the invite to participate in the research could be extended to their team and parents.

Focusing on pupil responses in the first instance, as these were at the centre of the investigation, 100% pupils either agreed or strongly agreed with the statement 'Through taking part in the LEGO® League, 'I think science is more enjoyable'. On one level this was not unanticipated, given previous evaluations and teacher testimonies. However, research shows that often young people who participate in science outreach activities have an established interest in science (Markowitz, 2004; Husher, 2010; Miranda and Hermann, 2010) and therefore one concern I held about the scheme was that the competition may only appeal to those already interested in science and technology (and so the benefits could be limited from a widening participation perspective, as the children would be likely to progress in STEM subjects anyway). Prior to data collection, I thought this may manifest in a small way in responses to 'think that science is more enjoyable'. The participants may already find science very enjoyable and therefore did not agree with 'more'. This is however not the case, with 100% children thinking that science is more enjoyable through participating in the scheme. So, whilst there is no robust evidence that pupils were not self-selecting, beyond anecdotal testimonies from teachers, the outreach activity has at least gone some way to increasing interest in science. Enjoyment of science was discovered to be a significant factor influencing the decision to study post-compulsory science across ethnic-minority students in the study by Springate *et al.* (2008), suggesting that this outreach activity, in making science more enjoyable, could potentially have a positive impact on widening participation.

Some studies, such as Barmby, Kind and Jones (2008) and Reiss (2004) point to young people entering secondary school in Year 7 with positive attitudes towards science and these attitudes declining in subsequent years, so, with participants of secondary age, the initiative may go some way to stemming this decline. In supporting pupils' affective experiences, it may allow a long-term engagement with science to grow (Millar *et al.,* 2019). However, there is considerable research that shows that young people are generally interested in science (e.g., L. Archer *et al.*, 2013; Butt *et al.*, 2010; Dewitt and Archer, 2015; NFER, 2011) and that this interest is not necessarily translated into post-compulsory science participation. As L. Archer *et al.* (2012) assert, although young people may enjoy 'doing' science, it does not mean that they want to 'be' a scientist.

Identity is included within the statement 'I think that science is for everyone regardless of background', where 96% agreed or strongly agreed, but, from the literature, most related to anticipated future engagement, participation and identity in science appear to be, in descending order:

- scientific literacy
- perceived transferability and utility of science
- family influences.

Considering scientific literacy, 96% of pupils felt they had developed a greater awareness of scientific ideas and 89% felt that they had developed scientific knowledge, skills and understanding. The fact that pupils had explicitly recognised these developments to this level was surprising, as prior to data collection, I was unsure whether they would have this awareness. A greater awareness of scientific ideas, and increased scientific knowledge, skills and understanding, are likely to lead to enhanced science self-efficacy, which is cited by Syed *et al*. (2019), as well as Chemers *et al*. (2011) as an important factor influencing young people's commitment to a science career. Whether ultimately leading to the study of higher education science or employment within a scientific field, it is important to remember that, as Hartmann (2013) argues, increased science literacy benefits individuals throughout their lives, allowing individuals, for example, to make more informed decisions about their health or critically evaluate proposed government policies. As such, increasing scientific literacy, the outreach activity is achieving a laudable aim from a social justice perspective.

In terms of the transferability and utility of science, 96% reported both that they had a greater understanding of how learning science could be useful for future career options and how a science qualification can help get many types of job. The statement in fact showed 74% of pupils strongly agreed, which could be interpreted as evidence of a substantial impact on a key dimension of science capital, given that several studies, such as Osborne and Collins (2000), Cleaves (2005) and Butt *et al*. (2010), have highlighted how the value of a science education to a young person's career options can positively influence engagement in the subject. The findings suggest that this outreach activity goes some way to answering the call from Adamuti-Tranche and Andres (2008), as well as Lyons and Quinn (2010), for more to be done to make explicit the value of science qualifications for future employment. By highlighting how science relates to a variety of careers, and raising awareness amongst pupils that science subjects would help them develop skills that are sought after by employers, this outreach activity has the potential to encourage more young people to progress to higher education science.

If family influences are considered, 93% pupils who participated in the study agreed or strongly agreed that they had talked more about science with siblings and parents – as well as friends, neighbours and others in their community. 89% also felt they had met more people who work in science, with some teams having interviewed leading figures in STEM industries as well as working alongside STEM Ambassadors. As the findings of the NFER (2011) highlight, this is important as a way of supporting young people in discovering the value of, science education, as well as developing a greater understanding of contemporary scientific topics and approaches to scientific investigation (Millar *et al.,* 2019). As Flicker (2003, p.307) claims, "most people have never and will never personally meet a scientist" and meeting more people who work in science provides support and opportunity for (scientific) community involvement, the development of 'science social capital' and fostering a sense of belonging (Herzig, 2004). In establishing connections with professionals, it will also allow young people to view scientists in more realistic ways, as opposed to the often-held stereotypical images (Woods-Townsend *et al*., 2016), thus consolidating their own science identity. In the local context, this is particularly pertinent to isolated areas of the region where some young people have limited opportunities to meet people that work in science-related roles. As Aschbacher, Li and Roth (2010, p.578) argue from their own study young people who receive robust support for science from several sources are "more likely to consolidate their science identities and persist in their S(T)EM aspirations … than students with less breadth and depth of support". These findings highlight the potential for this outreach activity to support young people in developing their social capital and encouraging them to talk about science more in everyday life, a key dimension of science capital.

These findings are strengthened when considered alongside parent responses in terms of how their own views towards science have changed through their child participating in the FIRST® LEGO® League. Generating the strongest level of agreement from parents from all items in section 5.3.2, 80% parents (n=8) strongly agreed with the statement 'through my child participating in the LEGO® League I think that science is useful for my child's future'. A further 20% parents (n=2) agreed. All parents (n=10) felt that they thought science was more interesting through their child participating in the FIRST® LEGO® League. Given that parents can have a major influence on how young people perceive careers (Buzzanell, Berkelaar and Kisselburgh, 2011) and parents' level of interest in science often overlaps with a young person's level of interest (Cleaves, 2005; Butt *et al.,* 2010), the findings suggest greater parental interest may foster young people's willingness to engage in science education. If parents place a higher value on science subjects through their child participating in the FIRST® LEGO® League, this may lead to the development of a more meaningful and shared engagement with science between a parent and child, thus lending support for their child's science identity.

The findings around science media consumption are interesting in relation to the literature. Often there is little cross-over between studying science at school and leisure activities. NFER (2011) found that young people did not frequently use television, the internet or newspapers to expand their scientific knowledge. In this study, 81% pupils agreed or strongly agreed that they had used television, websites or newspapers to find out about science 37% pupils indicated that they had not read books and magazines to find out about science – a finding similar to the survey work of L. Archer *et al*. (2012) that reported that over a third of young people never read a book or magazine about science (36.6%).

For teachers, parents and volunteers, whilst the questions were phrased in slightly different ways, there was general agreement in their perceptions around the impact on these key dimensions. Percentages for three statements are less for volunteers, which may be because not all respondents would have been involved throughout the whole initiative and may have been basing their responses on snap shots rather than the full journey. However, across all groups there was greater than 75% agreement that participation in the league had impacted positively on children's science capital. Particularly from teacher responses, where 100% teachers agreed or strongly agreed, the activity appears to have strengths in developing scientific literacy and encouraging pupils to speak with more people about science.

The findings show that pupils, teachers, parents and volunteers perceived that participation in the FIRST® LEGO® League had a positive impact on the key dimensions of children and young people's science capital. Scientific literacy, perceived transferability and utility of science, and family influences are of particular importance and each show greater than 89% agreement from pupils, teachers and parents. Whilst the study is limited by not capturing a measure of science capital before and after, the findings suggest that participation in the League has supported the development of values, attitudes, expectations and behaviours in young people that promote attainment, engagement and participation in STEM education. As such, it has some potential value as a practical way of beginning to address the disparities in participation levels in STEM subjects, increasing the life chances of young people and going some way to meeting the skills needs of the economy. In creating further opportunities to enhance teaching and learning through the provision of real-life contexts and illuminating direct lines through education to employment, the FIRST® LEGO® League can also be seen as a way of reducing the likelihood of a young person becoming NEET (Morgan and Kirby, 2016) and supporting more into employment.

6.5 Summary

Increasing and widening participation in higher education science is complex, however, through consideration of the results from three individual studies, investigating 1. the key factors influencing the choice of first year undergraduate students to study science at university, 2. the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students and 3. the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific outreach activity on children's science capital, this chapter has identified several important findings. These are summarised below.

6.5.1 Student Study

The most important factors influencing young people's choice to study science at university are:

1. the university offers the programme the young person is interested in
2. the university has good links with industry and the sector
3. career opportunities
4. good university facilities
5. university staff research interests
6. good reputation of the degree programme.

The results suggest that, to increase participation in H.E science, these factors should form the core basis of marketing messages and be incorporated into outreach activities where the key purpose is the recruitment of students.

Earlier in a young person's education, thinking that science would be useful for a future career and a good subject to have, as well as finding science interesting, exciting and enjoyable to learn were found to be key factors influencing choice to study post-compulsory science after GCSEs.

6.5.2 Staff Study

University-led science outreach has an Important part to play in securing a pipeline of future scientists and contributing towards social justice.

The primary goal of university-led science outreach is perceived as recruitment, raising awareness and raising aspirations, but could be more clearly defined and it is felt that there is not a coherent overarching view of what university-led science outreach should be doing.

University staff involved in science outreach support widening participation despite operating within a marketised environment, but a focus on raising aspirations suggests a deficit-based approach which could be reframed to a more asset-based approach.

University-led science outreach includes concrete and measurable objectives around scientific and higher education literacy and evaluation of impact is aligned to the achievement of these objectives.

Science outreach activities are effective in raising awareness of university science provision, however, there is less confidence, particularly from professional services staff, that activities are effective in raising student aspirations and recruitment to the university.

University-led science outreach is valued by senior management, who, through seeking more evidence of impact, could strengthen evaluation and increase the effectiveness of outreach activities.

Care should be taken around designing outreach activities to meet school curriculum needs.

University-led science outreach has the potential to feed into other agendas within higher education around research and employability, as well as increasing and widening participation.

6.5.3 Outreach Initiative Study

Science capital provides a conceptual framework for the design and evaluation of science outreach activities.

Participation in the FIRST® LEGO® League has a positive impact on the key dimensions of children and young people's science capital, most notably scientific literacy, perceived transferability and utility of science and family influences.

Through their child participating in the FIRST® LEGO®, parents thought science was more interesting and that science is useful for their children's future.

In chapter 7 these findings will be drawn together to address the contribution to professional practice and knowledge around increasing and widening participation in higher education science.

Chapter 7: Conclusions and Contribution

7.1 Introduction

Levels of participation in STEM (Science, Technology, Engineering and Mathematics) education are an international, national and regional concern (Smith and White, 2011; Australian Industry Group, 2013; Eilam *et al.,* 2016; Hoyle, 2016; U.S. Department of Education, 2016; CECATS, 2017; HM Government, 2017a; OECD, 2019; van den Hurk, Meelissen and van Langen, 2019). Increasing participation in STEM subjects is seen to matter in terms of economic development, reflected in a prominent national policy discourse concerned with securing a pipeline of future scientists and engineers, and where STEM industries are viewed as critical to the future economic success of the country. Widening participation in STEM subjects is considered important politically also in terms of social justice, with a post-compulsory STEM education viewed as benefiting individuals and more widely offering the potential to address social inequality. These agendas around widening participation and securing the pipeline of future scientists and engineers frame the wide range of initiatives designed to encourage more people from more diverse backgrounds to study post-compulsory STEM subjects, as well as framing my own professional practice.

In this context, this study aimed to analyse critically approaches to increasing and widening participation in higher education science. Specific research objectives were:

1. To frame my professional practice through a critical review of the literature.
2. To investigate the key influences on undergraduate students in their choice to study science at university.
3. To investigate the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students.
4. To investigate the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital.
5. To contribute to professional practice and knowledge around increasing and widening participation in higher education science.

This chapter presents an overview of the project and brings together the findings from this study. Addressing the final objective, the contribution to my community of practice (both in terms of professional practice and knowledge) is considered. The chapter then reflects on what I have gained from undertaking the professional doctorate process, as well as the research quality, before concluding by proposing areas for future research.

7.2 Overview of Research Project

Embarking on the professional doctorate programme was seen as a way of providing a framework for investigating issues that shaped my professional practice. However, working in a complex professional environment, a major challenge initially was distilling out the key issues for investigation to allow the development of a focused, meaningful and achievable study. Through a process of reflecting on my professional identity, presented in chapter 2, tensions around marketing, widening participation and employability agendas within my professional practice emerged. The reflective process also brought to the fore what drives me as a professional, what my values are and how these relate to these professional issues. These professional issues were contextualised within the contemporary discourses on this area through a critical review of the literature and subsequently narrowed to provide a critical analysis of approaches to increasing and widening participation in higher education science, thus limiting the scope of the study to consider a young person's journey up to the point of entering higher education (H.E.). (Findings around employability were excluded from the study but provide opportunities for future research and dissemination). The synthesis of key literature relevant to this study, presented in chapter 3, charts the transformation of universities as a public good to a private good, where studying for a degree is conceptualised as an investment in self and practices in H.E. are driven by market values. This is important because it highlights how a focus on instrumental economic goals blurs distinctions between increasing and widening participation and overlooks structural constraints, which theory suggests should be considered to understand the disparities in participation levels. The refinement of Bourdieusian notions of capital to the concept of science capital provided a framework for exploring further approaches to increasing and widening participation with a view to increasing the effectiveness of university-led science outreach and engaging more young people from more diverse backgrounds in higher education science.

The importance of a robust research design was recognised for enhancing the value of any findings and, as explored in chapter 4, the research was positioned in a paradigm of critical realism and adopted an action research methodology. The philosophical perspective of critical realism foregrounds the complex and continuous interaction between individual agency and social structure (Shipway, 2013; M. Archer *et al.*, 2016; Haigh *et al.*, 2019), aligning with my assumptions about the nature of reality and knowledge, and my value system. As a methodology for change and development, the project initially adopted a participatory action research approach to increase the likelihood of findings being used in practice. However, the duration of the project, changes in my job roles, other staffing changes and a rapidly changing background context (exacerbated by the Covid-19 pandemic) necessitated a shift to a more researcher-led approach to facilitate successful completion. Within the timeframe of the project, local practices have transformed, and, whilst it was fortunate that I was able to collect all data just before lockdowns were imposed, it must be recognised that data were collected prior to the pandemic, thus providing a snapshot at a specific moment in time.

This data collection was informed by the critical review of theoretical, empirical and professional literature presented in chapter 2 and comprised three individual studies with participants recruited from undergraduate science students, university staff involved in the delivery of science outreach and participants involved in a specific science outreach initiative. Generating both quantitative and qualitative data the results of these three studies are presented in chapter 5. An analysis of questionnaire data collected from undergraduate science students in relation to demographic characteristics, as well as factors that influenced the choice of their current science degree and the choice to continue studying science after their GCSEs contributes to an understanding of the key influences on their decision to study science at university. Such insights are valuable in informing practice around widening and increasing participation in undergraduate science programmes, such as outreach activities, whilst an analysis of questionnaire data from university staff sheds light on their perceptions of the purposes, evaluation and impacts of current outreach activities delivered to science students. The results of the final study show the perspectives of teachers, volunteers and parents on STEM subjects in terms of social justice and the economic pipeline, as well as the perspectives of the same participants, plus children, on the impact of participation in a specific science outreach activity on children's science capital.

The findings are examined further within chapter 6, in light of academic and professional literature and informed by the conceptual model of science capital, with a view to evaluating the meaning, importance and relevance of these results. The analysis reveals the most important factors influencing young people's choice to study science at university and to study post-compulsory science after GCSEs. An awareness of these factors is directly relevant to those designing marketing messages or outreach activities designed to increase or widen participation in higher education science. Exploring staff perceptions of the purpose and impact of science outreach reveals that university-led science outreach has an important part to play in securing a pipeline of future scientists and contributing towards social justice but a focus on raising aspirations suggests a deficit-based approach which could be reframed to a more asset-based approach. Another key finding is that the primary goal of university-led science outreach is perceived as recruitment, raising awareness and raising aspirations, but could be more clearly defined and it is felt that there is not a coherent overarching view of what university-led science outreach should be doing. University-led science outreach is perceived to have concrete and measurable objectives around scientific and higher education literacy, and evaluation of impact is aligned to the achievement of these objectives. These findings are important to informing practice around university-led science outreach. Analysis of the results from the outreach initiative study shows that participation in the FIRST® LEGO® League has a positive impact on the key dimensions of children and young people's science capital, most notably scientific literacy, perceived transferability and utility of science and family influences, which is important in informing future development of outreach initiatives.

The key findings form the project are considered further below in relation to specific objectives.

7.3 Summary of Findings

7.3.1 Objective 1

Universities are key stakeholders in addressing the concern around levels of participation in STEM education and as a university lecturer my professional practice and this study are framed by agendas of widening participation and marketisation within higher education. Section 3.2 highlights four key policy reforms that have been particularly influential in shaping higher education - namely, the Robbins Report (Committee on Higher Education, 1963), the Dearing Report (National Committee of Inquiry into Higher Education, 1997), the Browne Review Review (Department for Business, Innovation and Skills, 2010) and the most recent review chaired by Philip Augar (Post-18 Education and Funding Review Panel, 2019). Providing the background context for this study, these policy reforms have shaped decision-making in higher education in general and, in creating the current focus on its contribution to human capital and instrumental economic goals, are important for understanding the positioning of approaches to increasing and widening participation in higher education science.

The Dearing Report in particular has been a key influence on the development of my professional practice and identity. Following its publication, government policy was committed to expanding the number of students entering higher education and widening participation became a central focus of university practice. It has been a key focus of my roles throughout my career; since that period to the present. The Dearing Report also facilitated the government to introduce tuition fees and, in grounding proposals for a new funding regime in the philosophy that quality and efficiency could be most effectively achieved through market regulation, had a significant part to play in shifting the paradigm in higher education to students as consumers within a H.E. marketplace. Subsequent policy reforms have exacerbated the marketisation of higher education, creating a context where universities compete for resources and a structural imperative to increase student numbers. Operating in an increasingly competitive market has created tensions in delivering the widening participation agenda and the way the university positions itself in relation to widening participation has shifted over the years. Whilst widening participation remains a central focus of the university, the structural imperative to increase student numbers drives practice on the ground. When universities are defined primarily by their capacity to meet market criteria, university practice is necessarily skewed towards meeting those market criteria. So, whilst widening participation may be seen as a laudable aim at institutional-level, practice is in fact primarily aimed at increasing participation i.e., increasing student numbers. This manifests itself, for example, in a mismatch between objectives and outcomes, where the objectives may be explicit in their focus on widening participation, but the outcomes – or measures of success – include increasing the number of students on science courses at the university. It may also mean that some activities are focused on recruitment to science programmes, adopting a pure marketing approach to increase participation in higher education science, whereas others may be conceived as widening participation activities, but show little difference in terms of the design and delivery of the scientific content. Market-driven approaches undoubtedly have a part to play in increasing participation in higher education science, as well as lending themselves to evaluation through the production of easily digestible data, such as the number of students who attended and how much participants enjoyed the activities. Whilst evaluation methods have developed recently, at the start of the project the evaluation of all science outreach activities was limited to the use of 'happy sheets', where participants were asked to rate their enjoyment of a session or how interesting they found the session. It was felt that these data were useful in identifying whether marketing goals have been achieved but contributed little to understanding the effects on student aspirations, and therefore offered limited value in influencing practice around widening participation.

Motivated by social justice and a desire to see more equitable access to higher education science education (to widen participation), but mindful of the need of the university to increase student recruitment and the need in the wider economy to increase the number of graduates with STEM-related skills, this project has allowed me to explore the wider factors that influence young people's participation in post-compulsory science education with a view to contributing to professional practice and knowledge in this area.

The sociology of education has provided an avenue for developing a deeper understanding of the disparities in participation in post-compulsory STEM education and a conceptual framework within which to locate approaches to increasing and widening participation in higher education science. Whilst policy assumes that young people make H.E. decisions and choices in a decontextualized manner, sociological theories provide an explanation of how these are unequal and socially patterned due to structural factors, habitus and capital (e.g., Ball *et al.*, 2002; Ball, 2006; Reay, 1998; Reay, David and Ball, 2005; Reay, Crozier and Clayton, 2010). Such conceptual standpoints illuminate how, in a perspective of decision-making that focuses on economic instrumental goals, the reasons for disparities in participation are detached from the social structures that create and frame participation. In giving little consideration to structural factors impacting on individual lives, such as access to financial resources, social networks and cultural capital, current policy discourse promotes a deficit model, exemplified by approaches to widening participation around raising aspirations. In seeking to change the ideas and aspirations of individuals, who are conceptualized as rational and instrumental consumers, such deficit-based approaches can be criticised for not recognising that structural constraints can impede a young person’s available options. Drawing on Bourdieu’s theory of social reproduction, this study has been strongly influenced by the conceptual lens of capital and its refinement to science capital, permitting exploration of how young people construct their science identities, whilst acknowledging wider structural factors that impact on their life chances.

As noted by L. Archer *et al.* (2012), Bourdieusian theory has not been used extensively in science education and so the findings from this study advance the academic discourse in this area, whilst giving a new perspective to my own and wider professional practice at the university.

As described in section 3.10, conceptually, L. Archer *et al*. (2015) and DeWitt, Archer and Mau (2016) advance an argument that Bourdieusian notions of capital – which essentially is an art-based conceptualisation - can be further refined to understand patterns of aspiration and participation in science education. The concept of 'science capital' they propose captures a range of science-related resources and legitimises a wider range of scientific knowledge. Covering what science a young person knows, how they think about science (their attitudes and dispositions), who they know and what sort of everyday engagement they have with science, as detailed in L. Archer *et al.* (2016), the eight dimensions of science capital have been used in this study as a part-basis for investigating the factors influencing undergraduate students in their choice to study science at university and as a framework for investigating the impact of participation in a specific outreach activity.

7.3.2 Objective 2

A myriad of factors impacts on the processes that lead a student to commit to a career in STEM. University marketing and outreach programmes seek to influence the decision-making process. By exploring the factors influencing the participation of young people in higher education science subjects and exploring approaches to increasing the effectiveness of outreach activities, this research contributes to a more nuanced understanding of how practices could be made more effective in influencing young people to participate in higher education science and ultimately pursue a scientific career.

Given the structural imperative at the university to increase the number of students enrolled on undergraduate science courses, a research-informed approach was taken to understand the key influences on current undergraduate students in their choice to study science at university. Whilst the findings are context-specific and reflect the views of students where a high proportion had a mother and father who had never attended university, the findings do identify potential ways to increase recruitment onto higher education science courses. Through cautious extrapolation to other institutional contexts, the findings offer the potential to shape and influence the development of marketing, recruitment and outreach practices at this university and more widely.

At different stages of a young person's educational career, the results from this study showed that employment factors were the most important influence on decisions leading to the study of science at university. These findings are supported by those of Munisamy *et al.* (2014), Veloutsou, Lewis and Paton (2004), Osborne and Collins (2000), Cleaves (2005) and Butt *et al*. (2010), adding weight to the assertion that marketing, recruitment and outreach activities should embed an awareness of careers and highlight the exchange value of science qualifications, leading to the recommendation that:

- **Student recruitment activities should embed an awareness of careers and highlight the exchange value of science qualifications**.

Other important factors influencing young people's choice to study science at university were found to be the university offers the programme they are interested in, the university has good links with industry and sector, good university facilities, university staff research interests and good reputation of the degree programme, suggesting that, to increase participation in H.E science, these should form the core basis of marketing messages and be incorporated into outreach activities where the key purpose is the recruitment of students. Such findings are useful to practitioners (academic, outreach or marketing) in the design of such activities, both at this university and more widely.

Earlier in a young person's education, as well as thinking that science would be useful for a future career and a good subject to have, the results from this study show that finding science interesting, exciting and enjoyable to learn are key factors influencing choice to study post-compulsory science after GCSEs. Nurturing emotion as a strong motivational force (Ballantyne and Packer, 2005), the findings suggest that, to complement the strategic factors linked with employability factors, presenting science as interesting, exciting, and enjoyable could have an impact on increasing and widening participation in science. Whilst these findings may reinforce what many teachers and outreach practitioners assume already, the warning of Adelman, Falk and James (2000) that enthusiasm wanes without reinforcement after an informal science intervention should not be ignored, meaning outreach activities must do more than simply deliver science in a fun and interactive way.

7.3.3 Objective 3

As argued in the literature and reinforced by the perceptions of both academic and outreach practitioners in this study, university-led science outreach has an important part to play in securing a pipeline of future scientists and contributing towards social justice. As a step towards considering Fear *et al.*'s (2001) provocation that there is an essential need to re-examine university-led STEM outreach in terms of purposes and impacts, this study investigated the perceptions of staff at the university delivering outreach activities to science students. Evaluating the success of outreach initiatives, beyond short-term measures of the quality of delivery, is difficult without a clear view of their purpose (Sadler *et al*., 2018). In contributing to professional dialogue around which university-led science outreach activities should be delivered, why and to whom, the findings from this study offer potential for increasing the effectiveness of approaches to increasing and widening participation in higher education science.

Whilst academic and outreach practitioners perceived the purpose to be recruitment, raising awareness and raising aspirations, the results suggest that the primary goal could be more clearly defined, and the overarching view of university-led science outreach could be more coherent – or at least more explicit so staff are more aware of the view. Knowing this ambiguity exists is valuable for senior management, highlighting a need for greater clarity to be communicated around the purpose of science outreach activities.

Despite this ambiguity at an overarching level, university-led science outreach does include concrete and measurable objectives around scientific and H.E. literacy, and evaluation is aligned to the achievement of these objectives. This will aid evaluation of the success of outreach activities, but in terms of success, whilst it was felt that science outreach activities are effective in raising awareness of university science provision, there is less confidence that activities are effective in raising student aspirations and recruitment to the university. A clear alignment between aims, objectives and evaluation methods may increase the effectiveness. Senior management, who the findings show value science outreach at the university, would be well placed to effect this alignment, as well as strengthening evaluation through seeking evidence of impact.

As well as increasing and widening participation, participants in the study felt that university-led science outreach also has the potential to feed into other agendas within higher education around research and employability. With universities under increasing pressure to meet the expectations of all stakeholders, including students, parents, employers, government bodies and professional organisations (AdvanceH.E., 2020), the wider potential of science outreach activities could be exploited further to provide CV-enhancing experiences for students and research.

As expected, given the complex nature of increasing and widening participation in higher education science, whilst some tentative recommendations can be made to inform professional practice, the findings suggest that:

- **Further debate is needed around which university-led science outreach activities should be delivered, why and to whom.**

It is worth returning to the finding that one of the primary goals of science outreach was reported as raising aspirations. This deserves note because, as described earlier, this suggests a deficit-based approach. Despite operating within a marketised environment, the findings also show that university staff involved in science outreach support widening participation, offering the potential to reframe activities within a more asset-based approach.

Given the findings of Moote *et al.* (2021), with 17/18-year-old students, which showed a link between levels of science capital and intentions to progress to higher education science, as a conceptual framework science capital could provide a clarity of purpose to university-led outreach activities, making more explicit their role in fostering the engagement of young people with science subjects, as well as encouraging progression to higher level study and STEM careers in the future. As such it could permit university-led science outreach initiatives to move beyond short-term indicators of success, such on the day delivery, and toward the development of an overarching vision. The concept could also be pragmatised as a reflective framework for the design of outreach activities, targeting the development of science-related resources related to future participation and identity in science. Whilst the concept is grounded in a holistic approach, specifically targeting the following may give the greatest impact:

- scientific literacy
- perceived transferability and utility of science
- family influences.

It is recommended that:

- **Science capital should be used as a reflective framework for the design of science outreach activities.**

In so doing, the approach would go some way to meeting the assertion of Sadler *et al.* (2018, p.590) that "frameworks, and ways to discuss and categorise STEM outreach initiatives, as well as evaluation approaches, are needed". Although science capital is recommended as a reflective framework in the design of outreach activities, the value of the concept to evaluate the impact of outreach initiatives is less straightforward. The complex nature of the concept does not facilitate quick or easy measurement (L. Archer *et al.,* 2016), however, science capital did prove valuable as a framework for researching the perceived impacts of participation in a specific outreach activity, namely the FIRST® LEGO® League.

7.3.4 Objective 4

The number of teams in the region participating in the FIRST® LEGO® League was growing rapidly, with a related growing number of organisations acting in support, either through sponsorship or volunteering expertise. Anecdotal evidence and findings from evaluations completed in previous years suggested at some level the competition was meeting the aims of enthusing and engaging young people in science and technology. It was felt however that more robust research was needed to understand the impacts of participation in the FIRST® LEGO® League, particularly in the local context. The design of the challenge is commensurate with the dimensions of science capital, of which I had a deepening understanding, and so the concept was used as a framework to research the perceived impacts of participation in the league.

In demonstrating that participation in the FIRST® LEGO® League gives perceived gains in the dimensions of science capital, most notably scientific literacy, perceived transferability and utility of science and family influences, the results suggest there is a higher probability that a young person will progress into post-compulsory science education.

It is recommended that:

- **Supporting the FIRST® LEGO® League provides a practical way of encouraging more young people from more diverse backgrounds to study higher education science.**

7.4 Contribution

This doctoral project makes several distinct contributions to my community of practice, which is considered to be the academic community interested in the participation of young people in higher education science, outreach practitioners who can bring about change in practice around outreach and recruitment, and managers who can influence policy decisions (see section 4.4). A cycle of research contribution was included in the methodology, and whilst some of the planned opportunities for impact have been influenced by the Covid-19 pandemic, the findings were disseminated through written reports, verbal reports and presentations to internal and external stakeholders, as well as a wider audience. The planned impact journeys designed to influence practice are given in appendices 9.10-9.12. The distinct contributions this study makes to professional practice and knowledge around increasing and widening participation in higher education science, addressing the final objective, are summarised in table 7.1 and further considered below.

Table 7.1 Contributions to Community of Practice

Contribution to Academic Community	Extends the use of Bourdieusian theory in science education, specifically within the university setting.
	Provides a deeper understanding of the value of science capital as a conceptual lens for illuminating the influences that lead to students choosing science subjects or not.
	Offers empirical data on the key factors influencing the choice of a science degree.
	Addresses calls to consider the purpose and impact of science outreach activities.
Contribution to Managers	Outlines a model for reframing approaches to increasing and widening participation in higher education science.
Contribution to Outreach Practitioners	Demonstrates a practical way of encouraging more young people from more diverse backgrounds to study higher education science.
	Develops a more nuanced understanding of how student recruitment, marketing and widening participation activities could be made more effective.
	Develops a critical appreciation of the interplay between individual agency and social structure in relation to participation in H.E. science.

7.4.1 Contribution to Knowledge

The project was conceived in response to an identified need in the local context to increase and widen participation in higher education science, which resonated with wider concerns both nationally and internationally. With the aim of acquiring information which could potentially solve the identified practical problem, an action research methodology was adopted to provide a robust framework for research. Effective action research depends upon an appropriate understanding of the problem being addressed (Eden and Ackermann, 2018)) and so theoretical perspectives were explored to understand the complexities of the situation.

In sections 3.8-3.10, I have argued that Bourdieusian theory and the conceptual lens of capital permits exploration of how young people construct their identities, alongside wider structural factors that impact on life chances. As noted by L. Archer *et al.* (2012), Bourdieusian theory has not been used extensively in science education and so the findings from this study advance the academic discourse in this area Through critically reviewing the literature around the refinement of the Bourdieusian notion of capital to science capital, I have offered its value in illuminating all the influences that lead to students choosing science subjects or not. Developed conceptually only in 2016, much of the literature around science capital reports research within a secondary school context and so in adopting the concept to investigate the key influences on undergraduate students in their choice to study science at university, as well as provide a research framework for understanding the impact of university outreach initiative, the theoretical focus has been extended and I have provided a deeper understanding of what is still an exploratory field of research. The findings of the outreach study were disseminated through presentations at the Erasmus+ MaCE international conference on educational inequity (Smith, 2020) and the Three Rivers knowledge exchange conference (Smith, 2021), and thus have contributed to academic debate around what can be done to support more young people to have successful lives.

As explained in section 3.6.1, a key feature of the literature pertinent to this study is the range of university-led science outreach initiatives described. The effectiveness of university-led science outreach initiatives, however, is called into question (Fear *et al.,* 2001; Scull and Cuthill, 2010) and, as Sadler *et al*. (2018) note, there is limited research that clarifies the role or wider impacts of outreach initiatives on increasing and widening young peoples' post-compulsory participation in science education. Other authors (Addi-Raccah and Israelashvili, 2014; Varner, 2014; Vignoles and Murray, 2016; van den Hurk, Meelissen and van Langen, 2019) also question how these outreach initiatives could be made more effective. Similarly, Eilam *et al.* (2016) assert that further investigation is needed into the contribution of universities to improving scientific literacy and supporting progression within science subjects. This research addresses these calls. In offering empirical data on the experiences and perceptions of undergraduate science students and practitioners involved in delivering outreach activities to science students, further consideration is given to which outreach activities to deliver, why and to whom and the findings contribute to academic discourse on the development of approaches to increasing and widening participation in higher education science.

This research aimed to present a critical analysis of approaches to increasing and widening participation in higher education science and, through synthesizing and updating academic perspectives on the topic, contributes to knowledge of the area. In section 3.2 though, I presented a picture of higher education where universities are primarily defined by their ability to meet market criteria. Certainly, in the local context, this focus on marketing approaches to increase participation feels to have intensified further through the duration of this project, strengthening my conviction that contribution to the academic discourse gives an avenue for influencing approaches to widening participation in future.

7.4.2 Contribution to Professional Practice

This research aimed to present a critical analysis of approaches to increasing and widening participation in higher education science and, in so doing, contribute to an understanding of policy issues. By employing an action research methodology, the study provides insight into the factors that influence a young person's choice to study science at university and a deeper understanding of ways to support the development of values, attitudes, expectations and behaviours in young people that promote participation in higher education science. The study synthesizes and updates professional and academic perspectives on the topic. In chapter 3, I have charted how studying for a degree is increasingly conceptualised as an investment in self and practices in higher education are driven by market values. In so doing, I have illuminated that an overarching focus on instrumental economic goals blurs distinctions between increasing and widening participation and overlooks structural constraints. This is important because current policy discourse conceptualises students as “rational and instrumental consumers” (Baker, 2019, p.2), with agency, and downplays the effect of structural constraints in shaping higher education choices. Findings from the study investigating the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students (see section 6.3) exemplify how policy often promotes a deficit model of ‘raising aspirations’. This is unhelpful, for example, if the students are not attaining or financial constraints restrict choices in terms of travel and living costs. Through exploration of Bourdieusian theory (section 3.8), operationalisation of the theory into data collection tools (sections 4.8.1.1 and 4.8.3.1) and consideration of the findings in light of academic literature (chapter 6), I argue that a different approach is needed to address the disparities in participation levels within higher education science. Identifying the context and the barriers resulting from limited resources could benefit policy. By identifying systemic changes that are needed, it would be possible to reframe approaches from, say, encouraging more working-class boys to take science subjects to removing barriers to subject choice for all young people. With greater consideration given to the constraints young people encounter when making decisions about progression to higher education science, more could be done to support young people in overcoming these barriers (or removing them), thus going some way to address the skills shortage, create a more equitable society and add diversity to scientific communities.

Previous empirical studies (see section 3.10) and findings from this study (see section 6.4) suggest that the refinement of Bourdieusian notions of capital to the concept of science capital provides a framework for a more asset-based approach to increasing and widening participation in higher education science. By shifting the focus onto the science-related resources of young people, the conceptual framework supports the development of values, attitudes, expectations and behaviours that promote attainment, engagement and participation in science (DeWitt, Archer and Mau, 2016). As a relatively new concept, implementation in practice is not widespread. Through using science capital to frame research into FIRST® LEGO® League, I have demonstrated how the outreach initiative offers the potential to influence school children’s post-compulsory education and career choices. In so doing, I have demonstrated the value of the FIRST® LEGO® League as a practical way of supporting young people’s progression to higher education science. This was important in not only informing the university’s future support for the initiative, but also the support of other stakeholders. As explained in section 4.8.3, development of the competition across the county has drawn on significant financial and in-kind support from a range of organisations, requiring the involvement of teachers, parents, volunteers and sponsors. The findings from this study validate this involvement and have been used by external organisations working in collaboration to garner further support. Notwithstanding the impact of the pandemic, which has limited activity around the FIRST® LEGO® League, the research has contributed to the development of the competition in the region.

More so, in employing a conceptual framework to understand the impact of participation in an outreach initiative, the study goes some way to meeting the need identified by Sadler *et al.* (2018) for frameworks to categorise and evaluate science outreach initiatives. As well as the value of the concept to evaluating the impact of outreach initiatives, section 3.10.3 considers its value as a reflective framework in their design, and science capital has been used as a conceptual framework for the development and delivery of a coordinated STEM outreach programme. In more clearly defining the STEM outreach offer, this contributed to a more coherent overarching view of what university-led science outreach should be doing. The programme included, for example, workshops to specifically engage widening participation target groups (such as white, POLAR quintile 1 males), activities to facilitate the university's contribution to science festivals and sustained interventions with a real-world focus around project design and the collection, analysis and presentation of scientific data. With scientific literacy, perceived transferability and utility of science, and family influences being identified from the literature as most related to anticipated future participation in science, the initiatives included a sharp focus on these factors in their design. Whilst budgetary constraints have since impacted on the sustainability of some activities, the programme provided a model for reframing approaches to increasing and widening participation in higher education science.

Drawing also on the findings of the student study, where the most important factors influencing young people's choice to study science at university were:

1. the university offers the programme the young person is interested in
2. the university has good links with industry and the sector
3. career opportunities

4. good university facilities
5. university staff research interests
6. good reputation of the degree programme,

this study further contributes to a more nuanced understanding of how student recruitment, marketing and widening participation activities could be made more effective. Such findings are useful to outreach practitioners in the design of such activities and have been incorporated into practice, for example, within the university setting, in the development of an outreach session entitled 'BTEC and Beyond'. The aim of the session is to clarify the pathways available for progression from BTEC courses through degree-level study and into a range of careers. Hosting a range of visits from key feeder schools and colleges, as well as providing support around curriculum delivery involving specialist equipment, has brought young people onto campus to experience first-hand the university facilities. Mindful that young people may gain their perception of the university's and degree programme's reputation from teachers, the related finding has fed into a strategic intention to develop meaningful relationships with key contacts in schools and colleges, leading to the delivery of CPD (continuous professional development) events to provide support in curriculum and lesson planning, signpost support material and free resources, as well as provide hands-on training on techniques relevant to the school curriculum.

7.5 Research Quality

It is important to evaluate the quality of the outcomes and consider limitations of the study. Chapter 4 justified the methodological approach in relation to its appropriateness for the research topic, as well as clarifying my positionality as researcher. The strengths and weaknesses of the data collection and data analysis methods were considered, with the design of questionnaires based in the literature to enhance the quality of findings. All research was conducted within a robust procedural framework, as well as employing a continuous process of critical scrutiny facilitated by principle-based decision-making around the interactions between researcher and participants, to assure ethical standards. Never-the-less, it is still important to consider the factors that may have affected the quality of the results.

As an *insider researcher,* potential bias and objectivity are important considerations. Objectivity was increased through the collection and analysis of quantitative data, where the reliability of findings was enhanced through rigorous questionnaire design, administrative control and clerical accuracy. Where qualitative data were collected, a rigorous and structured approach to analysis provided some mitigation against potential bias. In recognising potential bias could exist in the subjective interpretation of responses, ongoing reflexivity has been key in guarding against making predetermined judgements. Responding to the regular challenge of my Director of Studies and members of my community of practice, in discussing my analysis and findings, helped protect against making assumptions. Despite attempting to control for any bias, it must be recognised that, in working within the context under investigation and being close to the project, there is potential for unintentional bias to still exist. In declaring my position as an *insider researcher* and making explicit my beliefs and values (see section 4.2.2), I am allowing the reader to make the decision as to whether my positioning has impacted on the research quality. Any criticism of acting as an *insider researcher* should also be balanced against the value of the project in bringing about contributions to practice informed by my underpinning knowledge of the setting.

Ensuring that sampling is fit for purpose is also an important consideration in any research project. Participants in the three studies comprising cycle 3 were recruited from first year undergraduate students, university staff and participants involved in a specific outreach activity. In each study, participants were recruited from the entire population of interest and the response rates, reported in chapter 5, strengthen confidence that an adequate number of perspectives have been included to suggest the observed results represent the truth in the population and allow meaningful conclusions to be drawn about the experiences of those in the research setting (Patino and Ferreira, 2018). With qualitative data, focusing on the themes that show the greatest consistency across participants has strengthened internal validity. The emergence of several consistent themes indicates that the number of responses was adequate for the objectives of the study. The context-specific nature of the research, conducted at a single institution at a single point in time, however, does limit the external validity of the findings and the extent to which the results of the study are generalisable to other settings, creating a basis for future research, as suggested in section 7.6.

7.6 Future Research Directions

As noted above, generalising from the findings of this study can only be done tentatively. The results of this study may not apply to different populations in different contexts and therefore it would be interesting to test the findings in wider studies, such as with undergraduate science students and staff at other universities.

The study has generated insights into the key influences on undergraduate students in their choice to study science at university; the perceptions of university staff on the purposes and impacts of outreach activities delivered to science students; and the perceptions of children, teachers, parents and volunteers on the impact of participation in a specific science outreach activity on children's science capital through the use of questionnaires. The questionnaires were used with rigorous design, administrative control and clerical accuracy to enhance reliability, but whilst these questionnaires have produced some qualitative data, the majority of the data has been quantitative in nature. As explored in section 4.5, interviews would provide a method of generating further qualitative data and a route to adding richness and deeper insight. As a means of gathering data to explore people's experiences, it would be interesting to use interviews to investigate further with participants some of the findings emerging from the questionnaires. For example, it was evident from the student study that more females than males are recruited to the science courses at the university, and it would be valuable to investigate further with this demographic group the influences that led them to study higher education science. Also, participants in the staff study agreed that the outreach activities change students' attitudes positively towards the university, change students' attitudes positively towards science, are effective in raising student aspirations, are effective in raising awareness of university science provision and are effective in recruiting students to the university. There was also agreement that the specific goal of raising student aspirations for science careers is being met by university-led outreach. As discussed in section 6.3, often practitioners claim outreach initiatives are successful without robust evaluations of their impact on increasing and widening participation (Bogue *et al.*, 2013) and so it would be worthwhile exploring further the basis of these perceptions. Equally though, using an experimental design to investigate causality would be a valuable approach to further researching the effectiveness of science outreach initiatives. Results from the outreach initiative study also showed some significant differences between teachers and parents and volunteers in terms of their perceptions of STEM subjects, and again interviews may be useful in generating a deeper understanding of these differences. In-depth interviews would also be an appropriate tool for collecting rich data and illuminating changes in science capital as a result of future outreach activities.

There is the possibility of analysing the data from the student study in relation to the background of students in order to understand if the influences on the choice to study science at university differ across gender, parents' educational background and ethnicity. This would provide more nuanced insights that may allow for the development of more targeted interventions at a future stage.

As discussed in section 3.10.3, other authors have researched interventions attempting to use a science capital approach in practice in the context of secondary education (L. Archer *et al.,* 2017). The project was framed as a small-scale, exploratory study, but provided some useful insights in terms of teachers' and students' perceptions and experiences around the operalisation of the science capital concept. Given that a key recommendation from this project is that science capital should be used as a reflective framework for the design of science outreach activities, it would be a sensible next step to adopt a similar study design to explore how outreach practitioners and academics operationalise science capital in the context of science outreach practice. Such findings may be useful in enhancing the effectiveness of science outreach activity and increasing and widening participation levels in higher education science.

7.7 Reflections on my Journey as a Researching Professional

As discussed in section 2.4, based on the conventional view presented by Macfarlane (2011), my own academic practice was not fulfilling the holistic nature of academic identity, focusing mainly on teaching and service. Accepting that research was important to fulfil the holistic nature of academic identity provided the initial trigger for embarking on the professional doctorate programme and so it is valuable at this stage to reflect on my journey as a researching professional in terms of my personal and professional development. Drawing on the researcher development framework (Vitae, 2011) my development is considered below within the domains of knowledge and intellectual abilities (A), personal effectiveness (B), research governance and organisation (C) and engagement, influence and impact (D).

7.7.1 Domain A: Knowledge and Intellectual Abilities

At the start of the doctoral journey, whilst I had questions and concerns about areas practice within my workplace, I was comfortable with my own professional practice. With over 20 years of teaching experience, I had both the tacit and explicit knowledge to carry out my professional role and did so in a mostly unquestioning way. The description offered by Fulton *et al.* (2013) of being on autopilot resonates strongly and it was a moment of revelation when the robotic nature of my practice struck home. Despite embracing the role of teacher as reflective practitioner, previous reflections had focused on practice. I used to consider what I had done, what the consequences were and what should be done next. The professional doctorate programme steered me down a route of reflecting on me as a person. Working in the field of science, where objectivity is key, personal reflection has been intensely uncomfortable at times, but important in distilling out what drives me, my view of practice and my values. It has been crucial in clarifying my personal epistemology, which, as explored in chapter 4, underpins the research design for this project. Recognising and acknowledging my beliefs and values has brought meaning to my professional practice and led to more credible research outcomes.

Working in a complex professional environment, I have had to navigate tensions between marketing, widening participation and employability perspectives. This has meant acknowledging that, whilst adopting a social justice approach resonates most loudly with my values, market-driven approaches have their part to play in increasing participation levels at the university and meeting the expectations of other stakeholders. Drawing on insights gained through a critical review of the literature has helped frame my approaches and develop a deeper understanding of the recent developments within my profession. Considering relevant theoretical frameworks has led me to a place of analysing the interplay between individual agency and social structure – something that was not even on my radar at the start of this journey - and in so doing has allowed me to conceptualise, design and implement a research project for the generation of new knowledge

Throughout my journey, I have had to be open to new sources of ideas, drawing on literature from other disciplines and fields of practice to broaden the conceptual base of my understanding. I have also had to be creative and look at things from different angles. With a series of unknowns at every stage, I have had to draw on this creativity to question my own approaches and methods, give insights and develop meaning. This creativity has been crucial in delivering a meaningful project against a backdrop of constantly changing circumstances, where two changes of job role and substantial changes to teaching and outreach practices due to the Covid-19 pandemic have impacted on my professional environment.

Developing a deeper understanding of approaches to increasing and widening participation in higher education science has taken me away from a role in which I was confident to one of continual learning and questioning my own knowledge and practice.

7.7.2 Domain B: Personal Effectiveness

Seeing things differently to how I used to see them, and differently to other people, has brought joy, but also self-doubt, demoralisation, and frustration. Resonating with the advice of Vitae (2021), my journey to date as a researching professional has been highly exposing, with drops in my level of self-confidence and self-belief. Recognising critical feedback and the need to overcome setbacks as part of the learning process has been central to my development as a researcher. The project has also required a considerable investment of time, alongside work commitments, creating challenges around maintaining motivation, which has also dipped along the way. Compounded by personal circumstances and a desire to achieve a work-study-life balance, there have been several occasions when it has been difficult to approach my research with enthusiasm. Acknowledging this as normal in the first instance has been helpful, as well as setting myself some simpler, short-term tasks to keep moving forward. Most significantly though has been the determination to complete a successful doctoral-level research project to address issues identified in my workplace and contribute to positive change in this area of practice.

Although delivering research projects and results is central to the work of higher education (MacLeod, Steckley and Murray, 2012) and an expectation of every member of academic staff, the complex environment means there is a need to manage demands across the different elements of academic practice, around research, teaching and service, as explored earlier in section 2.4. Barnett (1999) describes the condition as 'super-complexity. With multiple and competing tasks, the primary task is often not clear and, as is often the case, can lead to anxiety and research being side-lined. I can identify with this feeling of anxiety and to manage this complexity in the past, I disengaged with research to protect my personal time. As MacLeod, Steckley and Murray (2012) reflect, I saw research and publication as for a privileged and elite few, creating a boundary that required too great an effort to break through into the field of research. As part of my journey as a researching professional I have had to constructively address factors affecting my engagement with research. They argue that containment is central to productivity; I needed to view writing as a primary task and find some time to focus on that activity. By engaging with research at a strategic level, I have been able to continue to meet other demands and embrace research as an integral part of my professional identity.

7.7.3 Domain C: Research Governance and Organisation

Implementing a programme of work spanning several years has been a significant challenge. Whilst I have conducted and completed projects in the past, I have not tackled one of this scale and complexity. Delivering results within the required timescales has required project management skills, such as prioritisation of activities and setting intermediate targets. Inevitably plans have had to be re-evaluated to accommodate unforeseen circumstances and managing the risks, such as those related to the uncertainty of research outcomes, has been crucial to ensure the correct information was delivered by the agreed deadline.

As explained in section 4.7, to respect the dignity, confidentiality and anonymity of participants, I have aligned the research with the guidelines for the conduct of ethical educational research of the British Education Research Association (BERA, 2011).

Seeking ethical clearance has been important in maintaining the integrity of the research and providing a firm foundation for me to develop as a researcher with the required level of professionalism.

7.7.4 Domain D: Engagement, Influence and Impact

Drawing on my experience of completing the doctoral study has enhanced my teaching. Having recently taken on module leadership of the dissertation module has meant I have been able to use my learning as a postgraduate researcher to support the learning of undergraduate students. The empathy gained through being in the role of student myself, as well as greater knowledge and understanding of research approaches, has allowed me to guide students, in both teaching and supervisory roles, through their journeys of conceptualising, designing, and conducting their own research projects. Whilst the context specificity of my work is education, I have also been able to use my findings to provide inspiration in different contexts for students studying across a range of disciplines.

From the outset I have been aware of the value of working collaboratively to benefit my research and for maximising the potential for impact. As such, the project initially adopted a participatory action research approach to increase the likelihood of findings being used in practice. However, as explained in section 7.2, I had to adapt my approach to facilitate successful completion, developing a more researcher-led approach. Never-the-less, actively seeking to strengthen relationships and networks within the university so findings could be used in practice to inform the development of widening participation, recruitment and marketing practices has been important. As described in section 4.7.2, this has been facilitated through showing consideration to others and being self-aware about interactions between myself and others. The research has also given me the legitimacy and confidence to develop collaborations with external organisations, such as professional associations and charities, which has fostered opportunities for efficiencies, shared working, and progression activity. The value of engaging in dialogue with such organisations at the design stage was particularly evident with the outreach initiative study, ensuring outputs of the research were valuable to end-users.

7.7.5 Future Development

I believed the Professional Doctorate programme would provide a framework for exploring issues within my professional practice, but I did not anticipate the extent of my personal and professional development. My journey as a researching professional has been challenging and uncomfortable, but ultimately empowering, in moving me along a pathway of emerging responsibility for research. In embracing teaching, service and research, my own academic practice is unquestionably now fulfilling more the holistic nature of academic practice, described in section 2.4. However, the journey does not stop here, and the research map shown in figure 4.5 (section 4.3) deliberately includes continued post-doctoral research cycles. Through the development of my own research skills, I feel I am now more effective in supervising the research process for undergraduate students and relish the possibility of transferring my learning to postgraduate level. I am keen also that my work to date should act as a platform for influencing further change and intend to continue to seek out opportunities to deliver more conference presentations and translate the findings into published peer-reviewed articles. I see dissemination of the findings through publications, such as the Journal of Higher Education Outreach and Engagement and the Journal of STEM Outreach, as a way of adding to the anti-deficit framing of science outreach activities and effecting wider impact. Future research directions flowing directly from this research project are considered in section 7.6, but, extending the scope of interest, I would also like to use the lens of capital to explore the development of science identities of undergraduate students, with a view to supporting academic performance and progression into scientific professions.

Chapter 8: References

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Chapter 9: Appendix

9.1 Ethical Clearance – Student Study

17 September 2019

Request for Ethical Clearance – Our Ref: 19/03
Project: Influences on undergraduate students in their choice to study science at university

Dear Nigel

Thank you for your revised documentation regarding the issues that required a response.

Approval is granted with no further changes or amendments required.

Kind regards

[redacted]

Professor [redacted]
Chair
Research Ethics Panel

9.2 Ethical Clearance – Staff Study

5 November 2019

Request for Ethical Clearance – Our Ref: 19/08
Project: University-led Science Outreach: perceptions of academic and professional services staff on the purposes and impacts

Dear Nigel

Thank you for your recent application for ethical review.

Approval has been granted with no changes or amendments required

Kind regards

[redacted]

Professor [redacted]
Chair
Research Ethics Panel

9.3 Ethical Clearance – Outreach Initiative Study

21 January 2020

Request for Ethical Clearance – Our Ref: 19/17
Project: The impact of participation in the FIRST® LEGO® League on the dimensions of science capital and employability

Dear Nigel

Thank you for your revised documentation regarding the issues that required a response.

Approval is granted, however, please correct the typographical error within the Parent PIS before dissemination.

Kind regards

[redacted]

Professor [redacted]
Chair
Research Ethics Panel

9.4 Student Questionnaire

Section A

What is your gender?

What was your age on your last birthday?

How would you describe your ethnic group? (Tick √ one box only)

Asian or Asian British	Black or Black British	Mixed	White	Other ethnic group (including Chinese)
☐	☐	☐	☐	☐

Many students enrolled in a degree programme are the first member of their families to pursue a university degree.

☐ My mother and father have never attended university

☐ Both of my parents attended university but never graduated

☐ One of my parents is a university graduate

☐ Both of my parents are university graduates

Which degree subject are you studying?

Before choosing your current degree subject, did you consider other subject areas? If so, which ones?

What career do wish to pursue after completing your degree?

Section B

In choosing your current degree, to what extent were you positively influenced by the following factors? Please tick the relevant boxes.

	No Influence	**Some Influence**	**Strong Influence**	**Major Influence**
Parents				
Brothers and/or sisters				
Friends				
Teachers				
Speakers from universities				
Speakers from employment				
Graduates from the university				
Open day/careers events				
Websites				

	No Influence	**Some Influence**	**Strong Influence**	**Major Influence**
Prospectuses				
Having a good science teacher				
Good job prospects				
Career opportunities				
High level of pay within this field				
High employability of graduates from this university				
The degree seemed easy				
The degree seemed challenging				
Good reputation of the university				
Good reputation of the degree programme				
University ranking in major league tables				
The university offers the programme I am interested in				
The university has good links with industry and the sector				
The cost of studying at this university (including distance from home and living costs)				

	No Influence	**Some Influence**	**Strong Influence**	**Major Influence**
Good university facilities				
Student to staff ratio				
University staff research interests				
Close to home				
Social life at the university				
Local social life				
Local infrastructure				
Personal employment opportunities whilst at university				

If there is anything else that influenced your choice of degree at this university, please tell us about it in the box below.

Section C

In choosing to continue studying science after your GCSEs (or equivalent), to what extent were you positively influenced by the following factors? Please tick the relevant boxes.

	No Influence	**Some Influence**	**Strong Influence**	**Major Influence**
I was good at science at school				
I thought I would do well in science				
I thought science was interesting				
I thought science would be useful for my future career				
I found science exciting				
I was advised to take science				
I thought this was a good subject to have				
I enjoyed learning science				
I thought having science qualifications would lead to good employment prospects				

By what age had you decided that you wanted to continue studying or working in science after school?

By what age had you decided that you wanted to study specifically for a degree in science?

Section D

Thinking back to before you completed your GCSEs (or equivalent) –

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
I thought a science qualification can help you get many different types of job				
One or both parents thought science is very interesting				
One or both parents explained to me that science is useful for my future				
I knew how to use scientific evidence to make an argument				
My teachers specifically encouraged me to continue with science after GCSEs (or equivalent)				
My teachers explained to me science is useful for my future				
I felt it was useful to know about science in my daily life				

	Never	Less than Once a Year	At Least Once a Year	At Least Once a Term	At Least Once a Month
How often did you go to a lunchtime or after-school science club?					
When not in school, how often did you go to a science centre, science museum or planetarium?					
When not in school, how often do you visit a zoo or aquarium?					

	Never or Rarely	Occasionally	Sometimes	Regularly	Always
When not in school, how often did you read books or magazines about science?					

Did you know someone who works in science? **Y** **N**

If yes, who did you know who works in science?

	Never	A Few Times A Year	Once a Month	Once a Week	Almost Every Day
When you were NOT in school, how often did you talk about science with other people					

Who did you talk with about science?

Thank you for taking the time to complete the questionnaire. The purpose of the research is to investigate the key influences on undergraduate students in their choice to study science at university and your responses will inform approaches to increasing and widening participation in higher education science.

If you have any concerns about your academic studies help is available from your tutors, LISS or the Mental Health and Wellbeing Service. More information is available via the 'My Wellbeing' tab on the Student Hub.

9.5 Staff Questionnaire

What is your role? Please tick the relevant box

Professional Services	Academic
☐	☐

In answering the following questions, please consider all outreach activities you deliver to young people studying science. I should be grateful if you would answer each question in order and not return to any questions after answering subsequent ones.

Section A

What types of outreach activities are you involved with? Please list as many as appropriate.

1.		6.	
2.		7.	
3.		8.	
4.		9.	
5.		10.	

How would you describe the **key purpose** of the outreach activities with which you are involved?

Any secondary purposes?

Please outline any specific objectives of the outreach activities with which you are involved.

What methods are used to evaluate the effectiveness of activities in achieving the aims?
Please tick all that apply

pre-survey	☐	observation during delivery	☐
immediate post-survey/evaluation sheet	☐	interview about activity delivery	☐
longitudinal survey/enrolment data of past attendees			☐
other/	☐	none	☐

What is the evaluation designed to assess?

Please outline any issues you perceive to be associated with evaluation.

What findings arise from the evaluations?

What impacts do you perceive the outreach activities to have?

Which outreach activities do you feel are most effective in increasing recruitment to the university?

Which outreach activities do you feel are most effective in enhancing science literacy

Which outreach activities do you feel are most effective in **increasing** participation in science subjects?

Which outreach activities do you feel are most effective in **widening** participation in science subjects?

How could science outreach at the university be improved?

Section B

Considering all outreach activities you deliver to young people studying science, please indicate your level of agreement with the following statements by ticking the appropriate boxes.

	Strongly Disagree	Disagree	Agree	Strongly Agree
The goals could be more clearly defined.				
I am confident that the activities are successful in achieving their goals.				
I feel that the activities change students' attitudes positively towards the university.				
I feel that the activities change students' attitudes positively towards science.				
I feel that the outreach activities are targeted at the correct age group to raise awareness of science provision at the university.				
I feel that the outreach activities are targeted at the correct age group to raise aspirations.				
From a university perspective I feel there is a coherent overarching view of what science outreach activities should be doing.				
I feel that senior management value my work around outreach activities.				

	Strongly Disagree	Disagree	Agree	Strongly Agree
I feel that the objectives of science outreach activities and what is actually measured in the evaluation are aligned.				
I feel the activities are effective in raising student aspirations.				
I feel the activities are effective in raising awareness of university science provision.				
I feel the activities are effective in recruiting students to the university.				
Outreach activities are heavily influenced by the needs of marketing.				
Outreach activities are heavily influenced by the needs of widening participation.				
Outreach activities are heavily influenced by the needs of the school curriculum.				
Outreach activities are heavily influenced by a personal interest.				
Outreach activities are heavily influenced by my personal contacts.				

	Strongly Disagree	Disagree	Agree	Strongly Agree
Outreach activities are heavily influenced by the employability agenda.				
The specific goal of raising student aspirations for science careers is being met by university-led outreach.				
University-led science outreach has an important part to play in contributing to the research agenda.				
University-led science outreach has an important part to play in contributing to the employability agenda.				
University-led science outreach has an important part to play in securing a pipeline of future scientists needed for the UK economy.				
University-led science outreach has an important part to play in contributing towards social justice.				

Thank you for taking the time to complete the questionnaire. The purpose of the research is to investigate the perceptions of academic and professional services staff on the purposes and impacts of university-led science outreach and your responses will inform the development of outreach and recruitment activities.

9.6 Outreach Initiative Questionnaire - Pupils

Section A

Please tick how much you agree with the following statements.

Through taking part in the LEGO League, I

	Strongly Disagree	Disagree	Agree	Strongly Agree
Have learnt about the world outside of school				
Have learnt how science is a part of my life inside and outside of school				
Have learnt interesting things about the world inside and outside of school				
Have developed a greater awareness of scientific ideas				
Think that science is more enjoyable				
Have developed scientific knowledge, skills and understanding				
Think science is relevant to everyday life				
Have a greater understanding that a science qualification can help get many different types of job				
Have a greater understanding of how learning science could be useful for my future career options				

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
Have used television, websites or newspapers to find out about science				
Have read books and magazines to find out about science				
Have gone to a science centre or science museum outside of school				
Have talked more about science out of school with friends, siblings, parents, neighbours and other people in my community				
Have met more people who work in science				
Think that science is for everyone regardless of background				

Section B

Please tick how much you agree with the following statements.

Because I took part in the LEGO League

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
My parents have explained to me that science is useful for my future				
My teachers have explained to me science is useful for my future				

Thank you for taking the time to answer these questions. The purpose of the research is to find out your thoughts on taking part in the FIRST® LEGO® League and what you tell us will help us develop other STEM activities.

9.7 Outreach Initiative Questionnaire - Teachers

Section A

Please indicate your level of agreement with the following statements.

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
STEM subjects offer the potential to increase the life opportunities for young people				
Participation levels in STEM subjects matter in terms of social justice				
The UK urgently needs employees with STEM skills				
STEM represents this country's economic future				

Section B

Please indicate your level of agreement with the following statements. Participating in the LEGO League has -

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
Supported pupils to learn about the world outside of school				
Supported pupils to learn how science is a part of their inside- and outside-of-school lives				
Supported pupils to learn interesting things about the world inside and outside of school				
Supported pupils to develop a greater awareness of scientific principles				
Made science more enjoyable				
Supported pupils to develop scientific knowledge, skills and understanding				
Made science relevant to everyday life				
Made explicit that a science qualification can help get many different types of job				
Highlighted the value of science education to pupils' university and/or career options				
Encouraged greater science media consumption - using television, the internet or newspapers to expand				

pupils' scientific knowledge				
Encouraged pupils to participate more in informal science learning contexts, such as science museums, science clubs, fairs etc.				
Created opportunities for pupils to talk about science out of school with key people in their lives (e.g. friends, siblings, parents, neighbours, community members)				
Created opportunities for pupils to talk about science with people outside their normal networks				
Built STEM identity by challenging stereotypes about STEM careers				

Thank you for taking the time to complete the questionnaire. The purpose of the research is to investigate the impact of participation in the FIRST® LEGO® League on the dimensions of science capital and your responses will inform the development of STEM outreach activities.

9.8 Outreach Initiative Questionnaire - Volunteers

Please indicate your involvement with the LEGO League –

Coach	
Judge	

Section A

Please indicate your level of agreement with the following statements.

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**
STEM subjects offer the potential to increase the life opportunities for young people				
Participation levels in STEM subjects matter in terms of social justice				
The UK urgently needs employees with STEM skills				
STEM represents this country's economic future				

Section B

Please indicate your level of agreement with the following statements, which relate to the children participating in the LEGO League. Participating in the LEGO League has -

	Strongly Disagree	Disagree	Agree	Strongly Agree	Don't Know
Supported pupils to learn about the world outside of school					
Supported pupils to learn how science is a part of their inside- and outside-of-school lives					
Supported pupils to learn interesting things about the world inside and outside of school					
Supported pupils to develop a greater awareness of scientific principles					
Made science more enjoyable					
Supported pupils to develop scientific knowledge, skills and understanding					
Made science relevant to everyday life					
Made explicit that a science qualification can help get many different types of job					

	Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**	**Don't Know**
Highlighted the value of science education to pupils' university and/or career options					
Encouraged greater science media consumption - using television, the internet or newspapers to expand pupils' scientific knowledge					
Encouraged pupils to participate more in informal science learning contexts, such as science museums, science clubs, fairs etc.					
Created opportunities for pupils to talk about science out of school with key people in their lives (e.g. friends, siblings, parents, neighbours, community members)					
Created opportunities for pupils to talk about science with people outside their normal networks					
Built STEM identity by challenging stereotypes about STEM careers					

Thank you for taking the time to complete the questionnaire. The purpose of the research is to investigate the impact of participation in the FIRST® LEGO® League on the dimensions of science capital and employability, and your responses will inform the development of STEM outreach activities and an employability framework.

9.9 ANOVA and T-Test Calculations on Outreach Initiative Study Data for Comparison Between Groups

The first four items on the questionnaires used with teachers, volunteers and parents sought their perspectives on STEM subjects in terms of social justice and the economic pipeline. For each of the four questionnaire items, ANOVA and Kruskal-Wallis tests were conducted on the data to explore whether the groups of participants resulted in significantly different responses to the questions. If a significant difference was evident, further t-tests were conducted to explore between which group pairs there was a significant difference in responses. The full set of calculations are given here to show whether or not there is a significant difference between the means (or medians) of teachers, parents and volunteers.

Item: STEM subjects offer the potential to increase the life opportunities for young people

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Teachers	12	48	4	0		
Parents	10	36	3.6	0.933333		
volunteers	21	78	3.714286	0.214286		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	0.988704	2	0.494352	1.558768	0.222906	3.231727
Within Groups	12.68571	40	0.317143			
Total	13.67442	42				

F-value less than F-critical value, therefore accept null hypothesis that there is no significant difference; p-value greater than alpha-value selected (0.05) therefore accept null hypothesis.

Item: Participation levels in STEM subjects matter in terms of social justice

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Teachers	12	45	3.75	0.204545		
Parents	10	32	3.2	0.844444		
volunteers	21	67	3.190476	0.661905		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	2.679347	2	1.339673	2.320977	0.111259	3.231727
Within Groups	23.0881	40	0.577202			
Total	25.76744	42				

F-value less than F-critical value, therefore accept null hypothesis that no significant difference; p-value greater than alpha-value selected (0.05) therefore accept null hypothesis.

Item: The UK urgently needs employees with STEM skills

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Teachers	12	48	4	0		
Parents	10	31	3.1	0.766667		
volunteers	21	73	3.47619	0.361905		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.559579	2	2.27979	6.450061	0.003733	3.231727
Within Groups	14.1381	40	0.353452			
Total	18.69767	42				

F-value is greater than the F-critical value for the alpha level selected (0.05). Therefore, there is evidence to reject the null hypothesis and say that at least one of the three groups has significantly different mean.

Another measure for ANOVA is the p-value. If the p-value is less than the alpha level selected (which it is), I reject the null hypothesis.

t-Test: Teachers and Parents		
	Teachers	Parents
Mean	4	3.1
Variance	0	0.766667
Observations	12	10
Hypothesized Mean Difference	0	
df	9	
t Stat	3.250418	
P(T<=t) one-tail	0.004995	
t Critical one-tail	1.833113	
P(T<=t) two-tail	0.009991	
t Critical two-tail	2.262157	
p two-tail less than 0.05 = sig. difference		

t-Test: Teachers and Volunteers		
	Teachers	Volunteers
Mean	4	3.476190476
Variance	0	0.361904762
Observations	12	21
Hypothesized Mean Difference	0	
df	20	
t Stat	3.990119	
P(T<=t) one-tail	0.00036	
t Critical one-tail	1.724718	
P(T<=t) two-tail	0.00072	
t Critical two-tail	2.085963	
p two-tail less than 0.05 = sig. difference		

t-Test: Parents and Volunteers		
	Parents	Volunteers
Mean	3.1	3.476190476
Variance	0.766667	0.361904762
Observations	10	21
Hypothesized Mean Difference	0	
df	13	
t Stat	-1.22765	
P(T<=t) one-tail	0.120672	
t Critical one-tail	1.770933	
P(T<=t) two-tail	0.241344	
t Critical two-tail	2.160369	
p two-tail greater than 0.05, no sig. diff.		

Similarly, Kruskal-Wallis test showed that at least one of the groups has a significantly different median.

Item: STEM represents this country's economic future

Anova: Single Factor						
SUMMARY						
Groups	Count	Sum	Average	Variance		
Teachers	12	48	4	0		
Parents	10	32	3.2	0.844444		
volunteers	21	69	3.285714	0.314286		
ANOVA						
Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	4.81196	2	2.40598	6.930807	0.002604	3.231727
Within Groups	13.88571	40	0.347143			
Total	18.69767	42				

F-value is greater than the F-critical value for the alpha level selected (0.05). Therefore, there is evidence to reject the null hypothesis and say that at least one of the three groups has significantly different mean.

Another measure for ANOVA is the p-value. If the p-value is less than the alpha level selected (which it is), I reject the null hypothesis.

t-Test: Teachers and Parents			
	Teachers	Parents	
Mean	4	3.2	
Variance	0	0.844444	
Observations	12	10	
Hypothesized Mean Difference	0		
df	9		
t Stat	2.752989		
P(T<=t) one-tail	0.011184		
t Critical one-tail	1.833113		
P(T<=t) two-tail	0.022367		
t Critical two-tail	2.262157		
p value less than 0.05 - reject null hypothesis - sig. diff			

t-Test: Teachers and Volunteers		
	Teachers	Volunteers
Mean	4	3.285714286
Variance	0	0.314285714
Observations	12	21
Hypothesized Mean Difference	0	
df	20	
t Stat	5.838742	
P(T<=t) one-tail	5.17E-06	
t Critical one-tail	1.724718	
P(T<=t) two-tail	1.03E-05	
t Critical two-tail	2.085963	
p value less than 0.05 - reject null hypothesis - sig. diff		

t-Test: Parents and Volunteers		
	Parents	Volunteers
Mean	3.2	3.285714286
Variance	0.844444	0.314285714
Observations	10	21
Hypothesized Mean Difference	0	
df	12	
t Stat	-0.27185	
P(T<=t) one-tail	0.395177	
t Critical one-tail	1.782288	
P(T<=t) two-tail	0.790354	
t Critical two-tail	2.178813	
No sig. diff.		

Similarly, Kruskal-Wallis test showed that at least one of the groups has a significantly different median.

9.10 Impact Journey – Student Study

Inputs

Feeding into the identified need to raise higher level skills attainment in STEM-related fields, the University is funded to actively widen participation in these subjects, whilst increasing the number of students enrolled on undergraduate science courses at the University is a perennial concern. I have a deepening understanding of the concepts and ideas reported in the literature and developing expertise to take a research-informed approach.

Activities

So, I will research the key influences on current undergraduate students in their choice to study science at university in order to be able to understand better how to increase recruitment onto the science courses at the University.

Outputs

Findings will be disseminated to sponsors through presentations and to management and colleagues (academic and professional services) through verbal and written reports. Opportunities will be sought to disseminate the findings more widely.

Translation

I will use the findings to inform the development of my own recruitment and outreach activities. I will draw on the findings to feed into the development of marketing and recruitment approaches at relevant meetings and training opportunities. The results will be evaluated and used by both academic and professional services colleagues in their recruitment and outreach practices. Sponsors will use the findings to satisfy themselves that activity has contributed towards meeting the objectives.

9.11 Impact Journey – Staff Study

Inputs

My own professional experience suggests the lack of clarity reported in the literature around the purposes and impacts of university-led science outreach, in terms of which activities should be delivered, why and to whom, exists in practice at the University.

Activities

So, I will investigate the perceptions of academic and professional services colleagues addressing the research question: How do academics and professional services staff perceive the purposes and impacts of university-led science outreach?

Outputs

Findings will be reported to management, as well as academic and professional services colleagues.

Submission to the Journal of Higher Education Outreach and Engagement.

Translation

I will use the findings to mediate my interactions with colleagues. I will draw on the findings to feed into the development of university-led science outreach at relevant meetings and training opportunities. The results will be evaluated and used by stakeholders to shape practices around science outreach.

9.12 Impact Journey – Outreach Initiative Study

Inputs

The number of teams in the county participating in the FIRST® LEGO® League is growing rapidly, with a related growing number of organisations acting in support, either through sponsorship or volunteering expertise. The University is one such organisation, this year providing sponsorship, as well as encouraging undergraduate students to volunteer their time and expertise to support the initiative. However, there has been little research around this initiative within the regional context and none within the local context. I have a deepening understanding of science capital and I have consulted with key organisations early on around the value of research investigating the impact on the science capital of participants.

Activities

So, I will research the perceived impacts of participation in the league on children's science capital.

Outputs

I will provide a written report to the key organisations responsible for growing the FIRST® LEGO® League in the region.

I will brief university colleagues on the key findings.

I will ensure wider dissemination of the findings through emailing participating schools and presenting at best practice sessions.

Findings will also be disseminated through presentations at suitable conferences, such as Erasmus+ MaCE international conference on educational inequity and the Three Rivers knowledge exchange conference.

Translation

Sponsors will use the findings to inform future support for the initiative.

The University will use the findings to inform future support for the initiative, recruitment and outreach plans and the development of outreach activities.

Other key organisations will use the findings to garner further support and sponsorship.

Schools (current and future) will use the findings to evaluate the costs and benefits of participation.

The results will be evaluated and used by others to inform approaches to increasing and widening participation in higher education science.