CHILDREN'S EXPERIENCES OF ENGINEERING EDUCATION ACTIVITIES IN RURAL SCHOOLS IN ENGLAND AT AGE 9/10: THE IMPLICATIONS FOR ENGINEERING EDUCATION AND OUR APPROACH TO BUILDING ENGINEERING CAREER ASPIRATIONS IN YOUNG PEOPLE.

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Doctor of Philosophy

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SUMMARY

Schools in England are offered a range of activities aiming to engage students with engineering and increase the number who progress to engineering careers. However, monitoring of engineering education prior to university remains limited, and low progression rates onto engineering courses persist in the UK. Although the majority of engineering education provision had historically been aimed at secondary level education, the lack of visible results encouraged a more recent move towards provision for younger children. The current research set out to explore primary school children's participation in Engineering Education Activities (EEAs); to achieve this, experiences of one-off EEAs were investigated from the first-person perspective of the children who participated in them. A case study approach was employed, using exploratory observations and semi-structured interviews to collect data from two cases across three school years (Year 5 to Year 7). The meta-analysis of the data, using a grounded theory approach, enabled a conceptual framework to be constructed. The framework facilitates an understanding of children's experiences of EEAs, providing a foundation upon which to build, contributing knowledge to the field through the identification of a number of important concepts and their previously unacknowledged inter-relationships; most significantly, the emergence of the concept of Engineering Capital, and the importance of the formation of engineering self-efficacy at a young age. This research found that participation in the observed EEAs did not impart accurate perceptions of engineering to the children involved, leading to complex outcomes of participation, with the children's personally held definitions of engineering appearing to influence their experiences of the EEAs and their engineering career aspirations. This work concluded that participation in an activity that does not impart accurate definitions of professional engineering to children, or build engineering self-efficacy, will have little positive impact upon their engineering career aspirations.

Key words: Pre-University Engineering Education, Qualitative Child Interviews, Grounded Theory, Perceptions, Engineering Self-Efficacy.

Dedication

To all of the adults and children who gave their time to participate in this research.

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ACRONYMS

A-Level	Advanced Level
AS-Level	Advanced Subsidiary Level
ASE	Association for Science Education
BBC	British Broadcasting Corporation
BIS	Department for Business, Innovation, and Skills
BTEC	British and Technology Education Council
CaSE	Campaign for Science and Engineering
CBI	Confederation of British Industry
CDIO™	Conceive, Design, Implement, Operate
DATA	Design and Technology Association
DBS	Disclosure and Barring Service
DCSF	Department for Schools and Families (now DfE)
DfE	Department for Education (formally DCSF)
D&T	Design Technology
EAL	English as an Additional Language
EEA	Engineering Education Activity
EEP	Engineering Education Practioner
EER	Engineering Education Research
EDT	Engineering Development Trust
ESFA	Education and Skills Funding Agency
ETB	Engineering and Technology Board
FE	Further Education

GAWS!	Get Ahead with STEM!
GCSE	General Certificate of Secondary Education
HE	Higher Education
HEI	Higher Education Institution
HESA	Higher Education Statistics Agency
HNC	Higher National Certificate
HND	Higher National Diploma
IB	International Baccalaureate
ICE	Institution of Civil Engineers
IChemE	Institution of Chemical Engineers
ICT	Information and Communication Technology
IET	Institution of Engineering and Technology
IMechE	Institution of Mechanical Engineers
IStructE	Institution of Structural Engineers
KS	Key Stage
LEP	London Engineering Project
NAS	National Apprenticeship Service
NFER	National Foundation for Educational Research
NVQ	National Vocational Qualification
Ofqual	Office of Qualifications and Examinations Regulation
PEI	Professional Engineering Institution
PIS	Participant Information Sheet
PSHE	Personal, Social, Health, Economic
PTA	Parent Teacher Association

RAEng	Royal Academy of Engineering
SEN	Special Educational Needs
SET	Science, Engineering Technology
SOA	Super Output Area
SRA	Social Research Association
STA	Standards and Testing Agency
STEM	Science, Technology, Engineering, Mathematics
STEMNet	Science, Technology, Engineering and Mathematics Network
THE	Times Higher Education
UCAS	University and College Application Service
UNCRC	United Nations Convention of the Rights of the Child
WISE	Women in Science and Engineering

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CHAPTER 1

1 Background

1.1 Introduction

This thesis is the presentation of research carried out between 2012 and 2018 undertaken as a part-time PhD (a timeline of the research is provided in Appendix A). The opening chapter introduces both the research and the researcher, presenting the origins and need for this research project alongside the scope and outline of the study.

Engineering education is a broad field, however at the time of enquiry into the outcomes of engineering education during the years of compulsory education in England (up to the age of 16), holds a relatively low profile within the body of research. In part this is due to the sporadic nature of engineering education provision prior to Higher Education (HE). This project has therefore investigated the affect that participating in an Engineering Education Activity (EEA) has on a child's perception of engineering careers. Focus has been given to children within rural schools as this group was under-represented within Engineering Education Research (EER) at the time.

As it focuses on a relatively unexplored area of research, the project took an exploratory approach with the aim of constructing a theory of participation to clarify and deepen our understanding of this experience. This is of benefit to both the EER community and the Engineering Education Practioner (EEP) community.

1.2 Origins of the research

In 2002 Sir Gareth Roberts published the SET (Science, Engineering, Technology) for Success report (Roberts, 2002), which resulted in an increased focus on STEM (Science, Technology, Engineering, Mathematics) education within UK secondary schools (BIS, 2015; Hoyle, 2016). However, the lack of recruitment and retention of qualified engineers continues to be globally recognised (CBI, 2015). Whilst research has been carried out to explore how undergraduate engineering courses can be enhanced (Meyer & Marx, 2014; Godfrey et al., 2010; Rodriguez-Falcon and Yoxall, 2010; Tudor et al., 2010; Sheppard et al., 2009; Akam, 2003), pre-university education is not often the focus of discussions regarding the efficacy of engineering education.

Engineering is not a core subject within the UK national curriculum and therefore is not required to be taught in UK schools. Recent Government attention (DfE, 2006; House of Commons Science and Technology Committee, 2013) led to the formation of an industry with a multitude of organisations, companies, and individuals offering a range of EEAs to schools (RAEng, 2016a), with little or no evaluation of their efficacy being carried out (Bultitude et al., 2010). As a result, teachers are being offered a wide range of resources with little or no knowledge of the impact that these have on students (a concept highlighted by the exploratory work of Clark & Andrews (2010a; 2010b)).

Growing unrest amongst the Professional Engineering Institutions (PEIs) has been displayed in reports regarding engineering education (Engineering UK, 2017; IMechE, 2016a) and it has been suggested that professional engineers do not consider the UK education system able to meet the needs of the engineering industry (Tata, 2017). Therefore, further research into UK engineering education at all levels is required if we are to understand and improve the present situation, creating a sustainable, long-term solution to the recruitment problems currently being faced.

1.3 Need for the research

It has been acknowledged that a well-educated STEM workforce is critical to the economic security and prosperity of a country (RAEng, 2016b; Roberts, 2002), leading to concerns regarding the number of adequately STEM skilled individuals entering the job market (CBI, 2012; 2015). For many years attention has been drawn to the deficit between the number of students pursuing engineering and the number of engineering vacancies each year in the UK, and a range of predicted uptake and progression levels have been presented. These include statements that 25% of school leavers are needed to follow engineering career paths (Semta, 2012), that there is a yearly deficit of 32,500 STEM graduates compared to the number of jobs in UK industry (RAEng, 2012), and that the UK requires an additional 182,000 engineering skilled individuals per year until 2022 (Engineering UK, 2016).

Data from the Higher Education Statistics Agency (HESA)[1] shows that the number of first degrees awarded in engineering in the UK is increasing, however this figure is not increasing at the required rate according to the statements above. Looking at the percentage of first degrees awarded in engineering to UK domiciled students in Figure

[1] HESA collect, process, and publish data about UK Higher Education (HESA, 2018).

1.1 it can be seen that the number remained steady at just above 3% of the total number of first degrees awarded until 2014/15 when it increased slightly.

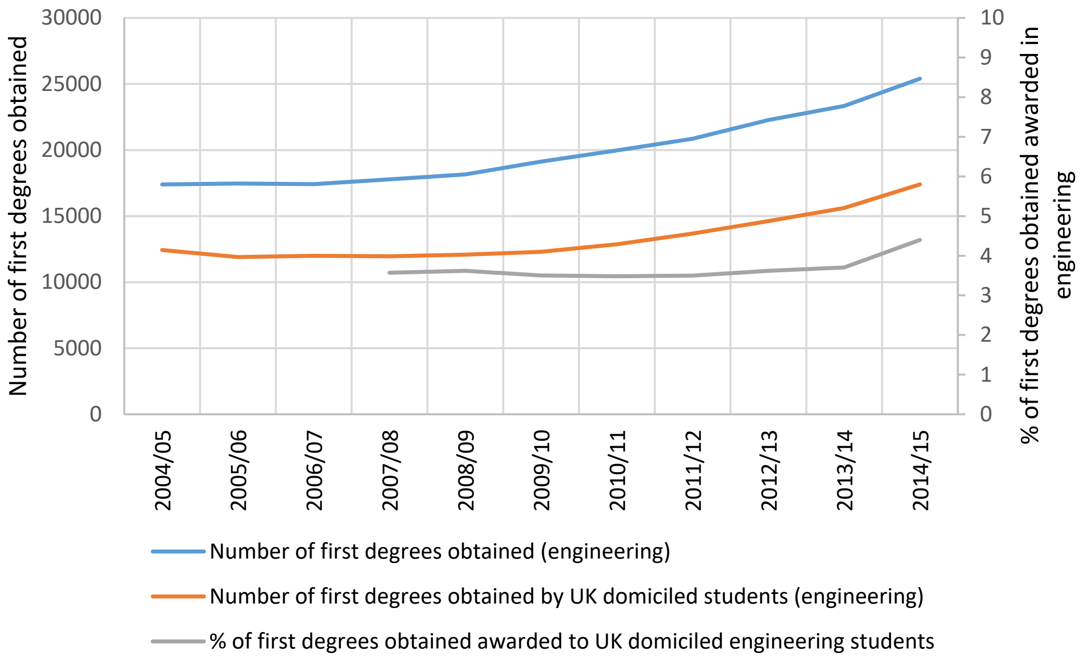

Figure 1.1: Number of first degrees awarded in engineering (constructed using data from HESA and Engineering UK (2017))

The Royal Academy of Engineering (RAEng), reflecting on the finding that approximately only 1% of the cohort of children taking GCSEs each year become professional engineers, concluded that there continued to be “substantial work to do to attract young people towards engineering” (RAEng, 2016a, pg. 23), a conclusion supported by the data presented above in Figure 1.1.

In addition to the absence of a tangible increase in the number of students studying engineering, Higher Education Institutions (HEIs) report facing difficulties recruiting and retaining adequately qualified young people onto undergraduate engineering programmes, as reported by the RAEng (2007, 2013). With many engineering education providers purporting to successfully engage large numbers of UK school children with engineering each year (including but not limited to statements from the Smallpeice Trust, 2011; The Big Bang Fair, 2018; Primary Engineer, 2017; and the EDT, 2014), the efficacy of this engagement is beginning to be called into question (IMechE, 2016a; Hoyle, 2016; Lauchlan, 2017).

This is of particular interest when it is considered that EEAs have associated monetary costs that are assumed by schools, government, industry, and individuals. According to information provided in the STEM Directories (2018) schools can be quoted anywhere up to £1450 per one-day activity, with the average cost quoted being approximately £460. In addition, a proportion of the annual fees paid to PEIs is allocated to Engineering UK (Engineering Council, 2017a), a not-for-profit organisation with the express aim of promoting engineering to future generations (Engineering UK, 2018a). Since their formation in 2002 it has been estimated by some that a total of £100 million has been provided to Engineering UK for this purpose (Fidler, 2018).

With little empirical evidence of the outcomes of these activities, and with the need to ensure an increase in the number of able individuals choosing to study engineering, it is vital that effective engineering education is provided. Attention therefore needs to be paid to the outcomes of participation in current EEAs within the UK education system.

1.4 The purpose of the study

The purpose of this study, as outlined in the following section, was to develop the EER community's understanding of the outcomes of participation in EEAs for schoolchildren in England, especially with respect to the bearing that participation has on progression into engineering careers.

1.4.1 Scope and limitations

At the commencement of this project the area of engineering education prior to HE was relatively unexplored, and little was understood about the outcomes of participation in engineering education for primary school children. Therefore, this study took an exploratory approach and it was envisaged that this thesis would create a conceptual framework regarding participation in EEAs, in order to inform the EER community's understanding of this area. This framework aims to provide context and focus for subsequent research, inviting others to continue and progress the development of theory from the framework presented.

1.4.2 Creation of a conceptual framework

As summarised by Imenda (2014), a conceptual framework informs tentative theories regarding a phenomenon. Ultimately, the purpose of this study is to create a conceptual framework concerning children's participation in EEAs and the bearing this participation has on their perceptions of engineering and engineering career aspirations. Due to the exploratory nature of the area of study, the creation of a conceptual framework as the conceptual basis for a theory of participation was deemed to fulfil the objective of this study.

1.5 The researcher

There is potential for researcher bias in all research, as Burr stated “no human being can step outside of their humanity and view the world from no position at all” (2015, pg. 172), and therefore it is important to understand the background of the researcher conducting this study (as argued by Rossman & Rallis, 2003).

The researcher holds a Masters Degree in Mechanical Engineering. The choice to study engineering was first explored during a conversation with her parents when choosing A-Level options at school, it was motivated by a voluntary role she held on a heritage steam railway. Immediately prior to, as well as during the first five years of this study, she worked freelance in the field of engineering education and therefore has experience of both engineering and EEA delivery.

The motivation to begin an EER project occurred whilst working at an educational charity, and arose out of a desire to understand the impact that her work on government and school funded engineering education programmes was having on the students who participated in them.

1.6 Definitions

As the focus of this work is engineering education, it is important to clarify what is meant by engineering and EEAs. The definitions used in this work are provided here for reference.

1.6.1 Engineering Education Activities (EEAs)

No single definition of an EEA exists in academia or practice. Reading the descriptions provided in the STEM Directories entries (2018) illustrates the variety of activities being offered by different providers, each with different aims and pedagogical approaches. Activities range from aiming to develop broad engineering awareness and “introduce engineering principles and examples of engineering challenges in real life” (Tomorrow’s Engineers, 2018a), to engaging students through “hands-on activity and stimulating engineering contexts" (RAEng, 2018a) or "genuine, real-life engineering problems" (IET, 2018a). In addition resources focusing on a specific sub-discipline of engineering are also available to, for example, "show and explain what civil engineering is, why it's important and what you need to do to become a civil engineer" (ICE, 2018a).

In the absence of an universally accepted definition, the following classification of an EEA has been adopted within this research study. Based on the definitions provided by activity providers and the experience of the researcher within the field of EEA delivery.

> *An activity taking place as part of the school curriculum or as an extra-curricular event which aims to engage children with the area of engineering in a hands-on or interactive way.*

1.6.2 Engineering

Engineering is a broad discipline and there are multiple definitions available. The Oxford English Dictionary (2005, p. 329) defines engineering as:

> *1. The branch of science and technology concerned with the design, building, and use of engines, machines, and structures.*
>
> *2. An area of study or activity concerned with development in a particular area: software engineering.*

In addition, an engineer is defined as:

> *1. A person who designs, builds, or maintains engines, machines, or structures.*
>
> *2. A person who controls an engine, especially on an aircraft or ship.*
>
> *3. A person who cleverly plans something.*

The Merriam-Webster website (2014) also defines engineering in a number of ways, including:

> *The work of designing and creating large structures (such as roads and bridges) or new products or systems by using scientific methods.*
>
> *The application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people.*

In addition to the myriad of dictionary definitions, PEIs hold individual definitions unique to their sub-disciplines of engineering that can be found on their webpages (see IChemE, 2018; IStructE, 2018; IMechE, 2016b; ICE, 2018b), or in published reports (RAEng, 2016c).

As a single definition of engineering is not agreed upon, a definition was created for this research adapted from those referenced above:

> *Engineering is the application of knowledge, and the creation of new knowledge, to help improve the world; it is both an art and a science. Engineers apply scientific and mathematical principles in a creative manner to solve problems, with the ultimate aim of helping people and improving society.*

1.6.3 Classification of rural areas

In this study a rural area is defined using the 2011 UK Government Rural and Urban Area Classification (RUC2011), which states that an area falling outside of a settlement with a resident population of less than 10,000 is classified as a rural area (ONS, 2017). Both of the cases associated with the research conducted in this study were classified as rural town and fringe using this categorisation.

1.7 Thesis structure

Chapter 2 presents the main findings from the literature review examining published works from a range of academic journals, professional bodies, and educational organisations, with a focus on children's progression into engineering and the provision of engineering education within England as it was at the start of this project. This critical review of the literature identified the gap in the existing knowledge that this research study set out to fill.

Drawing on the key concepts identified from the literature review, the conceptual model that informed the research question for this study is presented in Chapter 3. Chapter 3 also describes the research methods used and the rationale for the methodological decisions made in this research project.

Chapters 4 and 5 introduce the two research cases. Descriptions of the cases are given and the data collected from each case is presented with minimal analysis.

Chapter 6 presents a meta-analysis of the data from the two cases, identifying the key concepts affecting outcomes of participation in EEAs and engineering career aspirations, the similarities and differences revealed between the cases, and trends over the period of the research.

A discussion of the findings is presented in Chapter 7, presenting the relationships between the concepts across the entire period of the research, weaving the findings of this study into the existing body of literature, and uniting the findings presented in the previous chapter into a conceptual framework and theory of participation.

Chapter 8 ties the study together and concludes with the presentation of the key findings of this research, the implications that these findings have for the different stakeholders in engineering education, recommendations for future research, and a discussion of the effectiveness of the study in meeting its stated aim and objectives.

Finally, Chapter 9 reflects upon the research, addressing questions of validity and ethical rigour.

CHAPTER 2

2 A review of engineering education: research and practice

This chapter provides the context in which this research has been undertaken, critically discussing the field of research that existed when the project began in 2012-13, and providing an overview of the English education system. The review includes both the academic and industry perspective and is framed by the initial motivation behind this research, *how do we encourage more children to become engineers?*

This critique of the literature sets out to develop an understanding of the field in which this research is situated, highlighting unexplored areas of EER to identify gaps in the existing knowledge. In this way, the research question articulated in Chapter 3 remains located within the existing literature whilst making a unique contribution to the field.

EER is an emergent discipline, separating from STEM and science education research to form a distinct field of its own. For this reason, the breadth of specific EER was limited at the start of this research, and for this reason the other fields of STEM research have also been drawn upon. The inclusion of engineering education focused reports published by industry and PEIs have also been used to provide multiple perspectives of engineering education.

2.1 Introduction

The area of engineering education is complex, with many stakeholders (including government, industry, and PEIs) influencing the delivery of engineering education. In order to clarify the educational context in which this study takes place, a general overview of education in England is given before assessing the issue of engineering education. As there are differences between the education system in each of the devolved nations, England has been specified.

2.2 The Education system (England)

The UK education system was succinctly summarised by Sir Gareth Roberts in the SET for success report (Roberts, 2002) and although the education system in England has reacted to many policy driven changes in recent years (Engineering UK, 2017), the fundamental structure remains similar to that summarised by Roberts.

All children in England are entitled to a free school place between the ages of 5 and 16 (the ages of compulsory education) (UK Government, 2018a). There are a number of different types of school, either state or independently funded and/or run (UK Government, 2018a), each with a similar education structure. Between the ages of 5 and 16 children progress from Year 1 to Year 11 through discrete stages, information about these stages is provided to the public via County Council websites. The most common types of school for children between these ages are primary school (4 to 11 year olds) and secondary school (11 to 16 year olds); this is referred to as a two-tier education system and is aligned to the age-limits imposed by the Education Act 1944. However, the Education Act 1964 enabled schools to be set up with differing age-limits, which led to a three-tier school system being adopted in some English counties. In this system children attend First school (4 to 8 year olds), Middle school (8 to 12 year olds), and Upper school (12 to 16 year olds).

The majority of state-schools are required to follow the national curriculum (the exception being faith schools who can alter how they teach religious studies), this framework is structured around four 'Key Stages':

- Key Stage 1 (KS1): Year 1 - 2 (5 to 7 year olds).
- Key Stage 2 (KS2): Year 3 - 6 (7 to 11 year olds).
- Key Stage 3 (KS3): Year 7 - 9 (11 – 14 year olds).
- Key Stage 4 (KS4): Year 10 - 11 (14 – 16 year olds).

Programmes of study and attainment targets are set for each core subject at each KS and should be followed by schools (DfE, 2014a). The subjects mentioned in the current English national curriculum are English, mathematics, science, art and design, citizenship, computing, Design and Technology (D&T), geography, history, languages, music, and physical education. With religious education, sex education, and Personal, Social, Health, Economic (PSHE) education also being mentioned within the guidelines.

2.2.1 Routes of progression into engineering

There are a number of routes through the English education system into a career in engineering, a career route map for engineering in England devised and published by Tomorrow's Engineers is provided in Figure 2.1.

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Figure 2.1: Engineering Career Route Map - England (Tomorrow's Engineers, 2018b).

The focus of progression falls on the qualifications required at each stage of education, the first formal qualifications being taken at the end of KS4 in England. At this stage General Certificate of Secondary Education (GCSE) examinations are taken, spanning a range of compulsory subjects (including mathematics, science, and English) and optional subjects (for example a choice of humanities subjects). In addition to GCSE qualifications there are equivalent vocational examinations available, classed as work-related qualifications such as the British and Technology Education Council (BTEC) and National Vocational Qualification (NVQ), both of which offer engineering and related subjects (UCAS 2018; UK Gov, 2018).

Although compulsory education ends at the age of 16 students progress to Further Education (FE) in order to work towards a career in engineering, and students are required to study for A-Levels or equivalent (including the International Baccalaureate (IB), Apprenticeships (NAS, 2017), and appropriate NVQ and BTEC levels (UCAS, 2015)). From this stage of study, students can progress to HE, studying for degree, apprenticeship, or Higher National Certificate/Diploma (HNC/HND) qualifications in engineering or related subjects.

It can be seen that engineering does not appear as a distinct subject for many of these routes until reaching HE. As this research commenced, introduction to engineering at the national level in England was the engineering diploma for 14-19 year olds, equivalent to five GCSE qualifications and available since 2008. In the 2010/11 academic year there were 11,472 diplomas awarded in England, 19% of these were awarded for the Engineering Diploma (DfE, 2011a) corresponding to approximately 0.13% of the 14-19+ year olds in Secondary education in England at the time (DfE, 2011b). In January 2012 the Engineering Diploma was downgraded to become equivalent to one GCSE, as reported by the BBC (2012), and the criteria for the diploma in engineering was withdrawn from the UK Government website on 28th June 2017 (Ofqual, 2011).

Recently the increased focus on apprenticeships by the ESFA (Education and Skills Funding Agency) has promoted apprenticeship qualifications as a vocational route into engineering careers. According to Powell (2018), the number of apprenticeships in engineering and manufacturing technologies started in 2016/17 was 74,000. Although from the report it is unclear how many school age students were studying these apprenticeships, in the same academic year there were a total of 433,953 students aged 16 to 19 registered at state secondary schools (DfE, 2016a). The relatively small number of students progressing through vocational routes indicates that the academic route is still the prevalent educational route in England.

2.2.2 Trends in the number of students studying engineering

Looking at both the number of students applying to study engineering at university (Figure 2.2) and starting apprenticeships in engineering and manufacturing technologies in England (Figure 2.3 overleaf), there has not been a significant and sustained increase in the number of students studying engineering year on year. The number of engineering degree applications has persistently contributed 5-6% of the total number of university applications for the past seven years, and apprenticeship uptake has remained consistent since 2011/12. It should be noted that additional factors would have affected the trends visible in the data, including funding changes that have been applied to both apprenticeships and universities during the period of this research (not considered further here).

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Figure 2.2: Trend of applications to undergraduate engineering by UK domiciled applicants between 2007-08 and 2014-15 (data from HESA as reported by THE, 2016)

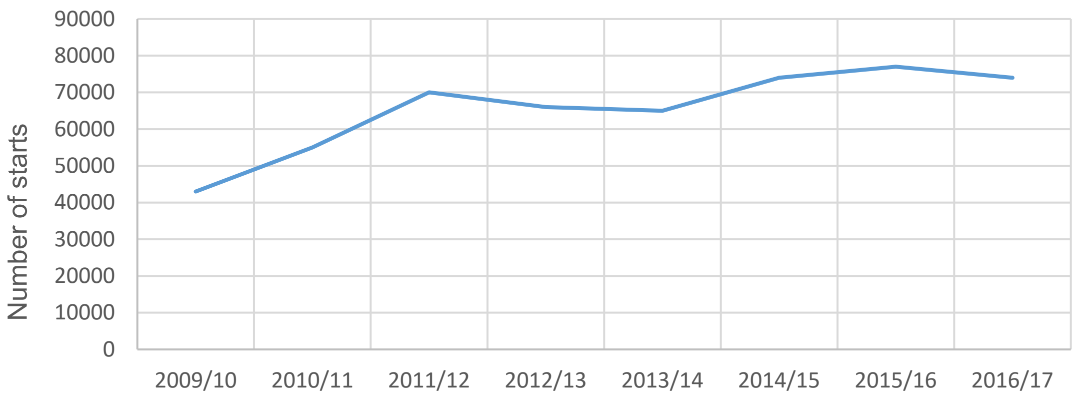

Figure 2.3: Number of engineering and manufacturing technology apprenticeships started in England each year between 2009/10 and 2016/17 (data from Powell, 2018).

2.2.3 Current provision of engineering education up to 16 years of age.

With engineering not forming part of the national curriculum, Clark and Andrews (2010a) concluded that the majority of children in compulsory education in England are reliant on an ad-hoc provision of engineering education via a “resource heavy initiative culture” (Clark and Andrews, 2010c, pg 6), which some teachers are reluctant to engage with. An overview of the provision of engineering education in primary and secondary schools in England is given by the RAEng (2016a), however with the number of students obtaining engineering qualifications at all levels remaining low (as was also discussed in Chapter 1), questions have been raised about the exposure to engineering that children receive via the education system. This is discussed further in section 2.4.

2.3 Deciding to study engineering and pursue a career in engineering

In the absence of school based engineering education, research into closely aligned (and pre-requisite) subjects such as science, mathematics, and D&T has been conducted. Although not a compulsory pre-requisite subject for many engineering undergraduate courses, the importance of achievement in D&T for developing engineering skills was emphasised by Roberts’ (2002), a link supported by the Design and Technology Association (DATA), and more recently promoted by the RAEng (2017).

A number of STEM education studies have been conducted into pre-HE education, utilising a range of methodologies to explore young people’s attitudes and beliefs regarding STEM subjects and careers; including the use of interview and survey data, (Bevins et al, 2005; Bennett and Hogarth, 2009; Haste, 2004; Archer et al., 2010), reports based on consultation with subject experts (IMechE, 2010), and mixed-methods approaches exploring teacher's views and experiences of learning and teaching STEM subjects (Murphy et al., 2005). At the time of starting this research there was a focus in the literature on the factors that influence a young person's decision to study STEM, generating a range of positive and negative factors that were considered to influence a student's decision to study STEM and aspire to STEM careers.

Research carried out by Dahmen and Thaler (2009) analysed interview data from 14 young people aged 14 – 16 years in Austria and Germany who declared an interest in SET subjects. Although only a small sample meant that generalising the findings was not possible, this work concluded that there were two key factors influencing the participants' interest in these subjects:

- Practical experiences.
- Personal connections.

The following factors were discussed by students who described themselves as interested in SET and were therefore considered as potentially important in nurturing a positive attitude towards engineering:

- Parents holding SET jobs and talking about them at home.
- Access to SET toys.
- Hands-on science lessons.
- Participation in SET based work through internships.

Approaching the same question from a different perspective, the Institution of Engineering and Technology (IET) reviewed existing literature and carried out consultations with professional bodies in the private sector, identifying five main "switch-off" factors negatively affecting a students' likelihood of continuing to study STEM subjects (IET, 2008):

- Teaching.
- Perceived degree of difficulty of STEM subjects.
- Transition from primary to secondary school.
- Gender.
- Negative perceptions and stereotypes about careers and future opportunities.

As interpreted by Clark and Andrews (2010c), the negative "pull" factors outweigh the positive "push" factors causing a net move away from engineering as a potential career for secondary school students. However, limited exploration into these factors was carried out and conclusions made recommendations for future practice rather than further research.

In 2010 the IMechE reported that student attitudes towards science rapidly drop off between the ages of 10 and 14 years, resulting in a focus on secondary level education. Academic research conducted since this time has challenged this perception, concluding that this age range may be less important than alluded to previously, and suggested that the decline in interest may actually occur later and thus not be linked directly to the transition from primary to secondary school (Archer, 2013). Through analysis of data gathered from over 19,000 surveys tracking attitudes and perceptions of students from age 10 to 14, Archer found that interest in science remains steady with only a slight drop in those thinking that they learn interesting things in science at age 13/14. However, although interest in science as a school subject persisted, the findings did identify that the number of students aspiring to a career in science did drop slightly between ages 10/11 and 12/13. This finding suggests that, although studying STEM subjects at school is a positive step along the STEM career trajectory, interest in science as a school subject does not correspond to an interest in science as a career (Archer, 2013; Archer et al., 2010). Indicating that using interest in STEM subjects as a metric to predict interest in STEM careers is flawed.

In addition, the influential IMechE report focused on science as an indicator of engineering progression, however the direct transposition of science education research findings to engineering education is not necessarily accurate. Findings from research conducted into primary school children's perceptions of SET subjects found that children in Year 5 perceived science and engineering in very different ways (Silver & Rushton, 2008). Therefore, the relationships between perceptions of science and studying science, and progressing to engineering remains unclear, highlighting the need for research focusing on this area.

2.3.1 Perception and awareness

It has been argued that "even those choosing to study engineering at undergraduate level often do so despite failing to fully understand what engineering is about" (Clark and Andrews, 2010c, pg 8). This is supported by findings from Engineering UK suggesting that in 2009 44% of 11-16 year olds held no view on engineering (ETB, 2009). This lack of awareness of engineering, and STEM more widely, by not only students but also their parents and teachers, has often been identified as a barrier to choosing to study STEM (Akam, 2003; IET, 2008, ETB, 2005; IMechE, 2010; Archer, 2013).

Also suggested as a barrier to engineering progression by the IET (2008) was negative perceptions of engineering careers. Work carried out by the Engineering Technology Board (ETB) (now Engineering UK) in 2009 suggested that at that time 11-16 year olds were the least likely age group to hold a positive view of engineering. Whilst only 18% of 11-16 year olds believed engineering to be desirable, 45% of 16-24 year olds did, and educated professionals were the most likely demographic to hold a positive view of engineering (69%). Although this could suggest improved perceptions with age, as data measuring perceptions was recorded simultaneously for all age ranges, only limited conclusions about the underlying reasons for this trend can be drawn, and would require significant interpretations by the researcher as the finding could be due to a paradigm shift between different generations.

Further reports by Engineering UK (2017; 2016; 2015) declared that improved knowledge and perceptions of STEM careers in young people and their influencers had been monitored. While this is an encouraging finding, this increase in positive perceptions has not been seen to lead to a significant increase in the number of students progressing to study engineering and the number of applications to engineering degrees and apprenticeships has remained relatively constant (as discussed in section 2.2.2). This finding may be explained by the finding of Archer et al. relating to the lack of correlation between interest in the school subject of science and interest in science as a career (Archer, 2013). It is possible that this is also reflected in engineering, as positive perceptions of engineering as a subject may not create positive perceptions of engineering as a career, or lead to studying engineering. However, without research conducted into this area, the relationship is purely speculative.

Whilst links between age and perceptions of engineering are unclear, there has been detailed research conducted into other demographic factors, with attention predominantly being paid to gender as a differentiating factor. Unpublished data from a US survey longitudinally tracking 2200 children between the ages of 12 and 14, undertaken by Adam Maltese and Robert Tai and reported by the IMechE (2010), suggested that both males and females decrease in positive attitudes towards science over this period, but that this decline is more marked for females. However, the cause of this decline remains unclear.

The exploration into young people's perceptions of what STEM careers entail is an area which is relatively unexplored in terms of qualitative understanding of perceptions. The majority of research has been aimed at quantitatively understanding perceptions of engineering based on numerical data, with both Engineering UK and Maltese and Tai (as reported in IMechE (2010)) using closed questions and Likert scale responses. Whilst information about trends in perceptions can be seen, this data alone is not enough to create a complete understanding of the topic. In 2018 Engineering UK stated that "27% of 11 to 14 year olds and 30% of 14 to 16 year olds reported an understanding of engineering in 2017, compared with 15% and 18% in 2013" (2018b, p. 65), however there is no indication of what this understanding was as participants were not asked to provide their definition of engineering. As young people have been found to hold inaccurate perceptions of engineering (Silver & Rushton, 2008; Akam, 2003) the meaning of this perceived improvement in understanding becomes less clear, and less significant.

In addition, research has suggested that interest in STEM is a more significant measure than enjoyment and positive attitudes towards STEM (IMechE, 2010, Archer et al., 2013b; Clark and Andrews, 2010a; Atherton et al, 2009). Although even this has been debated recently, with research suggesting that we need to move away from activities aimed at increasing interest to building science capital amongst families (Archer, 2013; Archer et al., 2012). Recent attention has also been given to identity as a factor affecting young people's STEM career aspirations, largely influenced by findings presented by the ASPIRES project (Archer, 2013), a five year study concentrating on young people's attitudes towards science and career aspirations using quantitative online surveys and repeated interviews with students ages 10-14 and their parents. One of the main conclusions of this work was that students who liked school science were not aspiring to careers in science due to a conflict between their image of a scientist and their image of themselves (DeWitt et al., 2013; Archer et al., 2013a, Archer et al., 2010). Further indicating that understanding the images of engineers held by young people is crucial in developing our understanding of the reasons why some children progress to careers in engineering and others do not.

Overall the current literature has focused on the positive and negative perceptions that different publics hold about engineering, however little exploration of the understanding that these groups have of engineering has been conducted, and studies have rarely included children under the age of 11 years.

2.3.2 Factors influencing children's perceptions of engineering

A number of factors influencing children's perceptions of, and progression to, STEM study have been identified in the literature, with key influencers often being cited as parents and teachers. These groups have been commonly believed to be key influencers regarding the perceptions and career aspirations held by 11-16 year olds

(ETB, 2009; IET, 2008), however the relationship between teacher and child perceptions of engineering has been challenged by research with younger children (Silver & Roberts, 2008), where the relationship was found to be unclear. The link between the perceptions of these groups is also called into question by data reported by Engineering UK who have repeatedly stated that influencers' perceptions have become more positive (Engineering UK, 2015; 2017; 2018b), yet no significant increase in uptake of engineering is visible. It should be noted that Engineering UK focus on STEM teachers, whereas research has suggested that teachers over a broader area of disciplines do not hold the same level of understanding of engineering (CISI, 2014).

This indicates that other factors affecting children's progression into engineering have more significance, and that young people may be using areas other than school to inform themselves about engineering. Since the commencement of this research Archer et al. (2014a, 2015) have developed the use of "science capital" as a theoretical lens for understanding student's science aspirations and educational participation (Archer et al., 2012), building upon the Bourdieusian concept of cultural capital (Bourdieu, 1986). Accounting for all of the experiences, attitudes, resources, and knowledge that a person gains throughout their life (KCL, 2018), this theory locates the influencers identified in earlier research within a web of exposure to science, illustrating the complex process of knowledge and interest generation that leads to progression to career aspirations in science.

The importance of the role of the school perseveres in the literature, as conclusions of research and recommendations from reports often highlight the need for better teaching quality and changes with the education system to improve the uptake of engineering education at undergraduate level (RAEng, 2016a; IMechE, 2010; Akam, 2003; IET, 2008; Clark & Andrews, 2009). However, the use of teaching quality as perceived by the students has been cautioned against by the findings of Dahmen and Thaler (2009), as it appeared that students were more positive about teachers they liked rather than considering the quality of education they received.

In addition to these 'key factors', there has been exploration into the media's role in building STEM career aspirations. Although the majority of these studies have focused on science (Nisbet & Dudo, 2013; Steinke, 2005), Dahmen and Thaler (2009) did evaluate the portrayal of SET in Austrian and German youth magazines, however in this work no attempt was made to relate these portrayals to young people's perceptions. Similarly, Holbrook et al. (2009) investigated the portrayal of engineers within children's fiction in one area of Australia, finding that although there was limited portrayal of engineers within the books, this medium had the potential to inform young people about engineering. Again, this work did not involve exploration into children's perceptions of engineers/engineering, and so there remains a scarcity of information regarding the influences that children and young people drawn upon to create their perceptions of engineering.

2.4 Engineering education provision for schoolchildren in England

As no framework for monitoring the provision of engineering education through independent initiatives exists, it is difficult to gain a coherent picture of what is being offered to schools and schoolchildren across England. Provision is likely to vary as activities have evolved largely in response to UK Government reports highlighting the need for a STEM skilled workforce (Roberts' 2002; DfES, 2006) and influential reports published by PEIs who have highlighted the need for an increased number of engineering skilled graduates (for example, IMechE, 2010; RAEng, 2012). The resulting industry offers activities that vary in size, form, and funding; from national initiatives, supported by public funding or professional fees, such as the Big Bang Fair[2] and the STEM Ambassador programme[3], to activity provision funded by a range of public and private sources, delivered by independent organisations and individuals, some of whom are registered on the STEM Directories[4].

This range of provision led to the term 'informal education' being used to define activities which take "place outside the classroom environment" (The Parliamentary Office of Science and Technology, 2001, pg. 1) and which "enrich and add value to their [students'] school experiences" (pg. 1). While the majority of EEAs would be classed as informal education, there are also formal education activities being delivered by teachers within the classroom. As the focus of this study is on educational experiences that take place within the school environment, it will include both formal and informal education.

There is no requirement to track that number of pupils being engaged with EEAs nationally, and, although individual providers are likely to maintain records, currently there appears to be no complete record of the total number of children in England

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[2] The Big Bang Fair is an annual event that began in 2009. It is described as a "celebration of STEM for young people in the UK" (Big Bang Fair, 2018)

[3] The STEM Ambassador programme creates opportunities for young people to meet volunteer ambassadors from STEM industries and backgrounds (STEMNet, 2013).

[4] The STEM Directories, initially a printed book but now only available online, is a compilation of STEM providers and activities available to UK schools and communities.

reached by EEAs each year. In addition, as a number of activities brand themselves as STEM activities, it is not always clear what level of engineering is involved, for example in 2012 there were 17722 STEM Ambassador profiles online however not all Ambassadors are linked to engineering; 40% stated an interest or specialism in engineering (STEMNet, 2013). There is also no guarantee that schools engage with these activities, as research suggested that although many schools are aware of the opportunities for STEM activities, only a small proportion actively engage with them (Clark and Andrews, 2010c), with uptake being reliant on ‘champions’ within schools (Clark and Andrews, 2013). In addition to this, findings from a review of STEM intervention activities provided in the UK suggested that some interventions are provided to “selected or self-selecting groups of pupils” (RAEng, 2016a, p. 42), which may also have implications for the diversity of students participating in EEAs.

This unstructured, unmonitored delivery has led to questions about the effectiveness of the provision of engineering education in response to the STEM skills shortage (Hoyle, 2016; RAEng, 2016a) and industry has concluded that changes being introduced to tackle the shortage of STEM graduates are not occurring fast enough (CBI, 2012). Although this indicates that there is concern about the outcomes of the current provision, without a clear picture of what is being provided and what the outcomes of participation are, it is impossible to understand the situation fully; changes to practice and provision must be informed by evidence in order to be effective, and currently this evidence is lacking.

2.4.1 Evaluations of EEAs

Issues with evaluation of individual EEAs, and the lack thereof, have been highlighted in the literature, with research conducted into the STEM Directories (Bultitude et al., 2010) suggesting that 94% of providers from the Directories regularly evaluated their activities but do not appear to make their methods of evaluation visible. Searching activity provider websites resulted in a number of providers stating the ‘number of people engaged’ with the activity each year as their only visible metric used to evaluate the efficacy of the activity (see for example The Big Bang (2018), The Smallpeice Trust (2012), Primary Engineer (IMechE, 2015), and Young Engineers (2012)).

Evaluative reports published by providers tend to be produced in-house and concentrate on quantitative measures of outcomes, gathered from data collected using surveys and questionnaires administered to participants immediately after the activity. Examples of this include evaluations carried out by The Smallpeice Trust (2011), and IET Faraday (2016; 2017). External evaluations of activities have begun to be conducted, although these have also tended to focus on quantitative measures (NFER, 2013; Lauchlan, 2017; Archer et al, 2014a; Banerjee, 2017). Conclusions from these studies have been mixed, research into participation in activities involving STEM role models concluded that involvement led to increased STEM career aspirations and enjoyment of science (NFER, 2013), conversely other research has concluded that participation in STEM activities during secondary school has no measurable impact on continuation of participation in STEM (Banerjee, 2017). Similar findings were presented in an evaluation of a one-off engineering activity delivered to secondary school students during Year 7, where no measurable impact on the children's attitudes to STEM subjects was visible after participation (Lauchlan, 2017). Yet research conducted in Australia concluded that participation in a one-off STEM activity (the Australia Challenge) for children in Year 11 and 12 (age 15-17) influenced the students' decisions to study mathematics, chemistry, and physics (Campbell & O'Connor, 2009). However, data was only collected from those students who had progressed to study science and mathematics, and no attempt was made to explore whether they would have continued to study these subjects had they not participated in the activity.

Direct comparison of these findings is not appropriate, as each focuses on different activities that had a different focus and required different timeframes of participation (one-off daylong activities, weekly club participation, and intensive programmes of up to six weeks), however this does illustrate the potential impact that the mode of delivery has on the outcomes of participation.

Much of the evaluation conducted in the UK has been focused on specific demographics, as widening participation and encouraging minorities into engineering and STEM more widely has been seen to be a priority (Read, 2008; Harrison, 2009; Smallpeice Trust, 2011; Archer et al., 2014a). These evaluations have mainly been conducted in the short term, concentrating on the immediate feedback gained post participation, and have been seen to present an increase in positive attitudes towards STEM after participation in a STEM activity (NFER, 2013; Archer et al., 2014a; Lauchlan, 2017). However, in the work of Lauchlan (2017) this increase in positive attitude did not indicate a measurable impact of participation, and Archer et al. (2014a) concluded that although attitudes towards science were improved, along with an understanding of where science could take the students, science career aspirations were not increased. Therefore, findings are beginning to indicate that attitudes towards engineering may not be an appropriate metric to predict progression into engineering careers.

In addition, although Lauchlan (2017) alludes to a longitudinal element, the post-test survey was conducted approximately 2 months post-participation, and so there are still unanswered questions regarding the long-term influence that participation has on students. A recent study did investigate the influence participation in STEM intervention activities at KS3 and KS4 had on studying STEM subjects at AS and A-Level and revealed no correlation, suggesting that participation did not increase the likelihood of a student progressing to study STEM post compulsory education (Banerjee, 2017). However, it should be noted that Banerjee could not guarantee that the control group used had not engaged with any STEM intervention activities, meaning that the conclusions drawn from the study should be treated with caution.

2.4.2 When should we be introducing children to engineering?

The majority of early studies into pre-HE engineering education were carried out focused on secondary school students, even though a retrospective study carried out by the Royal Society in 2004 found that a small but significant proportion of those people working in STEM began thinking of their career before the age of 11 (28% of 1141 respondents). Additional research into career aspirations more generally has also suggested that children begin forming their career aspirations before the age of 11 (Atherton et al., 2009), a finding supported by research conducted by Archer et al. (2010), that concluded that children are eliminating STEM careers before they transition to secondary school, and have fairly fixed career aspirations regarding STEM by the middle of secondary school (Archer et al., 2014a).

The importance of the age at which children are introduced to engineering was highlighted by work in the USA. Tracking school children's career expectations and progression it was concluded that students who expected to have a career in science at the age of 12-14 years were 3.4 times more likely to earn a physical science or engineering degree than students who did not hold similar expectations at this age (Tai et al., 2006). This finding has also been supported more recently, as Miller et al. (2017) found that, in the USA, interest in STEM remains consistent for students across their time at high school. A recent longitudinal study into participation in STEM activities in the UK (Banerjee, 2017) suggested that although there appears to be no significant influence of participation in STEM intervention activities during secondary school, earlier intervention during this stage of education (at KS3 only) has a greater positive effect on progression into STEM subjects than later intervention (KS4 only). With GCSE subject choices occurring at the age of 14 (end of KS3) engaging students with STEM activities during KS3 appears logical. Therefore, whilst the general significance of the factors mentioned above is not necessarily under debate, the lack of exploration into the factors affecting younger children's career aspirations and progression into STEM, limits the holistic understanding that the EER community holds. This potentially prevents the development and implementation of effective strategies for encouraging increased numbers of students to study engineering.

The findings of the research discussed above indicates that engineering needs to be introduced earlier than secondary school, and the focus of activity provision does appear to be moving from secondary school to primary school (the IET began a primary strand of their education programme, IET Faraday in 2017, and the IMechE became involved with Primary Engineer in 2014). Nevertheless, the idea that focus should be paid to the 11-14 age group persists, and in 2015 Engineering UK, a major provider and voice in the field of EEAs, called for the "continued improvement in the co-ordination, quality, reach and impact of engineering outreach activity" (2015, pg.XII) with the focus on career inspiration for 11-14 year olds. In order to move away from this perception, research needs to be conducted focusing on engineering education at primary school, in order to broaden the understanding of providers, PEI's, and industry as well as the research community. This age group has not previously been the focus of research into engineering education and a scarcity of literature existed when this study began.

2.5 Summary

This critique of the available literature has indicated that the current provision of EEAs is inconsistent, unregulated, and is not empirically supported. Additionally, it can be argued that the current provision of engineering education is not achieving the desired effect of increasing the number of students progressing to study engineering at HE level. Research that has been conducted into the field of formal engineering education has concentrated on undergraduate level, and evaluations of intervention or teacher led activities are scarce, with those available focusing on secondary school students and minority groups. With recent literature indicating that children may be eliminating engineering as a career whilst in primary school, it is imperative that research be conducted to understand this area of engineering education more fully.

In order to add original, meaningful knowledge to the field, this research focuses on EEAs delivered to primary school children in rural areas of England. This constitutes a gap in the existing literature and has the potential to contribute significant knowledge about the efficacy of the current model of delivery of EEAs in achieving the broad aim of increasing the number of students progressing to study and work in engineering. Due to the lack of literature in the area, an exploratory study was deemed necessary. In the following chapter the research question drawn from this focus, the methodology adopted, and approach taken in order to fill this gap in knowledge are presented.

CHAPTER 3

3 Research Design

3.1 Introduction

This chapter sets out the research questions asked by this study and the procedure through which the study sought to answer those questions. The approach encouraged by Punch (2009) of viewing two different stages of research, pre-empirical and empirical, is utilised to enable clear articulation of all aspects of the design of this research. To provide the context of this study the conceptual framework derived from the conclusions of the literature review is presented, along with the research questions, aims, and objectives. The research design is then presented, linking the philosophical approach (pre-empirical stage) to the methods employed (empirical stage). Finally, issues of ethics and validity are discussed to provide a solid foundation on which to present the research data, findings, and conclusions in the remaining chapters of this thesis.

3.2 Conceptual framework

A conceptual framework states the key concepts that guide a research study (Imenda, 2014; Miles & Huberman, 1994), providing a link with the concepts (identified from the literature) that support the need for the research (Rocco & Plakhotnik, 2009). The conceptual framework guiding this research was created following the review of the literature (presented in the previous chapter), where key concepts believed to affect a child's engineering career aspirations were identified. Integrating the published literature findings led to the child being the focus of the research, with three conceptual domains influencing their engineering career progression: Engineering Perceptions, Family Engineering Capital, and Engineering Education.

- **Engineering Perceptions**

The literature indicated that perceptions regarding STEM and STEM careers were a key factor predicting a child's progression into STEM study, therefore this became the first concept in the framework. Perceptions of engineering (mainly in the context of STEM) were discussed in the previous chapter, and it was seen that different groups of people hold different perceptions depending on their age and experiences. Therefore, this conceptual area includes perceptions of engineering including, but not limited to, a child's own perceptions. Within this concept are both children's perceptions of engineering and their perceptions of engineering careers, these are distinct areas as interest and understanding of a field does not necessarily correspond to an interest in a career in that field, illustrated by the work of Archer et al. (2014a).

- **Family Engineering Capital**

The second concept in the framework is that of family engineering capital, based on the adaptation of Bourdieu's theory of Social Capital to Science Capital by Archer et al. (2012, 2013a) and a term used by Cottrell (2015) and Andrews and Clark (2017). Archer et al. (2013a, p.176) describes family science capital as "the material and cultural science-related resources that a family may be able to draw on, such as science-related qualifications, knowledge, understanding ('scientific literacy') and social contacts", and argue that science capital shapes a child's career aspirations (Archer, 2012). From this perspective it is not unreasonable to assume that a similar situation arises for engineering, where family engineering capital is seen as a concept influencing the child's awareness of and aspirations to a career in engineering. Therefore, this conceptual area includes the role models, family networks, and social resources relating to engineering to which a child has access and this work defines Family Engineering Capital as the resources available via a child's family through which the child experiences engineering.

- **School Based Engineering Education**

The third concept in the framework is school based engineering education. The previous chapter illustrated that at present engineering does not exist as a standalone subject within the national curriculum in England, that an intervention approach to engineering education exists and that only a minority of children study engineering as a vocational qualification during compulsory education. The episodic nature of this provision of engineering education was highlighted, and although the influence that this concept has on a child's awareness and aspirations to engineering careers is unclear, significant resources continue to be devoted to this endeavour and formal education remains a key factor within the literature (Andrews & Clark, 2017; RAEng, 2016a)

- **The Child**

The "child" represents the interlinking concept, sitting centrally to the framework. In the UK a child is defined as "anyone who has not yet reached their 18th birthday" according to the Children Act 1989. Historically, children were seen as 'other' and research was carried out 'on' them rather than 'with' them (Danby & Farrell, 2004; Kirk, 2007). However, the United Nations Convention on the Rights of the Child (UN, 1989) changed the way in which children's voices were heard, especially within the research community, and children were encouraged to comment on their own lives (James & Prout, 1990). Research now acknowledges that children are "articulate social actors" (James, 2007, p.261), and Kirk (2007) argues that they exist in their own social, temporal, and cultural worlds making it is impossible for an adult to share a child's view of reality (Kellet, 2010; Punch, 2002; Mayall, 2002). This results in the need to involve children within research about their experiences, rather than obtaining the views of adults about the experiences of children (Jorgenson & Sullivan, 2010; Stark & Freishtat, 2014; Nolan et al., 2013; Kirk, 2007; Unicef, 2007). Graham & Fitzgerald (2010) argued that by failing to listen to children's voices adults are blind to their experiences of life.

These domains are combined within a conceptual framework presented in Figure 3.1, whilst the literature does not clearly define the interplay of these concepts it appears that a positive combination of all of these elements increases the likelihood that a child will aspire and progress to an engineering career. Although this research has focused on the educational aspect of this conceptual framework, it acknowledges that a child's education does not occur in isolation from the Family Engineering Capital and perceptions of engineering to which the child is also exposed, however the exact nature of how these domains interact is unclear.

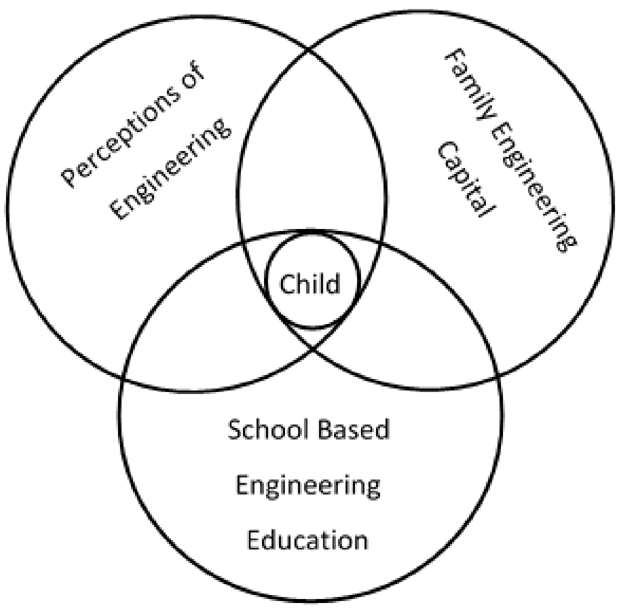

Figure 3.1: Conceptual framework illustrating the core domains affecting a child's progression to an engineering career, derived from a review of the literature.

3.3 Research questions

A critical review of the literature identified a significant gap in knowledge regarding our understanding of the outcomes and efficacy of engineering education prior to the age of 11. The critique also revealed that children's understanding of engineering is not well examined, especially in contexts outside of widening participation, but that this understanding may have a significant influence on a child's career aspirations and progression.

In order to address this gap in the knowledge, the main research question to be answered by this research is:

How does participation in an engineering education activity at age 9-10 (Year 5 in England) affect children's perceptions of engineering as a career at age 11-12?

To answer the main question the following sub research questions will be addressed:

- What are children's experiences of engineering activities at age 9-10?
- Having been involved in an engineering education activity at age 9-10 what are children's views of engineers and engineering at age 11-12?
- Having been involved in an engineering education activity at age 9-10 what are children's views of engineering careers at age 11-12?

3.4 Research aims and objectives

The aim of this research is to conduct a critical investigation into the effect of engineering education activities on children's views of engineering.

In order to satisfy the aim of this research and answer the research question, the research has the following objectives:

- Gain an understanding of the child participant's experience of engineering education activities in Year 5.
- Gain an understanding of the effect that participation in such an activity has on a child's perceptions of engineering as a subject and career over three years.
- Critically analyse a child's experience of an engineering education activity identifying the bearing that this may have on their progression into an engineering career.

- Build a conceptual framework regarding a child's participation in engineering education activities at age 9-10 to address the main research question.

The remainder of this chapter presents the design for how this research set out to achieve these objectives and answer the research questions.

3.5 Overview of the research design

An overview of the philosophical perspective, methodology, and methods employed in this study is given in Figure 3.2. Summaries of the relationships between these topics can be found in the literature regarding research methods, which are drawn upon throughout the following chapter (see Gray, 2014; Denzin & Lincoln, 2011; Cohen, Manion & Morrison, 2008; Punch, 2009; Shipman, 1997; Guba & Lincoln, 1994).

Ontology	Relativism – subjective, reality is local to the individual.
Epistemology	Subjectivism – Knowledge is individually constructed and is context bound.
Paradigm	Constructivism – Individuals construct their own reality and their interpretations need to be understood to understand an occurrence.
Methodology	Case study using a grounded theory approach to data collection and analysis.
Methods	Observations, interviews, constant comparison analysis.

Figure 3.2: Overview of the philosophical structure of this research, drawing information from Punch (2009), Denzin & Lincoln (2011), and Cohen et al. (2008).

The importance of making the research design explicit is due to these relationships, as the philosophical stance taken by a researcher defines what is to be researched, how it is to be researched, and what is to be found. Thus affecting the methodology and methods chosen to conduct the research. Therefore, philosophical decisions taken at the outset of a research project have a bearing on the research as a whole, including the knowledge created as the output of the research and the validity of that knowledge. Consequently, each of these topics is discussed in relation to the literature and the current research to provide a clear justification of the rationale behind the research and the validity of the claims made by the research.

This research adopts a constructivist stance and therefore utilises a qualitative approach, focusing on understanding the experiences and perceptions of children in order to develop a conceptual framework regarding their participation in EEAs, meaning that methods appropriate to collecting and analysing in-depth, qualitative data were required. A case study methodology, using a grounded theory approach to data analysis has been used to explore the experience of participation in an EEA from the children's perspective. The collection of data from multiple cases allowed concepts to be compared and thus enabled the development a conceptual framework that, although not generalisable, is grounded in the experiences of the participants within this study.

3.6 Methodological approach to the research

Research methodologies were considered, these are concerned with the overall approach taken in a research study, they take into consideration philosophies of reality and knowledge to define the research design and identify appropriate research methods (Cohen, et al., 2008; Punch, 2009; Maxwell, 2012). Hesse-Biber and Leavy (2010, p. 6) describe the methodology of a study as the "bridge that brings our philosophical standpoint (on ontology and epistemology) and method (perspective and tool) together". Consequently, prior to discussing the methods this research has employed, it is important to understand the philosophical stance from which the research is conducted.

3.6.1 Philosophical perspectives – our assumptions as researchers

All research contains assumptions, at a fundamental level these are assumptions about our reality (our ontology) and our acquisition of knowledge (our epistemology) (Creswell, 2014; Denzin & Lincoln, 2011). The following discussion is drawn from a range of work including Denzin & Lincoln (2011), Grix (2010), Punch (2009), Cohen et al. (2008), and Bryman, (2004).

Theories of ontology and epistemology help us to understand how we view and make sense of the world; our ontology concerns our views on existence and reality, our epistemology concerns our understanding of what constitutes knowledge and how it is created (Cohen et al., 2008; Punch, 2009). Therefore they have consequences for how research is conducted and it is important to make a researcher's ontology and epistemology explicit at the outset of a research study; the underlying assumptions not only guide their research design but also allow others to view the rationale of a research project much more holistically (Grix, 2010; Carter & Little, 2007).

Two prevalent ontological perspectives that have shaped the research community are realism and relativism (Ritchie et al., 2013; Cohen et al., 2008), the key features of both are shown in Table 3.1. Two contrasting epistemological theories persist within the literature; objectivism and subjectivism (Cohen et al., 2008; Waters & Mehay, 2010; Punch, 2009). An outline of their features is given in Table 3.2, a detailed analysis of the strengths and weaknesses of these epistemological perspectives can be found in the work of Cohen et al. (2008) and Denzin and Lincoln (2011).

Table 3.1: Comparison of the two dominant ontological perspectives (adapted from information in Grix, 2010; Punch, 2009; Cohen et al., 2008; Bryman, 2004)

Critical Realism	Objective	• Reality is “out there”, waiting to be discovered. • Reality is universal.
Relativism	Subjective	• Reality is local to the individual. • Reality is constructed uniquely by each individual.

Table 3.2: Comparison of two contrasting epistemological perspectives (created from information in Cohen et al., 2008 and Denzin & Lincoln, 2011)

Objectivism (foundations in Realism) Discover new knowledge	• Knowledge is external and is therefore universal and is stable across contexts and individuals. • Uses observation and reason to understand behaviour. • Explains phenomenon via scientific description. • Objectivity and measurability. • Understanding a phenomenon from outside it.
Subjectivism (foundations in Relativism) Create new knowledge	• Knowledge cannot exist without individuals to construct it, therefore there are multiple realities. • An individual’s reality is based on their interpretations of factors which are shaped by the culture in which they exist. • Explanations of phenomenon are contextually bound. • Individual understanding and interpretation. • Understand a phenomenon from within it.

Mason (2002) encourages the researcher to ask questions of themselves during the early stages of research design, uncovering the ontological and epistemological perspective of the researcher in order to understand how the research can be designed and conducted congruent with the assumptions inherent within the researcher. When considering views on reality and knowledge the researcher began by considering her understandings of self, notes made in her research journal on the topic of reality helped reflection on her own perspectives. The passage below describes a view of multiple representations of 'self' existing alongside each other depending on whose perspective is being used as a 'lens', emphasising the researcher's subjectivist assumptions about the world.

> *There are many ways to define one's 'self'. These can be from the point of view of the individual or from the community they exist in. There is not one single 'self' rather there are many interpretations of self, depending on whose perspective is used e.g. I define myself as […] but my friends may define me differently and society differently again. I use personality traits as definition and how I exist in society, others may use different markers such as social standing or material belongings.*
> (Research journal, March 2015)

The emphasis on the subjective nature of reality that surfaced in the researchers' reflections on reality align with a relativist ontology and a subjectivist epistemology. Therefore, a subjectivist epistemology was adopted within this research, following the lead of social scientists in acknowledging the researcher's place within the world and their research, employing reflexivity to continually acknowledge and 'check' their subjectivity throughout the research (Rossman & Rallis, 2003; Finlay & Gough, 2008). This need for the researcher's involvement in the research is also highlighted by Shipman (1997), although he approaches the process of identifying the philosophical underpinnings of a research study in a more pragmatic way, he raised an important question about objectivism in social research; is it possible for researchers to be detached from their research, to be 'objective'? Although we can aim to be open minded we are reminded by Dey (2007, p.176) that "we should not confuse an open mind with an empty head", therefore it should be acknowledged that prior to starting this PhD, the researcher had worked in the area of engineering education for many years and harboured an inherent interest in the field of study.

In keeping with the subjectivist perspective, and aligned with the view that the researcher should "state and make clear who you are" (Rossman & Rallis, 2003, p.36), a reflection upon the researcher's own experiences of engineering education as a child was required in order to provide a clearer understanding of the motivations and assumptions which drive this research. As explained in section 1.5, the decision to study engineering did not come from an experience within the education system, although the researcher did attended taster days for engineering at universities when considering engineering degree programmes, prior to FE she could not recall participating in any EEAs at school.

3.6.2 The research paradigm

Moving forwards from philosophical perspectives, a research paradigm draws together the ontological and epistemological assumptions to form a framework within which research can be organised. The main research paradigms acknowledged in the literature include positivism, post-positivism, critical theory et al., constructivism, and participatory action (Denzin & Lincoln, 2011, p.91). Discussions concerning the prevalent theoretical perspectives can be found in the literature, see Burr (2015), Ritchie et al. (2013), Denzin & Lincoln (2011), Waters & Mehay (2010), Collins & Hussey (2009), Punch (2009), Cohen, Manion & Morrison (2008), and Guba & Lincoln (1994), providing a detailed insight into the range of research frameworks, and therefore the range of structures that research studies can take.

Whilst the literature presents an array of paradigms and terminology, the convergence of these within education research described by Punch (2009) is used in this research for clarity and brevity. Punch argues that there are three main philosophical paradigms utilised within education research, positivism, interpretivism, and constructivism. A summary of the key features of each are given in Table 3.3, from which it can be seen that each paradigm aligns to a specific ontology and epistemology.

Having reflected on my own ontology and epistemology, and the aim of this research (exploring the views of individuals), a constructivist paradigm was considered consistent with both the overarching aim of the research and the philosophical stance of the researcher. Whilst it is clear that positivism is not appropriate, as it aligns with assumptions about reality that are not shared by the researcher or the aims of the research, the differentiation between interpretivism and subjectivism was not so clear. The decision to adopt a constructivist paradigm came through careful consideration of the paradigms and the research itself, as described on the following page, with the implications of this choice discussed in the following section.

Table 3.3: Key research paradigms (adapted from information in Punch, 2009, p. 18, Guba & Lincoln, 1994, and Schwandt, 1998)

Positivism	Reality is objective. Knowledge is discovered.	Realism Objective	Explaining (Erklären). Nomothetic knowledge.
Interpretivism (Dualist)	Focus on the meaning that people bring to situations that they use to understand the world. Knowledge is discovered through an individual's perspective.	Relativism Subjectivist	Understanding (Verstehen). Idiographic knowledge.
Constructivism (Non-Dualist)	Reality is constructed by the individual based on their experiences. Knowledge is created by the individual.	Relativism Subjectivist	Understanding (Verstehen). Idiographic knowledge.

From Table 3.3 it can be seen that interpretivism and constructivism share similar philosophical underpinnings, however there is a subtle difference between them. Punch (2009, p.18) describes the difference between them as the difference between "calling them as you see them" (interpretivism) and "them being nothing until you call them, then that's what they are" (constructivism). That is to say that interpretivism is a dualistic paradigm that conceives a mind-independent reality whilst acknowledging that individuals access this reality through their own perspective, whereas constructivism advocates that there is only the individually create reality, that knowledge is created based on perspective and that there is no "external" reality to discover. Using this differentiation we can deduce that interpretivism views knowledge as being discovered through an individual's own perspective, and constructivism views knowledge as being created within the individual's mind, therefore giving meaning to a situation through an individual's created reality of it. Yvonna Lincoln and Egon Guba clarified the constructivism paradigm further, and it is their work that has influenced the research paradigm informing this study. Initially discussed as “naturalistic inquiry” (Lincoln & Guba, 1985) and later acknowledged as a “constructivist paradigm” (Guba & Lincoln, 1994), constructivism is based on an assumption that reality is constructed in the human mind and is therefore plural and relative; there can be multiple meaningful constructions of a single event (Lincoln & Guba (1985) discussed by Schwandt (1998)).

Discussed frequently within the literature is the use of constructivism and social constructivism, especially in relation to learning and teaching (Amineh & Asl, 2015; Hodson & Hodson, 1998). Whilst the foundations of the two differ, constructivism is linked to psychology and social constructivism to sociology, the main difference between the two appears to be the environment in which individuals construct knowledge, Amineh and Asl (2015) reviewing the literature to argue that constructivism focuses on the individual and social constructivism emphasises the social context of knowledge creation. However, when consulting Guba & Lincoln (1994) their definition of constructivism includes both social and experiential construction of knowledge and concedes that although the individual constructs their own knowledge, “elements are often shared among many individuals and even across cultures” (p. 110). Therefore, constructivism as defined in this way is considered the most appropriate paradigm for this research as it allows for the social construction of knowledge but is not limited by this assumption.

The constructivist paradigm has implications for any research study, the fundamental tenet of constructivism being that reality is unique to the individual who constructs it. The implication of this paradigm is not only that children construct their own reality of participation in an EEA, but also that the researcher reconstructs this reality through the creation of knowledge from the data collected. Whilst it is therefore important to use appropriate methods to gather data relating to the participants’ constructions of reality, awareness of the researcher within the research is required.

3.6.2.1 Critique of constructivism

As stated above, the constructivist paradigm postulates that even though knowledge may be shared across different groups of individuals, knowledge is constructed in the mind of the individual (Guba & Lincoln, 1994) and therefore we cannot understand the reality of another without exploring the meanings that they give to a situation (Lincoln & Guba, 1985; Denzin & Lincoln, 2011). However, there are issues associated with revealing another’s reality and there arise two central criticisms of this paradigm when used in research:

1. Inequalities of power exist between individuals, this makes uncovering a person's own view, rather than that of the people in power around them, challenging (Nolan et al., 2013; Davis, 1998; Morrow & Richards, 1996).
2. Issues of authority exist as the interpretation of data during collection and analysis is shaped by the researcher's philosophical perspective and assumptions (Glaser, 2002; Arksey & Knight, 1999; Lincoln & Guba, 1985).

The implications for investigations conducted using this paradigm therefore culminate in an issue of voice, and thus validity. As the aim of this research is to understand the children's experience, it is their voice that needs to be heard, where the researcher's voice (views and perspectives) is heard above that of the participants validity of the findings is undermined (Lincoln et al., 2011). For this reason steps need to be taken to reduce the impact that inequalities of power and issues of authority have on the research itself. This is discussed later in this chapter in the context of this study in relation to the research methods used (section 3.8) and the validity of the conclusions drawn (section 3.10).

3.7 The research design – methodology and methods

Sometimes referred to as 'research approach' (Creswell, 2014), the research design provides the logic for how a research study answers its research question (Yin, 2014; Mason, 2002). For this reason it is important to link the research design with the research perspective in order to maintain validity (Grix, 2010; Carter, 2007). Considering the subjectivist epistemological perspective adopted in this research it is assumed that individuals construct their own reality through their experiences (Punch, 2009) and that human beings have ingenuity and do not obey a set of rules of being (Shipman, 1997), therefore there will always be factors which cannot be controlled by researchers.

As the individual's experience is sought in this research, a qualitative research approach was chosen for this research, allowing the participants' experiences to be explored through the researcher's interpretation of their world, as Denzin & Lincoln (2011, p.3) explain:

> *Qualitative research is a situated activity that locates the observer in the world. Qualitative research consists of a set of interpretive, material practices that make the world visible.*

There are a number of different methodologies associated with qualitative research, including narrative research, phenomenology, grounded theory, ethnography, and case study (Creswell & Poth, 2017). Methodology decisions took into consideration the ultimate aims of the research, the research question to be answered, and the research participants to be involved.

Ethnographic research advocates immersion within the world of the participants in order to understand the phenomenon of focus from a co-constructed reality created from personal interactions and observations (Punch, 2009). This was rejected as a methodological approach early on due to the limited contact time that the researcher was able to have with the child participants. As stated in section 3.3, this research aimed to answer the question of how participation in an EEA affects children's perceptions of engineering careers through the construction of a conceptual framework regarding participation. This required progression from descriptive outputs of research that narrative research and phenomenology tend towards (Ary et al., 2014; Creswell, 2014), and therefore these methodologies were not deemed appropriate in validly achieving this objective of the study. Whilst a variety of approaches were considered, to achieve the aim of this study a grounded theory approach to data collection and analysis was used within a case study methodology, this design created a study that explored children's participation in engineering education using a systematic approach in order to develop an understanding of participation grounded in the data collected.

Case study methodology was chosen as a strategy to inform the structure of the research, allowing for the recruitment of cases where children were participating in EEAs, without dictating the exact methods of data collection and analysis (Yin, 2014; Longhofer et al., 2017). To allow key concepts relating to the children's experience to be constructed and related to each other in order to develop a conceptual framework regarding their participation and thus address the main research question, grounded theory methodology was chosen. Developed by Glaser and Strauss (1967), grounded theory methodology encourages 'rich' data to be collected from purposively sampled participants, and analysed in order to identify concepts within the data and links between these concepts (Glaser & Strauss, 1967). Ultimately, grounded theory describes the world of the participants using data collected from the participants (Creswell, 2014; Punch, 2009). Both of these methodologies are now discussed in the context of their use within the current research.

3.7.1 Case study research

Case study research as defined by Yin (2014, p. 2) involves the investigation of:

> *a contemporary phenomenon (the "case") in its real-world context, especially when the boundaries between phenomenon and context may not be clearly evident.*

Yin (2014) describes different forms of case study including single and multiple cases, and embedded or holistic cases. Using a graphical representation employed by Yin (2014), the current study can be represented as two holistic, distinct cases, located within the same context, as shown in Figure 3.3, and can therefore be described as a multiple-case study (Yin, 2014). The contexts of the cases in this study are explained later in this chapter, when the two cases are defined.

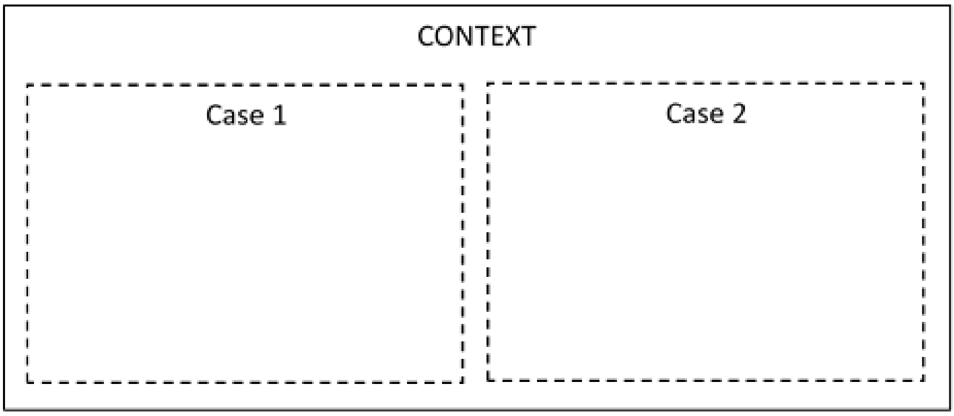

Figure 3.3: Visualisation of the multiple case research design (based on the work of Yin, 2014).

The decision to conduct a multiple-case study was taken due to the context specific nature of case study findings (Shipman, 1997), the strength of a multiple-case study comes from a cross-analysis between cases, identifying the similarities and differences between cases which allows the researcher to identify factors which are context specific (Yin, 2014). In this research the cases are treated separately in terms of data collection and initial analysis, and the findings from each case are then compared within a meta-analysis presented in Chapter 6 of this thesis. In this way, case specific concepts can be identified within the analysis, thus developing our understanding of the outcomes of participation in EEAs through concepts emergent from the participants' experiences.

3.7.1.1 Selecting the cases

As can be seen in Figure 3.3, the context and the cases need to be defined, bounding those who are included in the case and those who are outside of it (Yin, 2014). The use of the word 'case' rather than 'sample' is advocated in case study research due to the focus on context associated with case study research and the unwanted statistical generalisation connotations associated with the word 'sample' (Yin, 2014; Shipman 1997). This terminology is used within this thesis, however 'sample' is used to refer to the participants within each case, although this is not intended to convey statistical generalisation.

Yin defines the case as being "some real-life phenomenon that has some concrete manifestation" (Yin, 2014, p.34), the focus in this research is children's experiences of participation in an EEA within the school environment and therefore the following context for research cases was defined:

Organisations providing engineering education activities within the school context to children aged between 9 and 10 years, who attend rural schools.

The process for selecting the cases began by approaching organisations (both schools and external providers) who facilitated or delivered EEAs for children of the required age within the specified context. In total, initial contact was made with twenty-nine individuals/organisations who were identified through internet searches, providers known to the researcher, and local schools. All contacts were made based on a comparison of the case context specified above and the description of the activities provided (drawn from websites and first-hand experience). This group comprised one local council, two museums, one industry education centre, one interactive science centre, one engineering professional institution (who delivered two different engagement activities), two national engineering activities, thirteen schools/teachers, and seven STEM outreach providers.

Responses were received from fourteen of the individuals/organisations contacted, of these seven declined the opportunity to participate. The reasons for this are varied and can be found in Appendix B. From the remaining seven potential cases, four were eventually unable to participate, one created the opportunity to pilot the researcher's observation skills, and two schools became the research cases for this study and are known by the pseudonyms of Nant School and Phren School within this research.

3.7.1.2 Defining the cases and the sample within each case

Full details of the two cases that participated in this study are given in Chapter 4 and Chapter 5, and an overview is provided in Table 3.4. Congruent with the conceptual framework for this research (Figure 3.1) the principle participants within each case are children, a full list of the child participants within each case can be found in Appendix C, fundamental demographic details were collected to allow for the elimination or identification of compounding factors during the analysis of the data (Shipman, 1997), and are provided in Chapter 4 and Chapter 5.

The sample

The aim of this research was to understand the affect that participation in an EEA has on a child's view of engineering, from a constructivist stance this could only be achieved through the first-person perspectives of the participants themselves. Therefore, it was the children who participated in these activities that became the main participants of this study. In addition interviews with adults in each case were conducted towards the end of the fieldwork, to gain insights from multiple perspectives in order to challenge potential researcher bias, an approach argued for by Yin (2014) with reference to case study research and referred to as 'triangulation' of data (Creswell, 2014).

Table 3.4: Cases used within this research.

Nant School	Phren School
Primary School Reception – Year 6 (age 4 – 11) 120 children enrolled (2016/17)	Middle School Year 5 – Year 9 (age 9 – 13) 419 children enrolled (2016/17)
Rural town and fringe[5]. Staffordshire, England, UK.	Rural town and fringe[5]. Staffordshire, England, UK.
Engineering activity embedded within the school D&T curriculum.	Engineering activity provided by an external STEM provider.
Introduced to the Head Teacher via a colleague. Invited for an interview prior to permission being given to conduct research with the school.	Contact made with a teacher at a conference, teacher made arrangements for her school to participate in the research.
Entire year group given the opportunity to participate.	Teacher identified children who were invited to participate.
19 children observed. 19 children interviewed (12 males, 7 females)[6]. 1 teacher interviewed (female).	28 children observed. 28 children interviewed (15 males, 13 females)[6]. 1 teacher interviewed (female). 1 activity provider interviewed (male).

3.7.2 Data collection and analysis – A grounded theory approach

Although Yin (2014) states that part of ensuring high quality data analysis means addressing the most significant aspect of the case study, when faced with a phenomenon in its natural, real-world context, the researcher must make decisions about what data to collect (Shipman, 1997). Social situations are complex, it is up to the researcher to identify what is central and what is extraneous within the data collection and analysis

[5] As defined by the RUC2011 (ONS, 2011).
[6] For a breakdown of the number of children interviewed at each stage of research see Appendix C.

procedures, and grounded theory sets out a system for such decision making (Glaser & Strauss, 1967).

Traditionally, grounded theory is located in a post-positivist paradigm (Hatch, 2002) however since the seminal work by Glaser and Strauss (1967) grounded theory has taken on different transformations through the work of ‘second-generation’ grounded theorists[7], applying the same tools to different cases and contexts. Charmaz (2006) is one such grounded theorist who has sought to apply grounded theory within a constructivist research paradigm, arguing that “neither data nor theories are discovered. Rather, we are part of the world we study and the data we collect. We *construct* our grounded theories through our past and present involvements and interactions with people, perspectives, and research practices.” (p. 10). It is the work of Charmaz (2006) alongside the foundational work of Glaser and Strauss (1967; also, Strauss, 1987; Glaser, 1978; Glaser, 1992; Corbin and Strauss, 1990) that informs the data collection and analysis strategy of this research study.

The use of grounded theory as a data collection and analysis approach is particularly suited to this work as it embraces the inductive nature of exploratory social research, allowing themes to emerge from the collected data in order to develop theories, rather than testing data against known theories or prior hypotheses (Glaser & Strauss, 1967). An approach also acknowledged by Yin (2014, p.136) as “working your data from the ‘ground up’”. This approach allows the children’s experiences to be explored through their own words, providing a systematic structure for data collection and analysis whilst retaining the flexibility to follow the conceptual areas that the children present through their narratives. This strategy prevents the researcher imposing their views upon the research area through structured questioning which participants are not able to diverge from, a critical issue within a study such as this, which explores a relatively ‘new’ area of research with young children.

The elements of grounded theory employed in this study are concurrent collection and analysis of data, qualitative coding, constant comparison and memoing, and theoretical integration.

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[7] A comparison of the different application of grounded theory can be found in Allen (2010).

- **Concurrent collection and analysis of data**

Data collection and analysis occurred simultaneously as shown in the time plan in Appendix A, rather than in discreet blocks of time that follow each other chronologically (Glaser, 1978; Bogdan & Biklen, 2003). Analysis of the data occurred from the moment the observations began and continued whilst interviews were being conducted. During observations and interviews the researcher noted key themes and concepts as they emerged during the data collection (an example of a note sheet made during the interviews is presented in Appendix D). These were subsequently checked during the continued analysis that took place once the researcher had left the field.

- **Qualitative coding**

Initial coding succinctly captured what the participants had said by coding words, lines, or segments of the data (Glaser & Strauss, 1967; Glaser, 1998; Charmaz, 2006), this was achieved by open coding, used to identify the key concepts within the data. Once the initial coding was complete, focused coding occurred (Charmaz, 2006; Glaser, 1978), this involved being more selective in coding the large amount of data collected during the interviews. A sample from an interview transcript having undergone this coding is presented in Appendix E along with the coding guide used at this stage of analysis. In order to achieve a synthesis of the data, the most significant codes were established and the data were coded with these as a focus, ensuring that the codes initially chosen were adequate and that the coding was capturing the meaning of the data. This process occurred several times as later data was synthesised into the coding, resulting in new ways of 'seeing' the data through updated interpretations of the data, as new codes were generated, thus requiring a return to the earlier data for re-analysis. It is in this stage of coding that the data are presented initially in this thesis, the data for each case is presented in Chapter 4 and Chapter 5 within the main concepts that defined the data after the focused coding was completed.

Moving forwards with the analysis, axial coding (Charmaz, 2006, Corbin and Strauss, 1990) established the main concepts, and relationships between these concepts were identified. At this stage of the analysis the data were brought back together in order to "describe the studied experience more fully" (Charmaz, 2006, p. 60). The use of sticky notes to group concepts into categories and 'try out' different relationships was beneficial to the researcher at this stage, in order to help her make sense of the data. This stage of the coding blurred with the theoretical coding within this study, as both of these stages reconstruct the data into a whole. Charmaz (2006) argues for theoretical coding to follow directly from focused coding, with no need for axial coding, however, elements of both processes were undertaken, once concepts and categories had been established during axial coding, these were woven together as a conceptual framework during theoretical coding. In this way the conceptual framework presented in Chapter 7 was developed from the data collected from the two research cases.

Throughout the entire data collection and analysis procedure it was imperative that a chain of evidence was maintained (Yin, 2014), to achieve this initial codes were written on the transcripts next to the words from participant interviews, meaning that each code can be traced back to the data and the participant who provided that data. Direct quotes from the participants are presented in the case chapters (Chapter 3 and Chapter 4), alongside the pseudonym associated with the participant to whom the words belong.

- **The use of the constant comparison method and memoing**

Due to the interviews being conducted within the constraints of the school timetable, the need to conduct consecutive interviews was not uncommon within the field. In order to allow concepts to be incorporated into successive interviews, as required by the constant comparison method, the initial stage of the coding began within the field using memos noted on interview sheets identifying the key concepts emergent from the interview (an example of an interview sheet is provided in Appendix D). This process continued during the transcribing of the interview recordings and initial reading of the transcripts.

Memoing was used to record the researcher's ideas and thoughts about how the concepts fitted together and the relationships that existed between them (Glaser & Strauss, 1967; Glaser, 1998). This consisted of making notes about the main concepts as the researcher constructed them, as well as how the concepts in the data linked to one another. These concepts and relationships could then be 'tried on' by the data, in order to reject concepts and relationships that were not supported by the data, and identify those that were. This constant comparison of concepts meant that relationships between concepts could emerge and take shape. Through this process the data, fragmented by coding, were reconstructed as a conceptual framework that could be used to inform a tentative theory (Glaser, 1998). In order to achieve this a meta-analysis was conducted, described as the process of "aggregating and combining the results of comparable studies into a coherent account to discover main effects" by Cohen et al. (2007, p. 291). Although Cohen et al. relate meta-analysis to the synthesis of analyses from other studies, this research draws together the findings from the initial and axial coding from the two cases in order to create a coherent account of participation in an EEA for children in Year 5 in rural schools in England. Therefore, the results of the process of constant comparison and memoing are presented in the meta-analysis and discussion chapters (Chapter 6 and Chapter 7 respectively) and allowed for a comprehensive picture of participation to be built up, grounded in the collected data.

- **Theoretical integration**

The integration of current theory into the process of theory generation occurs as part of the grounded theory procedure, as the conceptual categories emergent from the data and the relationships between them are explored in relation to existing literature (Birks & Mills, 2015; Glaser & Strauss, 1967). This process is presented in Chapter 7, where the developed conceptual framework is discussed in the context of the existing body of knowledge; identifying links with, and challenges to, current thinking, thus making the contribution of knowledge made by this research clear.

3.8 The research methods

Research methods are the approaches used to gather data within a study (Cohen et al., 2007). These methods need to compliment the paradigm and aims of a research study (Yin, 2014; Shipman, 1997), enabling data to be collected which validly answer the research question. A range of texts have been used to inform the research methods chosen in this study, predominantly Cohen et al., (2007), Yin (2014), Shipman (1997), and Punch (2009). Through reading these broad focused sources (as well as the more specific sources referenced throughout this section), the research methods described in Table 3.5 were chosen to answer the research question and meet the aim of this research.

An overview of the research questions, alongside the sources and methods of data collection used to answer the questions is presented in Table 3.5, these methods are then discussed and evaluated in the context of this research in the following section.

Table 3.5: Overview of linkages between research questions and methods (references provided in the section text)

Research questions	Data sources & methods	Justification
Not aligned with a research question but conducted to inform the research study.	Children, Year 5: observer as participant observations	Observations enabled the researcher to view the children participating in an activity, revealing something of how the activity was presented and how the children engaged with it.
What are children's experiences of engineering activities at age 9 -10?	Children, Year 5: group interviews using photo elicitation. For triangulation: Teachers and/or activity providers: interviews	Interviews provided the children's accounts of the activity based on their own experience. Interpreted by the researcher, interviews reveal the children's reality of the EEA and how they build knowledge of engineering. Interviews with teachers and/or activity providers (if external) will enable a broader perspective of the children's engagement to be gained, allowing researcher constructed concepts to be challenged.
Having been involved in an engineering education activity at age 9-10 what are children's views of engineers at age 11-12?	Children, Year 6 and Year 7: group interviews using photo elicitation.	Interviews with the same children who were observed and interviewed in Year 5 allows for the exploration of their contemporaneous perceptions of the EEA, as well as engineers, and continued accounts of the areas the children identify as contributing to their knowledge and understanding.
Having been involved in an engineering education activity at age 9 -10 what are children's views of engineering at age 11-12?	Children, Year 6 and Year 7: group interviews using photo elicitation.	Interviews with the same children who were observed and interviewed in Year 5 allows for the exploration of their contemporaneous perceptions of the EEA, as well as engineering, and continued accounts of the areas the children identify as contributing to their knowledge and understanding.
How does participation in an engineering education activity at age 9 -10 (Year 5 in England) affect children's perceptions of engineering as a career at age 11-12?	All methods used in this study	A comparison of similarities and differences between concepts emergent from the data yielded from different cases enabled a conceptual framework and corresponding theory of participation in the EEAs to be created with respect to the children's perceptions of engineering and engineering career aspirations.

The schedule for each element of data collection can be seen in Appendix A, as well as being presented in the relevant chapters of this thesis. The timing of the adult interviews was deliberate, occurring at a time when any impact that this interaction with the teachers would have on the children participating in the research would be minimised. This timing also enabled the concepts emergent from the data to be discussed with the adults involved, in order to gain their perspectives, in the same way that Shipman (1997) likens triangulation to crosschecking and seeking second opinions in everyday life. This assisted the researcher in exploring the context of the EEAs and broadening the perspectives gained to check for researcher bias.

As discussed in Chapter 2, the field of EER in rural primary schools in England is relatively unexplored and therefore the base of knowledge was scarce when this study commenced. In addition, the range of EEAs being conducted in schools meant that exploratory observations of the EEA were required to allow the researcher to understand what activities the children were taking part in and how the children interacted with the activity. Although this resulted in descriptive data, it created a grounding for the interviews and subsequent data collection and analysis. Semi-structured group interviews were then conducted with the participants, exploring concepts drawn from the literature as well as exploring the child's participation in the EEA from their own perspective, although it is acknowledged that the use of group interviews brings potential limitations to exploration of individual realities (discussed later in the chapter). As 'experience' is an intangible aspect of participation in a social situation (Cohen et al., 2007), the research methods were chosen to allow the opportunity to gather meaningful data relating to the children's reflections on their experiences.

Although there are those who advocate the use of 'novel' approaches to data collection with child participants, for example drawing and writing techniques (Warin, 2011; Kirk, 2007; Punch, 2002; Nolan et al., 2013), these were not automatically assumed necessary when starting this research. It was believed that although children possess different competencies to adults due to their age and experience (James et al., 1998), 'child' is not a homogeneous group and both observations and interviews have been used successfully with children as illustrated in the work of Lewis (1992) and Greene & Hogan (2005). Therefore, using terminology from Christensen and Prout (2002), the research was based on a foundation of ethical symmetry and so the research methods used within this study reflect the capabilities of the human beings involved in this research (Christensen & Prout, 2002; Punch, 2002; Kirk, 2007).

To ensure that data collections were successful, prior to entering the field the researcher considered factors such as the participant's verbal competence, use of language, attention span, and potential inequalities of power (Danby & Farrell, 2004; Arksey & Knight, 1999; Nolan et al., 2013). Taking the lead from research conducted by Einarsdottir (2007) who, when working with children as young as 2-6 years, tailored interviews to participant's competencies and comfort, the research participant's individual needs and preferences were monitored and accounted for to ensure that the methods used in the field were suitable for both the participants and the research aims (Punch, 2002). As the participants in this research all spoke English as their first language, and were perceived as able verbal communicators during the observations, alternative non-verbal means of data collection were not deemed necessary. More details about the interview methods employed are given in section 3.8.2.

3.8.1 Observations

Observations as a research method used to collect data in the field are most commonly associated with ethnographic studies due to their aim of gaining knowledge as an 'insider' to a phenomenon (Flick, 2014; Ritchie, 2013). However, they can take different forms (see Cohen et al. (2007) for a summary) and are advocated as a research method in case study research by Yin (2014).

The use of observation data to provide a deeper understanding of a phenomenon is stressed within the literature (Yin, 2014; Flick, 2014; Ritchie, 2013; Cohen et al, 2007) and through observing a practice in its natural setting, this practice is made accessible to the researcher in a way that narrative accounts provided through interview do not allow (Flick, 2014). In this way observations aided the researcher in understanding the participation in an EEA. In addition, the observations also allowed the researcher to develop an understanding of the ways in which the children communicated, informing the interview design.

Overt, exploratory, observer-as-participant observations were carried out during the children's participation in an EEA. The reasons for this type of observation being conducted reflect the ethical and methodological foundations of the research. Covert observations were deemed unethical in this study, as these require the participants to be unaware that they are being observed and so informed consent cannot be given in this situation. Where observations are conducted in a public place there are arguments for the acceptability of covert observations (Ritchie, 2013), however this is not the case in this research where observations take place in schools.

When considering the role that the researcher takes within the observation setting the terminology presented by Ritchie et al. (2013) was used, where a researcher can take one of four roles: complete participant, participant as observer, observer as participant, and complete observer. In this study a complete observer role was untenable, as the assumption that the observer does not affect the observed that underlies this role could not be claimed. Cohen et al. (2007) suggests that a complete observer role can only be fulfilled when participants are not aware they are being observed, as the act of conducting even naturalistic observations impacts on the behaviour of the participants (Padgett, 2016; Punch 2009). This was exhibited within this research, as once in the field the children interacted with the researcher and therefore it would have been impossible to adopt a complete observer role. A complete participant role was equally untenable as this relies on the researcher being able to become part of the group that they are observing, an unsuitable approach given the age and experience differences between adults and children, and a reason for rejecting an ethnographic methodology.

Due to the acknowledged differences between the researcher (as an adult) and the participants (as children), as well as the interactions which occurred between the researcher and participants within the field, an observer-as-participant role was adopted by the researcher. This role acknowledges that the presence of the researcher affects the natural setting of the field but observation remains the dominant focus of the researcher (Ritchie et al., 2013).

The observations were recorded as contemporaneous field notes made by the researcher, defined by Monette et al. (2014, p.234) as “detailed, descriptive accounts of the observations made”. The observation notes remained descriptive, providing a general overview of the activity and the children’s participation in it (these notes are presented to provide the context for each case in Chapter 4 and Chapter 5).

3.8.1.1 Limitations of observations

The major limitation of observations is linked to the philosophical stance of this research, acknowledging that reality is constructed by the individual means that the researcher constructs the reality of the observations, as Shipman (1997, p.72) articulates, “observations are not the result of the senses detecting events out there that look the same to everyone”. Researchers have their own perceptions, personal values, attitudes, and prejudices, which shape their view of the world and it is this view of the world that is captured through observations (Ritchie et al., 2013; Shipman, 1997). For this reason, observations were not the main data collection technique employed in this study.

However, the data collected from the observations were used to inform the interviews and analysis.

3.8.2 Interviews

Interviews are narrative accounts presented by participants to the researcher, Yin (2015, p.34) summarises the goal of qualitative interviews as encouraging “participants to have the time and opportunity to reconstruct their own experiences and reality in their own words”. Therefore this method of data collection is highly suitable for the current research study as it allows perceptions, attitudes, and meanings of participants to be explored (Yin, 2014; Cohen et al., 2007), making them ideal as a data collection method to explore the children’s interpretations and meanings of engineering and the EEA they participated in.

Semi-structured, group interviews were carried out with the children at intervals after the observation (Bogdan & Bilken, 2003, Docherty & Sandlowski, 1999). Where the participants were adults, individual semi-structured interviews were used. The interview style for both children and adult participants was based on the definition of a ‘responsive interview’ given by Rubin and Rubin (2012, p.36):

> *The tone of questioning is basically friendly and gentle, with little confrontation. The pattern of questioning is flexible; questions evolve in response to what the interviewees have just said, and new questions are designed to tap the experience and knowledge of each interviewee.*

Although Corbin and Strauss (2015) advocate the use of unstructured interviews in grounded theory these are difficult to execute due to the inherent lack of guidance, and therefore require an experienced researcher to facilitate them effectively (Gray, 2014). Semi-structured interviews can be used to provide guidance for the interviewer through the use of an interview guide stating the themes to be covered, but not limiting the interview to these areas, therefore retaining flexibility for participant led conversation (Miles & Gilbert, 2005; Longhurst, 2010; King & Horrocks, 2010).

A sample interview guide used in this work can be found in Appendix F, this initial semi-structured interview guide is divided into five thematic areas based on the conceptual framework of the research: aspirations, play/interests, awareness/perception of engineering, engineering role models, and hands-on engineering experience. These themes were used as starting points for conversation, however as new conceptual areas were discussed by the children during the course of an interview these were noted, followed, and included in future interviews, similarly if an initial theme was not discussed by the children it was given less emphasis in future interviews. The most prominent example of this within the current research is the topic of gender, this concept did not form part of the initial framework but was mentioned by children during the second interviews (Year 6) and became a relevant conceptual area within the research.

Group interviews were chosen to overcome ethical and logistical issues. Ethically, group interviews mitigate issues regarding isolated contact between a child and an adult, logistically the time required to conduct individual interviews would have resulted in less participants being able to be interviews. Group interviews were also used to counter potential issues associated with inequalities of power, a technique used by Lewis (1992) and Einarsdóttir (2007) to reduce this issue. However, it should be noted that there are potential issues associated with group dynamics within group interviews leading to children's own realities not being reflected in the data, rather a group constructed reality being revealed (Bohnsack, 2004). As the children engage in conversations during the interviews, individual perceptions and understanding may be created and adapted during these conversations. This group constructed reality is seen by some as important additional data (Fray & Fontana, 1991), however the current study is concerned with the reality of the individual and so interviews had to be carefully managed to ensure that the children's own, contradictory, divergent realities were uncovered, in addition to the group reality that may be created. Although this could not be guaranteed, group interviews were essential for reasons of logistics and ethics. The decision to conduct group interviews led to four main considerations prior to fieldwork commencing: groupings, location, timings, and data recording.

Lewis (1992) conducted a review of the available literature when considering the use of group interviews with children of primary school age, with friendship groups reported to be an important factor in the grouping of children as well as the size of the group. Although it is agreed within the literature that the group structure and size need to be considered (Bloor et al., 2001; Mitchell and Amos, 1997), there appears to be no consensus on group size. In this research it was decided that group sizes of between four and six children were desirable; this ensured the benefits of the group interview would be present even if children were unavailable on the days of the interview but allowed groups to be manageable and ensured that all children were able to make their voice heard. In practice however, these group sizes were not always achieved. On occasion children did not attend interviews at the correct time, were late due to other commitments, or were early. In some cases the interviews could be rearranged and adjusted to allow for the changes which occurred in the field, however this was not always possible and so interview group sizes ranged from 2 to 8 children, although the majority of the interviews were conducted with groups of 4 or 5 children. Care was taken in each interview to tailor the process to the number of children present, ensuring that all children had time and were given the opportunity to have their voice heard.

The venue of the interviews also required consideration and, as advocated by Yin (2015), locations convenient to the participants were desirable. With this in mind the interviews were, where possible, held at the location that the activity was delivered, in this case the schools the children attended. The only time that this was not possible was during the last interviews in Nant School when the children had left the primary school and an alternative venue was used (as described in section 4.1.3). This location was chosen as it was convenient for all participants in the group interview, and it reduced the issues associated with organising interviews with children in the home environment (Bloor et al., 2001).

The school as a venue was chosen as it was convenient for the participants, as well as being a familiar place in which they felt comfortable and secure (Herzog, 2012), a crucial objective at the start of the data collection process. This decision was also made with consideration of the influence that the venue may have on recollection of the activity (as discussed by Herzog, 2012). Although the most beneficial interview venue, it did not come without potential issues. Mauthner (1997) cautions that negotiating privacy and time within a school can be problematic and in this research it did lead to the interviews being interrupted by other children, school bells, fire alarms, and teachers. In addition, the potential asymmetry created in the interviewer-interviewee relationship due to this choice of location was considered prior to entering the field and was reflected upon during the analysis of the data.

An additional matter considered prior to entering the field concerned the length of the interviews; although this is a consideration for any age of participant, the child participants are the focus here. Due to the exploratory nature of semi-structured interviews it is difficult to estimate the length of the interview prior to it taking place (Arksey & Knight, 1999), however it was important to be realistic about the length of time that the children could be expected to participate (Nolan et al., 2013). Although a maximum length of time was not set for each interview, the researcher assessed the behaviour of the children during the interview, as well as accounting for the time at which the interview was conducted (for example immediately prior to the school lunch or break). In this way, the researcher was able to react appropriately to the children's verbal and non-verbal requests for an interview to be concluded. This did lead to some shorter interviews being conducted when participants became distracted or responded to questions succinctly as they were keen to return to lessons.

The final consideration was how the interview data should be recorded. Although Glaser (1998) advocates noting themes as they emerge during the interview itself rather than recording and transcribing them, a verbatim record of the conversation was preferred as this can be referred to throughout the study (Bloor et al., 2001; Arksey & Knight, 1999) and satisfies one of Yin's checks of quality in data analysis, the chain of evidence (Yin, 2014). Therefore, digital audio recording was used for all interviews in this study (with appropriate participant consent), and a sample from an interview transcript is presented in Appendix E. Furthermore, the transcription process is classed as a research activity by some researchers (Silverman, 2001; Atkinson & Heritage, 1984), as it allows the researcher to become intimately familiar with the collected data. The researcher transcribed the entire interview data, and in doing so became familiar with the data and began to form the conceptual labels that described the data in the initial coding. This immersion in the data, a crucial first step of analysis according to Green et al. (2007), was also found to assist with the constant comparison of emergent concepts. The conceptual labels that emerged during the process were compared against each other, a process that assisted in the initial coding of the data as well as the axial coding of the data.

The level of detail required in the transcripts related to the research methodology adopted, as well as how the data is to be analysed and used (Arksey & Knight, 1999; Silverman, 2001; Lapadat & Lindsay, 1998). In this research the concepts within the data were the focus of analysis and therefore details of how words were spoken was not required (Bailey, 2008). This level of transcription, in conjunction with the researcher being the sole transcriber, meant that many of the issues of transcriber decision making and influence on the recorded data as highlighted by Tilley (2003) were avoided.

3.8.2.1 Limitations of interviews

In addition to the limitations of group interviews regarding constructions of reality, mentioned in the previous section, interviews carry additional limitations as a research method. While the aim of case study research is to examine a phenomenon in its context (Yin, 2014), interviews by their very nature produce researcher-provoked data (Silverman, 2001). Therefore, the artificial interaction created between the researcher and the participant during the interview has associated limitations, including compromised responses to 'private' views, and response 'bias' (Shipman, 1997; Yin, 2014; Ritchie et al., 2013). The open and friendly style of questioning to be adopted as described at the start of this section attempted to mitigate these issues. However, prevention of withholding of information (in the case of 'private' views) and providing the perceived 'correct' answer (in the case of response 'bias'), cannot be guaranteed in any study, and although these possibilities were considered when analysing the data, they form a potential limitation on the reliability of the data collected.

Due to the interactive nature of interviews, the process relies upon shared meanings of questions and answers, whilst clarification of participant's meanings was sought during interviews (Ritchie & Lewis, 2003), consideration was also given to how questions were asked and if participants could have misinterpreted what the interviewer was asking them (Shipman, 1997). Whilst awareness of this was taken into the field, enabling the researcher to re-phrase questions she felt had been misunderstood, the awareness continued into the transcribing process allowing for researcher reflexivity throughout the data collection and analysis process.

There is an argument that children are unable to adequately express themselves verbally, rendering interviews inappropriate (Punch, 2002), a subject discussed briefly at the start of this section. As discussed, flexibility in approach was taken to ensure that the specific communication needs of each group were met, and at the start of the interviews each child was asked to introduce their self and talk about their favourite hobbies and their dream job. These general opening questions acted as an additional gauge of the linguistic abilities of each child, thus allowing the researcher to adjust their language and interview approach accordingly (Danby & Farrell, 2004). All of the children who participated in this researcher were judged as able to articulate themselves adequately in a group interview setting.

Lewis (1992) highlighted an additional potential limitation to data collection through interviews, that participants may be shy or unwilling to talk to the researcher. To help overcome this possibility, photo elicitation was used as an approach to encouraging conversation. Photographs of the children participating in the EEA were taken and used during the interviews in an attempt to engage the children by "inserting a photograph into a research interview" (Harper, 2002, p. 13) in order to provoke dialogue. This approach has been increasingly used by researchers in conjunction with interviews with children to increase their engagement with the interview and expand the data that is collected (see Einarsdottir, 2005; Jorgenson & Sullivan, 2010; Kondo & Sjoberg, 2012 and Whiting, 2015; Cappello, 2005; Harden et al., 2000). Specific consent for the taking and use of photographs of children and children's work was sought from the parents as well as the children (Wang & Redwood-Jones, 2001), and the decision was made for the researcher to take the photographs, as child-led photography would alter the children's participation in the activity as well as creating ethical and methodological issues (Phelan & Kinsella, 2013).

Whilst photo elicitation and general opening questions were used to develop communication and generate conversation, in order to facilitate effective interviews time also needed to be given to building and maintaining trust and rapport between participants and researcher (Arksey & Knight, 1999; Miles & Gilbert, 2005; King & Horrocks, 2010). Whilst ever effort was made to build this trust and rapport through conversation, the limited time that the researcher spent with the participants may have created a constraint to achieving this.

3.9 Ethical considerations

The penultimate section of this chapter concerns the ethical considerations of the research design. The ethical process for most academic research begins, as it did in this study, with the university Ethics Committee. However, ethics is not a single event in research but a continual negotiation between the researcher and their work (Warin, 2011). The practice of ethical research extends far beyond the Ethics Committee, into the field and the day-to-day considerations and responses of the researcher. Guillemin and Gillam (2004) termed this duo of ethical discourse as 'procedural ethics' and 'ethics in practice' and it is these that are used to frame the discussion of ethics in this research.

3.9.1 Procedural ethics

Defined by Guillemin & Gillam (2004, p. 263) as usually involving "seeking approval from a relevant ethics committee to undertake research involving humans", procedural ethics are concerned with the formal practice of gaining ethical approval prior to commencing a study. In the case of this research, ethical approval was sought from Aston University School of Engineering and Applied Science Ethics Committee. The process involved the completion of an online form outlining the research aims, proposed methodology and methods, and a risk assessment covering the entire research project. The information submitted was considered by reviewers who requested further information about the taking of photographs of children, this information was provided and confirmation of ethical approval for the research was received in July 2015.

During the completion of the procedural ethics an ethical framework for the research was developed using the guidelines provided by the British Education Research Association

(BERA, 2011) and the Social Research Association (SRA, 2003) as reference. However, additional ethical guidelines for working with young children are given by a number of professional and research bodies, such as Shaw et al. (2011) and Save the Children (2000) and were also used to inform the conduct of the study. This literature was the inception of designing and conducting an ethical study, however continual ethical decisions were required throughout the study.

3.9.2 Ethics in Practice

The reactions and decisions taken whilst in the field have ethical dimensions that need to be considered but that are difficult to account for during the planning stage of research (Guillemin & Gillam, 2004; Warin, 2011). Davis (1998) splits the ethics of research with children into three sections: informed consent, confidentiality, and protection. Whilst strategies for ensuring adherence to these ethical considerations were provided during the procedural ethics process, the continual adherence and monitoring of these was carried out once in the field and these areas are considered in the context of the research in this chapter.

3.9.2.1 Voluntary informed consent

Informed consent prevents violation of the ethical principle proposed by Kant, that it is wrong for individuals to be used as a means to someone else's ends (1996). This forms a prominent issue in procedural ethics, especially when concerning child participants (Dockett et al., 2012; Gallagher et al., 2010; Einarsdóttir, 2007; Kirk, 2007). Efforts were made during this research to gain voluntary informed consent from all participants, examples of the consent forms and Participant Information Sheets (PIS) designed and used within this research can be found in Appendix G. Awareness of the potential issues surrounding the successful acquisition of informed and voluntary consent, presented below, ensured that the researcher was able to operate with ethical mindfulness and responsiveness whilst in the field.

Who consents?

Although "children are the final gate keepers to their own world" (Davis, 1998, p. 329) and were required to consent to participate in the research (BERA, 2011), they are also considered vulnerable by virtue of their age and social standing and consequently adult 'guardians' were also required to consent to the children's participation (UN, 1989). An approach similar to that of Gallagher et al. (2010) was taken to negotiating access through the hierarchy of organisational and adult guardians, viewing this process as ethically and logistically essential but as gaining the approval of adult guardians rather than their consent on behalf of the child, as well as the children. Consent forms individually tailored for schools, parents/guardians, and children were used to inform and document informed consent.

The process of gaining informed consent from all parties was explained to the organisations and schools when initially seeking access to the research field, for some organisations who showed an interest in participating, the barrier to participation came from this need for multiple levels of consent and so they withdrew from the project, this is an area discussed further in section 7.2. In the two research cases, consent was gained from the schools initially, once this was obtained the children and their parents were invited to consent although the process details differed for each research case, as described in Table 3.6.

When designing the approach to recruiting participants and gaining informed consent, the problems of understanding, information, and authority needed to be considered (Gallagher et al., 2010). It was important that all participants understood what was being asked of them and hence, both written and verbal methods of communication were used, allowing for both the researcher and the participants to ask questions (Guillemin & Gillam, 2004).

Table 3.6: Process of gaining informed consent in the research cases.

	Nant School	Phren School
Initial consent process	Gained via the head teacher, consent was then requested from the Year 5 class teacher (verbally) before entering the classroom. Consent requested from the children verbally by the researcher and from the parents/guardians of the children via written media prior to conducting research.	Gained via the science teacher at the school, verbal consent given by the activity provided before observing the activity. Consent requested from the parents/guardians of the children via written media and requested from the children verbally prior to conducting research.

Continual monitoring of consent

As this research had a longitudinal aspect, the act of gaining consent continued throughout the fieldwork (Warin, 2011). In addition to the signed consent form collected at the start of the research, verbal consent was obtained upon return visits to the field and indicators of dissent, such as body language and silences (Dockett et al., 2012; Einarsdóttir, 2007), continued to be checked whilst conducting fieldwork. The children were made aware of their right to withdraw from the study at any time, and information regarding the use of their data should they withdraw was explained both to them and the adults involved in the consent procedure (see PIS sheets in Appendix G).

This continual awareness of dissent was important as it is argued that the decision that a child makes in terms of their consent cannot be viewed in isolation from the adults in their world (Gallagher et al., 2010). Whilst blatant coercion may be identifiable and easy to avoid, subtle persuasion (particularly when a teacher-student relationship is used to recruit participants) and peer pressure are prevalent within school settings, but are much harder to plan for and attenuate within research (Gallagher, 2010).

During the group interviews, if children were quiet the researcher asked them questions directly to ensure that they had a chance to make their voice heard, however if they were not willing to answer questions their decision was respected and they were not pressed to contribute. An example of dissent occurred within the first interviews at Phren School when a child was very quiet and answered many questions with brief, deflecting answers, they had also asked questions regarding taking part in the research that the researcher answered both before consenting to take part and once the interview was finished. Although this child had consented to participate, their behaviour and questions led the researcher to believe that voluntary informed consent was unlikely in this case, therefore they were not included in the transcription or analysis of the interview data or in future interviews.

3.9.2.2 Confidentiality and anonymity

In line with ethical guidelines, participant data has been, and continues to be, treated confidentially (SRA, 2003, BERA, 2011), however anonymity could not be provided as the researcher was aware of the participants' identities due to the research methods employed and in order to maintain a chain of evidence. The data itself was anonymised for dissemination, reducing the risk of the disclosure of identities to anyone other than the researcher, and any data that could identify a participant was stored in line with the 1998 Data Protection Act (UK Government, 1998). The right to access participant data was restricted to the researcher and the participants (who could request to see the information held about themselves).

Pseudonyms are used throughout this thesis and in all other published work relating to this study (see Appendix I), to protect the participants' identity. Although common in social research, Lahman et al (2015) urge researchers to think carefully about their use and allocation, arguing that there may be occasions where the use of pseudonyms is not ethical. In this research pseudonyms were deemed essential, and were allocated to the children by the researcher rather than asking the children to choose their own. This decision was taken due to the issues that could arise from children creating their own pseudonyms, such as those seen in the work of Morrow (2008), who describes children using their nicknames that were recognisable to others, and of the researcher having to alter a pseudonym given to a town by her participants, an act that could potentially damage the trust between the participants and the researcher or reinforce the position of authority of the researcher.

3.9.2.3 Minimising risks of harm

Non-maleficence is well known from the healthcare professions, but it is also recognised that there is a moral duty to minimise the risk of harm to participants in social research (SRA, 2003). Harm spans a greater remit than physical harm, and social research is subject to rigorous ethical procedures due to the potential for emotional and psychological harm to be caused to human participants, especially when child participants are involved (Nolan et al., 2013; Fuchs, 2008; Punch, 2002; Thomas & O'Kane, 1998).

No potential risks of harm were identified prior to starting this research, and participants were made aware that they would not be exposed to harm additional to that experienced in everyday life, in line with the ethical guidelines set down by BERA (2003). However, the interaction between researcher and participants has the potential to cause subtle harms, which are difficult to specify and thus difficult to warn of, or minimise strategically, prior to starting the study (Guillemin & Gillam, 2004). Although no unexpected harms were identified, there were moments during the fieldwork when embodiment of ethics in practice was required to minimise emotional upset, two of these moments are presented as vignettes in Figure 3.4.

Emotional answers

At the start of this research I deemed there to be no physical or emotional risks to the participants beyond those of everyday life, whilst this view has not changed once in the field I learnt that even topics of discussion which are deemed non-sensitive can result in answers which are sensitive for some participants. It also became clear how ethically impactful the actions of the researcher and the participants can be. During a group interview at Phren School, whilst discussing the children's reasons for holding their career aspirations, a participant revealed that the death of a family member was her career motivation. This is clearly an emotional and distressing topic, and one that I had not considered prior to being faced with it during an interview. Whilst in the field I believe that I responded with care and compassion, and ensured the child's wellbeing through my response and handling of the situation. I did not probe, but acknowledged the information and admirable motivation and moved the conversation away from the child. This enabled the child to take a moment before re-joining the interview conversation. I visually checked that the child, who was clearly upset when recounting the information, was okay throughout the interview and was satisfied that no further action was required.

Conflicting consent

When observing the children at Nant School who were taking part in the EEA, photographs were being taken of the children as they worked, which resulted in an unexpected ethical dilemma. One child who did not have parental consent to take part in the research saw me taking photographs of other children and their work, and they wanted to be photographed. When I explained to him that I could not take his photograph he was visibly disappointed and so I asked him if he would like to take a photograph instead, he appeared happy with this compromise and the potential issue was resolved, minimising the potential of emotional harm.

Figure 3.4: Reflections on moments of ethics in practice that occurred during the research.

3.9.2.4 *Safeguarding and disclosure*

Safeguarding procedures such as obtaining an enhanced DBS (Disclosure and Barring Service) certificate (Number 001514809270) and undertaking appropriate safeguarding training were achieved prior to the researcher entering the field. Full details of the researcher's certificates were made available to the schools involved in the research.

Although confidentiality is a key ethical concern, disclosure also required careful consideration prior to entering the research field. The researcher has an ethical duty to breach confidentiality if it were believed that non-disclosure of information divulged by a participant would allow illegal activity to continue, or that harm to the participant or others would occur (BERA, 2011). All schools in the UK have appointed safeguarding officers (DfE, 2016b) to whom such information can be referred. In the rare case of this situation arising in the field careful consideration is required by the researcher. Happily no such incidents occurred during the research, however if they had, the child concerned would have been informed of the necessary actions to be taken by the researcher (Gallagher et al., 2010; Einarsdóttir, 2007).

3.10 Conducting valid and reliable research: whose voice is heard?

This chapter has set out the research design used for this study, and concludes by considering the validity of the data collected by these methods and the conclusions that can be drawn from the data. In addition to the ethical issues presented above, the acknowledgement of children and their voices within the research and the dissemination of findings are important in the ethical treatment of participants (Nolan et al., 2013).

The previous sections have demonstrated that the research design strives to accommodate children as participants and to promote their voice (Fuchs, 2008). Claims in the literature that data obtained from children is unreliable have been challenged in recent years (for example, Kirk, 2007). However, as Nolan et al. (2013) point out, children still exist in a world where adults are in positions of power (teachers, parents, politicians) and this brings preconceived ideas about how adults and children should act in the research setting (Morrow & Richards, 1996). Therefore, inequalities of power between the researcher and the participant continues to be the focus of much debate, as highlighted by Nolan et al. (2013) and Punch (2009).

Due to the location of the research being in the school setting, the children could easily cast the researcher in the role of 'teacher' and thus feel pressure to act in a certain way during observations and give 'correct' answers to questions in interviews (Punch, 2002).

Aware of this possibility, the researcher was sensitive to how they presented themselves to the children and so adopted a 'least adult' role, as advocated by Davis (1998). Whilst the adult-child relationship as researcher-participant can never truly be equal, adopting the role of 'least adult', similar to 'incompetent adult' as referred to by Corsaro & Molinari (2008), allows children to rebalance the power dynamic by being the authority and by leading interactions between themselves and the adult. This was achieved by the researcher asking questions of the children that highlighted the children's authority over hers, for example about school procedures, current computer games, and technology. This 'least-adult' role was clearly displayed when a fire alarm went off during an interview, the children had to lead the researcher out of the building and thus the children took authority in the situation. However, there were still times when the child-adult/student-teacher roles were visible in the way in which the children behaved during the fieldwork. Examples of these are when Stephen (M, Phren School) asked if all of the groups had the same *"test"* (meaning interview) and Matthew (M, Nant School) asked for help with his work during the observations. When replying to Stephen, the researcher assured him that the interviews were not a test and explained the purpose of the interviews more clearly, and Matthew's question was redirected to the group of children working on the same table, reducing the impact that the researcher had on the situation.

To further encourage the children's voices to be heard, group interviews were carried out with the children (Lewis, 1992), as described in section 3.8.2. However, although group interviews mitigate some of the potential issues of adult-child inequalities of power, they also create potential issues around inequalities of power amongst groups of children, as dominant speakers can drown out quieter individuals (Lewis, 1992). To ensure that all of the children were able to make their voice heard during the interviews, the researcher gently directed questions to children who had been quiet, and directed attention back to children who were cut-off by others during interviews.

Ultimately, the data to be included and the analysis of this data is in the control of the adult researcher (Punch, 2002), as analysis involves access to knowledge which participants may not be aware of (Haden et al., 2006). Although clarification was sought during the interviews the use of language differs between different generations (Arksey & Knight, 1999; Docherty & Sandlowski, 1999) that can result in the analysis of data being open to adult interpretation (Fine and Sandstorm, 1988; Nutbrown, 2010). This is one of the stages where researcher bias can enter research work. To counter this, awareness and reflexivity was required to ensure that it is the voice of the participants heard in the reporting of this research, rather than that of the researcher (Davis, 1998). Acknowledging the limitations of the research methods within the research paradigm, researcher reflexivity was used throughout the study. As Kleinsasser (2000, p. 155) describes, reflexivity is “an acknowledgement of the inquirer’s place in the setting, context, and social phenomenon” and so opportunities were made for the researcher to reflect critically on her own biases formed from her experiences. An example of this being the consultation of the researcher’s written observation notes when forming interview questions, as well as during the latter stages of analysis to provide a “check” to ensure that concepts regarding participation were grounded in the data. If concepts and relationships proposed in the researcher’s memos were not supported by interrogation of the data then they were adapted or discarded. In this way, the researcher examined her own bias throughout the analysis of data and, through making the research design, methods, and analysis explicitly clear, it is hoped that the reader is also able to evaluate critically the claims made in the later chapters of this work.

The aim of this process was to understand the impact that the researcher had on the research, as well as the impact that the research had on the researcher (Davis, 1998; Guillemin & Gillam, 2004). The critical appraisal of the role of the researcher is discussed later in this study in Chapter 9, as well as briefly at the end of each case chapter an option for incorporating self-reflection into a research study as argued for by Creswell & Miller (2000).

3.11 Summary

This chapter has presented the research questions this study aimed to answer, the methodology underpinning this research and the methods chosen to answer the research question posed. Through the linking of these elements described within this chapter, validity has been ensured through the use of appropriate research questions pertaining to the area of study and appropriate research methods answering those research questions. These strategies, alongside those undertaken to ensure an ethical study was conducted have also been presented, in doing so this chapter provides the foundation on which this research has been built. The following two chapters present the two researcher cases and the data collected, before moving on to the meta-analysis of this data.

CHAPTER 4

4 Case 1: Nant School

This chapter presents the first research case, giving information about the School and the child participants to provide the context of the data collected. Following the description of the case itself, the descriptive data from the exploratory observations is presented, followed by the data collected from the interviews in Year 5, Year 6, and Year 7, as well as adult interviews.

4.1 Introduction

Information about the case was collected from a range of secondary sources: the school website and information from local groups, in addition to conversations with the head teacher.

The first case, referred to as Nant School in this research, is a one form entry primary school in a residential area of the village of Boulder in Staffordshire, UK. The village is rural, set within a green belt, agricultural landscape but close to major conurbations and close to the motorway. According to the Neighbourhood Plan for the area, the village has a little over 3000 residents with a high number of residents being retired. The dominant industries that the residents work in are public admin, education, and health, however the village has more professional, scientific, and technical workers than in the surrounding areas and a high proportion of residents aged over 16 are educated to degree level or above, a higher proportion than in neighbouring areas.

The latest Ofsted report rated the School as ‘outstanding’. The School is the sole local catchment school for the village, however a number of children travel from outside of the catchment area and the head teacher described a mixed demographic of children who come from a range of backgrounds. The school feeds a variety of private and state secondary schools in the local area. The School was oversubscribed and there were usually appeals to get children a place, the head teacher assessed the parental body as being supportive and engaging with the school. At each visit the researcher made to the school the staff and students were friendly and welcoming, work was displayed on a table in the entrance hall and there were display boards and photographs on the walls.

There was an anticipation from the school leadership that the children would aspire to go on to study at HE, however the head teacher had observed an increase in aspirations to apprenticeships, and reported that a number of past pupils had gone on to study engineering.

A total of 210 children were enrolled in the 2016-17 academic year, from Reception to Year 6 (ages 4 - 11) and the gender split at the school was 102 Female to 108 Male. The KS2 (Years 3-6) school day was split as shown in Table 4.1.

Table 4.1: Structure of the school day for KS2 at Nant School (from information available on the school website)

Time	Session
8.55am	Registration
9.00am – 10.25am	Teaching Session 1
10.25am – 10.40am	Assembly
10.40am – 10.55am	Morning playtime
10.55am – 12.05pm	Teaching Session 2
12.05pm – 12.55pm	Lunchtime
12.55pm – 3.10pm	Teaching Session 3&4
3.10pm	End of the day

The sample comprised 31 children, of which 23 gave consent (both child and parental) to participate in the research: 13 male and 10 female. Those children without both child and parental consent were noted (along with their position within the classroom) during initial observations and did not participate in the research. Due to illness/absence, a total of 19 children actively participated in the research; 12 male and 7 female. Details about the participants are given in Table 4.2. Gender consistent pseudonyms have been used to protect the identity of the children, none of whom were identified as having English as an Additional Language (EAL) or being registered for Pupil Premium (for definition see UK Government, 2017) and all but three of whom was White British. One child within the sample received Special Educational Needs (SEN) support, although the details of this support were not disclosed to the researcher, information about children with SEN in general is provided by the UK Government (2018b).

Table 4.2: Child participants at Nant School

Pseudonym	Gender	Age at start of research
Will	M	9
Billy	M	10
Jane	F	10
Stewart	M	Unknown
Jack	M	9
Jackson	M	10
Jenny	F	9
Judy	F	9
Ella	F	10
Scott	M	10
Jay	M	9
Matthew	M	9
Bryn	M	10
Chris	M	10
Kat	F	10
Paul	M	9
Matty	M	9
Becka	F	9
Nicky	F	10

4.1.1 The Activity

The EEA at Nant School was a D&T project considered by the head teacher and class teacher to be an engineering activity, delivered within the school curriculum during Year 5. Lesson time was given as well as a full day devoted to the project.

The activity was entitled *Moving Toys* and had two aims:

1) Research and investigate moving toys.
2) Learn how to make a moving toy using a cam[8] mechanism.

[8] A cam is a device used to transfer rotational motion into linear motion, for a simple overview of cam mechanisms see GCSE Bitesize (BBC, 2014)

Each child was provided with a work booklet (a reference copy of which can be found in Appendix H) that they worked through during the lessons, annotating diagrams and drawing ideas. As can be seen in the booklet, the project was split into different stages:

1. Investigating toys (pages 3 – 4 in the booklet)
2. Investigating cam mechanisms (pages 5-6 in the booklet)
3. Design criteria and developing ideas (page 7 in the booklet)
4. Design specification (page 8 in the booklet)
5. Planning (pages 9 – 10 in the booklet)
6. Evaluating (pages 11 -12 in the booklet)

The children made their own toy between stage 5 and 6, a full day was given to this part of the project.

Although the pedagogic approach was not stated, the activity (and material supporting the activity) was deemed to engage the children in active learning. The role of active learning in engineering education is not new and a universal definition is not agreed upon in the literature. Prince (2004) presents a general definition as active learning being “any instructional method that engages students in the learning process” (pg. 223), and goes on to refine this definition to specify active learning as taking place in the classroom. This classroom based engagement with the learning process is echoed in the definition provided by Felder and Brent (2009) who (although speaking in relation to HE) define active learning as “anything course-related that all students in a class session are called upon to do other than simply watching a lecture and taking notes” (pg. 2). The activity observed embodied a large amount of independent work, and the children were involved in informal discussions, group work, computer based research, and hands-on creation of their own design. Throughout the activity the children were encouraged to work together either in small groups or in pairs, even though the ultimate aim was to make their own moving toy.

A range of resources were used within the project, stage 1 utilised school laptops to conduct research on the internet, and a moving toy class kit was provided for stage 2 to enable the children to create and explore cam mechanisms. The kit included pre-punched cardboard sheets, dowels, cotton reels, assorted cams, thread, and instruction sheets. For reference, similar project kits can be found on educational supplies websites such as TTS (2018). This kit was also available for the children to use when they created their own toys, however the children were encouraged to bring their own resources.

4.1.2 The venue for the activity

The school is a brick built, single storey building. The EEA took place in the Year 5 classroom, the general layout of which is shown in Figure 4.1. The classroom was well lit and spacious enough to allow the children and teacher to move easily between the tables, it was a comfortable temperature, and outside noise was not noticeable.

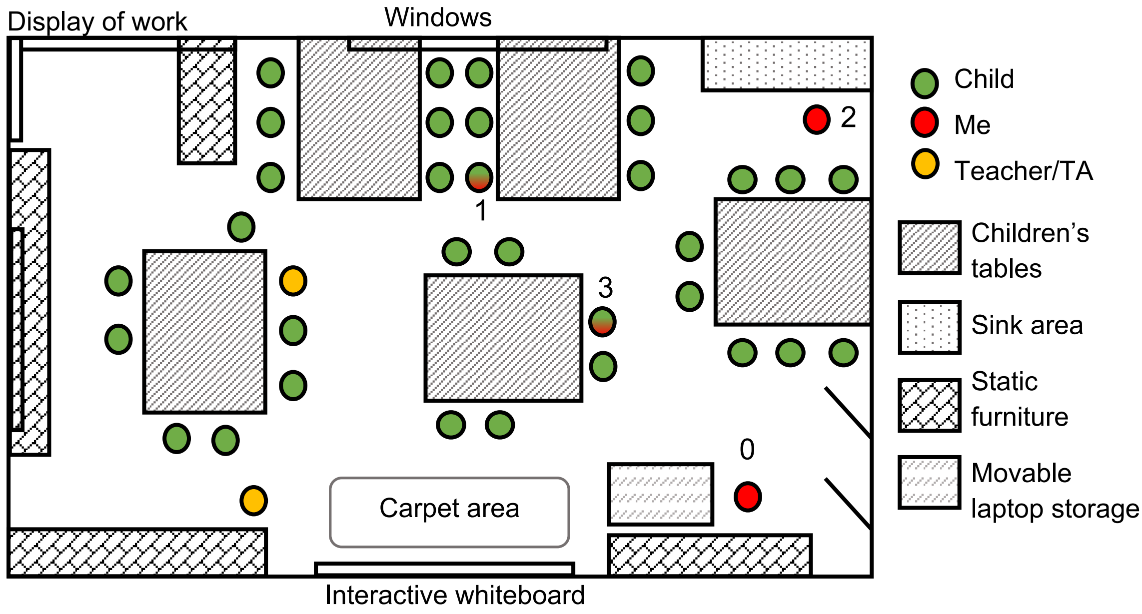

Figure 4.1: Nant School Year 5 classroom layout.

Children appeared to have specific seats around shared tables, and there was a carpet area at the front of the room large enough for the whole class to sit on. The carpet area faced an interactive whiteboard and there were displays of work covering the majority of the walls. One wall was titled "Our Magnificent Flying Machines" and had a creation made from Stixx[9] (rolled newspaper tubes), it was revealed during the interviews that this was a sleigh.

4.1.3 The interview venues

The first and second interviews took place in a variety of locations at the school, either conducted on the carpet area in the classroom (during a time when the rest of the class were in the main hall), in the school computer room (a room with a table and chairs in

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[9] A tube rolling device to make strong paper tubes from newspaper distributed by Jeremy King (n.d).

the centre), or in a small classroom off the main hall containing rows of tables and chairs. All locations allowed the interviewer and children to sit in a group, rather than in rows facing each other across a table.

The third interview was conducted at a different venue as the children had left the School and were now attending different secondary schools. For this interview the venue was a church hall in the same village as Nant School, the layout of which is shown in Figure 4.2.

Figure 4.2: Layout of interview venue for Year 7 interviews with children from Nant School.

(Illustration removed for copyright restrictions)

4.2 The fieldwork timeline

The timeline of the fieldwork is given in Table 4.3, outlining the schedule of observations and interviews conducted with Nant School.

Table 4.3: Timeline of fieldwork at Nant School

Research activity	Date	School year	Venue	Notes
Introduction	13/01/16	Year 5	Year 5 classroom.	
Observations	10/02/16 29/02/16	Year 5	Year 5 classroom.	Full day. Half day.
Interviews (0-1 month)	10/02/16 29/02/16	Year 5	Year 5 classroom, computer room and small room off main hall.	
Interviews (6-12 months)	20/03/17	Year 6	Computer Room.	
Interview with head teacher	21/06/17	Year 6	Head teacher's office.	
Interviews (18-24 months)	02/12/17	Year 7	Church hall local to the Primary school	

4.2.1 The initial introduction

Access to Nant School was negotiated through the head teacher who interviewed the researcher prior to consenting to participate. The initial visit to the School involved being introduced to the Year 5 class teacher, a female in her early 40s, who consented to allow the researcher access to her classroom, as well as being introduced to the Year 5 class. The second visit was conducted once parental and child consent had been obtained.

When initially meeting the researcher, the teacher appeared nervous about the presence of an engineer within the classroom, however this trepidation was attenuated once the researcher and teacher had discussed the aims of the research and the format of the fieldwork.

4.3 Observations

Observations were carried out as described in Chapter 3, the aim of the observations was to gain an insight into the activity and the children's participation in it.

4.3.1 Observation notes – 10/02/16

The schedule for the observations carried out on 10th February 2016 is given in Table 4.4.

Table 4.4: Observation schedule for 10/02/16 observations of D&T project at Nant School.

Time	Location	Activity	Researchers' location within the room	Notes
11.00am – 11.55am	Year 5 classroom	Research and design.	On a chair at position 1 in Figure 4.1.	
Lunch break				
1.00pm – 3.10pm	Year 5 classroom	Research and design.	On a chair by the sink area, position 2 in Figure 4.1.	Supply teacher takes the class.

The children began by sitting on the carpet as the teacher gave them information about the activity. The children were quiet, they listened attentively and raised their hands to answer questions. Some of the children, such as Jay and Scott, were quick to answer questions and talk about their ideas.

After the initial introduction to the activity, the children returned to their seats. In this session the children were labelling cam mechanisms in their workbooks and were designing their own moving toy, which they would subsequently build. The room was quiet during the initial task but the noise level increased during the activity.

Although this was an individual task there were interactions in the room throughout the session. Some children asked for help from peers, and there was almost constant discussion about the task between the children and the teacher, as well as between the children on each table. Specifically children asked questions about appropriate cams to use for different designs. Although many of the conversations were task orientated, some that were overheard were not, for example Matthew was heard talking with others on his table about the price of computer games. Matthew also asked the researcher a question related to the task *"We've forgotten about cams…"*, in response he was directed to ask other children on his table and went on to complete the labelling exercise in his workbook (page 2 of the booklet in Appendix H).

The children used the space provided in their workbook to design their own moving toy. The children were free to design the toy and each child appeared to draw inspiration from the things in which they were interested, and designs varied throughout the classroom with some children drawing animals, transport, or flowers as part of their moving toys. A number of children queued to show the teacher their ideas and designs.

The afternoon session involved an exploration of cams using a construction kit. The hands-on element was clearly exciting and there was an audible "*Yes*" from Matthew when the class were shown the kits they were to use. A number of children rushed straight to the cams kits whilst others stayed at their tables to finish their design work from the morning session (Figure 4.3).

The cam kits were placed on the carpet at the front of the room, whilst a group formed on the carpet around the box of resources (Figure 4.4), resources were also taken back to the children's tables and a range of individual, pair, and group work occurred during this stage (Figure 4.5 and Figure 4.6). The cam kits contained instruction sheets that were followed during this stage of the activity (Figure 4.7), rather than children making their own designs, appearing to support the children's learning by scaffolding their knowledge and skills in order to enable the children to create their own toys in future stages.

Figure 4.3: Individual design work.

(Illustration removed for copyright restrictions)

Figure 4.4: Children working in a group on the carpet area to explore the cam resources

(Illustration removed for copyright restrictions)

Figure 4.5: Children working together, using the instructions to explore the cam resources

(Illustration removed for copyright restrictions)

Figure 4.6: Children working in a group at their table to explore the cam resources

(Illustration removed for copyright restrictions)

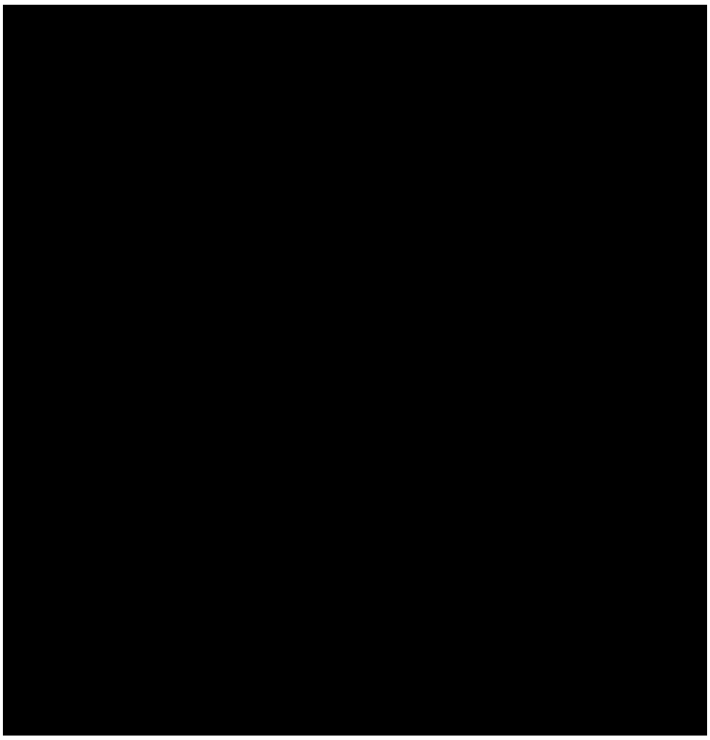

Figure 4.7: A child reads the instructions that accompanied the cam kits

(Illustration removed for copyright restrictions)

The interaction of the children with the teacher and each other varied, some children were keen to share their progress with others, including Scott who approached the researcher to share his creation and frequently engaged with the teacher. This pride in the creations was also illustrated when the teacher asked the children to take the models apart at the end of the session, as audible reluctance was heard within the room.

Part way through the afternoon session the teacher moved the activity away from construction and back to the written design work. Some children showed a reluctance to return to written work, Matthew made an audible “Awwww” sound at this news and other children took their time moving away from the cam kits and back to their D&T booklets.

The final design stage of the session involved a greater amount of sharing of ideas than the task immediately previous. Each child worked individually on their design however there were frequent “magpie sessions” where the teacher stopped the group, and the children shared their ideas. In between this facilitated sharing, the children share their ideas with each other in an unstructured way.

4.3.2 Observation notes – 29/02/16

The observation schedule for the second observations carried out at Nant School is given in Table 4.5 below.

Table 4.5: Observation schedule for observations on 29th February 2016 at Nant School

Time	Location	Activity	Location within the room
9am – 10.25am	Year 5 classroom	Building own moving toy	At a table at the back of the room (position 3 in Figure 4.1).
Assembly and Break			

The teacher began the session by explaining the plan for the day and making the children aware that they would be working with their "D&T buddy". Exploration and positivity were reinforced at this stage as the children were asked what the important points for the day were, responses were *"thinking"* (Scott), *"play"* (Jay), and *"not worrying"* (Paul).

The children supplied their own resources to build their toy designs, these included cardboard boxes, paper, material, and straws. The teacher had also provided some resources for the children to use. Scott, Jay, and Judy, all brought a large quantity of resources with them and Judy had started working on her moving toy prior to this session. Other children, for example Jack and Matthew, were solely reliant on the kit that the teacher provided.

The classroom was busy throughout this session as children moved around their tables. A number of children were observed engaging in 'off-task' behaviour during the session, for example Paul cut a straw into small bits so that they flew across the table. For the majority of the time the children appeared to be actively engaged with making their moving toys and progress was quick; by 9.45am production of the toys was well underway. Children made hand gestures as if acting out the motions of their design, the children discussed their designs with each other, and helped each other throughout the session. Accomplishments were celebrated by the children and excitement was seen and heard when children began to create working cam mechanisms, Scott exclaimed "*cam's in business*" when his cam mechanism rotated.

The children were encouraged to work collaboratively, and the teacher often deflected questions from the children to the rest of the class, encouraging them to offer advice and solutions. Once Scott got his cam mechanism to rotate, he found that he could not connect the other parts of the cam mechanism correctly, he showed the teacher who shared it with the class and Becka offered a solution.

4.3.3 Summary

The observations provided a grounding for the interviews, both in terms of insight into the activity and the children's participation in it. The activity was led by the teacher, a non-engineer, and was seen to include a range of engineering skills, including engineering thinking as defined within the RAEng report in 2014, and the processes of designing, creating, and problem solving. Although the activity embodied engineering, the term itself was not observed to be discussed by the teacher or the class as part of the activity.

The observations also provided the opportunity to assess the communication skills of the children, the children were observed to be confident and able to express themselves verbally.

4.4 Interview Data

Data collected from the interviews conducted with the participants from Nant School are presented in the following section. Although the analysis is presented in Chapter 6, the analysis of the data began at the start of the first interview as the constant comparison method was adopted, and so the key concepts were continually noted and it is these concepts and the data relating to them that are presented in this chapter.

4.4.1 Interview 1: Year 5

A total of 19 children participate in the interviews, 12 boys and 7 girls. The groups for the interviews were chosen based on opportunity and availability, whilst trying to maintain the friendship groups that had been observed during the activity. A total of 5 interviews were conducted with groups of between 2 and 5 children. The interviews lasted between 15 and 25 minutes, the average interview length was 20 minutes. The groupings are given in Table 4.6.

The initial interviews were used to explore the observations that the researcher made from the perspective of the children, as well as exploring the children's view of engineering. A semi-structured interview guide was used (see Appendix F), as discussed in Chapter 3 this was divided into five thematic areas: aspirations, play/interests, awareness/perception of engineering, engineering role models and hands-on engineering experience.

Table 4.6: Year 5 - Nant School interview schedule

Date	Group	Participant	Gender	Age	Length of interview
10/02/16	Group 1	Matthew	Male	9	15 m 17 s
		Bryn	Male	10	
		Jane	Female	10	
		Ella	Female	10	
		Becka	Female	9	
29/02/16	Group 2	Jay	Male	9	16 m 42 s
		Will	Male	9	
		Nicky	Female	10	
		Judy	Female	9	
	Group 3	Chris	Male	10	22m 20 s
		Matty	Male	9	
		Kat	Female	10	
		Jenny	Female	9	
	Group 4	Scott	Male	10	18 m 36 s
		Paul	Male	9	
		Stewart	Male	?	
		Billy	Male	10	
	Group 5	Jack	Male	9	25 m 23 s
		Jackson	Male	10	

4.4.1.1 Perception: What is engineering and what do engineers do?

The initial focus of the interviews was the children's perceptions of engineering and many views of engineering were expressed during the interviews. Although the initial questions invited children to talk about their knowledge and understanding of engineering and engineers, their views and beliefs of engineering, expressed both explicitly and implicitly, were presented at various points through the interviews.

None of the children mentioned the EEA they were observed participating in when talking about engineering. Whilst a number of children stated that they had no or limited knowledge about engineering or contributed little to discussions about engineering, there were also those who confidently expressed their views of engineering and engineers. Other children exhibited awareness of engineering but exhibited uncertainty through the form of questions directed to the interviewer in response to questions about engineering.

> *Does it have something to do with cars and like fixing things?*
> (Kat, F)

The dominant conceptual area used to describe engineering by the children was physical artefacts in the form of products, where transport was prominent.

> *I know lots about cars and all the sort of stuff*
> (Bryn, M)

> *…in engineering you can make stuff and fix things and change things a little bit, say if you wanted to be a person that fixed cars you would be an engineer.*
> (Scott, M)

> *I think trains and planes are engineering, I think.*
> (Becka, F)

Processes such as designing, making, and fixing were also understood to be engineering by the children and job attributes such as shift work, workload, active, and good pay were also mentioned by children.

> *You would also know like how to build stuff and, erm you know how stuff works.*
> (Bryn, M)

> *They design some stuff.*
> (Jane, F)

> *They build modes of transport, and stuff, erm, they build anything really.*
> (Bryn, M)

There was evidence that children were able to describe engineers in terms of the role that engineering and engineers have in society and the different roles that engineers can hold.

> *Depends what engineer you are.*
> (Scott, M)

> *They help the world move on to like high tech stuff.*
> (Jay, M)

In the main, discussions around what the children perceived engineering to be contained no judgement with neither negative nor positive inference (either verbal or non-verbal) being made by the children. A divergent case was Chris, who described engineering as *"cool stuff"* when talking about the physical artefacts he associated with engineering (cars, transport).

Children's perceptions of engineering were also displayed when talking about their hobbies, Jack and Jackson spoke of their hobbies, building Airfix models and model railways respectively. When asked about whether they considered these hobbies to be engineering they displayed uncertainty.

> *ahhhh err maybe because engineering is repairing.*
> (Jack, M)

During the conversation regarding this, Jackson began with the clear assertion that his hobby was engineering, however Jack associated engineering with repairing and so did not associate his hobby of Airfix with being an engineer. Within their conversation, Jackson seemed to alter his view once Jack had defined engineering as repairing.

The importance of role models

Although previously identified as a theme within the literature the concept of role models was invariably introduced into the conversation by the children themselves and role models were viewed by the children as a potential source of knowledge about engineering. Some children placed importance on knowing an engineer, indicating that they expected to know about engineering.

> *Oh, ooooh. I should know quite a lot because my dad's first job was as an Aston Martin engineer.*
> (Jack, M)

Whilst family members were cited most commonly as role models, when the children talked about their understanding of engineering, teachers were also mentioned as a source of information about engineering.

> *In assembly once Mr. S said "here I've got an Apple watch imagine what your watches can do in, in like when you're my age."*
> (Nicky, F)

> *They were talking about like in olden days like computers how long they would load and how different they are from now.*
> (Jay, M)

The influence of the media

When the children spoke about how they developed their ideas about engineering, the media (specifically TV programmes and computer gaming) was a recurrent theme.

> *…I've never experienced it but it looks fun, the stuff I watch on telly like Top Gear.*
> (Matthew, M)

> *I think it's the game that's put me into it it's fascinating.*
> (Jack, M)

4.4.1.2 Views of engineering education activities

As the children did not initiate discussion of the EEA, the interviewer prompted the children to consider the EEA, asking whether they thought it was engineering or not. This led to a variety of responses from the children with the EEA viewed either as separate from engineering or as engineering for a variety of reasons.

> *It's not like actually engineering, like a proper car or something like that.*
> (Will, M)

> *It's designing and making.*
> (Jane, F)

> *…cos you're designing your own thing.*
> (Jay, M)

> *…because we're still cutting things up and making them move and stuff.*
> (Will, M)

In one interview, Stewart viewed the activity as separate from his interest in cars and so did not feel as though it was engineering however, Scott perceived that engineering was concerned with planes and as he had incorporated a plane into his design he therefore was able to view the activity as engineering:

> *…for me it is not exactly separate cos I'm doing a plane engineer thing…*
> (Scott, M)

When reflecting on the engineering involved in the EEA a few children did mention that they found the activity harder than they had anticipated.

> *It looks easier than it is.*
> (Scott, M)

> *I thought it would just be simple and it would be really easy but actually it is really hard when you are actually doing it.*
> (Stewart, M)

Peer influence

For some children opinions were influenced by the conversation that occurred within the group interview, as was exhibited when the interviewer asked the children whether they thought the EEA was engineering. For example, Matthew held a firm belief that engineering is related to cars and when discussing the EEA they had participated in, Matthew was unsure about the engineering content of the activity until he was able to frame it in the context of his existing perception of engineering.

> Matthew (M): *a little bit…*
>
> Bryn (M): *yes, yeah.*
>
> Matthew: *…but I don't know why.*
>
> Jane (F): *it's designing and making.*
>
> Becka (F): *designing and making, yeah.*
>
> Matthew: *I mean you could design a new Lamborghini but…*
>
> Becka: *yeah and you could like design a new engine.*

In the exchange below, Jay began with the idea that the EEA was engineering, as this fitted with his perception that engineering is making and "*designing your own thing*". The rest of the interview group did not share this perception and a subtle shift in how Jay articulated his view of the activity occurred during the conversation.

> Will (M): *because it's not like actually engineering, like a proper car or something like that*
>
> Nicky (F): *or a helicopter*
>
> Judy (F): *It's not like building machines or anything*
>
> Jay (M): *well this is a machine, kind of*
>
> Nicky: *not really*
>
> Judy: *not a machine, it's like a thing.*
>
> Jay: *moving…*
>
> Nicky: *It's not really a…*
>
> Judy: *A toy*
>
> Jay: *a moving toy basically*
>
> Nicky: *It's a toy, It's a cam…*

Although this finding is only an indication that Jay's perception was altering, it may have been that he altered his answer to fit in with the majority of the group, rather than reflecting his true belief.

4.4.1.3 Career aspirations: engineering as a future career

The data show that children do hold career aspirations at this age, however engineering focused ambitions were scarce within the participants. Career aspirations ranged from very clear and focused aspirations to other careers for example, footballer, therefore leading to engineering being discounted as a potential career, to less firmly held career aspirations that allowed the child to consider engineering as a possible alternative.

> *I'd have it as a back-up job*
> (Matthew, M)

> *If like maybe when I get a bit older like after if I am an RAF pilot I might be an engineer for the RAF or something so I can fix the planes and stuff*
> (Scott, M)

A mixed response to engineering as a possible career was exhibited by the children, responses were based around the concepts of interest, perceived ability and knowledge and the children tended to describe themselves as either able or not able to be engineers.

I like cars as well so maybe engineering might be like something that I want to do.
(Stewart, M)

I don't really know much about cars and stuff.
(Jenny, F)

I would like that job as I'm interested in cars and learn more about engines and how erm they work and everything technical.
(Jack, M)

Children were also seen to view their limited knowledge of engineering as a reason for them being unable to consider engineering as a career.

I'm not sure, it's just I don't really know much about engineering
(Ella, F)

4.4.2 Interview 2: Year 6

A total of 17 children participated in the second set of interviews, 10 boys and 7 girls (see Table 4.7). A total of 5 interviews were conducted, group sizes ranged from 2 to 4 and the interviews lasted between 14 minutes and 26 minutes, the average interview length was 18 minutes.

One child had left the school and another was not invited to take part due to his behaviour towards the other children in his group during the first set of interviews. Although the researcher understands that the children may change, and their behaviour alter over the course of the data collection, the decision not to invite the child back was deemed the most ethical, and was taken in order to protect the other children from potential discomfort.

Table 4.7: Year 6 - Nant School interview schedule

Date	Group	Participant	Gender	Age	Length of interview
20/03/17	Group 1	Jack	M	10	21m 20 s
		Billy	M	11	
		Paul	M	10	
		Chris	M	11	
	Group 2	Scott	M	11	25 m 33s
		Matty	M	10	
		Bryn	M	11	
		Jay	M	10	
	Group 3	Jenny	F	10	13 m 43 s
		Judy	F	10	
		Ella	F	11	
	Group 4	Jane	F	11	16 m 44 s
		Nicky	F	11	
		Kat	F	11	
		Becka	F	10	
	Group 5	Stewart	M	10	14 m 40 s
		Matthew	M	10	

The semi-structured interview guide was used again, focusing on the concepts emergent from the initial interviews whilst allowing the children to lead the conversations and explore new concepts. The children were asked to recall the EEA they had carried out, and their perceptions of engineering were once again explored during the interviews.

Perceptions were similar to those discovered in the Year 5 interview data and the focus on transport and physical artefacts as defining engineering for the children was seen to persist, there was a slight increase of emphasis on the role of engineers in society within the children's narratives, however process and product orientated definitions continued to dominate. Uncertainty was still present within the children's perceptions of engineering, and there is evidence to suggest that participation in the EEA was not considered by the children when reflecting on their engineering knowledge. Self-interest and perceived ability continued to be the dominant concepts regarding the children's consideration of engineering as a career.

4.4.2.1 Recollection of the activity

The researcher began the interviews by asking the children if they could recall the activity they had taken part in the previous school year. The children exhibited limited recollection of the activity and the photographs taken during the activity were used with all of the interview groups. Where children linked the activity with engineering immediately their reasoning was not always clear, and others focused recollections on their perceived success or failure during the project.

> *Yeah the toys one they said it was engineering erm, and most of our DT that we do is engineering, based on engineering.*
> (Scott, M)

> *To learn about engineering […] I don't know [why it was to learn about engineering].*
> (Chris, M)

> *Oh I remember that and then we had to like make it in class … I did like a monkey swinging from trees but it failed really badly.*
> (Nicky, F)

Where engineering was not discussed in reference to the EEA, the researcher used questions to initiate conversation and probe this area, questions included *What skills did you use?* (G2), *If I said that was an engineering activity would you agree or disagree?* (G4), *Did you learn anything about engineering from that activity?* (G5). When discussing the perceived engineering nature of the activity, children focused on the processes involved, making and planning, and the materials used.

> *Engineering…because we were making stuff.*
> (Ella, F)

> *Cos it's like building stuff and working stuff out.*
> (Stewart, M)

> *Yeah cos it's like making stuff and working with stuff.*
> (Nicky, F)

> *Cos it's about how things work.*
> (Kat, F)

…we had to plan it and then build it.
(Ella, F)

It was kind like engineering cos of how the mechanisms work and stuff but then again it was just with like paper and stuff, but then again it was still engineering … we still had to like make the mechanism work and stuff and that's part of being an engineer and stuff.
(Paul, M)

When talking about the activity some children spoke of the influence that the activity had had on their understanding of engineering, mainly focusing on the lack of information they had prior to participation, or an alteration to their existing awareness.

Since we learnt about this and this was called engineering we started watching more things on engineering because we thought it was cool so we didn't really have an idea about engineering until then really.
(Scott, M)

We didn't really know anything before.
(Jane, F)

I didn't realise that they had to go through many stages to get it built, like planning and designing.
(Ella, F)

I thought "Oh it looks very easy" and you just put all the stuff together but it's actually really hard.
(Judy, F)

For some children participation in the EEA altered how they looked at the world.

…when you get like a new toy that's electronic, you don't think how it's made you just wanna play with it but when you think from the technical side they have loads of things inside.
(Matty, M)

Cos as Bryn says it like changes how you think of stuff like you see something and you "Ahh that must be to do with this".
(Jay, M)

Although not emergent as a strong concept from the data, children were seen to regard the activity as a nucleus for developing an interest in and better understanding of engineering.

… if you weren't at school you wouldn't have known about engineering, but then I took it home and just watched it all on YouTube…
(Scott, M)

However, not all children viewed participation in the EEA as an experience of engineering, when the interviewer asked them about whether they thought they had done any engineering.

Well I've had little stuff but not proper.
(Judy, F)

4.4.2.2 Engineering

A number of children expressed that they had no understanding of engineering whilst and others held perceptions of engineering but struggled to provide a detailed definition.

I don't know but my brother wants to be one.
(Nicky, F)

Well it depends what kind of engineer, that like, there's like loads of different ones
(Judy, F)

…like you can think of things and then most things are to do with engineering is what I'm saying basically.
(Scott, M)

Uncertainty was exhibited through the use of questions directed to the interviewer or statements indicating a level of confusion surrounding what constitutes engineering.

I've got a toy car, a remote control one. I don't know if that is engineering or not.
(Jane, F)

…say you went to theme park, is rides engineering?
(Matthew, M)

Yeah would you say engineering was building a summer house? Building anything?
(Ella, F)

I dunno if this is engineering but he's a jeweller of sorts […] but I don't know if that is to do with engineering.
(Scott, M)

In response to questions such as these the interviewer re-directed questions to probe the children's understanding of engineering. In the cases above, Matthew went on to use his existing perception of engineering to explain why rides are engineering.

> *Because they, I hope not but if there's an accident then they would know how to fix it.*
> (Matthew, M)

Jane considered the technology as engineering in particular the functionality of the remote control.

> *Maybe a bit…cos like in the car it needs to be like able to see that you are pressing the buttons on the remote and it needs to connect in some way.*
> (Jane, F)

When probed Ella did not consider building a summer house to be engineering however another member of the interview group associated building with engineering.

> Ella (F): *Not really, kind of.*
>
> Jenny (F): *Building is sort of.*

Scott likened the jeweller to an engineer in terms of the processes involved, building and making new items.

> *Cos he build he makes jewellery and he makes different things for different people so like different patterns and different sized diamonds and has to deal with loads of things like that and, he makes something. It's not something that someone has done before he makes it like whatever somebody wants, even if it hasn't been made before he can do it.*

Process, artefact, and impact

The concept of using a process to define engineering was seen, also used were physical artefacts in the form of products, and the impact that engineers have on the world. A focus on transport as a product of engineering formed the core of what engineering is for the participating children, however other products were also referred to.

> *Engineers are making like cars work and stuff like that.*
> (Nicky, F)

> *Building cars, isn't that engineering?*
> (Ella, F)

They build stuff so like an engine in a car, the engineering, they would build the engine for the vehicles.
(Becka, F)

If we didn't have engineers then we couldn't have any army cos we couldn't make any of, we couldn't like make anything to defend ourselves.
(Scott, M)

For others engineering was seen as a process or skill e.g. fixing, building, inventing.

Building is sort of.
(Jenny, F)

I always thought they just make stuff and sometimes they invent stuff and they build stuff and they fix stuff
(Paul, M)

They don't invent stuff, no, they just build it.
(Ella, F)

Well like in normal life we just see the end product and stuff and they're the ones that do everything to make it.
(Paul, M)

Like when you talk about engineering you talk about building…
(Matthew, M)

In addition to product and process focused views of engineering, there were children who were seen to hold perceptions not orientated around a product or process, rather they perceived engineering in terms of the impact it has on our world and the personal attributes of engineers.

If there were no engineering like I said, you wouldn't have anything here, nothing in this room would have been made except for us without engineering really.
(Scott, M)

Helping the planet move on I think.
(Jay, M)

…what about producing food like if you tried to grill something engineering make the stuff to grill the food.
(Matty, M)

> *I think you would definitely need to be resilient cos if one thing breaks just like that and then you say I'm not doing it anymore then you wouldn't be a very good engineer.*
> (Paul, M)

The differences between children's perceptions of engineering is highlighted in the segments from a conversation between the interviewer and two boys. The quotes below show the boys using their existing knowledge and interests in the formation of their descriptions of engineering.

> Matthew: *Erm, like fix stuff, mend stuff. They build stuff like inventions?*
>
> Stewart: *I'd say like maybe invent new ideas and how to make stuff so…*

When the interviewer probed the children to find out what type of *"stuff"* they thought engineers work on, the boys both related engineering to transport.

> Matthew: *Cars.*
>
> Stewart: *Planes.*
>
> Matthew: *Any type of like vehicle cos mechanics are engineers.*
>
> Stewart: *No wait because they fix stuff and get it working and stuff.*

It can be seen that Matthew and Stewart held different definitions of engineering; Matthew viewed engineering as the processes of fixing, mending, and building associated with cars, and whilst Stewart also viewed engineering in terms of processes, he refers to inventing new ideas and how to make things. Although Stewarts relates planes to engineering, he does not appear to be as product specific as Matthew in his perception.

The subtle difference between these perceptions became clearer when the children spoke about engineers; Matthew viewed mechanics as engineers as they fix vehicles (two key parts of engineering in Matthews perception), however Stewart did not view them in the same way. His perception of engineering is the invention process rather than instruction-following processes and so fixing does not align with his definition.

4.4.2.3 Aspirations to engineering

When considering if they could become engineers the children spoke in terms of interest and perceived ability.

Well I like planes and I like doing practical stuff and I think that'll be a good job for me when I'm older.
(Stewart, M)

Personally I'm not very good at building and even if I try I can't do it that much.
(Matthew, M)

No because my monkey thing [referring to the moving toy activity] failed.
(Nicky, F)

Cos if something don't work they've got to do it again and then find what does work and I'm not very good at that.
(Chris, M)

I like electronic remote control stuff and when they break I take it apart and make other stuff with the motors and things.
(Jay, M)

No, I might be a good engineer but I don't think I consider doing it […] because there might be like other jobs to do, like other opportunities.
(Ella, F)

I might be like designing for engineers but I'm not very good at actually making the stuff but maybe.
(Judy, F)

Neutrality dominated the children's responses, with any positive or negative judgements of an engineering career being verbalised indirectly.

Cos it sounds fun.
(Billy, M)

It's not a boring job.
(Paul, M)

When asked if they thought they would make good engineers a range of answers were presented, these encompassed reflections on skills, and experience.

Probably not cos I'm impatient.
(Chris, M)

I haven't really tried.
(Paul, M)

If we had the right training then we probably would.
(Billy, M)

4.4.2.4 Linking D&T and engineering

Children began to use their definitions of engineering to interpret past experiences and a link between D&T and engineering appeared, with the two words becoming interchangeable for a number of children.

> *…like you have to do it yourself and make it and then a lot of the time it moves and stuff so I just thought that would be to do with engineering.*
> (Scott, M)

> *When I was in Key Stage 1 I found engineering really boring but then when I moved up to Key Stage 2 I learnt more and did more of the activities I now like it.*
> (Becka, F)

This link emerged when the children were asked to recall any other engineering activities they had participated in at school. This also saw continuity emerge as a concept as children spoke about the lack of engineering activities in school due to preparation for the SATs[10].

> *I don't think we've done anything in school.*
> (Kat, F)

> *We were starting fairground rides but we never actually go to it […] we are doing it after SATs.*
> (Judy, F)

> *Cos we started a topic but we didn't finish it cos we were doing SATs and then we were going to finish it after SATs but they did last year and we are going to do it this year and we've started it, it's fairground rides.*
> (Becka, F)

> *…we've been like practicing for SATs mostly.*
> (Jane, F)

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[10] SATs are national curriculum assessments carried out in Year 2 and Year 6 in England (see STA (2017) for more details).

4.4.2.5 Interactions with engineering

Other areas of information were highlighted within the interview data; television, social media, family, and external activities were all mentioned when the interviewer explored this area with those children who said they knew what engineering was or had some experience of engineering.

> Jay (M): *More watching people do it I guess.*
>
> Matty (M): *Yeah*
>
> Jay: *In programmes on telly.*
>
> Scott (M): *On TV, yeah.*
>
> Jay: *Yeah, like How It's Made*[11]

Other children spoke of the toys that they play with, such as Lego, K'Nex and Meccano.

> *….and you can like build stuff and engineer with it and stuff.*
> (Becka, F)

> *You have to engineer it and make it yourself.*
> (Scott, M)

Role models and other people who informed the children's views of engineering were mentioned. However not all children accessed information from engineering role models, as Jack recalled that his dad used to be an engineer at Aston Martin but that he didn't talk to him about engineering:

> *Nothing about engineering, just what he did.*
> (Jack, M)

Previous school based activities were perceived as engineering during these interviews, with a Year 5 activity being mentioned, although this had not been spoken about during the first interview.

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[11] How It's Made is a science documentary television programme produced in Canda (Bell Media, 2018)

Scott (M): *Yeah we've done things in school on engineering.*

Jay (M): *Yeah.*

Matty (M): *I remember us learning about the car, axis…*

[…]

Bryn (M): *Oh yeah I remember that.*

[…]

Matty: *I put mine in the bin.*

Scott: *Yeah we made cars, we made like proper.*

4.4.3 Interview 3: Year 7

The final interviews with the children took place 22 months after they had been observed participating in the engineering education activity. A total of 3 children participated in the third interview (see Table 4.8). The children had left primary school and were now attending different secondary schools. At the end of Year 6 contact details were requested from parents so that the children could continue to participate in the research. A total of 7 children returned forms to the researcher and of these seven, three attended the final interview.

Table 4.8: Year 7 - Nant School interview schedule

Date	Group	Participant	Age	Gender
02/12/17	Group 1	Becka	11	F
		Matty	11	M
		Jay	11	M

The interview recording was 53 minutes in length and started with the children being asked to introduce themselves before moving on to talk about engineering and the activity that the children took part in in Year 5.

Perceptions were seen to persist, with products and processes continuing to influence the children's definitions, however the children were seen to be more specific in their definitions, and required qualifications and skills represented a shift in focus within the children's perceptions. Stereotypical views of engineers also appeared more strongly and were also observed in the imagery the children used when talking about engineers.

4.4.3.1 Recollection of the Engineering Education Activity

The children initially recalled the EEA in broad terms, focused on the success or failure of the models they produced during the EEA more strongly in this interview than in the Year 6 interviews. The photographs were again used to elicit further recollections, the children continued to comment on the success or failure of their models but with reference to the investigating cams stage of the activity where they were using the cam kits supplied by the teacher. An example of a design made using this kit is shown in Figure 4.8 as this photograph was referenced by the children during the interview.

[redacted]

Figure 4.8: A child showing the researcher his working model produced using the cam kits provided by the teacher during the first observations of the activity.

(Illustration removed for copyright restrictions)

> *Oh I was doing like a flower growing but it kind of turned out like really badly.*
> (Becka, F)

> *Ours didn't work, the Lego man just fell off…*
> (Matty, M)

> *We did these to start with and tried to practice on these [indicating the cam kits in the photographs] and these went really well, and then when we tried the real things they went really badly.*
> (Becka, F)

> Yeah, these [the cam kit models] worked so well. Then the real thing worked horrific
> (Matty, M)

When discussing the engineering involved in the EEA, engineering was identified, however the school subject that the EEA was associated with, D&T (referred to as design by some children), was also identified rather than engineering itself.

> *Yeah cos like you had to like make a structure and you had to, cos it was a moving thing so, yeah.*
> (Jay, M)

> *Well I knew it was design.*
> (Matty, M)

> *… when somebody mentions the word engineering I remember this.*
> (Becka, F)

4.4.3.2 Cadence of formal engineering activities

The children could not recall any other engineering activities that they have done during primary school, SATs were mentioned by the children as the reason they thought they had not done any more D&T, continuing from a concept raised in the Year 6 interviews.

> *We were meant to do fairground rides but we didn't do that.*
> (Jay, M)

> *Yeah we were supposed to be making a fairground ride but we didn't get time because of all the preparing for SATs…*
> (Becka, F)

The link between D&T and engineering was reiterated as the children spoke about exposure to engineering in their secondary schools.

> *Well I'm doing design, in design I'm doing textiles, I don't know if you would call that engineering.*
> (Matty, M)

> *Not really but we have done design classes and stuff, I've done textiles and food so far.*
> (Jay, M)

Although for some children confusion occurred as they attempted to align the D&T they were currently doing with engineering.

> Becka (F): *I'm not [doing D&T].*
>
> *Matty (M): No, food tech is design, it's like part, no design is split into different things.*
>
> *Becka: Yeah I'm doing food tech.*
>
> *Matty: Food tech in design.*

None of the children could recall anybody mentioning engineering in their secondary school, however, the children used their own perceptions of engineering to decide if activities they had done at secondary school were engineering.

> *Well, I think it kind of was cos it's putting together, it's like Lego but it's not Lego.*
> (Matty, M)

Although the children's responses highlighted the lack of discussion around engineering and a dearth of engineering activities within school, they did talk about things they do at home which they classed as engineering.

> *Oh actually one thing I do at home which is engineering, so like build these Lego things...*
> (Becka, F)

> *Yeah, I have like this wood kit that I like have lots of wood and I make stuff out of it…and there's also these metal sheets, you have to connect like, connect them.*
> (Jay, M)

> *My dad's gonna take me on like a trip to it [JCB], cos he is allowed to go there, they show him around it.*
> (Jay, M)

4.4.3.3 Perceptions of engineering

The children's perceptions of engineering were again explored, direct answers to the question *what is engineering?* as well as the ways in which the children spoke about engineering throughout the interview contributed to the data presented in this section. The children were observed to speak about four distinct categories; technical skills, processes, products, and job attributes.

1. Technical skills such as maths and coding.

> *Isn't it fixing things and is it a lot, don't you need to be really good at maths to do it?*
> (Becka, F)

> *…if you want to get into engineering you need to choose stuff like design, sometimes ICT, just so you can programme.*
> (Matty, M)

2. Processes such as planning, making, fixing and designing.

> *I think it's like, kind of like part designing, like you're thinking about an idea and putting it into real life.*
> (Jay, M)

3. Physical artefacts (products), for example cars, planes and boats.

> *Building cars!*
> (Matty, M)

4. Attributes of the job.

> *They think of an idea and they draw, kind of like design it and produce it kind of thing.*
> (Jay, M)

> Matty (M): *Yeah I can imagine me, like with a hat on, working all day on this one engine.*
>
> Becka (F): *Covered in oil*

Some uncertainty was once again seen and the children were observed to explore their own perceptions of engineering during the interview.

> *Is an engineer someone who could be like someone who builds a building?*
> (Matty, M)

> *Like, they might not build but they do all the planning and sort out all the pipes and walls and everything, I think. […] A bit like an architect but engineers can like, like, either like fix things in their house if like your boilers broken or something.*
> (Becka, F)

4.4.3.4 Gaining knowledge of engineering

The impact that participating in the EEA had on the children's perceptions of engineering was discussed during the interview, the main concept that these conversations produced was that of existing knowledge. Reflections on the limited knowledge of engineering that were brought into the activity were present in the data.

> *Like at first I didn't know what engineering was so I didn't know that this [the activity] was but then when I went to talk to you out the class, you then talked about engineering and told me what it was, then I realised, when I came back I realised that this was engineering.*
> (Becka, F)

The previous quote from Becka shows how participating in the research alongside the activity, and the researcher's involvement in talking to the children became joined together in her recollection, highlighting the impact that participation in the research process may have had on her perceptions about engineering. For other children who felt that they had arrived at the activity holding a perception of engineering, this was then discussed when talking about whether taking part in the activity had changed their views about engineering.

> *Not really. It was kind of like, I've already done that kind of thing before.*
> (Jay, M)

When the children spoke about the bearing that the activity had on their engineering knowledge, they spoke of the change in their perception of the engineering process rather than displaying a change in their definition of engineering.

> *I thought it would just be the same thing every day, it would be all repairing, but then I was thinking like how many different things you could do, like on cars you wouldn't do the same car every day, you'd have different engines come in, different types and everything in the car, and if you're doing planes you get big ones, small ones…*
> (Matty, M)

When discussing where the children felt they found out about engineering, school was not a key area, and television and social media continued to act as engineering informers for the children. However, occasionally informal engineering activities were mentioned.

> *You Tube and television programmes, there's like big engineering programmes on like How It's Made and stuff like that…and like challenges, like this one called Scrap Heap Challenge.*
> (Jay, M)

> *Like Top Gear, how they talk about how, what the car is, how fast it goes, horse power, about the engine, the wheels as well and the structure of the car.*
> (Matty, M)

> *The news, there's also some stuff about it, like a big, bridges that have just been built and amazing structures, yeah.*
> (Jay, M)

> *I went to, is it the Big Bang? No, not the Big Bang, it's like a big shed, all like people of engineering like things, JCB were there, er the Royal Navy Engineers were there, like searching for like employees for like later on, like I went there with my brothers.*
> (Jay, M)

However, everyday experiences also appeared to influence the children's views of where engineering could take them, and interactions with other people were viewed as an important source of information, although the researcher was sometimes identified as the children's source of information.

> *Like grownups just telling you about it.*
> (Jay, M)

> *Cos before you came in they didn't actually mention engineering.*
> (Becka, F)

This resulted in dialogue about engineering being raised by the children as a key factor in helping develop an understanding of engineering.

> *We were really lucky for you to come into our school and do this but if you went to more schools like people did, and told them about engineering then they'd know more…*
> (Becka, F)

> *People could go round like primary schools and teach it, so in a session just telling them what it is and maybe doing a little activity.*
> (Jay, M)

4.4.3.5 Engineering career aspirations

One child identified engineering as a possible future career (Jay had expressed this aspiration since the first interview in Year 5), and all children verbalised that anyone could be an engineer. The children's perceptions of the capability of someone to become an engineer was couched in ability, skill, interest, and knowledge, and the children were able to identify themselves as potential engineers if they had an interest and could demonstrate an ability at what they perceived engineering skills to be.

> *Cos I like planes.*
> (Matty, M)

> *Cos like at school I'm good at art and design classes, and I really like making things and doing stuff.*
> (Jay, M)

> *Er, like I don't really know, I haven't really thought about it.*
> (Becka, F)

However all children (both those who hold engineering aspirations and those who have not considered it as a career) were seen to hold ideas about what they would need to do to become engineers. These were focused around experience, knowledge, and qualifications.

> *Like do well in my GCSEs and like maths and science and stuff, and then go to university and study it.*
> (Jay, M)

> *Know about engineering, read more books about it and do more, like more activities.*
> (Becka, F)

> *At school, you have to like choose different options in Year 8 going to 9, so you wanna choose, like if you want to get into engineering you need to choose stuff like design, sometimes ICT, just so you can programme.*
> (Matty, M)

> *Well it depends on our GCSEs cos if I don't get the right amount, if I want to be an engineer, I'd need to get a good kind of score, and if I don't I'll have to change my mind and think about it.*
> (Jay, M)

4.4.4 Adult Interviews

In addition to the interviews conducted with the children, an interview was also conducted with the head teacher of the school. This provided additional information about the school as a whole and was also used to gain a supplementary perspective on the concepts that emerged from the interviews with the children.

The head teacher, a middle-aged female, had been at the school for 21 years, first employed as the Deputy Head, she became Head of the school in 2004. She was interested in the children's voice and conducted a Masters research project, which focused on discussions with 4 year olds.

4.4.4.1 Engineering

When describing engineering the head teacher placed a focus on the creative aspect but also the overall aim of engineers and their role in society.

> *Engineering means to me, creativity, it means thinking outside the box, it means innovation, it means testing yourself and testing others and coming up, hopefully, with solutions to perhaps some of the problems that we face in the future.*

The head teacher independently recognised the existence of a *"gender issue"* in engineering and spoke about females leaving primary school with strong science and maths who do not translate this into engineering. She also spoke about female engineers who she has known which may have informed her view.

> *I remember one of the students who left here saying, she actually did go into engineering, I remember her saying I'm the only girl that's doing this…*

When discussing the engineering backgrounds of the staff at the school gender appeared again.

> *I have to think through the current staff, I mean probably to be honest, familywise some of the teachers do in that their husbands, dare I say that but it's true, their husbands are involved in the engineering field.*

4.4.4.2 The curriculum

The head teacher viewed engineering as part of the "*long term curriculum plan*" at the school and there was a "*thematic approach*" to it within the curriculum, however it was not labelled as engineering and was not taught discretely or necessarily discussed within the curriculum. Rather it was viewed as a cross-curricular topic that is within the curriculum at the school.

> *Engineering as such if you said that to a lot of teachers they would probably think well we don't actually do that, but actually we do but it comes under the remit I suppose of, we call it Design Technology in the primary school and to a degree science.*

So I think it links to, I don't see it as necessarily as just a discrete unit, I think it's an area that links and feeds into many other areas of the curriculum.

Although the head teacher viewed engineering positively, she highlighted the relative unimportance of engineering in comparison to other subjects when talking about the external facilitators who the school pay to deliver enrichment activities, the focus of the funding being to support sports. Similar opportunities for engineering activities in primary school were not apparent.

We do quite a lot, in terms of sports we have something called the sports premium which is a government initiative, it's a grant that you basically get and on the basis of that we tend to offer those sports that perhaps we feel that we can't.

For some reason those opportunities [national engineering activities available to secondary schools] don't seem to be available in the primary sector.

However, the head teacher was keen to give students a broad range of opportunities and identified times when the school engaged with engineers directly, as well as areas where she would like to see more engagement.

…we see so many children that have got skills in the non-core at the moment subjects, and if you don't give those children that opportunity then, they are never gonna shine, so I think that is really really important.

We've done something here on the world of work where we've had engineers as part of that where we've had people coming in and talking to the children about careers and aspirations

I'd love to have more real life, real world engineers coming into school because I think that's important as role models

When talking about the D&T curriculum, the head teacher reflected that transport was often a theme upon which projects or challenges were based within the curriculum.

…we have different challenges for the KS1 and KS2, so KS2 have done things in the past that they've had to design a container to transport eggs, we've had where they designed a boat and again that had to transport the eggs […] we did the cars etc and all of that kind of thing so I'm thinking that we do a lot actually, an awful lot in school that probably does relate to a transport kind of theme.

4.4.4.3 Learning and Teaching

The head teacher emphasised the promotion of independent learning within the school, and the children's use of technology within the curriculum to conduct independent research.

> *…in everything we are trying to encourage that ownership and that individuality.*
>
> *Children want to go and want to find out and want to research, you know and do it as part and parcel of the curriculum and they are very confident with the new technologies*

Not restricting the children was also a key theme woven through the head teacher's narrative during the interview.

> *I think if anything we've got to be careful that we don't restrict it, I think that's what worries me, you know there's this real creativity and innovation and wanting to explore and if we're not careful we can you know, put limits on it*
>
> *You've got as a teacher you've got something in mind and you can think well actually this is what the end product will look like and I'm constantly saying to staff, "Well you know actually give the children the opportunity to..."*

Policy and results pressures were clearly felt and were seen to influence the curriculum the school delivered, the worry being that policy did not encourage a holistic approach to education.

> *…we've tried as much as you possibly can in the current climate to have a balanced curriculum but you probably know that Ofsted are quite concerned that the curriculum has been narrowed in a lot of school because of the pressure of the preparation for SATs and it is a concern because you know, it's, if you are not careful you do have a very limited experience for children and a limited skill set.*
>
> *…it's a conflict to be honest because my heart has always been with a balanced broad curriculum as you have probably gathered, however, you can't be, you can't be ignorant of the pressures that are around you and the accountability that there is…*

4.5 A brief reflection on the researchers role within the research case

Although Chapter 8 reflects upon the research as a whole, taking into account the researcher and the participants, a brief reflection of the researcher within the case is presented here.

It has been seen from the narratives of a few children within the case that the presence of the researcher is likely to have influenced their exposure to engineering, as both Becka and Scott directly referred to the researcher or the research as sources of awareness of engineering. This influence is clearly stated and as a finding can be woven into the analysis, as it has indications for the level of exposure children would normally have and the role that repeated exposure and discussion regarding engineering may have. However, more subtle influences may have occurred and those are the focus of the reflection at this point.

The introduction of the researcher as an engineer by the teacher may have put the researcher into a position of authority with the children, indeed the researcher was asked questions relating to engineering and the EEA by the children. Conversely, this may also have led to the children asking the researcher questions about engineering that they may not have asked had they not been aware of the researcher's background, consequently it is felt that these questions enabled the researcher to gain a deeper understanding of the engineering knowledge and curiosity that the children had.

4.6 Summary

The concepts emergent from the data, alongside supporting qualitative data, have been presented in this chapter. Analysis of this data has been kept to a minimum, however concept identification was required for the presentation of the data (as explained in Chapter 3). Following the presentation of Case 2 in Chapter 5, a meta-analysis and discussion of the data are presented in the following chapters.

CHAPTER 5

5 Case 2: Phren School

In a similar format to the previous chapter, this chapter provides the case description for the second case within this research as well as presenting the data collected from this case.

5.1 Introduction

In addition to primary research, background information about the case was collected from the school website, the Parish Council website, and displays within the school.

Phren School is a middle school (described in section 2.2) located in the rural village of Tetley Bush in South Staffordshire, UK. The village is accessed by B roads and country lanes and dates back to Anglo-Saxon times. According to census data the population of the village in 2011 was 2,614, and according to the Department for Communities and Local Government, the village resides in a neighbourhood that is amongst the 40% least deprived in the country.

The science teacher at the school described a mixed demographic of children drawn from a number of villages and towns in the surrounding area. The School had a total of 419 pupils aged between 9 and 13 years old. The majority of the pupils who attend the School join in Year 5 and arrive from four feeder schools, all local first schools. A number of pupils join the school in Year 7 from local primary schools, however some pupils also leave the middle school after Year 6 to attend secondary school, the science teachers refers to the students that leave as bright students who leave to attend private schools.

In 2009 the School was awarded Specialist Science College Status and it received a Primary Science Quality Mark Gold in 2014. However, the school received a poor Ofsted report in 2016 which found the overall effectiveness of the school as ‘inadequate’, and in 2017 the school became part of an Academy Trust. At the time of writing the school had been reassessed and had achieved an Ofsted rating of ‘good’.

The Year 5 cohort comprised four tutor groups of 25 children, from this sample of 100 children the teacher selected 40 children, 10 from each tutor group to invite to participate. The selection criteria used by the teacher ensured that a range of abilities was included, and that the group of children were likely to continue studying at the school until Year 8. Parental consent was sought and acquired for 31 children and ultimately 28 children participated in the research. Details about the participating children are given in Table 5.1 (gender consistent pseudonyms have been used to protect the identity of the children). None of the children were identified as having English as an Additional Language (EAL), although the ethnicity for all of the children was provided as British, all but one of the children was identified by the researcher as White British. A small number of children were registered for Pupil Premium, and one child was registered as having SEN (although the details of this were not disclosed to the researcher).

Table 5.1: Child participants at Phren School

Activity Group	Pseudonym	Gender	Age at start of research
Group 1	Matt	M	10
	Ivy	F	10
	Kat	F	10
	Stephen	M	9
	Pete	M	10
	Damon	M	9
	Nick	M	10
Group 2	Zara	F	10
	Tim	M	9
	Jessica	F	9
	Rebecca	F	9
	Gabe	M	10
Group 3	Frankie	M	9
	Paul	M	10
	George	M	10
	Abbie	F	10
	Anne	F	10
	Anna	F	10
	Ellen	F	10
	Den	M	10
Group 4	Ruth	F	9
	Diane	F	10
	Jackson	M	9
	Gregory	M	10
	Bryony	F	10
	Miller	M	9
	Sue	F	10
	Harry	M	9

5.1.1 The Activity

The EEA took place as an off-timetable, enrichment activity provided by an external organisation. The provider was an educational trust, an independent joint venture company whose website stated their aim as working in partnership with educational organisations to ensure that every child and young person receives a good education and is given expert guidance to realise their full potential.

The activity which they facilitated at the school was called *Build a Rocket Car*. The activity focused on building a balloon powered car using a range of physical resources. The children had a booklet comprising two pages of photographic instructions for building a prototype rocket car, a page of scientific calculations to record and calculate the cars performance during testing, a design page for potential improvements, and a page containing questions and a word search of key terms such as friction, axle, and aerodynamic. A copy of the booklet is provided in Appendix H, the booklets were given to the children prior to the day of the activity, and the children brought their booklet with them to the hall for the activity.

The teacher (a female in her early forties) who organised the activity was keen to engage with STEM and was present throughout the activity. In addition, present throughout the day were four STEM Ambassadors from a local engineering company (3 males and 1 female) and one activity leader from the educational trust who deliver the workshops (male). The teacher moved around the room as the activity took place, the STEM Ambassadors were assigned a table of children to supervise during the activity and their role changed between different groups (as described in the following observation notes). The STEM Ambassadors were not formally introduced to the children at the start of the session, a general introduction was given and individual introductions appeared to happen at the tables during the activity.

The session was a stand-alone activity for each tutor group, and each session delivered culminated in a competition to see whose car travelled the furthest, measured using a test area that had a tape measure on the ground, with winners in each group. The competition was limited to the group taking part in the session at the time and there was no inter-group competition. There was a goody bag prize for each of the winners, supplied by the STEM Ambassadors and containing items from their company. There was no marking criteria other than the furthest distance travelled, and where more than one prize was awarded (there were more than four goody bags available), the adults in the room chose the additional winners. The winning children in each session were awarded the goody bag at the end of their session, although this was done informally without celebration.

Although the activity differed slightly in delivery during the day (as detailed in the following observation notes) the overall aim remained the same, and the intended learning objectives of the activity were stated by the activity provider as:

- Being able to build a balloon powered car.
- Being able to identify what makes one car travel further than another car.

Aspects of the activity were adapted from the National Curriculum – Working Scientifically as children were encouraged to take measurements and record their findings (page 4 of the booklet in Appendix H). Information provided by the activity provider showed that the activity structure was also aligned to the KS2 Science and D&T curriculum (DfE, 2014a) as follows:

- Identify the effects of air resistance and friction on motion (Science - Forces).
- Engage in an iterative design and make process (D&T - Design).
- Use of a range of tools, materials, and components to perform practical tasks (D&T - Make).
- Evaluate own ideas and consider the views of others in order to improve work (D&T - Evaluate).
- Apply understanding of improving structural properties of more complex structures (D&T – Technical Knowledge).

As within the previous case, the pedagogic approach was not stated by the activity provider, however it was observed to engage the children in active learning (see section 4.1.1 for a brief description). Within the session, children built their own vehicle, and were involved in informal discussions, watched demonstrations, and took part in hands-on creation and testing.

5.1.2 The venue for the activity

The activity took place in the School, the red brick building had been extended over time and the activity took place in the main school hall (Figure 5.1). This area had a painted brick interior and provided a well-lit, large, multi-purpose space, allowing ample room for each group to participate in the activity without feeling crowded. During visits to the School, the researcher observed the hall being used for Physical Education lessons (the equipment around the edge of the hall and the markings on the floor visible in Figure 5.1 are associated with these classes), for additional seating at lunchtime, and the provision of school assemblies and celebration events. It was unclear whether the children had used the hall for extra-curricular activities prior to this session.

Figure 5.1: Photograph of the hall taken from the demonstration table at Phren School.

(Illustration removed for copyright restrictions)

There were photographs on one of the walls of the hall (seen on the far wall in Figure 5.1) showing students from the school engaging in a range of different outdoor activities. Although the activities were not immediately obvious from the photographs they appeared to have been taken on school trips.

The hall was laid out prior to my arrival with six tables as labelled in Figure 5.2; one demonstration table and five tables for the children, during each session the tables accommodated up to five children supervised by at least one adult. The tables were standard folding tables approximately 1800mm x 600mm x 700mm, similar to Gopak™ economy folding tables, which are widely available via office furniture suppliers. The tables were not covered during the activity and the children stood at them to work. The majority of the resources the children required for the activity were set up on the tables when each group entered the room, with the exception of the plastic water bottle (which the children provided themselves) and the balloons (which the teacher handed to the children during the activity). Each child had access to the necessary resources to build their vehicle (as outlined on pages 2 and 3 of the work booklet in Appendix H).

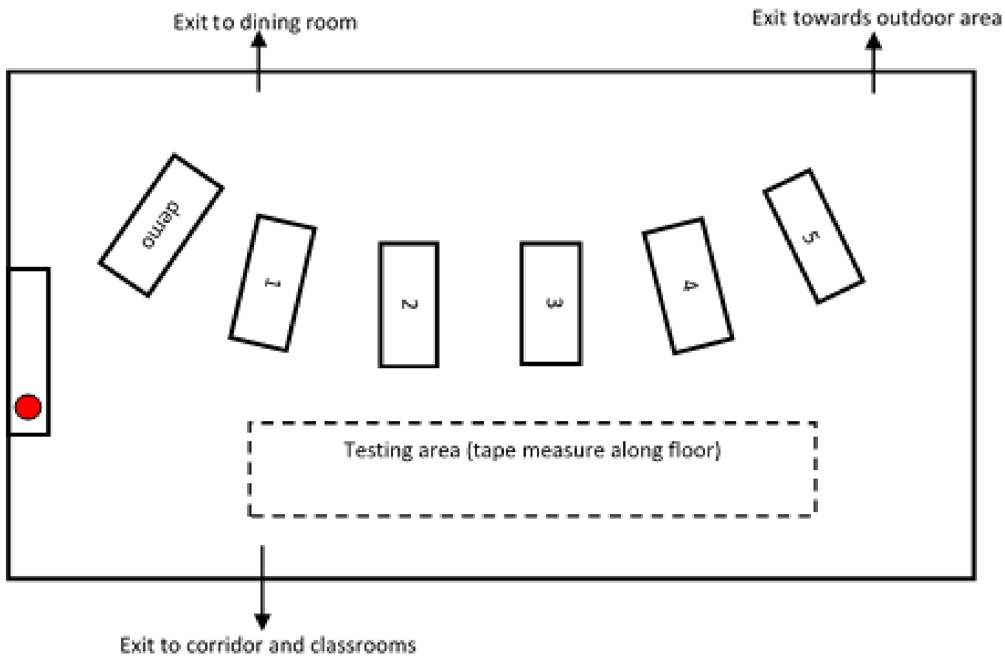

Figure 5.2: Layout of the activity area within the hall at Phren School.

There was a screen on one wall of the hall with a PowerPoint presentation projected onto it (the corner of which can be seen in the top left corner of Figure 5.1). This presentation was referenced at the start of each session but was not the focal point of the activity once the introduction was completed, the hands-on element of the activity was then focused around the tables. The sequence of the activity is described in more detail for each of the groups in the following sections of this chapter.

Initially positioned on a bench at the side of the room (shown as the red circle in Figure 5.2), the researcher could observe the children as they entered the hall. Once the activity began the researcher moved around the room observing the children participating in the activity.

The children initially tested their vehicles on any free area of floor, however the competition to see whose vehicle could travel the furthest was conducted in the testing area (shown in Figure 5.2), where a tape measure had been laid on the floor to measure the distances travelled.

5.1.3 The venue for the interviews

The interviews took place in the conference room at the School, located upstairs above the hall used for the EEA. There was a large table surrounded by chairs in the centre of the room (Figure 5.3), and the walls housed photographs and displays covering topics about the school, its leadership and ethos. To create a relaxed interview environment the seating arrangement was altered depending on the size of the group attending the interview. During the first and second set of interviews the table formation was as shown in the top picture of Figure 5.3, although chairs were moved around during the interviews and groups were encouraged to sit around the curved end of the table (to the left). During the final interviews the tables were separated and chairs were arranged so that the interview group sat around a semi-circular table as shown in the bottom picture in Figure 5.3.

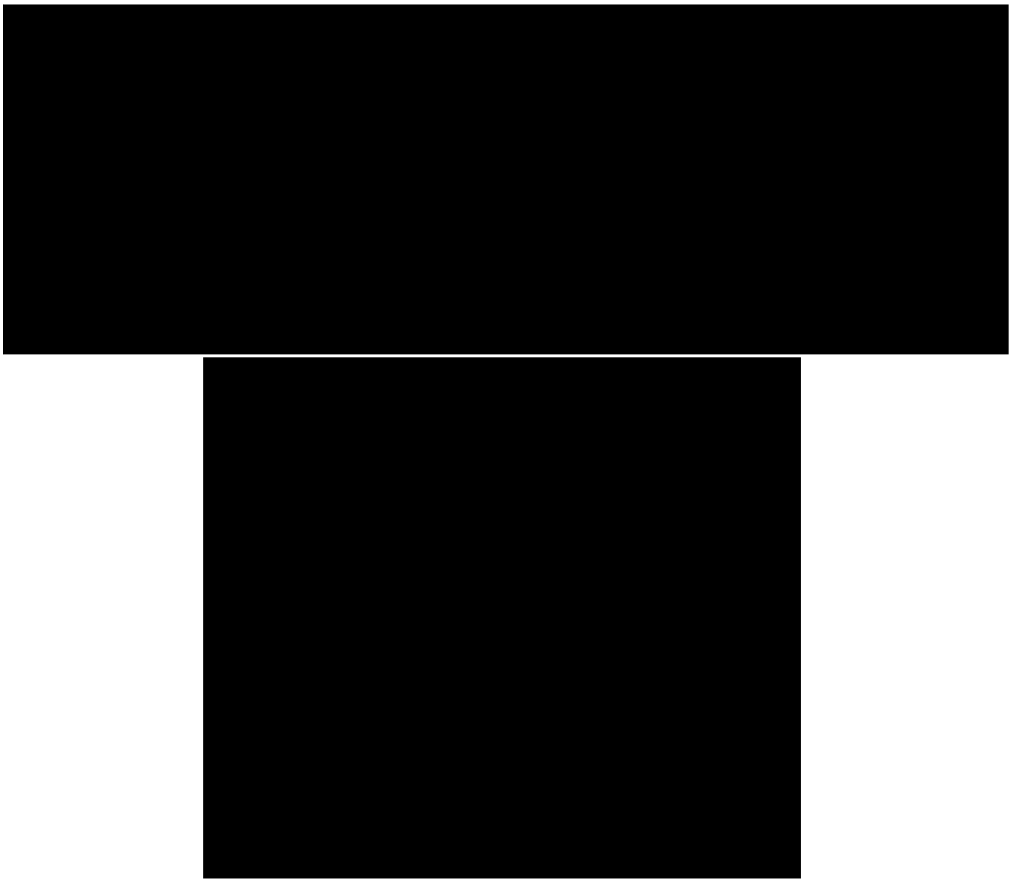

Figure 5.3: Phren School conference room furniture configuration interviews 1 and 2 (top), interviews 3 (bottom)

(Illustration removed for copyright restrictions)

5.2 The fieldwork timeline

The timeline of the fieldwork is given in Table 5.2. An interview with the teacher was conducted during the final interviews with the children in Year 7, so as to minimise the impact that the researcher had on the children via their teacher. An interview with the activity provider was also carried out in late 2017 during the final stages of the analysis, this provided an additional perspective in order to triangulate the data as discussed in Chapter 3.

Table 5.2: Timeline of fieldwork at Phren School

Research activity	Date	School year	Venue
Observations	27/04/16	Year 5	School Hall
Interview 1 (0-1 month)	13/05/16	Year 5	School conference room
Interview 2 (6-12 months)	26/01/17	Year 6	School conference room
Interview 3 (18-24 months)	29/11/17 30/11/17	Year 7	School conference room
Staff interview	30/11/17	Year 7	School conference room
Activity provider interview	21/12/17	Year 7	Breakout room at company's main offices.

5.2.1 The initial introduction

As described in Chapter 3 (Table 3.4), access to the case had been negotiated through the science teacher at the School. The teacher had selected the children who were approached to consent to take part in the research, those with the required consent were observed participating in the activity. The children met the researcher at the start of the observations and were able to ask the researcher questions about participation.

5.3 Observations

During the observations the participating children were identified by the teacher and wore a sticker allowing them to be identified as they moved around the room. All of the children were aware of the researcher being in the room, however those who were not participating in the research were not photographed and their specific actions were not observed.

The activity was repeated four times during the day, once for each tutor group. The timetable for the day is given below in Table 5.3. The sessions were timed to fit within the school timetable and so each session was a slightly different length. Observations were carried out in each session to gain an insight into the activity and the children's engagement with the activity.

Table 5.3: Activity timetable

Group 1	9.30am – 10.30am
Break	
Group 2	10.45am – 11.40am
Group 3	11.40am – 12.25pm
Lunch	
Group 4	1.40pm – 2.30pm

5.3.1 Observation Notes - Group 1

The students arrived quietly, they were directed to sit on the floor in front of the presentation screen and they listened to their teacher as they were given general instructions about the activity. The activity began with an interactive PowerPoint presentation which introduced the concept of forces to the children and involved a demonstration of forces in action (a child sitting on a skateboard was pulled across the room). The children were all attentive whilst the presentation was given, many hands were raised when the activity lead asked for a volunteer. The presentation set the scene for the activity, although engineering was not heard to be mentioned specifically.

Once the presentation was complete the activity lead demonstrated the steps involved in making the balloon powered vehicle, this took place at the demonstration table that the children stood around to watch. The children were quiet and attentive and the instructions given were clear, a small number of steps relating to the steps provided in the children's work booklet were given before the children dispersed to their own tables where they worked individually or with those children around them to complete the steps themselves. There were between three and five children on each of the five tables in the room along with an adult (a STEM Ambassador or the activity lead) who assisted the children. In this way the activity was split into hands-on build sessions approximately 5 minutes in length, after each task was completed the children returning to the demonstration table to view the next steps. The children all moved back to the demonstration table when asked and all of the children started working as soon as they returned to their own tables, there was a low level of noise in the room as the children resumed working on their own vehicles.

Whilst the external adults (STEM Ambassadors and activity provider) were assigned a table to supervise, the teacher moved around the room giving praise and encouragement, and the children shared their work with her. Although this was an individual task, there were many opportunities for interactions between the children, some of these were task oriented as children helped each other complete steps and problem solve. The children discussed their ideas and thoughts with each other, the STEM Ambassadors, and teacher, as the activity progressed, and also shared what they were doing with the researcher. For example, Stephen talked to the researcher about his axles, revealing that he was going to decorate the wheels at home, based on VW wheels his mum had.

One part of the activity seemed to capture the children's attention more than any other; this was the stage where a hot metal wire was used to cut through their plastic bottles. The children were not allowed to melt the plastic themselves and so they watched intently as an adult did this for them, as shown in Figure 5.4.

Figure 5.4: Watching as a STEM Ambassador uses the hot wire cutter to cut a hole in the plastic bottle

(Illustration removed for copyright restrictions)

The children worked at different rates and frequently stopped to check their work, either with the adult on their table or with the other children on their table. Children also asked questions such as "*Do I need to do the blu tack bit now*?", suggesting that the adults leading the activity at each table played a key role in guiding the children through the stages of building the vehicle and that the stages of the build were determined by the adults rather than the children at this stage. This structure was further indicated when the children reached the point of attaching the balloon to their vehicle. It seemed that some of the children were confused as to what was required, there were audible exclamations of "*Oh, I get it now*" and "*Oh I get how it's gonna work…so we blow it up…"* further indicating that the children were not fully aware, or did not understand the overall concept of the vehicle until this point. However, when the children came to test their vehicles, a number of them placed the vehicle on the floor facing the wrong direction indicating that they did not fully comprehend how the escaping air from the balloon provided the force to move the vehicle.

One of the key points of the activity was summed up on page 1 of the work booklet, where the children were posed the question 'What will make your car go further?', this was explored during the session at the point at which the cars were almost complete (at stage 9 on page 3 of the booklet). At this stage the activity lead gathered the children around the demonstration table and spoke about how the children could adapt their vehicles in any way they thought would improve the performance, he encouraged them to test their vehicles and change them to enhance their work. Following this some of the children ran back to their tables to finish constructing and begin testing on the floor of the hall, as shown in Figure 5.5. At this stage many of the vehicles did not move, many were still not functional by the end of the session meaning that not all of the children were able to take part in the competition.

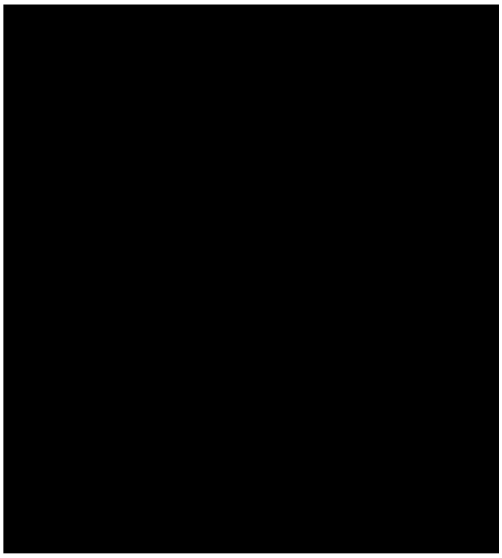

Figure 5.5: Testing the vehicle

(Illustration removed for copyright restrictions)

The teacher drew the session to a close by encouraging the children to take their vehicles home and improve them, she also told the children that they could be taken outside during break (which immediately followed the session), encouraging the children to race them then. Whilst the majority of children left the hall with their vehicles, some children appeared determined to create a functioning vehicle and continued to work, making adjustments into break time.

5.3.2 Observation notes - Group 2

The STEM Ambassadors reset the room and slight changes were made to the activity between group one and two due to the slightly shorter time for the following session and the requirement to have longer for the children to create their vehicle (as many of the children had not finished at the end of the first session). The room layout remained the same but the activity was adapted removing the initial presentation and demonstration and assigning a STEM Ambassador to each table where they ran the activity for the children on that table, rather than all of the children converging on the demonstration table at each stage.

The children arrived a few at a time for this session straight from break. Whilst waiting for all of the children to arrive a conversation about engineers was started by one of the male STEM Ambassadors who discussed what STEM stands for with the children. A discussion that did not occur for the first group.

The children were then split into groups of between 3 and 5 per table, with one adult (STEM Ambassador or activity provider) present at each table to guide the activity. There was quiet chatter in the room as the children worked and all of the children appeared busy carrying out the tasks. Some of the children asked the teacher questions during the activity, Tim asked about streamlining and stated he held an ambition to become an engineer. Some of the children were quiet throughout the activity, working individually, whilst others worked together on their tables. There was laughter and the noise level rose as the challenge progressed.

The hot wire cutter, used to cut a hole in the plastic bottle, captured the children's attention again, with exclamations such as "*That's awesome*" heard. The children watched intently as adults used the hot wire cutter (as seen in the previous group, Figure 5.4).

Towards the end of the session the adults at each table encouraged the children to test their vehicles and adapt them to improve their performance, once again the children moved to free areas of the floor to test their vehicles individually. Again many of the children put their cars down backwards (with the front pointing backwards) when initially testing their vehicle, suggesting a lack of understanding of the forces involved.

There were varying degrees of success across the group that the children dealt with in different ways; whilst confident determination in getting their vehicle to work was observed, other children were observed to be less confident, such as Jessica who stated out loud "*Mine's not going to work*" before she tested her vehicle. A wheel fell off Jessica's vehicle and she was reassured by a STEM Ambassador and put the wheel back on, when she pushed her vehicle it moved and she exclaimed "*Oh my gosh, that is so cool*". When the vehicle still didn't move without being pushed she returned to her table and the STEM Ambassador suggested that she change how the balloon was attached, Jessica displayed a level of comprehension and ownership over her vehicle as she questioned the advice by asking "*Won't that affect how much I can blow the balloon up though?*". When she tried it again, the vehicle still did not work and she went back to the table to come up with her own improvements to the design without asking the STEM Ambassador for assistance.

5.3.3 Observation Notes - Group 3

The structure of the activity was maintained from the previous session, the children arrived quickly and sat down on the floor while the teacher talked to them about learning from trying things out. The activity continued to be guided at each table by the STEM Ambassador or activity leader, who talked the children through the process of building their vehicle using the steps in the work booklet.

The children were attentive and engaged with the directions they were given, Den, Ellen, Anne, and Frankie were observed to watch the demonstration on their tables as the STEM Ambassadors explained the steps required to build the vehicle. Once again, the children appeared most visibly captivated by the hot wire cutter as it was used by an adult to cut a hole in the plastic bottles.

There was a low noise level in the room as some children talked to the STEM Ambassadors during the activity and, although the activity was an individual one, some children did help each other to complete their vehicles (Figure 5.6), as was also observed in previous groups.

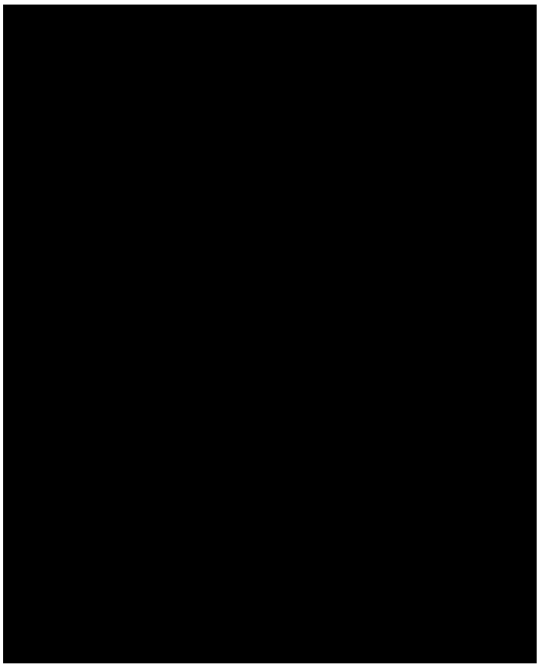

Figure 5.6: Children working together to join the wheels to the axles for one of their vehicles.

(Illustration removed for copyright restrictions)

Throughout the activity some of the children appeared to be waiting for something, Frankie frequently stopped working and looked around his table; it was unclear if he was ahead and waiting for instructions, unsure of what to do, or was comparing his progress or ideas with others on the table. The children approached the activity differently, some looked for assistance from the activity leader, the STEM Ambassadors, and teacher and some proceeded independently or with assistance from other children. This led to a range of different learning experiences, ranging from independent learning to peer assisted learning and teacher (including the STEM Ambassadors and activity facilitator) assisted learning, as the adults helped children complete parts of the construction that were causing them problems. There were steps that required a certain level of dexterity (for example steps 9 and 10), which appeared to be beyond the capability of some of the children.

The level of understanding of the principles underlying the functionality of the vehicles that the children had varied, indicated again when vehicles were placed on the floor facing in the wrong direction. Cars frequently did not work first time when tested independently by the children, when this happened the children usually took the vehicle back to their table as observed when Anna's car did not work to begin with, after a few attempts she took it back to her table saying "*It's still not working*". Children tested their vehicles many times, making adjustments and improving the performance after it started moving, however not all children continued working on their vehicles once they had started moving.

Ellen was one of the winners from this group, other children crowded round her once she had been given her prize (the company goody bag). Again, at the end of the session the teacher encouraged the children to take their cars home and make adjustments/improvements.

5.3.4 Observation Notes - Group 4

For this session the teacher brought the children in promptly from lunch, they were talkative but followed instructions and sat at the front whilst the STEM Ambassadors set up the room as it had been cleared over lunch as the space was used as additional seating for the canteen. There were additional support staff linked to a child in this group present in this session and they chatted to the children as they waited for the room to be set up.

The session began with the teacher talking to the group, telling them about the prizes and explaining that they could take their cars home at the end of the session. The children were split into groups and they moved to their tables where an adult guided them through the activity. The children talked about their task as they moved from the floor to their tables, Gregory pondered aloud "*I think I may need…*" with relation to how he was going to make his vehicle work.

The room was quiet as the children watched the STEM Ambassadors demonstrate the activity on their tables. The children spent most of the activity working independently from each other, following the steps that the STEM Ambassadors gave them, however they did help each other when required. As in previous groups there were conversations between the children and the STEM Ambassadors about the activity, checking their progress *"Is this right?"* and working out the next steps, Miller asked questions about the activity, *"So we're not going to use these?".*

The noise level in the room increased as testing began and the children moved to free areas of the floor, and reduced again as the children tested and refined their vehicles. Once again vehicles were placed on the ground the wrong way around so that they moved backwards, indicating a lack of understanding of the design they had built.

Three children were observed closely during the testing stage of the activity. The first, Miller, was seen to achieve success as his vehicle functioned the first time he tested it. However, he went on to investigate alterations he could make in order to improve the functionality of his vehicle, and was observed altering the position of the balloon whilst the vehicle was moving in order to assess the effect of this on the vehicle's motion. He also went on to investigate the positioning of the wheels. Another child, Diane, made alterations until her vehicle functioned but stopped making changes to the design as soon as she got it to work, laughing she appeared to be surprised and delighted as she said "*It works, it actually works!".* A third child, Gregory, was also not immediately successful and was observed deep in thought looking at his car, seemingly contemplating where improvements could be made to fix his vehicle.

[redacted]

Figure 5.7: A child making changes to his vehicle during testing.

(Illustration removed for copyright restrictions)

[redacted]

Figure 5.8: A child testing his vehicle.

(Illustration removed for copyright restrictions)

It was suggested from these observations that this part of the activity encouraged "critical thinking", engaging children in thoughtful reflection and problem solving. On occasion the changes that Miller made to his vehicle prevented it from working, in these situations he was observed to be thoughtful and said out loud "*I know what I'm going to do*" before proceeding back to his table to implement his ideas. When Gregory's vehicle did not work he stated "*I'm going to keep trying and trying*" as he returned to his table where he discussed his ideas with the teacher.

Diane was one of the winners awarded a prize in this session, however even after the prizes had been awarded the children continued to alter and test their vehicles. It appeared that although the children were keen to get their vehicle to move the furthest, winning the competition was not the main motivation for improving their vehicles.

5.4 Interviews

The observations of the activity provided an insight into the children's participation in the EEA; the photographs used to illustrate some of the points above were used in the interviews (along with additional photographs taken during the activity.

5.4.1 Interview 1: Year 5

Interviews were conducted 16 days after the EEA with a total of 29 students, 15 boys and 14 girls (Table 5.4). Due to the timings of the observations, it was not possible to interview the children immediately after they had completed the EEA, and so it is possible that the children had discussed the activity amongst themselves or with their teachers and/or families prior to the interview. These post-participation interactions may have influenced the children's reflections that were subsequently the focus of conversation in the interviews.

Groupings were made based on form groups; these were the groups in which the children had participated in the EEA. Issues arose on the day due to the predetermined interview timeslots not providing enough time to conduct the interviews, leading to the rearrangement of groupings on the day. In total there were six interviews, groups contained between 3 and 8 children and interviews lasted 18 minutes on average.

Once again the children led the interview conversations allowing concepts to emerge naturally from the data, although the researcher used the semi-structured interview guide provided in Appendix F to direct the interview where necessary. As these interviews occurred subsequently to the initial interviews at Nant School, although the same interview guide was used the researcher was aware of the concepts that were already emerging from the data and so these concepts were also explored in the interviews at Phren School where appropriate. This procedure is aligned to the grounded theory approach adopted within the design of this study, where emergent concepts are explored with participants, and did not take the form of rigid questioning. Rather, if key concepts emergent from the initial interviews were not mentioned by the children, exploratory questions in these areas were used.

Table 5.4: Year 5 - Phren School interview schedule

Date	Group	Participant	Age	Gender	Length of interview
13/05/16	Group 1	Diane	10	Female	25 m 47 s
		Jackson	9	Male	
		Gregory	10	Male	
		Bryony	10	Female	
	Group 2	Ruth	9	Female	16 m 38 s
		Anne	10	Female	
		Anna	10	Female	
		Ellen	10	Female	
		Harry	9	Male	
		Sue	10	Female	
		Den	10	Male	
		Miller	9	Male	
	Group 3	Frankie	9	Male	15 m 24 s
		Paul	10	Male	
		George	10	Male	
		Abbie	10	Female	
	Group 4	Zara	10	Female	19 m 55 s
		Tim	9	Male	
		Sunni	9	Female	
		Rebecca	9	Female	
		Gabe	10	Male	
	Group 5	Damon	9	Male	26 m 30 s
		Pete	10	Male	
		Nick	10	Male	
		Stephen	9	Male	
	Group 6	Matt	10	Male	9 m 6 s
		Ivy	10	Female	
		Kat	10	Female	

5.4.1.1 Perceptions of engineering

As in the first case, the initial interview explored the children's perceptions of engineering with the perceptions that the children held about engineering appearing throughout their narratives. A diversity of views were expressed, ranging from little or no knowledge of engineering to confidently held perceptions of engineering, dominated by physical artefacts (products), for example, cars, machinery, houses.

> *When you do a car up or something like that.*
> (Frankie, M)

> *You could for example you could engineer a car or a train or a plane.*
> (Stephen, M)

> *…maths because they need to add up the price of the car and like it if gets overheated what degree the, how heated it is.*
> (Pete, M)

> *…you also need maths and you also need a bit of art because you need to draw like what you need in the cars to actually design it.*
> (Tim, M)

Children also used the processes involved in engineering as a way of describing engineering, for example, building, planning, designing, fixing, and improving. The discussions focused on the processes that engineers are actively involved in, however children were also seen to define engineering by the processes that engineers are not involved in.

> *I think engineering could be like, like finding something out maybe.*
> (George, M)

> *It's like designing, it's not like, I don't think you do like the building it is just like designing, ideas and machinery.*
> (Matt, M)

> *Do the engineers like design and like plan it and then the builders build it?*
> (Diane, F)

> *You build stuff and like everyday life so you build houses and fix cars and fix stuff basically.*
> (Nick, M)

The following quotes illustrate a conceptual way of thinking about engineering rarely exhibited during the interviews, referring to engineers and engineering in terms of the attributes of the role engineering plays in society.

> *Is engineering like some kind of way of using something out of electricity and power to help you in your everyday job…*
> (Damon, M)

> *…my dad tries to fix it which he normally does fix but if it gets too complicated or he is gonna hurt his fingers he gets like an engineer to come in and do it for him.*
> (Gregory, M)

> *Well you could design the cars if you don't want to do all the maths because there will be other people who could help you who are also qualified to be engineers.*
> (Tim, M)

Perceptions of engineering were predominantly broad in nature, including general terms such as *"cars"* and *"building"*. However, where detailed perceptions were revealed these also fell into the classifications of product, process, and role.

> *Well I know about engineering you have to get the right aerodynamics to actually make a car and you have to see how fit the wheels are and like everything in the engine what goes on to power it like the fuel consumption in the car*
> (Tim, M)

Whilst confidently held perceptions of engineering did emerge, uncertainty in the perceptions help was common place, demonstrated through the use of phrasing responses as questions.

> *Do they like fix things?*
> (Ruth, F)

> *Do they like create and make stuff?*
> (Anna, F)

> *Do they experiment on stuff to try and make it better?*
> (Harry, M)

Whilst this could be indicative of uncertainty, it is possible that this style of answering was a sign that the children were keen to provide the correct answer, a potential issue of perceived interviewer authority within an interview setting (see Chapter 3).

In terms of knowledge acquisition, a range of areas were highlighted as sources from which information about engineering was drawn by the children; including computer games, internet searches, parent's jobs, and television programmes.

The role of the media

Television, the internet, and computer games were all identified as playing a role in the children's perceptions of engineering.

> *I, I watched this programme on CBBC and it's called the Engineers and like they build dens for people at school, I forgot.*
> (Jessica, F)

Whilst TV shows were discussed by a few children, the internet was seen to be mainly used by those who already had an interest in engineering and wanted to find out more.

> *I actually wanted to design cars and then decided to research.*
> (Tim, M)

Engineering role models

Importance was placed on the part that role models play in the children's awareness of the role of an engineer, and reference was made to either knowing or not knowing engineers when children spoke about their understanding of engineering.

> *No, I don't really know anyone who does engineering or anything.*
> (Rebecca, F)

> *I think, well my dad […] his first job was as an engineer but it wasn't for very long so I still don't know much about it.*
> (Gabe, M)

> *That's what I thought cos my dad usually fixes planes and stuff.*
> (Paul, M)

> *That's what my mum and dad do […] my, cos my dad tried to make something it wouldn't work like straight away so he had to keep like trying again and building it again.*
> (Ellen, F)

In addition to the importance that these children ascribed to the access they had to role models, the interactions they had with them also appeared as a concept.

> *Oh I think my step dad's a bit of an engineer […] because he fixes stuff like I dunno what he fixes.*
> (Abbie, F)

> *Yeah, my Dad [is an engineer] […] well he's designed, I think he's doing a helicopter and he's done like a ride, I think he is either doing or done the ride […] I don't pay much attention.*
> (Matt, M)

> *In my family most of the erm people like people are like engineers […] my mum and dad make stuff cos they work in the same place but I can't remember what they make, it's something that we use like today.*
> (Ellen, F)

The role models spoken about most often by the children were family members, however not exclusively.

> *They were doing sewers on our road and the people who were doing it were engineers and they were designing all the stuff and they {unclear} everything to plan and planned to dig out the sewers and stuff.*
> (Jackson, M)

The engineering credentials of the role models spoken about were not checked, however they were explored with the children during the interviews, revealing that the engineering status of the role model themselves was determined by the children who spoke about them, a decision appearing to be dictated in part by the child's own perceptions of engineering.

> *…my dad tells me stuff about engineering because he works for a car dealership and I don't understand what he means.*
> (Pete, M)

When probed further Pete gave a limited account of what they talked about, focusing on the number of cars sold and broken cars.

School

The EEA was not referenced by the children during the interviews when initially discussing engineering, and although engineering was not mentioned as a subject or topic within the school, there was evidence that the children recognised aspects of engineering within their school lessons.

> *I'm not quite sure if it's engineering but I think it is, I can't remember this person's name they were famous for it and we learnt it in science they made up like these simple things.*
> (Anna, F)

> *Yeah I learnt about that at school, the, how it needs to be aerodynamic and like air resistance and up thrust…err that's what I learnt in science and the rest I looked up on my computer.*
> (Tim, M)

> *Well engineering does involve a bit of science I think because it's seeing what could work to do something, so testing things out.*
> (Anne, F)

The role of parents (parental support)

The interviews demonstrated that children used parental engineering role models were used when making sense of the subjects learnt at school and relating them to engineering careers.

> *My dad used to be an engineer […] he did a little bit of science like, bit like we doing in science now, like pulleys...*
> (Ruth, F)

In addition, parental engagement with the engineering activity in the home was also spoken about (the children were all given the opportunity to take their balloon vehicle home after the engineering activity session).

> *Me and my dad were fixing, well my dad fixed mine and it went across the whole kitchen.*
> (Gabe, M)

> *…my mum helped me with it.*
> (George, M)

5.4.1.2 Children's views of the Engineering Education Activity

Participation in the EEA was remembered but several participants could not elaborate on the details of the activity, the few descriptions of the activity that were given focused on factual accounts of the steps taken during the activity, and for some the focus was on whether their vehicle had been successful.

> *We were designing, we were building a car and we had to like stick all the axles on and then the wheels on…*
> (Jackson, M)

> *We had to build a rocket car and we had to like get a, a water bottle and then there's like this special warm thing that he, the person put it in and then it burnt a bit so that we could fit the straw for the balloon in...*
> (Diane, F)

The interviewer guided discussions to whether the activity was engineering, when asked whether the children thought the activity constituted engineering or not a range of responses were given.

> *It was engineering but it just didn't work.*
> (Harry, M)

> *…because you were trying to create something and then try and make it work.*
> (Ruth, F)

> *Yeah, yeah cos you get to make the car.*
> (Ivy, F)

> *[You got to] evaluate it, yeah. […] You didn't really get chance to design it though because you just had to follow instructions […] So like an engineer would start from scratch, we were given instructions.*
> (Matt, M)

> *It was like making a real car cos like you had the wheels and you had like the bod [sic] of it and you had to find, think of the engine which was the balloon so it was…*
> (Gabe, M)

In addition to the processes that the children linked to engineering, inconsistencies between the materials used in the activity and by engineers were also identified during the interviews.

> *Yeah it's not like made out of metal and all that […] It wasn't using diesel…*
> (Nick, M)

Enjoyment and apprehension

Enjoyment and apprehension regarding the EEA were both spoken about during the interviews, demonstrating apprehension about taking part in the activity and the competition element of the activity.

> *[I was unsure about taking part] because I really like science… but, I also really like making things but I, usually when I do it doesn't work out that well because when I finished the thing it didn't work and the balloon wouldn't blow and the wheels kept falling off.*
> (Stephen, M)

> *I wasn't like "Yes, I won haha I beat you" because I didn't really think it was that fair.*
> (Nick, M)

> *I don't think it was fair because like some people finished really early and some people finished quite later so not everyone had the same amount of practice goes as others.*
> (Pete, M)

5.4.1.3 Career aspirations: engineering as a future career

When discussing engineering as a possible career it did not appear as a dominant career aspiration amongst the participants. Alternative careers were not always cited as a reason for not wanting to become an engineer, dominant in this area was the concept of awareness as a number of the children were unable to view themselves as engineers due to a lack of knowledge about engineering itself, or the fact that they had never considered engineering as a career before.

> *I don't know what certain jobs you could get for engineering so I'm not quite sure […] I would be able to make a decision if I knew what you could do like what jobs there is.*
> (Rebecca, F)

> *I don't really know because I don't really know much about engineers so I dunno what it would be like to be one.*
> (Gabe, M)

> *I haven't really thought about being an engineer.*
> (Kat, F)

Additionally it was seen that children are able to link their interests and perceptions about engineering with their view of engineering as a career.

> *The thing is I like mechanics more than engineer (sic) cos I like the more making, fixing type thing.*
> (Matt, M)

> *I like hands-on making things.*
> (Kat, F)

5.4.2 Interview 2: Year 6

Second interviews at the School were carried out 9 months after the children had participated in the activity with a total of 26 of the original children, two children were absent from school on the dates of the interviews. Interview groups consisted of between 2 and 6 children and the average interview length was 31 minutes.

The groupings were altered from the first interviews to encourage the children to voice their views, these changes were made based on reflections of whether the initial interviews had been successful in terms of children being able to speak freely, the groupings for the second interviews are given in Table 5.5.

Again the semi-structured interview guide was used, focusing on the areas covered in the first interviews, whilst providing scope for concepts to emerge. The second interview also incorporated recall of the EEA that the children had taken part in. As in the first case, the interviewer began by inviting the children to introduce themselves, giving their name, age, hobbies, and dream job, and the children were then asked to recall the EEA.

Perceptions were seen to have remained similar between Year 5 and Year 6, with products and processes continuing to dominate the definitions provided by the children. Recollections of the EEA were varied and limited recall or focusing on the elements of the session, for example building a car or racing the vehicles, were observed. Links between the activity and engineering did not appear to have been made, and were not often verbalised by the children without questions from the interviewer exploring this area.

Table 5.5: Year 6 – Phren School interview schedule

Date	Group	Participant	Age	Gender	Length of interview
26/01/17	Group 1	Jackson	10	M	23m 14 s
		Tim	?	M	
		Nick	11	M	
	Group 2	Gregory	?	M	30 m 1s
		Jessica	?	F	
		Miller	10	M	
	Group 3	Ruth	10	F	32 m 47 s
		Bryony	10	F	
		Kat	11	F	
	Group 4	Sue	11	F	36 m 18 s
		Anna	11	F	
		Rebecca	10	F	
		Zara	11	F	
		Ivy	11	F	
		Abbie	10	F	
	Group 5	Gabe	10	M	23 m 1 s
		Damon	10	M	
		Den	?	M	
	Group 6	Stephen	10	M	50 m 36 s
		Anne	11	F	
		George	11	M	
		Harry	10	M	
		Pete	10	M	
		Matt	10	M	
	Group 7	Paul	10	M	24 m 41 s
		Ellen	10	F	

5.4.2.1 Recollection of the activity

Recollections of the EEA were varied, from very little or no recollection, recollection of the overall aim of the activity, to recall of the stages of the activity. Whilst the culmination of the activity was observed as being a test to see whose car went the furthest, this was recalled as being a ‘race’.

> *I can’t remember any of that.*
> (Sue, F)

> *I can’t remember but I can only remember a bit of it, I can remember, building that and a bit of the racing.*
> (Paul, M)

> *Was it where we were like building a rocket and then we had a race to see whose went the furthest?*
> (Anna, F)

> *We were building cars, something to do with engineering.*
> (Damon, M)

> *Erm, it was that balloon car.*
> (Ellen, F)

> *Were we doing like, like making cars, like airpower cars?*
> (Jackson, M)

> *Was it that rocket thing? When you do a balloon and then, and it connects to a plastic bottle. I can’t remember.*
> (Bryony, F)

> *…is it about them car things downstairs that we made with the big balloon?*
> (Miller, M)

Evaluation of perceived success also occurred as children recalled the activity.

> *I won the bag.*
> (Ellen, F)

> *I think mine didn’t go because I think the air was coming out cos the Sellotape wasn’t working properly on mine.*
> (Paul, M)

I remember when my car wouldn't work and then it would work and then it wouldn't work.
(Pete, M)

We had to blow up the balloon and then, on the start line kind of thingy and then it was supposed when it went down it was supposed to go, but mine didn't.
(Anna, F)

The concept of success/failure was also mentioned in terms of others winning the prizes associated with the competition element of the activity.

I'm not saying the names cos, there is one girl who won it and four boys.
(Miller, M)

An articulated link between the activity and engineering was not made until the interviewer probed this area with directed questions, participants went on to refer to the processes they went through, as well as the physical object that was created in relation to the engineering content.

Was it!?
Anna (F)

Cos we were building the things, oh and the teacher said so.
(Damon, M)

You were making something, like building it.
(Anna, F)

I think it's about engineering cos you're like trying to put together the body of a car.
(Matt, M)

Maybe, I think it maybe in a way it was an engineering activity because it might be a way that some model cars work.
(Stephen, M)

In addition, the materials used in the activity were spoken about within the discourse around the links between the activity and engineering.

I think it is, I think engineering is to do with building cars because, but it will be harder for people that are actually building cars with metal, but we just built it with like plastic and cardboard.
(Matt, M)

Because it is making it, and you have to put them in the right place but it is a bit more easy than engineering because for engineering you have to use proper engines and stuff, that's just paper.
(Gabe, M)

Like learn how to make things like not like engineers sort of like if you say like car they use like all the proper stuff.
(Ivy, F)

Both the similarities and differences between the activity and the work that an engineer is involved in were present in the data.

It's like you are getting a taster of it…but you're not doing it like as if it was real. Like literally.
(Bryony, F)

It isn't like what you would do for engineering so you wouldn't actually know like what you would do for engineering so that hasn't really helped because it isn't proper engineering.
(Rebecca, F)

Participation in the EEA did appear to have the potential to influence perceptions of engineering.

…it just made me think more about engineering.
(Ruth, F)

…it's not all about fixing and making it can also be about other things cos I always thought it was about going under cars and like fixing and building and making and stuff, but it can also be about like erm, trying to get like different parts together to make, yeah.
(Bryony, F)

It changed my opinion of what like engineering really is […] and like that it can be, like girls can do it as well […] I think that I thought the boys were gonna be all really good at it but some, like the girls were good at it as well.
(Kat, F)

I thought it was gonna be easy but it was really challenging. Cos watching my dad do it, it seems easy but it's actually not.
(George, M)

This was summarised by Damon who saw the activity as a way to encourage children to do more engineering, pointing out that using simplified, everyday materials was encouraging for children.

…normal engineering seems like boring and complicated because of all the parts in a car but because we used everyday objects like bottles and sticks and balloons it made it slightly more fun so we could encourage us more to do it.
(Damon, M)

5.4.2.2 What is engineering?

At this stage the children's views of engineering were seen to be relatively unchanged from those exposed in the initial interviews. During the interviews a variety of definition of engineering were given by the children, a dominant theme emerging being the perceptions of engineering to be directly related to physical artefacts (products and components), predominantly transport and cars.

I don't really know much about engineering but I know about some of the different parts of the cars.
(Bryony, F)

Anything mechanical really…so anything which is made from wires, not wires, but anything which does something.
(Pete, M)

Isn't when you engineer, like making things and like fixing stuff, like when your car breaks down and an engineer comes and fixes it?
(Gabe, M)

In addition, processes such as fixing, making, and building, also played a role in the articulated definitions of engineering.

…they are actually designing the part.
(Tim, M)

Programming on the computer is a bit linked to engineering…because you have to build the stuff not just programme it.
(Harry, M)

…you are being creative and building things and things like that.
(Anne, F)

…if you need to engineer something you need to have a blueprint and to have a blueprint you need to have a model…
(Damon, M)

I think they like fix stuff like gas or something like that.
(Paul, M)

Fixing and making.
(Ivy, F)

Less dominant were the aspects of engineering such as the complexity of the job, or the attributes of the work, concepts that reappeared when the children spoke about engineering as a potential career (section 5.4.2.5).

I know that when you're doing engineering you won't be on your own at all.
(Nick, M)

Very tricky.
(Miller, M)

Conflicting perceptions were sometimes exhibited, especially where children in the interview group viewed engineering in different ways. The following conversation occurred after Damon mentioned a television show called the Dengineers[12], Gabe had a very clear view that engineers fix things that move and therefore did not consider structures such as dens to be part of engineering.

Gabe (M): *They could do any vehicle to be honest, they could do anything that they can go…*

Den (M): *Anything that moves.*

Gabe: *…yeah anything that moves.*

Damon (M): *Dens can't move.*

Gabe: *Yeah, exactly.*

Damon: *But then you can engineer…*

Gabe: *But that's a different type of, cos engineers are like where you have to fix stuff that moves, Dengineers just {unclear} dens.*

A range of areas appeared to be used by the children to gain knowledge about engineering in addition to engineering role models. The focus being television

[12] The Dengineers is a children's programme on the British Broadcasting Corporation (BBC), it is a makeover show where two presenters transform rooms into dens (BBC, 2018).

programmes (Top Gear, Car SOS, Dengineers), car adverts, computer games, and the internet.

> *Because I like cars and stuff and I'm interested about them so I play lots of car games quite a lot and every time I play, I learn something new about a car.*
> (Den, M)

> *…and it [Forza[13]] shows you where you put the engine and how much you need to add and stuff, so that sort of gets me a bit more into engineering.*
> (Gabe, M)

The EEA was not commonly referenced when describing engineering, and where it was, the descriptions that occurred did not indicate a firm understanding of engineering.

> *All I know is that it includes maths.*
> (Jessica, F)

Jessica went on to explain that she knew engineering included maths because during the activity an acronym had been spoken about and one of the letters stood for maths, but she could not remember what the other letters represented. It should be noted that Jessica was in the second group to take part in the activity, as this group arrived a STEM Ambassador had led a conversation about STEM and engineering, something that was not part of the EEA for the other groups (section 5.3.2).

Similar to the initial interviews, uncertainty in knowledge about engineering was exhibited, observed when the children spoke about the areas that they associated with engineering but were unsure if they actually comprised engineering or being an engineer.

> *There's this guy called Brian, fixes my dad's car but I don't know if he is an engineer and he wears the blue things.*
> (Sue, F)

In addition, uncertainty was indicated where adaptability of perceptions of engineering was seen when groups spoke about what engineering is, as the short extract between Bryony and Ruth below shows.

> Bryony (F): *Fixing things maybe*
>
> Ruth (F): *Making things*
>
> Bryony: *Yeah making things*

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[13] Forza is a video game series published by Microsoft, the games focus on motorsports (Microsoft Corporation, 2018).

5.4.2.3 Engineering role models

The importance that the children placed on engineering role models as a source of information about engineering was revealed once again as children spoke about the activity and their view of themselves as future engineers. Engineering role models were mentioned as influencing a child's knowledge or as the reason for their lack of knowledge about engineering.

> *Maybe I'm a bit uncertain cos I don't know any engineers to know what they might need to do.*
> (Anne, F)

> *I think it's kind of engineering cos my dad's an engineer and he does more like planning stuff and maths, and then he gives it to somebody else to build.*
> (Pete, M)

Observations of role models 'doing' engineering were mentioned, with role models tending to be parents or family members, however children also spoke of engineers whom they had met or seen who they were not acquainted with.

> *My mum's an employee and my dad's kind of like the boss […] they did this day for kids to go and look around.*
> (Ellen, F)

> *I know what some engineers do, like plan stuff and figure out where everything is. Cos we had sewers done on my road and we got a tour round it and everything and we saw the mech, engineers and everything.*
> (Jackson, M)

> *My dad works for a dealership but I've seen people working on cars when I went there when my dad was working, like there's this like garage place where they all work on the cars.*
> (Matt, M)

> *When my mum and dad take my cars to the place when they get their cars fixed when they break down {unclear} I see the like the big metal things that the cars are on when they lift them up.*
> (Stephen, M)

> *If say I'm ill and my mum's out then my dad will do his work at home on the computer so sometimes I will see that and just see what he is doing.*
> (Pete, M)

I like watching my dad do it [engineering] and I like helping give him the stuff and just like work it out with him.
(George, M)

It was seen that knowledge of engineering amassed from observing and talking to their role models was used when evaluating their engineering potential and interest in pursuing an engineering career trajectory.

Well my dad does lots of maths and thing and I just don't like the sound of that.
(Pete, M)

I used to want to be an engineer because I wanted to fix cars and then my dad told me that engineers don't fix cars what he does he doesn't fix cars, he plans stuff and he says that mechanics do do things like that.
(Pete, M)

However, the children were not always able to access the engineering information that they perceived their engineering role models to have.

I don't really listen to the engineers when they are talking to my dad at work because I don't know any of the stuff that they are talking about and I'm like "What does that mean?
(Matt, M)

Engineers in the media

As well as engineering role models whom the children knew or met in real life, girls in G3 and G4 had also seen engineers in films.

It shows you how they go on that [unclear] is on a skateboard and they go underneath the car and they fix things.
(Bryony, F)

Like you see them [female engineers] in some of the films and they have like blue dirty overalls on.
(Ivy, F)

…the film's aren't really based on engineering it just has like people like their job is fixing and being an engineer.
(Bryony, F)

5.4.2.4 Parental support

Parental support was mentioned by a number of the children who, although rarely directly, spoke about their parents involvement in activities at home which could be construed as engineering or could be seen to foster engineering skills (making, designing).

> *We were trying to like make my car work but my mum kept trying to take over.*
> (Ellen, F)

> *Well every time my dad comes home well he gets this box into the house and opens it where I'm sitting and then we just, like spare parts, and then we just building stuff together we like building well loads of stuff really.*
> (George, M)

> *The robot took a lot of time and I know that when you're doing engineering you won't be on your own at all cos I had my mum to help.*
> (Nick, M)

> *When I went home I told my dad about it and he said that we could like modify it [the balloon vehicle].*
> (Pete, M)

5.4.2.5 Aspirations to engineering

Within the interviews the children were asked whether or not they would consider engineering as a career in the future. Engineering career aspirations were not widely held amongst the participants, however when the subject was probed the discussions surrounding this topic revealed perceived knowledge and ability to be key factors which the children consider.

> *Well I don't know if I'm, I actually know enough about it yet.*
> (Paul, M)

> *I think I'd be alright because I do play a lot of computer games and I learn some from that.*
> (Harry, M)

> *I think I would be a good engineer because I know a lot when it comes to computer and machines.*
> (George, M)

I don't think I would be a relatively good engineer because, for one I'm not good at drawing or with computers or designing much.
(Anne, F)

Children were seen to be put off engineering by their perception of engineering as a dirty job that involved working with cars.

I wouldn't want to do it because I don't really like cars and it seems really difficult to do the things.
(Matt, M)

I don't want to get dirty…I don't want to get oil all over my hands.
(Anna, F)

I'm not really into that sort of thing, like into cars or things like that.
(Stephen, M)

I don't know it's just not the right thing that I would wanna do and I'd just feel uncomfortable doing it…because I don't really like lying on the floor like in a garage when you go under a car, I wouldn't like to do that.
(Matt, M)

Whilst perception about the role of an engineer and comparisons of interests and ability to this were seen to be used to inform children's thinking about becoming an engineer, gender also emerged as a factor.

It's just for boys. Well they could [become engineers]. Well probably some girls probably could but I don't want to.
(Anna, F)

…I'm more of like a girly type of girl, it's not really something that I'd like to get like mucky and stuff like that.
(Bryony, F)

…it's usually the men who do all of the like work and the engineering stuff like that.
(Bryony, F)

5.4.3 Interview 3: Year 7

The final interviews with the children took place 19 months after they participated in the activity described in this chapter. A total of 23 children participated in the final interviews, two children had left the school and the other children were not in school on the days of the interviews. Six groups were interviewed over two days, the groups were chosen based on the groups in which the children took part in the activity. The decision to split the interviews over two days was made as this allowed the children longer to talk if required, as well as ensuring that the interviewer had space between each group to make notes and prepare for the next group.

The interview schedule is shown in Table 5.6. The interviews lasted between 27 and 70 minutes, and the average interview length was 50 minutes. The interview guide used for the interviews focused on similar areas to the previous interviews, with the addition of a topic regarding how children could be taught about engineering.

Table 5.6: Year 7 – Phren School interview schedule

Date	Group	Participant	Age	Gender	Length of interview
29/11/17	Group 1	Pete	11	M	61 m 34 s
		Kat	11	F	
		Ivy	12	F	
		Bryony	11	F	
		Jackson	11	M	
	Group 2	Ruth	11	F	38 m 6 s
		Harry	11	M	
		Sue	12	F	
	Group 3	Anna	11	F	69 m 26 s
		Anne	12	F	
		Abbie	11	F	
		Ellen	11	F	
30/11/17	Group 4	Den	11	M	53 m 10 s
		Frankie	11	M	
		George	12	M	
		Paul	11	M	
		Miller	11	M	
	Group 5	Gabe	11	M	53 m 21 s
		Jessica	11	F	
		Tim	11	M	
	Group 6	Stephen	11	M	27 m
		Nick	11	M	
		Matt	11	M	

5.4.3.1 Recalling the EEA

Recollections of the EEA were minimal and tended to be focused on the children's perceived success of their end product or their general enjoyment of the activity.

> *It was something like science I think.*
> (Ruth, F)

> *We made something, and I can't remember what we made.*
> (Sue, F)

> *I don't really remember it that well.*
> (Den, M)

> *I remember. It was a STEM activity.*
> (Harry, M)

> *I enjoyed it, mine didn't work but I enjoyed it.*
> (George, M)

> *…we'd talk about if ours had worked or not.*
> (Bryony, F)

> *Mine failed.*
> (Jessica, F)

> *Mine didn't work, it like didn't go far, but it was fun to make.*
> (Abbie, F)

> *I got it furthest, I got a prize, I've still got it.*
> (Ellen, F)

> *I won that.*
> (Nick, M)

> *It was just an activity I enjoyed doing.*
> (Harry, M)

When the interviewer turned the focus of the interviews to the engineering content of the activity, the object (the car) or the processes involved in the activity were identified.

> *…when we did that engineering thingy downstairs we did the, making the rockets and balloons and stuff.*
> (Anna, F)

The racing bit wasn't really engineering
(Stephen, M)

I think the racing bit was a test if you could build it and it would work.
(Nick, M)

Like engineers might test cars after they've just fixed them.
(Matt, M)

The fact that it was like a car might have put a little fact that it was bit engineering.
(Ruth, F)

Cos you were building it wasn't you, you were trying to find a way to build it.
(George, M)

Not all of the children thought about the activity in terms of engineering, and they were not always clear about whether they had ever been told that the activity was an engineering activity.

I just thought you were making, I didn't, I thought it was, I didn't really know what we were doing.
(Ellen, F)

I don't think they did [tell us it was engineering] I think they just said, I think we already knew about what we were doing and then they just said they'd, you were put in groups and your target, what you were gonna try and make and the steps and it, I don't think they ever said does anybody know what this is like engineer or anything.
(Sue, F)

No, I just think it's engineering cos of what we were doing.
(George, M)

The idea of 'proper' engineering arose during the children's narratives around the engineering involved in the activity.

Not really no, like properly engineering.
(Jackson, M)

It's like, kind of but it is linked but not proper, like we didn't have like proper like materials and it wasn't like a proper car or anything but it was linked [to engineering].
(Sue, F)

Other engineering activities that the children had taken part in in school since the observed activity were also spoken about, these included a marshmallow-spaghetti tower and a marble rollercoaster. They were also aware that there were school trips coming up in Year 7 that incorporated what they perceived to be engineering activities.

> *We did marshmallow and spaghetti towers…they said it was STEM.*
> (Pete, M)

> *I think there's a […] trip that we are stopping there overnight I think that we're doing more like building and stuff there.*
> (Ruth, F)

> *We done one last year in class, it wasn't really to do with engineering but it was building like spaghetti stuff with, [...] marshmallows […] and you had to get it as high as you could but you had to make sure it stood up and it could hold a crème egg at the top.*
> (Matt, M)

When probed, Matt explained why he thought that the activity he described was not engineering, relating engineering to physical products that were not present in the marshmallow tower activity.

> *Yeah because it's not to do with like engines and stuff or like building transport.*
> (Matt, M)

5.4.3.2 What is engineering?

As before, the interviews focused on the perceptions that the children held about engineering, with engineering being described in various ways. Again, engineering was spoken of in terms of physical artefacts: materials and products.

> *Cars is engineering.*
> (Jessica, F)

> *Is it something to do with like engines and stuff like transport?*
> (Matt, M)

> *I just think, when I think of engineering I just think of cars and, movement and engines and stuff, I don't really think of making stuff to see if it would work.*
> (Ruth, F)

> *Has engines got anything to do with engineering?*
> (Sue, F)

Like metal I've always thought, whenever like engineering the first thing that pops into my head is like fixing stuff.
(Jessica, F)

Characteristics of engineers and their work also emerged within the children's narratives.

Clever people designing stuff.
(Jackson, M)

I always thought if you were an engineer then you work in a factory.
(Anna, F)

They always wear clothes that they don't care about cos, if like a car and you do something wrong then they get all oil over them and stuff.
(Frankie, M)

…and getting all just like dirty, I don't know why I just picture it like that.
(Sue, F)

I think you'll need to like use your hands.
(Gabe, M)

Hard hats.
(Paul, M)

Maybe people who go in the house like to fix the radiators maybe?
(Miller, M)

Well I think of robots sometimes, like drilling into the carbon.
(Tim, M)

Someone like under a car on like this think with like wheels and it goes under cars, fixing stuff.
(Stephen, M)

As did the impact that engineering has on people's lives and the world.

I kind of think of them as helpful people and like, they fix like, they like help fix stuff so they are quite, they help a lot.
(Gabe, M)

Engineering links into everything that you do in everyday life.
(Jackson, M)

…building stuff in general for people to enjoy and yeah just building stuff for people.
(Nick, M)

The processes that children perceived engineering to involve including, designing, making, building, and fixing. These were not always articulated in isolation from the artefacts associated with engineering by the children.

…you need like tools and then you'd like just see what's happening and then if you see what's wrong you fix it.
(Frankie, M)

I think it's just making stuff and designing.
(Nick, M)

Fixing stuff.
(Ruth, F)

I also think that engineering links into building cos as well if something is broken then you are going to have to rebuilt it, like rebuild the piece of the car or something.
(Bryony, F)

When I think about it, it's just like fix, like cars and that. Fixing parts of cars and sometimes making some decisions or something.
(Gabe, M)

Like architecture as well I think, like building buildings.
(Paul, M)

When I first think of engineering I think designing all the engine parts of like planes, cars, tanks.
(Tim, M)

Planning stuff, like planning machines.
(Harry, M)

Links between engineering and school subjects were apparent, and definitions of engineering as a process (making things) were seen to be used to determine if lesson content was engineering.

I think it would definitely be linked with science and maths.
(Harry, M)

Would science come under the heading of engineering as well?
(Anne, F)

Probably not, well yeah you're making things so it might be.
(Den, M)

We've made some like cells and stuff, that's sort of engineering to make them.
(Anna, F)

Perceptions that engineering is a challenging activity requiring qualifications and training also emerged.

It looks really hard.
(Matt, M)

I'd try hard at school cos I know how hard that job is.
(Jessica, F)

When you go to like the MOT or something like it looks easy because they are like trained and stuff.
(Frankie, M)

…it looks like a really complicated job.
(Ruth, F)

It sounds like quite hard.
(Ellen, F)

The benefits of knowing about engineering were identified, with a focus on saving you money, maintaining a focus on engineering being the act of fixing.

…it's also a good skill to have for when you are older and you don't have anyone to do it for you, you can still do it yourself.
(Bryony, F)

…if you had children and they want you to fix something you could fix it.
(Nick, M)

If like you know like engineer and stuff, so like if you've broken your car or something like you've scratched it on a wall you don't have to like waste your money on someone repairing it for you, you can just do it for yourself so you are like saving some money.
(Frankie, M)

Uncertainty was once again exhibited through the use of questions, prefix statements, and qualifying remarks when speaking about engineering.

…I don't really know much about it.
(Ivy, F)

I don't really think about it and I've never really been like told what it is properly so I haven't really ever like thought about it because I don't really know what it is.
(Sue, F)

Is inventing kind of?
(Frankie, M)

I don't know if it's engineering…
(Anna, F)

…I don't know if that counts?
(Miller, M)

…I'm not really sure if it would go under engineering…
(Ellen, F)

I think it's to do with like making it, I'm not quite sure if I'm right or wrong but…
(Anna, F)

…it might be classed as engineering…
(Anne, F)

My brother in law kind of fixes computers but that's not really it but only for us! [but I'm not sure if that is engineering] because it's fixing stuff and like, I dunno.
(Stephen, M)

…so he [dad] was gonna design a helicopter and they were gonna build the helicopter together but I don't know if building it is still engineering, or what.
(Pete, M)

You know engineering, is it like, would you make the whole of the car or would you make just the metal bits or would you make the wheels and everything?
(Gabe, M)

Although school was not mentioned as a source of information by the children, other sources of information were discussed by the children, with the media, computer games, and parents emerging again.

> *I just learn it off You Tube and games*
> (Frankie, M)

> *Cos when I went home and my dad's like "what did you do?" and I said like STEM, and started a big conversation about it.*
> (Pete, M)

> *We didn't talk about it in school but my mum and dad always talk about it.*
> (Ellen, F)

Family engineering role models

Family influence and engineering role models were discussed when talking about what they think engineering during the interviews.

> *[My dad has] got a new job and it's not really engineering [he is now a manager].*
> (George, M)

> *I'm not really sure, my mum and dad do it, is it like making stuff? Cos my mum and dad do making plane parts.*
> (Ellen, F)

> *My dad always has a go when you say like a mechanic is an engineer, so, like my dad's told me a bit.*
> (Pete, M)

Reference was also made to parents and engineering role models as a source of seeing the work of engineers.

> *My dad works at like a car dealership and I went in the garage there and I seen people in like overalls, in red overalls, and they were just fixing cars.*
> (Matt, M)

> *If I walk into the office then I'll see him on like a big, like be on the designing […] and then if I walk in at other times they'll be a big page with all these sums on.*
> (Pete, M)

…because he [grandad] took me to his work once, because he had like, it was like a parenting day except I was his grandchild not his daughter.
(Ruth, F)

Like one day he [uncle] took me round with him to do something, stuff like, he took me to the place he like worked and it was all about fixing cars and stuff like that.
(Gabe, M)

Engineering career aspirations appeared to be able to be influenced by family members who were engineers.

My ideal job is to be an engineer like my dad.
(George, M)

…my job, an engineer cos my dad's erm, my dad fixes airplanes and was teaching it, I think he's now getting a new job to do with engineering as well.
(Paul, M)

A link appeared to have been made between DIY and engineering, demonstrated when the children spoke about the engineering that they believed their engineering role models carry out.

…I don't know where he gets the skill from, I don't know if it is engineering or if he just knows it.
(Pete, M)

My dad used to be an engineer, he mostly did things like cars and stuff he didn't really, he wasn't a serious engineer, he was just like someone who fixed just stuff, like small stuff.
(Ruth, F)

My dad's not an engineer but he likes to fix up his car and like I think at the moment he's trying to paint up the banisters on the stairs. His job's wildlife, but he works to fix things like the cars. [So he is doing engineering] but he doesn't get paid for it really, he just does it for our benefit.
(Den, M)

Gender

When talking about engineers gender appeared in descriptions of engineers and engineering.

When I picture [an engineer] I see a man wearing a hard hat and orangey vest.
(Den, M)

I feel like it's kind of like a men's like something a man would do more, I'm not saying like women can't do it but I just picture it more of a manly kind of job.
(Sue, F)

5.4.3.3 Changes in perceptions

The conversation moved to discussions about what the children felt they had learnt about engineering from the EEA, and how their perceptions had changed over the course of the research.

Perceptions of engineering held at the time that they participated in the activity were reflected upon by the children.

I knew about it but I didn't know exactly what it was.
(Matt, M)

I knew it existed.
(Stephen, M)

I didn't think it [the activity] would be as hard as it was.
(Stephen, M)

…and that was with models so I can't imagine what it's like with an actual transport.
(Matt, M)

…this kind of changed the concept of engineering for me because I found it fun, like when I first thought of engineering, "oh, it's boring, just fixing cars all day" but like what type of job is that? But now I've done that I know that it is fun…
(Jessica, F)

Yeah cos I used to think that engineering was just like they were people who just like went around and fixed cars, I didn't know that they actually made them, it made me think that they actually made them.
(Gabe, M)

I thought engineering was like when they just go to a place and fix up a car {unclear}... but now I know there's like loads of stuff.
(Miller, M)

However, where children spoke more generally about engineering, for example Miller above, it is difficult to know if the children were referring to changes due to participation in the EEA, or participation in the EEA and interviews.

Participation appeared to have the ability to reinforce interest in engineering, or develop the belief that engineering is not the career for them.

> *It makes me more confident in engineering.*
> (Tim, M)

> *I think this activity has helped me because I think I'd be a rubbish engineering to be honest […] I couldn't get it [the balloon vehicle] as far as everyone else.*
> (Jessica, F)

> *I found out that probably not my kind of job like, making like cars.*
> (Gabe, M)

5.4.3.4 Sustained interest

Where children identified an initial interest which taking part in the activity stimulated, they also highlighted the lack of continuation of engineering education during the education system.

> *I think it hasn't done a big change but at the day I think it did but then it's been changing over a couple of years.*
> (Miller, M)

> *In Year 5 it made me more interested and then through Year 6 I was still but I sort of am now, but not as much.*
> (Nick, M)

When asked to expand on this thought Nick went on to recall that the last activity they did was a marble run midway through Year 6 and reasoned that the lack of EEAs had caused his decline in interest.

> *…just not done it in ages, that's why.*
> (Nick, M)

Cadence of EEAs

When speaking about their lack of knowledge about engineering, the concept of cadence of EEAs within their school life emerged.

At school we don't really talk about it.
(Bryony, F)

Anna (F): *I don't think from last year we haven't really…*

Ellen (F): *…done anything.*

Anna*: ...no so we're talking the same.*

Only in like DT when we had DT class in Year 5.
(Tim, M)

We might do it like for a lesson but that's it.
(Miller, M)

…in Year 6 we've been focusing on the SATs and revision and we didn't really have much time for anything else.
(Anne, F)

I hoped that they would carry on doing it like every year, like something different but it sort of stopped.
(Nick, M)

After the activity somebody in my class did ask if we were allowed to do another, like another project like something like that.
(Ruth, F)

This lack of continuation was highlighted by other children as well who explained that they did not really think about the activity (or engineering) anymore.

We don't really talk about it. But if like we did it another one obviously cos it's been like quite a while since we did it, it'd be like, like two days later we'd talk after we did it.
(Bryony, F)

It was quite a while ago so I don't really think about it or anything.
(Sue, F)

Well, exactly the same [view of engineering as before] because we didn't do many, we haven't done much like handy work and much.
(Tim, M)

I just think that it was like you coming back and talking about all this again because I completely forgot until now.
(Ruth, F)

5.4.3.5 Engineering career aspirations

The children were asked about whether or not they would consider becoming an engineer in the future. Lack of knowledge about engineering as a career appeared as a barrier, preventing the ability to consider engineering as a possible career.

> *I don't think I can be an engineer, I'm not really that, well I think if we did learn about it that I'd listen, and I'd get interested in it, but then I'd have to then say I like it or I wouldn't like it.*
> (Anna, F)

> *Well, I'm still not sure what you can do in engineering so maybe if I find out I might want to be an engineer.*
> (Harry, M)

> *…then you could see whether or not you like it and you wanna go further in it.*
> (Sue, F)

This area of conversation opened up additional conceptual areas regarding the perceptions that the children held about engineering in relation to becoming engineers, as job attributes were mentioned.

> *I just think it would be too hard.*
> (Stephen, M)

> *I think it would be really stressful and hard and frustrating.*
> (Matt, M)

> *I don't like getting my hands dirty.*
> (Anna, F)

Experience of engineering and observing role models conducting the duties of the engineer were seen to both motivate children to believe they could become an engineer, or dissuade them form holding this career aspiration.

> *I just seem okay at it and I enjoy it but I don't think, I'd be something like an engineer but I don't know if I would be an engineer […] Cos like, my dad just sits at a computer and does maths and designing, but I wanna do something more practical.*
> (Pete, M)

> *Yeah cos I've learnt from my dad.*
> (George, M)

The concepts of perceived ability and interest emerged from the children's conversations in this area.

> *Nah, I don't think I could do one cos I'm not very good at building.*
> (Matt, M)

> *I think it is, erm, I don't really know erm because I quite like doing science and English and maths and I quite enjoy it erm if it weren't for that I am terrible at art.*
> (Anne, F)

> *Even though I'm good at like building stuff like I wouldn't take engineering as a job because I think it's just a bit too like hectic cos if you think everyone just comes in saying I want to do that, I want to do that, I want to do that…*
> (Miller, M)

Correct qualifications and training were identified as required in order for engineers to be able to do their job. Things which the children would need to complete if they wanted to become engineers.

> *I don't think like someone who hasn't done, has only done like English as their GCSE or PE, they can't really know how to design it because they don't really know how big it's going to be.*
> (Jackson, M)

> *If I like the training course then I would but like it depends how the training course is.*
> (Ruth, F)

> *I think anyone could be an engineer […] as long as they get the correct qualifications and enjoy it, and want to do it then I think anyone could.*
> (Anne, F)

> *Anyone could [be an engineer] if they get the qualifications from the university or college.*
> (Tim, M)

Engineering career aspirations were not common, clear reasons were articulated for this but there were those who were not sure why they did not consider engineering as a potential future career. The discourse around engineering careers highlighted three areas as to why children were not considering engineering as career: perceived inability, lack of interest in engineering, interest in other areas.

Not really [changed my mind about doing engineering] cos since I was little I've been interested in make-up.
(Bryony, F)

I don't want to be an engineer, I want to be like a Police Officer or something like in the Armed Forces, like you know something saving people, like emergency.
(Miller, M)

I think I'm just interested in other things.
(Kat, F)

Yeah because I always think of engineering as like fixing things and I don't think that like it would really be my life's dream to be an engineer cos I don't really like, I'm not really interested in it.
(Bryony, F)

Not really no, I've never really been interested in engineering.
(Stephen, M)

I like doing the activities but I'm not very interested in engineering as a whole.
(Matt, M)

5.4.3.6 Influences

Although it was seen that the activity had the potential to alter perceptions of engineering held by the children, the EEA was not the focus of the children's discussions. Different entities were identified by the children as influencing their knowledge about engineering; including toys, books, computer games, internet, experiences, and TV.

Family was a consistent concept as the children spoke of different experiences, including family organised trips to museums and engineering experiences, known engineers and engineering role models, and family bought presents.

There was this thing that my mum bought me for Christmas…
(Nick, M)

…I've been on about three or four hour trip in the Jaguar experience, watching a Jaguar get made.
(Tim, M)

Like, not like museums from like old stuff, I mean like museums like things you can test and see what like engines sound like and stuff.
(Ruth, F)

I went to a science museum in Amsterdam.
(Anna, F)

Cos my uncle's an engineer […] he sort of like describes what you do, like they make cars and {unclear} stuff, so I've sort of like learnt off him telling me all about his jobs.
(Gabe, M)

It's because I like, I had an interest in like cars, I knew all the car names and I wanted to know how they were made, my grandad was an engineer so I thought I could be one as well.
(Tim, M)

5.4.4 Adult Interviews

Accompanying the interviews conducted with the children two additional interviews were conducted, one with the teacher who organised the engineering activity at the school, and one with the individual who facilitated the activity. Interviews with the STEM Ambassadors were not possible, as consent could not be gained.

The purpose of these interviews was to gain an additional perspective on the activity as well as the concepts that had emerged from the data collected from the children's interviews (see discussion of triangulation in section 3.8).

5.4.4.1 Science Teacher

An interview was conducted with the science teacher at the school, who organised the EEA for the children. The aim of the interview was to gather additional information about the school and to discuss the emergent findings of the research to gain an additional perspective.

The education system

The teacher emphasised her concerns over the science futures of the children once they leave the middle school, as they are put into sets once they transfer to high school affecting the stream that they progress along; triple science or double award science[14].

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[14] Triple award science consist of the three science subjects (Biology, Physics, Chemistry) being taught as separate subjects, each one equivalent to one GCSE. Double award science splits the content of the three subjects across lessons and is equivalent to two GCSEs (Select Committee on Science and Technology, 2002).

…they [the children] come back to me and say “I’m in Set 2” and I’m like no way are you in Set 2, you should be in Set 1 and you should be doing single science, you should be doing triple award and you should be doing higher papers.

The implementation of the new assessment of science at GCSE (see Ofqual (2016) for more information) was also raised as a possible issue for children wishing to study science, especially as it seemed to be the teachers making decisions about the streaming of the children.

…so they’re telling children that they’re, yes they’re gonna do triple award, yes you are gonna do higher paper but in actual fact the teachers don’t make the choice ‘til Feb, whose doing it, because they are so uncertain about the papers.

Engineering

The teacher organises an annual trip to The Big Bang Fair [Big Bang Fair, 2018) to encourage children to explore the range of careers that science can bring and this was referenced when she was asked to describe engineering, her response initially focused on other’s rather than verbalising her own personally held belief.

…it’s basically everything isn’t it, so it’s everything that we use and I know from being a regular at the Big Bang […] so it’s not just boys building trains is it? It’s everything, and what I love about it is the design in it as well […] all those people that can use their art skills and transfer it to engineering.

Gender was mentioned within this definition of engineering given by the teacher and was also mentioned again later in the interview when the teacher talked about a new robotics club which the school were going to be running targeting Year 8 children to increase their interest before they leave the school.

…but it’s going to be the boys that are absolutely tech kids, engineering kids…

However when discussing gender issues in engineering the concept of fairness was prominent, and it appeared that the teacher viewed boys and girls differently when it came to engineering.

…girls in engineering day which brings, kind of it’s wrong in a way because our boys would be really cross if I did a girls trip, they would be happy if I did a boys trip as well, but if I started doing girls in engineering it would really annoy them.

I learnt the other day which I thought was quite powerful, for the girls is that, I can't remember who told me […] these girls came into schools as ambassadors and talked about engineering and they've gone into the make-up industry but as engineers, and I just thought that's really powerful…

Extra-curricular activities

The teacher listed the extra-curricular STEM activities that the science department had conducted during the previous year and talked about the different activities that were run. A total of 16 activities had occurred, including participation in this research (although some related to the same projects delivered at the school, for example applying for funding and then running the activity). The focus was on STEM and when asked about the engineering specific activities that were provided, the teacher talked about the same activities that were mentioned in the interviews with the children. A range of engineering focused activities (conducted outside of the normal curriculum) appeared to occur over the years that the children attend the middle school, however the word engineering did not appear to be used when the children take part in these activities.

The concepts of time and energy emerged within the conversation, reflecting potential engagement in engineering activities for the children as a function of the energy and time that the teachers have.

…in science week always do an engineering task even if it's erm, spaghetti and marshmallows or in the past, depending on how much energy we've got they paper roll […] and then they build structures with nuts and bolts, and we've got this tubing and they do a roller coaster.

The theme of time and money were repeated throughout the interview when talking about engineering education both within this school and across other schools in the area.

…I used to pay him to come in and he'd run days for the kids, but all that money has just gone.

…my time goes on Bushcraft and I guess that's my passion, and I just can't do two afterschool clubs.

…it's the time to find the funding.

When talking about a teacher at another school who was funded by an engineering institution to promote engineering activities to schools the issue of uptake across schools was raised.

> *…she held this meeting and there must have been ten of us […] and it was only me and this other really enthusiastic woman […] that said we want to take part…*

The teacher acknowledged the role that social media plays in the children's lives, the communities they are part of, and their career aspirations, as well as the lack of subject links the children make during school.

> *…they don't see it as science, so getting engineering in to kids at that age, when they don't even think they do science at first school is quite difficult.*
>
> *…they are all so obsessed by YouTube, it's quite scary, and YouTubers, and that has taken over from wanting to be a footballer to now they want to be YouTubers…*

5.4.4.2 Activity Provider

An interview was also conducted with the provider of the engineering activity observed in the school. The interview took place at the organisations main offices.

The facilitator, James (pseudonym used), a male in his late 40s, had been working at the educational organisation for two years, prior to this he was a primary school teacher for 16 years, and he worked at BT in telecommunications engineering prior to this. He declared himself a school failure.

> *I was a classic school failure, drifted into engineering so career wise, I dropped into a computer firm at the age of 16, got involved with electronics, transferred from there went to work for BT, so telecommunications engineer's my background.*

His current role involved working on educational workshop development and delivery as well as coordinating the STEM Ambassador programme for the region. The STEM Ambassador programme is mentioned frequently throughout the interview. Schools can request and fund workshops delivered by the company, a full day workshop delivered to a year group costs approximately £600, or schools can access the STEM Ambassador programme free of charge.

The EEA

When talking about the EEA that was observed at Phren School, James spoke of what he learnt from the activity, which was one of the first activities he had delivered for the organisation.

...thinking well actually it didn't work, the children I think their expectations were that they were going to get a balloon powered car that was going to fly across the hall, whereas actually their expectations were a little bit too high at the time, now I did nothing there to actually say to them "Look this might not work" and I think this needs to be incorporated into the lesson that I delivered…

James' experience is that there were not many students in primary or secondary school who understood what STEM stands for, at a girls event he ran in a primary school he said that only two out of approximately thirty-one girls knew what STEM stood for and none of them had any understanding of STEM careers. He talked about the changes he had noticed in school engagement with STEM during his career as a teacher and in his current role.

STEM engagement through [the organisation] is not something that I would say is taking off.

...it's getting the school engagement and that tends to be a little bit of an issue as well

Appreciating that schools do not have the money to fund many STEM activities James talked about the priorities of schools being a greater barrier to uptake of engagement activities.

I think the problem that you've got with schools is "Why should we do it?"

…there are a lot of teachers out there that would engage, that would embrace STEM but it just isn't worth it.

These barriers to engagement meant that he and others were looking for ways to *"add value"* to their workshops to make them more attractive to schools, however there is a balance between selling activities as having value to schools whilst achieving the organisation's desired aims.

…so we'll link it more to the curriculum […] so it will sell even better, and then your feedback from the students is "it's just like another lesson"…

Learning and teaching

James mentioned statutory testing (SATs) resulting in numeracy and literacy levels being of greater importance within primary schools than STEM education. SATs were mentioned throughout the interview as part of the tensions between the school agenda and the STEM agenda.

…she [head teacher] turned around to me and said that the main thing that she found was providing that the literacy and numeracy results were good, they could justify anything else within the curriculum.

…it's justifying that all the other subjects are taken care of, then any sort of questions that do come from Ofsted you feel comfortable about answering.

…everything else is cut from the timetable, now as soon as the science SAT went, I will hold my hands up and say yes, I didn't focus on science at all.

Due to these pressures James believed that in order to increase school engagement with STEM there needed to be assessment associated with STEM education.

…we need some sort of assessment that proves that STEM works […] if you went to a school are said "Right this is the STEM Agenda, this is how you assess against it, this is what you will be measured on, Ofsted will be looking for this" then schools would engage straight away…

You've got to have some sort of measure in there again, to make teachers engage, make schools, make head teacher engage with it…

Gender

At various points during the interview gender was mentioned, either directly or indirectly.

The other thing about primary school is that it is predominantly female dominated, and again, girls into STEM obviously there is a government drive which is fantastic and great.

I think this needs to be emphasised with a lot of primary female teachers because the boys and the girls need to see those female role models delivering engineering STEM activities.

…but actually why can't we be looking at something more along textiles and I'm not saying girls can't do that type of engineering, but it's the different sort of processes there are, and textiles for boys is particularly interesting because not all boys want to build catapults…

I do think role playing areas in primary schools are really important because you can get female engineers, you can get male nurses…

…making certain that female teachers understand their importance of influencing girls into STEM. But also boys into STEM as well…

5.5 A brief reflection on the researcher's role within the research case

As in the previous chapter, the role that the researcher played in this research case is reflected upon briefly. It was seen that the interview process had the potential to influence the recollection of engineering of the children.

> *Oh yeah, cos I remember last year when we had this interview and we were talking about engineers.*
> (Abbie, F, Y6)

This must be considered as the data is analysed in the following chapters as it has implications for the findings. Although some children reflected upon the activity during Interview 2, showing how participation had altered their perceptions of engineering (section 5.4.2.1), there is the possibility that for some children, their perceptions regarding engineering were developed due to discussions during Interview 1 rather than the activity itself.

5.6 Summary

The data collected from children at Phren School, their teacher and the engineering activity facilitator has been presented in this chapter. Verbatim quotes have been given so as to minimise the interpretation of the participant's words by the author and minimal interpretation and ordering of the data has been carried out in order to present the data in this chapter. The analysis of this data through a meta-analysis is presented in the following chapter in order to identify the relationships between the concepts identified from the data and between the concepts identified in each of the research cases.

CHAPTER 6

6 Meta-Analysis

6.1 Introduction

During this research observations and interviews have been conducted with children in two schools who have participated in an EEA, as well as adults connected with each of the two research cases. In Chapter 4 and Chapter 5 the key concepts that emerged from the data in each case were presented. Following the initial, open coding of the data to reveal these key concepts, the relationships between these concepts were explored through axial coding, and the conceptualisations discovered during the process are presented in this chapter, thus answering the three research sub- questions presented in section 3.3. Discussion is presented alongside the analysis of the data, acknowledging the link between the research and the researcher, as qualitative data can never be divorced from the researcher's interpretations of the nuances of the data.

As described in Chapter 3, a meta-analysis is presented, comparing and contrasting the two cases, developing the depth of analysis through comparison of case data whilst avoiding the repetition of analysis that would necessarily have occurred by treating the cases discretely throughout the analysis process. In the current chapter the analysis is carried out at each interview time period, Year 5, Year 6, and Year 7, providing the basis for developing our understanding of the outcomes of the EEA for the children. Whilst links with existing literature begin to be made in this chapter, this process continues into the following chapter and the discussion of the findings.

6.2 Comparison of the two cases (description)

Before setting out the analysis of the data a comparison of the research cases is given, making the differences and similarities between the cases visible in order to understand the contextual conditions of the two cases (Yin, 2014). Descriptions of the cases are provided in Chapter 4 and Chapter 5, a summary of which is given in Table 6.1 and Table 6.2 on the following page.

Both schools voluntarily engaged with this research and expressed an interest in STEM education and the importance of encouraging young people into engineering. These were conveyed by the Head Teacher at Nant School and the science teacher at Phren

School, who received support from senior management in providing STEM enrichment activities for the children at the school.

Although previous experiences of engineering varied between the children (discussed further later in this chapter), in both of the cases the children did not appear to be aware of taking part in any explicitly engineering focused activities in school prior to the observed activities, and participation in EEAs outside of school was not a common theme within the interviews. However, the interview data indicates that the children did not always relate the EEA to engineering, therefore it should be acknowledged that the children may have engaged with engineering style activities prior to this research but that they did not possess the criteria to judge these learning activities as being "engineering".

Table 6.1: Overview of research cases

Nant School	Phren School
Staffordshire, UK	Staffordshire, UK
Rural town and fringe	Rural town and fringe
Primary School	Middle School
4-11 years	9-13 years
Non-faith school	Faith school (Christian)
Co-educational	Co-educational
Sample is predominantly white British.	Sample is predominantly white British.
Low number of SEN supported pupils in the sample.	No SEN supported pupils in the sample.
Pupil Premium for sample unknown, school is lower than national average.	Small number of Pupil Premium children in the sample.
Intake from immediate locality as well as accepting children from outside of local villages.	Intake from immediate locality as well as accepting children from outside of local villages.
No provision of EEA outside of curriculum, focus is within D&T projects.	No provision of engineering within the curriculum, extra-curricular STEM activities.

Table 6.2: Summary of key information regarding the EEAs observed at the research cases.

	Nant School	Phren School
Facilitator	Class teacher	External provider and STEM Ambassadors (engineers).
Aim	Design and Build a Moving Toy	Build a balloon powered car
Venue	Year 5 classroom	Main school hall
Fit in curriculum	Part of the D&T curriculum.	One-off, STEM enrichment activity.
Duration	Project completed across multiple lessons.	45 – 60 minute session, off timetable.
Overview	Individual and pair work. Children helped each other. Sharing of ideas encouraged throughout. Mix of computer based, hands-on, and written work. Children were free to create their own design. Work booklet for children to complete individually.	Individual work. Children helped each other. Competition element with a winner. Focused on hands-on work with instructions to follow to create the vehicle. Work booklet for children to complete individually.

6.3 Experiences of engineering education: Year 5 (age 9-10)

This section draws on the data presented in section 4.4.1 and 5.4.1. The focus of the data collection at this stage of the research was the children's perceptions of engineering and their perceptions of the EEA, analysis of this data enabled links to be drawn between the data pertaining to the perceptions about engineering held by the children and the efficacy of EEAs in terms of influencing perceptions of engineering. Presented in this section are the findings that the participating children held ideas of engineering, which they brought into their participation in an EEA, resulting in individual experiences influenced by the lens of the children's own ideas about engineering.

The analysis and discussion which follow examine the perceptions that the children held about engineering in terms of accuracy and certainty, the areas from which the children drew their information about engineering (in the absence of formal or informal engineering education), and the children's view of their participation in the EEA.

6.3.1 Existing ideas about engineering

In both cases, children expressed existing ideas about engineering during the initial interviews. Although there were children who explicitly identified themselves as having no awareness of what engineering entailed or were unsure about what engineers do, implicit ideas about engineering were visible in the narratives when talking about the activities that engineering involves and engineering careers. Although the interviews were conducted post participation in the EEA, links made between the activity and engineering were not identified within the data and the sources referred to by the children did not include the activity as a reference point.

Multiple perspectives about engineering were expressed, with no single dominant definition of engineering articulated. Across both cases the ideas about engineering held by the children in Year 5 were dominated by two sub-concepts, although these were not always expressed discretely in the children's accounts of engineering:

1) Products (for example cars, planes, trains), and
2) Processes (for example, building, fixing, and designing).

A third concept was also present in the data, although it was not as prominent in the children's narratives:

3) Attributes (of either character or job) (for example, qualified, knowing how stuff works, active, shift work, complicated).

In addition to these was the sub-concept of the role that engineering plays in society, with a focus on the idea that engineering helps people (section 4.4.1.1 and 5.4.1.1). Damon (M, Phren School), Gregory (M, Phren School), and Jay (M, Nant School), all described engineers in terms of people doing something to help someone else. However, when analysing the way in which these children described engineers, differences were visible. Damon and Gregory described engineers as helping people by using specific processes or products; Damon referred to the use of electricity and power, and Gregory referred to an engineer as doing complicated fixing to help prevent injury. In contrast, Jay spoke of engineering more broadly, describing engineers as people who help the world progress, with no link to a specific process or product. He was the only child at this stage to uncouple engineering from products and process, to talk about the aim of engineering generally.

Of interest in this study is that during discussions about engineering the children did not offer an evaluation of engineering in terms of it being ‘good’ or ‘bad’; their perceptions were expressed as descriptions rather than positive or negative judgements. This lack of overt judgement is contradictory to the ‘traditional’ evaluation of children’s perceptions of engineering (as seen in reports tracking the public’s perception of engineering such as Engineering UK (2017), as well as the basis of analysis of other studies into attitudes such as Silver & Rushton (2008)). As the children did not classify their ideas by positive or negative associations, to interpret the definitions of engineering given by the children in this way was considered inappropriate, as it would have required significant interpretation by the researcher, leading to the possibility of researcher bias entering the analysis.

In addition, and discussed further in section 6.3.2, during the axial coding it emerged that the children appeared to use their own perceptions of engineering to make wider judgements about engineering careers. Therefore, the children’s understanding of engineering and the accuracy of their perceptions about engineering are of greater importance than whether they were arbitrarily deemed positive or negative by the researcher.

6.3.1.1 Accuracy of perceptions

The accuracy of the perceptions articulated by the children was established through comparison with the definition of engineering adopted in this research (presented in section 1.6.2). When comparing the product-focused or process-focused definitions expressed, it can be seen that there is little similarity with the overall definition of engineering. The definition used in this work views engineering as a profession applying knowledge to solve problems and improve people’s lives, to view engineering as being a specific product or process does not convey this holistic view of the profession.

Nevertheless, when listening to the children describe engineering it was impossible not to make links between their words, and the engineering that the researcher had been exposed to during her education and career (see section 1.5 for further details of the researcher’s background). In my experience, the definitions given by the children of designing and making things, of contributing to products such as cars and computers, and of using maths to perform calculations, all form part of an overall definition of engineering and the work that an engineer can be involved in. This finding indicates that although the children’s ideas about engineering do capture parts of what engineering is, they do not create an accurate view of engineering as a profession. The narrow views expressed are part of a broader definition of engineering that the children do not appear to internalise at this stage. This topic is further explored in the discussion of the data in the following chapter as it persists across the data collection points (see section 7.4.2.1).

6.3.1.2 Uncertainty

The use of questions and qualifiers such as *"Does it have something to do with…?"* (see section 4.4.1), *"Do they…?"* (see section 5.4.1) in the interviews when talking about engineering, indicated that the children were uncertain about the knowledge they held about engineering.

Considering that perceptions are the way in which we understand and interpret the world around us (Efron, 1969), and that the EEA is ostensibly the children's first formal introduction to engineering it is unsurprising that children exhibited uncertainty. However, it appears that participation in the EEA did not clarify engineering for these participants. When reflecting on their perceptions, the children revealed a range of sources of information they used (discussed in section 6.3.3), with perceptions appearing to be built through unintentional contact with the world of engineering.

It is also possible that the children were nervous about giving incorrect information to someone who they perceived to be more knowledgeable, especially due to the adult-child relationship inculcated within the educational environment (Christensen, 2004; Holt, 1982). However, it is argued that tentative views of engineering are held at this age, due to the broad descriptions of engineering, such as fixing, building, and engineering a car, used rather than specific descriptions of engineering as a profession or activity. It was also observed that children were able to adapt their articulated views based on the influence of peers' perceptions given during the interviews (see section 4.4.1.2), indicating that they held a fluid rather than fixed perception, which they are able to adapt when they receive new information that challenged their existing mental model of engineering.

The importance of these tentative perceptions became clearer in later interviews, as they appear to go unchallenged and persisted throughout this research, an area discussed in the later stages of this analysis (section 6.3.2) and in the following chapter.

6.3.1.3 What role did the school that the children attended play in the children's perceptions about engineering?

Commonality of perceptions across the two cases presented in this research indicate that in these cases, the school attended by the children did not influence their perceptions of engineering. It should however be acknowledged that although the size and type of school differed (see Table 6.1), there were similarities as both schools were located in the same county of England and in rural areas as was the focus of this study. Although this research focused on a small number of rural schools, the findings of this work supports evidence within the literature that the school attended is not a major factor in influencing children's perceptions of engineering. The perceptions presented in this study are also found to be congruent with those presented in the research of Silver and Rushton (2008), who conducted research into children's perceptions of SET in Primary schools of at least one form entry within a UK market town. The absence of a link between school and perceptions of engineering held by children is also a conclusion drawn by Capobianco et al. (2011) in the US, who did not find a difference between the perceptions of engineering held by children in urban and suburban school communities.

It should be noted that neither of the schools participating in this research were STEM specialist schools, or were engineering academies and so no conclusions can be drawn generalising this finding across all types of school in England. In addition, the children in this study indicated only a limited number of known interactions with engineering occurring within their school; in-school interactions with engineering were hardly mentioned by the children, and none of the children recalled the word "engineering" being used before the EEA.

Whilst it is deemed unlikely that in these cases the school itself was a contributing factor to the children's perceptions of engineering at this age, the school is not in isolation from the community that it is located in, and the catchment area of rural, suburban, or urban schools will differ. However, as mentioned above the perceptions held by the children in the rural cases focused on in this study were comparable with the perceptions published by other studies where children attended schools in urban and suburban locations, both in the UK (Silver & Rushton, 2008) and the US (Capobianco et al., 2011). This suggests that there may be no distinct difference in general perceptions about engineering held by children in rural or urban areas, however this conclusion is tentatively suggested as the data regarding perceptions is limited and further study is required. This topic is returned to when discussing the sources of engineering knowledge identified by the children, which in most cases are nationally or globally available to children with access to certain television channels and the internet (section 6.3.3.1).

6.3.2 The impact of perceptions

Whilst the finding that Year 5 children hold perceptions of what engineering entails is important it is not new, the implication of this finding is due to the impact that these perceptions have on a child's experience of participation in an EEA conducted at this time, as well as their considerations of engineering as a potential career.

6.3.2.1 Engineering perceptions and views of participation in an EEA

Overall, scant evidence suggesting that the EEA informed the children's perceptions of engineering was found at this stage of the research. However, a connection between the perceptions of engineering that the children expressed and their experience of the activity did emerge.

When examining how the children spoke about their participation in the EEA, the importance of the perceptions held about engineering became evident. Initial recollections of the activity were dominated by factual descriptions of what the activity involved; "*making a*…", "*we were designing a*…", "*we were building a*…", and none of the children explicitly mentioned engineering as being part of the activity. When this was probed, a range of opinions regarding the engineering content of the activity as perceived by the children, were exhibited. The diversity of engineering content identified by the children indicates that it may not be the activity itself that informs the children's perceptions of engineering, rather existing views may be used to evaluate the engineering content of an EEA.

For children who perceived engineering predominantly as a product (they clearly defined engineering as focused on a specific product, or spoke largely about a product(s) when talking about engineering), views of the engineering involved in the activity were chiefly provided through the lens of this product(s).

> Matthew (M, Nant School) defined engineering in terms of cars and engines. He described his ability to become an engineer in terms of his interest in cars and described the EEA in terms of its applicability to cars.
>
> Will (M, Nant School) spoke of engineering in terms of products such as cars, computers and cranes. When describing the EEA, he was unable to view it as actual engineering as it did not involve an artefact such as a car.
>
> Pete (M, Phren School) exhibited perceptions based around cars throughout the interview, although he stated that he was unsure about what engineering involves. He described the EEA as partially engineering, because although it was not actual engineering it did involve building a car.

This relationship between perception and identification of the engineering involved in the activity was also observed for those children who viewed engineering in terms of processes, in these cases the activity was viewed through the lens of the process(es) they associated with engineering.

> Jane (F, Nant School) viewed engineering as designing, and regarded the EEA as engineering due to the elements of designing and making involved.
>
> Matt (M, Phren School) perceived engineering to be the designing of items rather than the building. When discussing the EEA he viewed it as different to engineering because engineers would start from scratch and the children did not get the chance to design, they just followed instructions.

At Nant School it was observed that where the children held views of engineering based around products, the consolidation of the EEA within engineering appeared harder than when engineering was viewed as processes, reflected in the quotes in section 4.4.1.2. where links with processes were seen but differences with products were identified. This is perhaps due to the focus of the activity, none of the children articulated their views of engineering as relating to making toys, however links between engineering and cars were visible in the data and this may have made linking the EEA at Phren School to engineering more possible in this case. In section 5.4.1.2., it was observed that children were able to link both products and processes associated with the activity to their perceptions of engineering.

Another illustration of viewing the EEA through the lens of existing perceptions emerged at Phren School, as it was revealed that the product or process itself was not always enough for an activity to be considered as “engineering”. Although processes or products were involved in the perceptions of engineering, the physical artefacts of engineering in terms of the materials used also emerged as an important factor. Nick (M) defined engineering as fixing and building, but struggled to see the EEA as engineering because of the materials used (section 5.4.1.1). This indicates that Nick held a perception of engineers working with certain materials, and that he used this perception to evaluate the relevance of the EEA to engineering.

These links were perceived to be strongest for the children who clearly articulated a perception of engineering, however as was seen in the case of Nick, perceptions became clearer as children evaluated engineering experiences. Without discussing the EEA, unconscious perceptions may not have surfaced, and talking about engineering without this context and focus may not have been sufficient to explore the children’s perceptions. Although Nick stated a perception about engineering, this was also observed for children from Phren School who were unable to articulate explicitly what engineering meant to them, but whom presented perceptions of engineering when they evaluated the engineering content of the activity. It is unclear whether the children unconsciously held these perceptions prior to the EEA or whether perceptions were created through participation in the activity. Noting that the perceptions articulated were linked to the focus of the activity implies that participation in an EEA may create perceptions of engineering for children who hold a limited awareness of engineering.

6.3.2.2 Did the type of activity affect the participants' perceptions of engineering?

The finding presented above regarding the link between the focus of the EEA and subsequent views of engineering held by the children, was not observed for all children and was not observed at all at Nant School. The EEA conducted at Phren School focused on cars, an area commented upon in the literature as a stereotypical view of engineering held by the public (RAEng & ETB, 2007) and mentioned by children in both cases when describing engineering. However, the product that was made during the EEA at Nant School, a moving toy, is not traditionally associated with definitions of engineering in the same way, and was not considered as engineering within any of the children's descriptions. It is therefore asserted that creation or reinforcement of stereotypical perceptions may occur when activities focus on a specific product stereotypically associated with engineering.

Although the two cases presented different EEAs to the children, the perceptions of the children were seen to be broadly similar across both of the cases in this research, which suggests that the EEA does not alter or inform perceptions of engineering. The link seen between the children's definitions of engineering and their view of the EEA suggests that children use the same mental model (comparison of perceptions and experience) to internalise the engineering content of the EEA. This indicates that this is a personal process, unique to each individual, and therefore the outcome of participation differs for different children based on how the focus of the activity compared to their perception of engineering. For those whose perceptions aligned to the focus of the activity (be they processes such as designing or products such as cars), the children felt as though the activity had been engineering focused. For those whose perceptions differed from the focus of the activity, the activity tended to be regarded as not actually or not quite engineering. Therefore, a direct relationship between the focus of the activity and the broad outcomes of participation for all participants is meaningless.

This finding does however illustrate the importance of acknowledging children's perceptions of engineering prior to introducing hands-on activities. Without understanding the perceptions that children hold we are unable to understand how the children will interpret the engineering involved in the activities we provide to teach them about engineering. The two EEAs are compared in Table 6.2 at the start of this chapter, whilst the product differed between the cases, both of the activities used an active learning pedagogy and took the form of a hands-on activity with the aim of building a product. In both cases the children were given the goal of creating a product but no context as to why they were making the product; neither activity was presented as an engineering problem to solve and there was minimal discussion concerning the nature of engineering prior to, or during the observed activities. This lack of explicit discussion around the context of the problem, and engineering in general, within the format of the EEA is considered important bearing in mind the use of the children's perceptions in their interpretation of the EEA. Ultimately, it appears that engaging children in an EEA without explicit discussion regarding engineering, may not result in them learning about engineering or having their existing views of engineering challenged.

There are therefore three conclusions that may be drawn from this area of analysis:

1) For those children who hold an existing perception of engineering, the experience of participation in an EEA appears to be determined by their perception of engineering.
2) For those children who assert no existing perceptions about engineering, participation in an EEA may not impart an accurate perception of engineering.
3) Participation in an EEA may act to reinforce engineering stereotypes for some children (those who hold little awareness of engineering or those with existing stereotypical perceptions).

6.3.2.3 Children's perceptions of engineering and their view of themselves as a potential engineer

Separate from influencing the experiences of an EEA, perceptions were also seen to influence the children's view of their ability and desire to become an engineer. The data shows that in Year 5 engineering was not a dominant career aspiration for the participants and when discussions focused on considerations of engineering as a potential career, perceived awareness of engineering was seen to be important to the children. Children in both of the cases identified their perceived lack of awareness as a barrier to aspiring to a career in engineering. Whilst some of these children held perceptions of engineering, they did not feel as though they knew what engineering entailed as an occupation meaning that they were unable to visualise themselves as an engineer. In effect they were unable to "try on" engineering as a career in order to make a decision. This is illustrated in the words of Ella (F, Nant School), Zara (F, Phren School), Gabe (M, Phren School), and Rebecca (F, Phren School) who all stated that they did not know enough about engineering, and the jobs available to engineers to make a decision about whether they wanted to be engineers or not. This finding supports the second conclusion drawn in the section above, as it indicates that an understanding of engineering was not developed through participation in the EEA.

For those children who held perceptions about engineering and in doing so felt they had an awareness of engineering, comparisons between their own interests and knowledge, and their perceptions about engineering appeared to be important. At Nant School, for the children holding product-focused perceptions of engineering, consideration of themselves as a potential engineer appeared to be determined by their interest in, or knowledge about, the product they associated with engineering. An example of this is Jenny (F) who described engineering in terms of cars and fixing, and perceived herself as unable to be an engineer as she didn't know much about cars (section 4.4.1.3). This relationship between perception and career aspiration was also echoed when children held perceptions of engineering focused on processes, Scott (M) viewed engineering in terms of transport and fixing, his perception was focused on his interest in planes and although he aspired to be a pilot he could see himself as an engineer fixing planes (section 4.4.1.3).

This relationship was also observed to a lesser extent at Phren School, where Matt (M) considered engineering as the designing of machines rather than the building of them, he spoke of preferring the role of a mechanic to that of an engineer as he preferred making and fixing things (section 5.4.1.3). Although it appeared that Matt had considered engineering as a career prior to the interview, the relationship between interests, perceptions, and career development was also visible for children who may not have previously considered engineering as a career. Kat (F) was uncertain in her perception of engineering and stated that she had not really thought about engineering as a career (section 5.4.1.3), however she went on to speak of liking "*hands-on making things*" as a reason why she thought she could become an engineer.

Across the two cases, interest appeared to be dominant in the career decision making process for the children, with children assessing whether they are interested in the processes and products they associate with engineering. The links between this finding and the career development theories presented in the literature are discussed further in later sections and the following chapter as this finding becomes more prominent in the later interviews.

6.3.2.4 How did the type of perception held by a child influence their aspirations to engineering careers?

With so few children openly aspiring to engineering careers, any conclusions drawn in this area are tentative and further research into the relationships identified is required. However, focusing on the children who clearly stated intentions to progress to engineering careers there appears to be no consistency in the type or accuracy of the perceptions held by the children. For example Jay (M, Nant School) held an impact-focused perception of engineering and Tim (M, Phren School) held a predominantly product-focused perception. Both children were interested in cars and aspired to engineering careers concerning cars at this stage, interest in tangible engineering products is therefore potentially of greater significance than the form of the perceptions held about engineering.

6.3.2.5 Is gender a factor in the perceptions held about engineering?

The findings of this research suggest that perceptions about engineering in Year 5 were consistent across both the boys and girls involved in this research, and that the children did not view gender as a barrier to progression into engineering at this stage. Gender did not emerge as a concept within the interview data at this stage, although gender has often been a factor focused on within the STEM education literature (for example see: Cheryan et al, 2015; Archer et al., 2014b, Dasgupta & Stout, 2014; Archer et al, 2013a, Milgram, 2011; and Little et al., 2009).

Whilst the children did not explicitly use gender as a factor when considering progression into an engineering career, it should be noted that those children who openly aspired to be engineers were male, and other work has suggested that boys hold a more positive view of engineering than girls do in Year 5 (Silver & Rushton, 2008). However, when this statement is considered in the context of the current work no clear relationship between gender and positive perceptions emerged from the data. As previously stated ‘positive’ and ‘negative’ views were not expressed by the children.

Both boys and girls were seen to eliminate engineering careers due to a lack of interest in what they perceived engineering to be, and no clear relationship between the types of perceptions held and gender was found. Although there was no evidence to suggest a connection between perceived engineering potential and gender emerged from the data at this stage, there is the possibility that girls were more cautious about stating a knowledge of engineering than boys when discussing aspirations to engineering careers.

It appeared that girls were more likely to say that they did not hold enough knowledge to make a decision, however further research into this area is required.

Gender does appear as a concept in future interviews, although not appearing consciously as a marker in the children's decision-making process the impact gender has on engineering career aspirations may be more subtle (see section 6.4.3 and 6.5.1.2).

6.3.3 Formation of perceptions of engineering

During the interviews the children spoke about the sources of engineering information they felt had taught them about engineering, evidence suggests that the children viewed their perceptions as having formed prior to Year 5, from sources other than formal EEAs. Dominating this area are sub-categories concerning interactions with engineering (including exposure to engineering via digital media and real-life engineers), and interactions with non-engineering informers (defined as people or activities not associated with engineering but which children identify as having an influence on their perception of engineering).

The use of different sources appeared to depend upon the level of interest in engineering exhibited by the child. In both of the research cases a predominantly passive approach to gaining information about engineering was displayed, children spoke of engineering looking enjoyable or interesting based on what had been seen on television or learnt from playing computer games. At Phren School, it was not until an existing interest in engineering existed information about engineering was actively sought using digital media in the form of internet searches (section 5.4.1.1). Focused internet searches directed towards engineering only appeared where an existing interest in an area of engineering was present (Tim, M, Phren School, section 5.4.1.1). The use of the internet to access information about engineering is not surprising considering the prevalence of internet enabled devices used by children (Livingston et al., 2017) and the focus within the new Primary Information and Communication Technology (ICT) curriculum for KS2 (DfE, 2013). However, this finding indicates that prior interest may be required in order for children to actively seek out information about engineering, suggesting that interest is of greater significance to whether a child gains information about engineering than solely having access to information sources.

6.3.3.1 The role of the media

According to the Oxford English Dictionary (2018), media are “the main means of mass communication”, this can include printed media such as magazines, newspapers, and books, television, and radio. Pavlik (2012) extends this definition by defining digital media as systems used to communicate information to the public, including “all the traditional media of mass communication” whilst also including “emerging new media accessed online and through other digital delivery media” (p.8) such as digital news sites, apps and games, and social media sites.

The children in both of the schools referred to a range of media when talking about engineering, with television programmes and computer games dominating the sources referred to by the children (see section 4.4.1.1. and section 5.4.1.1). This use of nationally and in some cases globally[15] available information may explain the finding discussed earlier, that perceptions of engineering held by Year 5 children do not appear to vary across different schools. Whilst this finding suggests that digital media has the potential to inform perceptions about engineering across different populations, further research is required explore its impact and reach. Especially as it is not clear whether the programmes created the children’s perceptions of engineering or the children linked the programmes to engineering based on their perceptions. Investigation of the nucleus of the children’s perceptions of engineering was outside the scope of this study but may be required if we are to make significant improvements to the uptake of engineering careers in the future.

6.3.3.2 Interactions with real-life engineers and engineering

This area of discussion draws on the data from sections 4.4.1.1 and 5.4.1.1. The children in both research cases raised the importance of engineering role models when discussing their knowledge of engineering. A role model is defined as “a person who other people look to as an example to be imitated” (Oxford English Dictionary, 2012, pg. 628), and this term has become a focus as a way of encouraging girls into STEM careers. An example being Microsoft (2018) who argue that access to a STEM role model improves STEM career aspirations for girls, and in the UK the relationship between access to STEM role models and aspirations to STEM careers is embodied within the

[15] Top Gear was reported to be broadcast in 50 countries simultaneously over 4 continents in 2015 (BBC, 2015).

STEM Ambassador[16] programme. However, the findings of this research indicate that there is not necessarily a clear relationship between knowing an engineer and holding an accurate perception of engineering at a young age.

Although children cited role models as potential sources of information, these children's perceptions were observed to be no more accurate than the perceptions held by those children who stated that they did not know any engineers. It was seen that for some children their perception of engineering fitted the narrow job role of a family member, such as George (Phren School), whereas for others role models seemed to create a broad yet vague perception as the children understood the general work that their role model undertook but not the details, as for Ellen (Phren School). Therefore, it is suggested that although children place importance on having access to role models, this access results in different outcomes in terms of perceptions regarding engineering; with role models having the power to constrain perceptions of engineering careers, create broad yet vague perceptions, or impart little awareness of engineering to children.

Overall it appears that access to engineering role models did not correspond with an accurate perception of engineering, however this may be due to the types of interactions that the children spoke about, as family members were most commonly cited as real-life engineers whom the children knew. This resulted in the interactions with engineers that the children recalled mainly being verbal and in the home environment rather than in the engineering context, the exception being Jackson (Phren School) who spoke of non-family members whom he had observed and spoken to whilst they were at work.

It is also noted that although STEM Ambassadors were present during the EEA at Phren School, the children did not mention these individuals when they spoke about engineers they knew. Although the children were free to interact with the STEM Ambassadors during the EEA, they were not clearly introduced as engineers at the start of the activity. Therefore, whilst the findings of this research suggest that role models are indeed an important aspect of children's interactions with engineering at a young age, the introduction and form of the interactions the children have with role models needs further investigation in order to better understand the relationship between 'knowing engineers' and gaining an understanding of engineering through 'knowing engineers'.

When considering the sources of information from which the children appear to draw their perceptions of engineering, it is important to be cognisant that the child appears to

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[16] The STEM Ambassador programme is a government funded initiative to provide UK schools with access to individuals who work in STEM careers.

choose whom they regard as an engineer. This finding emerged from the children's discussions during the interviews where a child's discernment appeared to be more meaningful for the child than the actual qualifications of the person; this suggests that some children used their perceptions of engineering to determine who they consider as engineers. However, no attempt was made to confirm the accuracy of the children's portrayal of the individuals, the groupings of individuals and the children's classifications were used in the analysis of role model influence. Further research could be conducted into the accuracy of children's identification of engineers in order to improve our understanding of their access to perceived role models, however this was beyond the scope of this research.

6.3.3.3 The influence of parents

Although there was no evidence to suggest that having a parent who works as an engineer led to children holding an accurate view of engineering, moving beyond the role of the parent as an engineering role model saw parental support emerge as a concept from the data collected at Phren School. This was visible from both parents who were and were not described as engineers by the children. At the end of each EEA session at Phren School, the teacher encouraged the children to take their balloon vehicles home, parental support became evident through the narratives of children who spoke of their parents helping them complete fixes and additional testing of their balloon cars once they had taken them home. However, this interaction was not seen to improve the accuracy of perceptions of engineering or interest in engineering held by the children.

6.3.3.4 The school and the curriculum

As discussed in the initial section of this chapter it appears that the school attended did not influence the perceptions of engineering held by the children in this study. Although teacher perceptions were not explicitly explored, the interviews with the adults involved with each case exposed different perceptions expressed in each case (section 4.4.4 and section 5.4.4). These perceptions were not reflected in the perceptions held by the children. However, the children will have contact with many different teachers whilst at school, and so without further investigation into this specific area it would be inappropriate to draw any conclusions from the data.

The head teacher at Nant School contemplated the impact that the D&T curriculum, which focused on transport based projects, had on the perceptions of engineering displayed by the children. However this transport focus within the curriculum was not seen to exist at Phren School (according to the school website). As the perceptions across both Schools were comparable, it is unlikely that the focus of D&T projects had actually influenced the formation of perceptions of engineering, indicating that early perceptions of engineering are unlikely to be founded on school experiences.

6.3.3.5 Engineering Capital

The concepts discussed above relate to areas of subject specific capital, as identified by Archer et al. in relation to science (2013a, 2012), and briefly discussed in Chapter 2, and in section 3.2 in the context of Family Engineering Capital. The findings of this research suggest that different sources of Engineering Capital hold different levels of significance for the children; through their narratives, it appears that the children assign importance to knowing engineers, however they appear to draw information about engineering from television programmes and computer games. This finding has potential implications for our understanding of the role that Engineering Capital plays in developing a child's perception and awareness of engineering and how this ultimately influences their career aspirations and progression. Further discussions are presented in Chapter 7.

6.3.4 Summary

Returning to the research question, the data suggests that within the "immediate" time period (0-6 months) following participation in an EEA, participation may not play a key role in influencing children's perceptions of engineering.

For children who held ideas about engineering, these were seen to play a role in the children's experience of an EEA, and in how they viewed themselves as a potential engineer. The findings of the research suggest that these ideas resulted in personal definitions of engineering, which have a greater influence on the children's experience of an EEA than participation in an EEA has on their definition of engineering.

Whilst participation in an EEA did not appear to alter the perceptions that the children held, it appears that the children use a range of sources to gather information about engineering, with digital media playing a key role. The data suggests that these children acquired information about engineering passively unless they held an existing interest in engineering, at which point a child may actively seek information about engineering.

6.4 Experiences of engineering education: Year 6 (age 10-11 years)

This analysis draws on data presented in sections 4.4.2 and 5.4.2, the focus of the data collection 6-12 months post EEA participation was concerned with the children's perceptions of engineering, their recall of the EEA, and their aspirations to engineering careers. Perceptions of engineering were seen to be largely unaltered from those expressed in Year 5, and uncertainty continued to be exhibited. The children's recollection of the Year 5 EEA they had participated in were seen to be limited in both research cases, and prompts were required in the form of photographs taken during the EEA. Initial recollections from the children described the EEA in terms of the broad aims of the activity or were focused on the child's own perceived success, children were then seen to use this perceived ability to influence their engineering career aspirations.

6.4.1 Recall of the EEA and outcomes of participation on perceptions of engineering

6.4.1.1 Sense of achievement

This style of recollection was visible in both cases, appearing at both Nant School (section 4.5.1.1) and, more prevalently, at Phren School (section 5.4.2.1) appearing to be largely linked to the competition element of the session (see section 5.1.1 for the description of the activity). Although visible at both Schools, the higher occurrence of the concept of perceived success at Phren School than Nant School suggests that, although not the only cause of this form of evaluation, the inclusion of a competitive element in an EEA may exacerbate this form of recollection. This is considered in more detail in the following chapter, although it was considered that the school ethos could have played a part in the children's evaluation of personal success or failure, rather than this being a result of the style of the EEA. However, in both cases children were observed being encouraged to try their best, and to assist each other in achieving the aims of the activity (see section 4.3 and 5.3).

Engineering self-efficacy

This outcome of participation is important as, although not always explicitly linked to the child's performance in the EEA (the exception being Nicky at Nant School), children in both cases were seen to link their perceived ability in the areas they associated with engineering to their ability to become engineers (section 4.4.2.3 and 5.4.2.5). The outcome of children perceiving themselves as having low levels of success during the EEA is not straight forward as the child's perception of the EEA as engineering may also factor, as well as the child's perseverance and attitude to perceived failure. As was noted during the observations at Phren School, the children dealt with 'failure' in different ways (section 5.3). Nonetheless, this creation of self-efficacy through experience links with the findings of Lent (2013) who built upon Bandura's definition of self-efficacy as "people's judgements of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p.391).

It should be noted however, that when considering the category of engineering self-efficacy, the children used interests and ability derived from other areas of experience more dominantly than the EEA, this area is discussed in more detail in a later section.

6.4.1.2 Children's perceptions of engineering and participation in the EEA.

This analysis draws predominantly on the data presented in section 4.4.2.1 and 5.4.2.1. As in the Year 5 interviews, prompt questions were used to explore the children's perceptions of the engineering aspects of the EEA. The data collected in Year 6 exhibited similarities to the data from Year 5, and the children were seen to continue to use their perceptions of engineering to determine their experience of the EEA. For example, it was seen that if a child considered engineering to involve the use of certain materials, they did not believe that they had experienced true engineering if the EEA did not involve using those materials. Conversely, if a child considered engineering to be designing and building, then they considered the activity to be engineering if it involved these processes. This was most clearly visible when the concept of "*proper*" engineering was raised, by children in both cases (Judy at Nant School and Ivy, Bryony, and Rebecca at Phren School). There were children who recalled being told that the activity was engineering, but they were unable to provide clear explanations when questioned further, and little change in the accuracy of the children's perceptions was seen.

Whilst this finding suggests that personal perceptions of engineering continued to be used by children to evaluate their formal experiences of EEAs, there were subtle differences across the two cases implying that the focus of the EEA had an impact on the outcomes of participation. In the case of Nant School the links drawn between the EEA and engineering were focused around processes, for example designing and making (section 4.4.2.1). However, in the case of Phren School links were drawn predominantly between processes and products, and the engineering involved in the EEA. When talking about the engineering involved in the EEA at Phren School, the distinction between the processes involved and the product being created were blurred, as some children's evaluations of the engineering involved processes (making) and products (cars), intertwined with each other (section 5.5.2.1).

This finding supports the finding relating the focus of the EEA to outcomes on perceptions of engineering discussed in the Year 5 data (section 6.3.2.2), suggesting that the focus of the activity may play a part in the outcome of participation. It is again argued that stereotypical views of engineering as product oriented (such as cars) may be reinforced by activities focused on these products.

Whilst there was no evidence to suggest a relationship between participation in the EEA and the formation or adaption of perceptions about engineering, there were two divergent groups seen in the data. Perceptions were seen to be altered for those girls whose gendered perceptions of engineering ability were challenged by participating in the EEA, and for some of the children interest in and awareness of engineering may have been created by participation in the EEA. These two area are discussed in the following sections.

6.4.1.3 Impact of participation on gendered perceptions of engineering

Whilst gendered perceptions of engineering were not commonplace in the children's narratives in either case, gendered views of engineering ability became apparent for some of the girls at Phren School as they discussed the personal outcomes of participation in the EEA (section 5.4.2.1). This finding suggests that for some children (those who held the view that boys are better at engineering than girls), participation in a co-educational EEA challenged these perceptions, challenging the idea that the provision of female only events effectively promotes engineering to girls (a strategy often seen within the UK). Although not dissmissing this format, the finding of this research suggests that it is important to allow girls to see their ability in comparison to their male peers at a young age in order to challenge gendered perceptions of engineering ability early on and encourage positive engineering self-efficacy.

Another conclusion of this finding is that outcomes in participation may differ for boys and girls, a finding akin to one presented by Miller et al (2017) who found that increased interest in STEM careers due to participation in a STEM competition was more profound for girls than boys in US high schools. Although many factors may affect this, it is possible that a contributing factor is a change in gendered perceptions for a number of girls, a point reflected in the emergent findings of Brereton and Lay (2018) who analysed the applications from 28 UK domiciled UCAS engineering applicants (14 males and 14 females), finding that female students applying to engineering courses at York University were more likely than their male counterparts to reference participation in Outreach activities in their UCAS personal statements. Although the research conducted into UCAS applications is currently inconclusive and there are additional questions that need to be asked of the data, there is initial evidence that suggests that girls are either more likely to be offered outreach activities or that outreach activities have a greater impact on girls than they do boys.

Whilst there are a number of unexplored factors, the fact that this concept was only seen at Phren School may indicate that:

1. Gendered views of ability exisited for the children at Phren School but not at Nant School.

The science teacher did exhibit gendering in her interview as she refer to a STEM club that was to be set up aimed at the "*tech boys*" and female engineering role models who had entered the beauty industry. This could imply that different genders were treated and targeted differently when it came to engineering activities at the school. Whilst the head teacher at Nant School was clearly aware of the gender issue in engineering, there were no specific STEM activities being offered to either gender at the school. Therefore it is possible that the girls and boys at Phren School were encouraged to take part in engineering activities in different ways, influencing the girls views of ability in relation to the boys prior to the EEA.

2. The competition element of the EEA at Phren School enabled girls to directly compare their achievements and abilities to the boys.

The competitive element of the EEA at Phren School was not visible in the EEA at Nant School, it is possible that this competition encouraged and enabled the children to judge their performance against each other, and as such allowed the girls to view themselves as comparable to the boys.

3. The presence of the female STEM Ambassador at Phren School provided girls with a role model.

The importance of role models for girls as an underrepresented group in engineering has been discussed within the literature (Microsoft, 2018; Drury et al. 2011). As no engineering role models were present during the Nant School EEA, this may be a factor, although the limited data relating to this area makes drawing any conclusions difficult.

6.4.1.4 A source of inspiration?

Although it is possible that the activity acted as a nucleus of inspiration (see Scott in section 4.4.2.1 and Ruth in section 5.4.2.1), the findings of this reserch suggest that this was not a common occurrence for the children. This finding is of importance due to the role that inspiration appears to have in many of the engineering activities provided to schools across England.

Engineering UK was established in 2002 as a charity with the purpose "to inspire tomorrow's engineers" (Engineering UK, 2018a), and in 2015 called for improved engineering outreach activities with a focus on career inspiration for ages 11-14. Further the word inspiration occurs frequently on websites and in marketing regarding engineering outreach activities being offered to UK schools, such as those found on the websites of the IET (2018b), Smallpeice Trust (2018), Imperial College London (2018), and the University of Nottingham (2018). In addition, a review of university led Outreach in Australia by Husher identified inspiring interest in STEM subjects as a major objective of Outreach activities (cited in Sadler, et al. (2018)). With inspiration being seen as a key outcome of participation in EEAs, the finding of this current study indicates that further research into the efficacy of these activities in achieving this is required.

6.4.2 Perceptions of engineering

Evidenced by the data from both research cases, the perceptions about engineering that were seen in Year 5 continued to dominate the perceptions held by the children in Year 6. The children appeared to continue to draw information from a range of sources, with interactions with engineering via the media and real-life engineers continuing to be key concepts (see section 4.4.2.5 and section 5.4.2.3). In both research cases the perceptions held by children were focused around processes and products, in both cases there were also children who spoke about personal or career characteristics; deviation between the cases was seen as there was only evidence for children using the impact that engineering has on the world as part of their definitions at Nant School.

The accuracy of the perceptions held by the children was once again explored through comparison with the definition of engineering stated at the start of this work. Through doing so, it can be seen that the children continued to hold vague and/or narrow perceptions of engineering, which are ultimately inaccurate. For example, it can be argued that Ella (F, Nant School), who focused on engineers building rather than inventing (section 4.4.2.2), holds a narrow and inaccurate perception of engineering, Tim's (M, Phren School) perception of engineers as designers of cars (section 5.4.2.2) is partial and narrow, engineers do design cars but this is only one possible role for an engineer. The only divergent case is that of Jay (M, Nant School), who can be seen to hold a more accurate view of engineering, his definition aligned to the impact that engineers have on people's lives (section 4.4.2.2). However, Jay was seen as a unique case within the research as he held engineering aspirations from Year 5 through to Year 7 and spoke about gaining information from the adults he was in contact with (family and friends of his family), as well as attending engineering activities such as The Big Bang Fair.

Again it was seen that children tended to hold vague or uncertain definitions of engineering, uncertainty was exhibited as children sought clarity from the interviewer through questions about engineering (see section 4.4.2.2 and 5.4.2.2). When the interviewer redirected the children's questions back to the children they invariably used their existing ideas about engineering to help them make sense of what does and does not constitute engineering (section 4.4.2.2). Whilst this displays uncertainty in the understanding of engineering that the children possessed, it also indicates that the children had questions about engineering that were unanswered by their existing exposure to engineering. This finding indicates that children were not being given the opportunity to explore perceptions of engineering fully through discussion. It appears that this forces children to use their existing definitions of engineering to evaluate different situations, thus potentially reinforcing their narrow, inaccurate perceptions of engineering. This can also be seen when analysing the consistency of the children's views of engineering across the interviews, examples are given in Figure 6.1 and Figure 6.2. The data provides evidence that the child's perception continues to define engineering for that child, this definition was then seen to be used when evaluating the job that an engineer does, and in some cases the engineering content of the EEA and the child's own ability and interest in becoming an engineer.

Matt (M) stated that he thinks "*engineering is to do with building cars*" and went on to describe engineering in terms of other transport. However, he returned to cars as the focus of his definition of engineering when talking about what engineers do (go under cars) and why he did not want to be an engineer (doesn't like cars). He also spoke about the engineering involved in the activity in terms of the car that was created.

Bryony (F) stated that she did not know much about engineering but linked it to cars, this product oriented perception appeared continually throughout her narrative; she spoke about seeing female engineers in films going on skateboards under cars, and engineering begin not just about fixing cars but also about constructing them from different parts.

Figure 6.1: Examples of the consistency of children's perceptions of engineering (Phren School)

Jack (M) talked about engineering as fixing cars and he believed that engineers need to know how things work in "*engines for cars*". He also talked about engineering being a set of step-by-step processes, an interpretation of engineering that fits with the role he associated with engineers as those who MOT cars; his thoughts focused on the perception that engineers fix things.

Scott (M) concentrated his discussion around his definition of engineers as "*makers*", he talked about different aspects of engineering around this theme, including military applications and transport. He also relates construction toys such as Lego and K'Nex as relating to engineering, in keeping with his view of engineers making things.

Figure 6.2: Examples of the consistency of children's perceptions of engineering (Nant School)

6.4.3 Gender

As noted in the previous section, during the interviews at Phren School there were girls who displayed gendered perceptions of engineering ability, in addition gender-typing of engineering as being a job that men are more likely to do than women was also observed (section 5.4.2.5). Gender-typing of careers due to ability stereotypes is a concept defined by Master and Meltzoff (2016), who argued that stereotypes are “gatekeepers” (pg. 219) which play a part in deciding a girl’s interest in STEM. Whilst the current research has shown that stereotypes regarding the perceptions of engineering held by the children were held by both genders, the stereotype of gendered ability appeared to be a factor for a number of the girls within this study.

Master and Meltzoff (2016) found that children as young as 6 years old were reflecting adult held stereotypes regarding boys being better at STEM subjects such as robotics and programming than girls, although this stereotype was not held for broader areas such as science or maths at this age. Implicit gender stereotypes were visible within the narratives of the adults in both cases, with awareness of the gender bias within engineering being held (section 4.4.4 and 5.4.4) but also subtle stereotypes being visible, as described in section 6.4.1.3. In addition, gender stereotypes were visible in the words of James (the activity facilitator at Phren School) who spoke of the focus of EEAs being male or female oriented, using catapults and textiles as examples (section 5.4.4.2).

Whilst this research did not focus on gender stereotypes or the link between adult and child participants, further research into adult held stereotypes, their existence in EEAs and the delivery of engineering education in schools, and their internalisation by children at this age would be beneficial.

6.4.4 Perceptions of engineering and aspirations to engineering careers

The findings indicate that the children continue to use their perceptions of engineering to assess their personal interest and ability when deciding whether to eliminate or pursue engineering as a potential career. Children were seen to use self-identified inability to eliminate engineering as a potential career (as seen in section 4.4.2.3 and section 5.4.2.5). Although it is acknowledged that children’s career development is a complex field (Howard & Walsh, 2010; Armando Ferreira et al., 2007; Trice et al., 1995), this finding does support some areas of occupational aspiration development theory. The work of Gottfredson (1981), further discussed by Trice et al. (1995), set out a theory that between the ages of 9 and 12 years, children used their perceptions of their own abilities to eliminate careers that they perceived as too difficult. A finding which is echoed in this work for Year 6 children, through the children's use of phrases such as *"I'm not very good at…"* when discussing if they could be engineers. This perceived inability was then used when talking about career decisions, either a child's elimination or pursuit of an engineering career. Lent (2013) argues that successful experiences linked to a specific domain tend to raise self-efficacy in relation to that domain, in this case the domain of concern is engineering, and the findings of the current research suggest that participation in the EEA does appear to hold some influence in the creation of self-efficacy. This is of importance as self-efficacy has been seen to be a significant predictor in career indecision in older students (Taylor & Betz, 1983, Bet & Luzzo, 1996, Bandura et al., 2001), of concern is the finding that poor engineering self-efficacy may be instilled at a young age, and therefore negatively affect engineering career progression at a later stage.

In addition to their ability, the children's career aspirations also appeared to be informed by their own interests, the use of phrases such as "*I like doing practical stuff*" and "*I like planes*" indicated an interest within the child that was being used to decide if they wanted to become an engineer. This evaluation of interests relies upon the children's perceptions of engineering as a marker of what engineering entails, for this reason the perceptions of engineering held by the children at this age lead to a comparison of interest with inaccurate perceptions of engineering, hence children may be eliminating engineering careers without fully understanding what engineering is.

6.4.4.1 How does gender influence aspirations to engineering careers?

Once again although gender was not explicitly mentioned, gendered assessments of engineerign careers were implicit in female participant's narratives, with "*dirty*" engineering involving cars being seen to be at odds with their femininity, as illustrated by the words of Bryony (Phren School). This echos a finding of Archer et al. (2013) who explored 10 - 11 year old children's perceptions of science careers, finding that girls were likely to eliminate science careers as they did not align to the children's views of femininity or self. It is possible that perceptions of engineering as being "dirty" may constitute a barrier to engineering career aspirations, especially for some girls. Inf act, the work of Bandura et al. (2001) recommended that early intervention is required to reduce sociostructural biases in girls' career development (based on a study conducted with 11 – 15 year olds).

6.4.5 Cadance of EEAs

The discontinuity of formal engineering education emerged from the data at this stage of the research due to SATs occurring during Year 6 in the UK. At Nant School, disruption of lessons due to SATs preparation was identified by participants. This was supported by the head teacher at Nant School who also spoke of the need to focus on numeracy and literacy, whilst balancing this preparation for the SATs with the provision of a broad curriculum. This concept also formed part of the discussion during Year 7 where it is discussed further (section 6.5.3).

6.4.6 Engineering Capital

The focus of Engineering Capital spoken about was parental support. This emerged as a concept in the data from Phren School (see section 5.4.2.4), and was also visible within the data at Nant School (section 4.4.2.5), as children spoke about attending informal education activities with parents such as attending the Big Bang Fair (an informal STEM education activity, see Big Bang (2018) for more information). Parental support did not necessarily involve parents who were engineers, and the range of support varied between verbally conversations, facilitating attendance at informal engineering activities, assisting with engineering projects at home, and the purchase of construction toys and computer games.

However, the findings of this research suggest that there is not a clear link between parental support and the formation of accurate engineering perceptions or positive aspirations. There is no evidence that parental support (provided via toys, hands-on activity provision, visits to engineering activities) results in aspirations to engineering careers. However, a link between parental support and interest in engineering was observed (for example, Jay (Nant School) and George (Phren School), however it is unclear whether the interest occurred as a result of the parental support, or if the parental support was a result of the child's interest and thus sustained it but did not form it.

6.4.7 Summary

At this stage (12-18 months post-participation in the EEA), children's perceptions about engineering were seen to remain unaltered, with the findings indicating that the perceptions about engineering exhibited in Year 5 persisted remaining focused around products or processes. One notable exception was the challenging of gendered views held by girls at Phren School. Although it was seen that the EEA may have temporarily increased awareness of engineering, this was not seen to result in the formation of accurate perceptions of engineering.

Perceptions of engineering as a profession were seen to continue to be inaccurate or partial, and engineering self-efficacy and disinterest appear to be used to eliminate engineering as a potential career, based on the children's evaluation of themselves compared to their personal perception of engineering.

During this stage of interviews, it emerged that the children had questions about engineering and that they may not be being given the opportunity to ask these questions during the course of their education. The children reported a dearth of engagement with engineering activities within both formal education and informal education settings. Although the findings of this research suggest that family support and engineering toys may hold limited influence on the accuracy of the children's perceptions of engineering at this age anyhow.

6.5 A child's experience of engineering education in Year 7 (age 11-12 years)

The data pertaining to this analysis is presented in section 4.4.3 and 5.4.3. The final interviews were conducted 18-24 months post-participation in the observed EEA, at which this stage the children at Nant School had transitioned from primary to secondary school (see section 2.2 for details about the UK school system). The interviews at this stage explored the children's perceptions of engineering, their recollection and experience of participation in the EEA, and additional interactions with engineering. The core perceptions were seen to persist, however the definitions of engineering offered by the children were more varied at this stage, and additional concepts and stereotypes emerged in the descriptions of engineering provided by the children. A deeper analysis of the accuracy of the children's perceptions was enabled as the children offered more extensive, in depth perceptions during these interviews, highlighting potential issues associated with the broad definitions of engineering available to the children. At this stage the discontinuity of EEAs fully emerged from the data, with the children reflecting on the lack of exposure to engineering they received during the period of this research.

6.5.1 Accuracy of perceptions of engineering

The evidence suggests that children use their personal lens when reflecting on their understanding of engineering, whilst the product and process focused perceptions of engineering persisted in both cases, a broader range of perceptions were visible at this stage. At Nant School, perceptions of engineering were broadly split into four different categories; technical skills, processes, products, and job attributes (as presented in section 4.4.3.3). At Phren School, the categories of processes, products, and job attributes were also present (see section 5.4.3.2), however the impact that engineers have on society were also present in the perceptions.

There remained children who stated that they held no perceptions of engineering at this stage, and although there were confident perceptions held, uncertainty was still prevalent, exhibited through the use of questions rather than statements when the children spoke about engineering.

As with previous data, comparisons of the perceptions with the definition of engineering used in this research (section 1.6.2) allowed the evaluation of the accuracy of the children's perceptions of engineering. At this stage, a variation in the accuracy of the perceptions held by the children was found, inaccurate views of engineering were seen to be dominant, however those participants who articulated a continued interest in engineering appeared to hold broader, more accurate views of engineering then in previous interviews. The emergence of stereotypes of engineers also began to emerge from the data, indicating a shift at this point between children who were developing their understanding of engineering and an accurate perception of engineering, and those who were not. To illustrate this point two children's perceptions of engineering are compared below:

> Jay (Nant School) spoke of engineering in terms of bringing ideas into reality, a sentiment that is congruent with the overarching definition of engineering presented at the beginning of this research, it can therefore be said that Jay holds an accurate perception about engineering.
>
> Becka (Nant School) viewed an engineer as a person who fixes things such as a broken boiler in a house, being good at maths, who may be covered in oil. This misses crucial elements of engineering, such as creativity and problem-solving, present in the definition used in this research and is not deemed to be an accurate perception of engineering as a career.

However, it is also important to view the possible interpretations of the definition used in this research. Focusing on Becka's perception of an engineer as a person who fixes the boiler in someone's home, one could argue that she is describing a person who solves a problem in order to help someone, a key part of engineering as defined in this research. The timing of the final interviews may also have influenced the descriptions of engineering internalised by the children, as adverts often run advertising 'engineers' who can fix boiler problems during the winter months (for example, British Gas (2018)). Whilst not explicitly stated by the children, television and digital media were prominent sources of information cited by the children when talking about their perceptions in Year 5 and Year 6, and may therefore inform their views at this age as well. This is discussed further in the following chapter.

Although Becka stated that she had not considered engineering as a career whereas Jay was actively pursuing engineering as his future career, across the cases there does not appear to be evidence of a link between accuracy of perception and holding a positive engineering career aspiration. This was illustrated by George (M, Phren School) who aspired to be an engineer like his dad, but who exhibited a narrow perception of engineering as fixing machines as that was the work that he had observed his dad undertaking. This finding suggests that those children who have an interest in engineering but no role model to observe, may actively seek out information to inform their perception of engineering (leading to a more accurate perception). However, for those children who believe that they already hold an accurate perception of engineering based on the acquisition of knowledge from sources available, there may be no motivation to find out more about engineering to increase their understanding.

6.5.1.1 Engineering and school subjects

The findings suggest that at Nant School the children had created a relationship between D&T and engineering that became visible through a number of the children's narratives (see section 4.4.3.2). This may be linked to the fact that the EEA was presented as a D&T project and is where Nant School focused engineering within its curriculum. The children at Phren School were not seen to make this link, and although links were made between engineering and school subjects such as science, mathematics, and D&T, these links were limited and appeared to arise from the children being aware of the STEM (Science, Technology, Engineering, and Mathematics) acronym.

6.5.1.2 Gendered images of engineers

Although across both cases explicit gendered views of engineering were rare, and the children were unanimous in the view that anyone could be an engineer, at Phren School both girls and boys were seen to display gendered images of engineers as men. Although these children still believed that anyone could become an engineer, they tended to describe engineering as a job for a man (section 5.4.3.2). This view of engineering adds to findings from a survey conducted by the IET exploring children and parent's mental images of engineers, where 61% of the children aged 9 – 16, and 71% of the parents surveyed viewed engineers as male (IET, 2017b).

This finding has importance as previous work has suggested that perceived male environments may discourage females from entering certain subjects (Cheryan et al., 2009). Therefore, the impact that this subconscious view of engineering as a male profession may result in girls eliminating engineering as a potential career. Although the work of Cheryan et al. focused on physical objects, such as stereotypical items within a classroom environment, it was suggested that these physical objects may create an environment that dissuades women from entering computer science courses, but that it does not have the same discouraging effect on males. Therefore, it is possible that the gendered views exhibited by the participants in the current study may result in girls mentally 'closing the door' on engineering careers at a young age.

6.5.2 Recall of the EEA and perceptions of engineering

The initial recollections of the EEA were mainly focused around perceived success or failure, and the perceived difficulty of the activity (section 4.4.3.1 and 5.4.3.1). This focus of recollection has implications for the children's perceived engineering self-efficacy, an example of this is Jessica (F, Phren School) who stated that she thought that she would not make a good engineer as a result of perceiving herself as not as good as her peers during the activity (see section 5.4.3.3). However, Jessica was also observed to say that she did not think that her vehicle would work prior to testing it during the observed EEA (section 5.3.2), therefore it may be concluded that Jessica had low engineering self-efficacy prior to the activity but that the EEA did not improve this. An area that requires more focused research prior to drawing any conclusions.

6.5.2.1 The influence of participation on perceptions of engineering

The data informing this area of analysis can be mainly found in sections 4.4.3.4 and 5.4.3.3. In both cases, the reflections of the children revealed that there were children who felt that they had no knowledge of engineering prior to participation in the activity in Year 5, and there were those who felt that they had already known about engineering. Whilst those children who were seen to hold confident perceptions, felt that participation had not informed them about engineering, some of the children who did not hold such confident perceptions felt that participation in the EAA had added to their knowledge about engineering.

Perception changes appeared to be focused upon the difficulty of engineering, with the activity being harder than expected. Where children believed that participation had altered their perceptions, it appeared that the main focus of the child's perception was not altered. For example, Gabe (M, Phren School) was seen to alter his perceptions of engineering based on the EEA, however his focus remained on cars and the change was limited to altering his perception that engineers fixed cars, to engineers make cars. Although the focus of the EEA that Gabe participated in was a car, this focus on transport was not unique to Phren School as Matty (M, Nant School) also mentioned that he moved from seeing engineering as repetitive repairing, to a wider variety of activities, however still with a focus on transport.

This suggests participation in the activity did not change the children's core perceptions of engineering, rather the outcomes focused on the difficulty of the activity and the implications that this had for engineering as a career. The persistence of inaccurate perceptions into Year 7 is cause for concern as research has suggested that children's interest or disinterest in STEM subjects persists throughout secondary school (Miller et al., 2017) and that STEM career interest may remain fixed regardless of participation in engagement activities during secondary school (Archer, 2013).

6.5.2.2 The influence of participation on engineering career aspirations

For those children who arrived at the EEA appearing to hold aspirations to engineering careers, participation did not appear to change these aspirations. However, no shift towards engineering career aspirations was observed for those children who did not appear to aspire to an engineering career. Interestingly, this was the case for both children who did not feel that their perceptions of engineering were altered through participation in the EEA and those who did. For example, through participation in the EEA Jessica (F, Phren School) found that engineering could be fun, however participation did not improve Jessica's belief that she was an able engineer (as described at the start of this section) and therefore it is suggested that participation in the EEA did not improve her engineering self-efficacy.

6.5.3 Cadence of formal engineering education

Although this appeared in the Year 6 data, this concept was developed in the Year 7 data, with lack of continuity of engineering education activities being referred to by children in both cases. Of particular interest was the consensus that engineering was not discussed within the schools that the children attended, linking to a finding drawn from the Year 6 data where children had questions about engineering which appeared to be unanswered in formal education.

Whilst the children from Nant School were unable to recall any additional engineering activities they had participated in, those at Phren School spoke of STEM activities that had taken place in Year 6 (such as building marshmallow and spaghetti towers). However, there were mixed perceptions amongst the children as to whether these constituted engineering, in a similar way to their perceptions of the observe EEA as engineering. In both cases the concept of disruption due to SATs appeared (section 4.4.3.2 and section 5.4.3.4).

The lack of engineering within the National Curriculum and vocabulary of schools has been highlighted in the literature regarding engineering education, as discussed in Chapter 2 and has been cited by some as the source of the lack of progression of people into engineering (Akam, 2003). This lack of exposure and discussion is supported by the findings of this research where inconsistent engagement with EEAs was seen to result in a reduction in interest and awareness of engineering (section 5.5.8.4).

6.5.4 Perception of engineering and aspirations to engineering: specific ability, interest, and progression

Once again the concept of limited knowledge appeared in the data, with a number of children indicating that they did not feel as though they had enough information about engineering to make a decision about careers at this stage (see section 4.4.3.5 and section 5.4.3.5). Although potentially not an issue unique to engineering careers (an area outside the scope of this research and so not considered in depth here), this further illustrates the finding that participation in an EEA during Year 5 did not result in children feeling as though they had been informed about, or experienced, engineering in a way they could translate to career evaluation.

At this stage the difference in perceived knowledge about engineering was also seen to affect the children's ability to plan for engineering career progression. At Nant School in particular, but also visible in the data from Phren School, it appeared that children who had not considered engineering felt as though they required more basic information to enable themselves to progress to a career in engineering. Whereas children who held firm views of engineering (regardless of their accuracy) were seen to be more focused on the next stages, for example doing well in the correct GCSE subjects at school (see section 5.4.3.5). However, it should be noted that the children were not always aware of what these required qualifications were. This awareness of education progression is consistent with more general career development literature. Based on developmental levels of career choice in children Howard & Walsh (2010) presented work that found children between the ages of 8 and 12, choose jobs based on interest and a process of matching themselves to the job requirements. The concepts of interest and ability were seen to continue to be important, as children appeared to use their personal definitions of engineering to determine the attributes they thought they needed in order to become engineers and evaluated themselves relative to these. Variations in the perceived progression into engineering appeared to be dictated by the knowledge, and certainty of this knowledge, which the child believed they held.

6.5.5 Summary

At this stage the children exhibited a limited amount of impact from participation in the EEA during Year 5, with any influence on interest in engineering appearing to have dissipated due to the discontinuity in engineering education at school for both Schools. Perceptions of engineering were similar to those found in both Year 5 and Year 6, however a larger variation in the strength of perceptions was found, although the accuracy of perceptions of engineering remained low across the cases. The influence of the children's personal definitions of engineering appeared to persist, as the children assessed their own interest in engineering and their ability to become engineers. At this stage it was also seen that children had begun to consider the next steps along an engineering career route, with the perceived knowledge that the child held being an influential factor in determining the point at which they were starting from.

6.6 What influenced the outcomes of participation in EEAs?

As the experience of an EEA has been found to differ according to different factors, in order to answer the first research sub-question of this study (section 3.3) it is crucial to understand the factors that influence the outcomes of participation. The perceptions about engineering and the mental processes that the children appeared to use to evaluate the EEA and engineering as a career, were seen to be largely comparable across the two cases, indicating that in this work, the school attended did not influence the perceptions held by the children.

One factor that appeared to have an influence on the outcome of participation in an EEA was the activity itself: the focus, the structure, the delivery. Whilst further investigation is required to understand fully their importance, the findings of this work suggest that these three areas of the design of the EEA may have the potential to influence different groups of children.

Although participation was not seen to challenge or alter the ideas about engineering that the children held, the focus of the EEA appeared to have the ability to reinforce perceptions held by the participants. This is of particular concern considering that the children tended to hold narrow, inaccurate views of engineering. In the case of the activity at Phren School, the focus of the activity being a car may have acted to reinforce the stereotype of engineers working on cars. Although this stereotype was also visible in the perceptions held by the children at Nant School, it did not appear to be reinforced by participation in the activity, whose focus was a non-traditional engineering product.

The structure of the session was also seen to influence the experience and recall of the activity, with a competition element appearing to lead to recollections of success and failure more quickly than a non-competitive activity. The importance of this was seen when a number of the children used their perceived success or failure of participation in the EEA to inform their engineering self-efficacy and then used this to evaluate their potential as future engineers.

The delivery of the activity can be split into two sub-concepts, associated lessons and co-educational delivery. Whilst no difference of participation was seen regarding teacher or external provider facilitation, the timetabling of the activity was seen to make a difference to the children's outcomes of participation. Those at Nant School who had taken part in an EEA within their D&T class appeared to have formed strong links between D&T and engineering which they found difficult to comprehend once they had transitioned to secondary school where D&T was split into different subject topics (section 4.4.3.2). This relationship between engineering and D&T was not seen to the same extent at Phren School, D&T was mentioned by the children but the link between doing D&T and doing engineering at school was not visible. The other area of the delivery of the EEA that appeared to affect the children's perceptions of engineering was the co-educational environment in which it was delivered. It was seen that this had the potential to challenge girls' gendered views of engineering ability.

6.7 Conclusion

A meta-analysis of the data collected from both cases has been presented in this chapter, identifying the concepts affecting the children's experiences of an EEA, and the outcomes of participation in the EEA.

The analysis presented provides answers to the sub-research questions articulated in section 3.3. The following chapter presents a discussion of the findings, answering the main research question and building a conceptual framework regarding the children's participation in an EEA an their perceptions of engineering and engineering career aspirations.

CHAPTER 7

7 Discussion of the findings

7.1 Introduction

The analysis of the data presented in the previous chapter allows an insight into the perceptions about engineering that the children held, how these perceptions were informed, and how these perceptions informed the children's experience of an EEA and their aspirations to a career in engineering. Whilst comparisons of the findings over the three school years (Year 5 to Year 7) were briefly touched upon in Chapter 6, the current chapter draws the findings of the research together and presents an overall conceptual framework, thus answering the main research question.

To begin, the experience of recruiting participants is considered, the findings concerning the role that EEAs play in the children's perceptions of engineering and their aspirations to engineering careers is also presented. The conceptual framework constructed from the findings of this research is then discussed.

In keeping with the methodology of this research, the relationships between the main concepts are examined in the context of the research cases, as well as the wider literature (described under the heading of theoretical sensitivity by Glaser (1978)), in order to provide a meaningful discussion and enable valid conclusions to be drawn.

7.2 Accessing the field: What recruiting participants tells us about Engineering Education in schools

A table of the anonymised organisations and schools contacted during the research case recruitment is provided in Appendix B and this process has been briefly discussed in section 3.7.1.1. However, the reasons behind the issues of recruitment onto this study are worthy of additional focus as they may hold implications for the current provision of engineering education.

Many of those contacted rejected the opportunity to participate in the research, with barriers stated including that they did not work with children of the required age, that the organisation did not feel its activities fit the criteria of 'engineering', and that the organisation did not have any relevant bookings. As all contacts were made based on the selection criteria required for this research as outlined in section 3.7.1.1., a lack of alignment between publicly available information and practice of the organisations appeared during the recruitment process.

The recruitment process revealed two main barriers to participation, the level of consent required and the existing provision of EEAs delivered in schools. Issues of school engagement with STEM was noted by James during his interview (section 5.4.4.2), and references to funding and priorities in schools were mentioned as potential barriers by the adults in both cases. It was also suggested that opportunities available to primary schools are not always apparent to the school, as spoken about by the head teacher at Nant School, although the science teacher at Phren School was well aware of the vast array of activities on offer but cited energy, time, and funding as barriers to engagement. This suggests that for schools to engage with external EEAs there needs to be a member of staff who is knowledgeable and engaged with the network of providers, supporting the suggestion made by research conducted by Clark and Andrews (2013) that EEA engagement occurs where there is an engineering champion at a school. In both of the cases involved in this research, the teaching and leadership staff showed an interest in promoting STEM within their schools, however this is not assumed as the case across the whole of the education system. Especially as it is known from the literature that not all STEM teachers view engineering as a desirable career (Engineering UK, 2015) and not all teachers are aware of what engineering is (CISI, 2014).

7.3 Overall view of the role that EEAs play in children’s perceptions of engineering and their aspirations to engineering careers.

The main findings from this research study relate to the role that EEAs play in a child’s perceptions of engineering and their engineering career aspirations. The following sections present discussions about the factors indicated as influential for the children in this study, locating the findings of the current study within the existing literature.

The main factor found to influence the outcomes of participation in the EEA for the children are the perceptions of engineering that are held, and the children’s perceived engineering self-efficacy. Within these, a number of sub-concepts were seen to contribute to the complex outcomes seen across the participants. These are examined individually in the following sections.

7.3.1 Structure and focus of activity

One of the factors affecting the children's experiences of the EEA and the outcomes of participation that emerged from this study was the structure and focus of the activity.

The competition model of STEM education is a prevalent model within the industry and a study conducted in the US with students aged 14-17, explored the correlation between participation in STEM competitions during high school and STEM career interest (Miller et al., 2017), concluding that "competitions are an effective way to foster career interest in specific STEM careers" (p. 110). Although only one of the observed activities utilised a competitive element, this study finds that the competition element may provide both positive and negative outcomes for the participants, including the focus on success and failure when recollecting the activity, and the personal evaluation of their ability as an engineer through comparison with their peers. The outcomes of these processes depends on whether the child assess themselves as able in comparison to the others they are observing, and whether they feel as though they have been successful in completing their aim. Therefore, it appears to be important that EEAs do not set children up to fail, this does not mean that prototypes are required to work first time, but it does mean that time and resources are available for the children to complete iterations and that the successes that they have achieved during an activity are made clear to them.

The focus of the activity was also seen to influence the children's experiences of the EEA, with a focus on a product that was traditionally associated with engineering observed to lead to the reinforcement of stereotypical views of engineering. Overall however, the perceptions held by the children post-participation in the EEA were not seen to be accurate, holistic representations of engineering. Neither of the EEAs were framed as engineering projects without additional subjects; at Phren School the activity was a STEM activity, and at Nant School the activity was a D&T project. This lack of explicit focus on engineering may have influenced the outcome of participation as cross-discipline impacts of activities have been challenged by findings of research conducted in the USA that suggested that only interest in the specific domain of the activity is influenced. For example a computer science activity was seen to lead to an increase in computer science interest but not an increased interest in engineering or mathematics (Miller et al., 2017). Whether this is true of more general activities (as were observed in this research) is unclear, and other research has found cross-discipline influence as Campbell and O'Conner (2009) concluded that participation in the Australian Challenge influenced students' decisions to study Chemistry, even though this was not a focus of the challenge.

In addition to these areas, it was seen that the children had many unanswered questions regarding engineering when they came to the interviews. This suggests that participation in the EEA did not answer the children's questions about engineering and thus did not aid them in developing a clear understanding of engineering. Discussions about engineering were not observed as forming part of the EEA for either of the observed activities in this study, and it appears that although the activity was described as being 'engineering', this did not mean that the children made this association. From the analysis of the data, a clear link was shown between the perceptions of engineering held be the children and their experiences of the EEA, with the structure and delivery of the activities observed to do little to acknowledge and challenge the ideas that the children already held. The need for discussions about engineering to form part of EEAs is illustrated by theories of learning, as highlighted by Bransford & Donovan (2005) when they emphasised that "instruction in any subject matter that does not explicitly address students' everyday conceptions typically fails to help them refine or replace these conceptions with others that are scientifically more accurate" (p. 400).

Overall it appears that the structure and focus of an EEA may influence outcomes of participation, especially when the activity focuses on a stereotypical engineering product and where engineering is not explicitly discussed with the participants. This finding holds implications from EEAs as the focus and delivery of the activity, more so than purely being 'interactive' or 'hands-on', has been seen to have implications for the outcomes of participation.

7.3.2 Gender of participant

The findings of this research suggest that the gender of the participants may influence the outcomes of participation, although the experience of the EEA appeared broadly similar for both genders in this study there was an area where the experience was perceived to be different. This was seen where girls were able to see their ability in comparison to the boys during the activity, thus altering their perceptions regarding the ability of girls to become engineers (see section 6.4.3). In this way it appears that this alteration in perception may have built engineering self-efficacy for girls who had held views that girls were generally less able to succeed at engineering than boys.

Differences in the outcomes of participation between the genders has emerged in previous research, conducted with older participants. Campbell and O'Conner (2009) reportedly found that participation in a STEM competition for Year 11 students in Australia had a larger impact on subject interest and progression for the females than the males. No exploration of the reasons behind this finding were made, however looking at the current study it is possible that the female students were able to reassess their STEM ability through participation in the Australian Challenge activity. These explanations are offered tentatively due to the limited information available from the initial study, but it appears that the perceptions of engineering which each gender brings may alter their experiences of an EEA.

7.3.3 Discontinuity in formal engineering education and the influence cadence of EEA delivery has on perceptions

The findings suggest that preparations for national tests occur in Year 6 removing the focus that is usually put on D&T in other years, and reduces the amount of time available for engineering activities to be provided. Other work has suggested that aspirations to engineering careers fall as children enter Year 10 in secondary school (Engineering UK, 2017), one possible reasoning is that GCSE preparations reduce the practical aspects of science (as discussed by Sir John Holman (2014)), an area identified as a potential progression factor by Dahmen and Thaler (2009). This hypothesis could be echoed in Year 6 children as they prepare for the SATs that focus on maths and English, as described by the children who highlighted the lack of many of the more practical subjects (D&T and art) during this period. The discontinuity in engineering education that appears to occur due to focus on SATs preparation diverts resources away from sustaining engineering awareness and interest, potentially leading to some children's interest diminishing. Master & Meltzoff (2016) refer to STEM learning opportunities as charging stations, which give children the opportunity "to charge up their skills and motivation in STEM" (p. 226), in the case of SATs preparation in Year 6 it may be that the opposite is true, where a gap in these activities allows children's interests to weaken and motivations wane (section 6.5.3). The lack of continuity of EEAs in schools may mean that any interest inspired by participation in an earlier EEA is not capitalised on.

7.4 Conceptual framework

Using the findings gained from the data collected in this research, a conceptual framework concerning the influences that act upon a child when considering engineering as a potential career, and the role that EEAs delivered during primary school play in this process, has been created.

In Chapter 6 it was seen that for the participants in this research, the school attended did not appear to influence the perceptions of engineering held, neither did the gender of the child (although gendered perceptions did). These, therefore, do not form part of the conceptual framework presented in Figure 7.1 and Figure 7.2. The concepts of perceptions (including accuracy, form, and certainty), perceived engineering ability, interest in engineering, and the form, structure, and delivery of the engineering education activity, emerged as the main concepts from the data and the interplay between these main concepts forms the basis for the children's formation of engineering career aspirations at age 11-12.

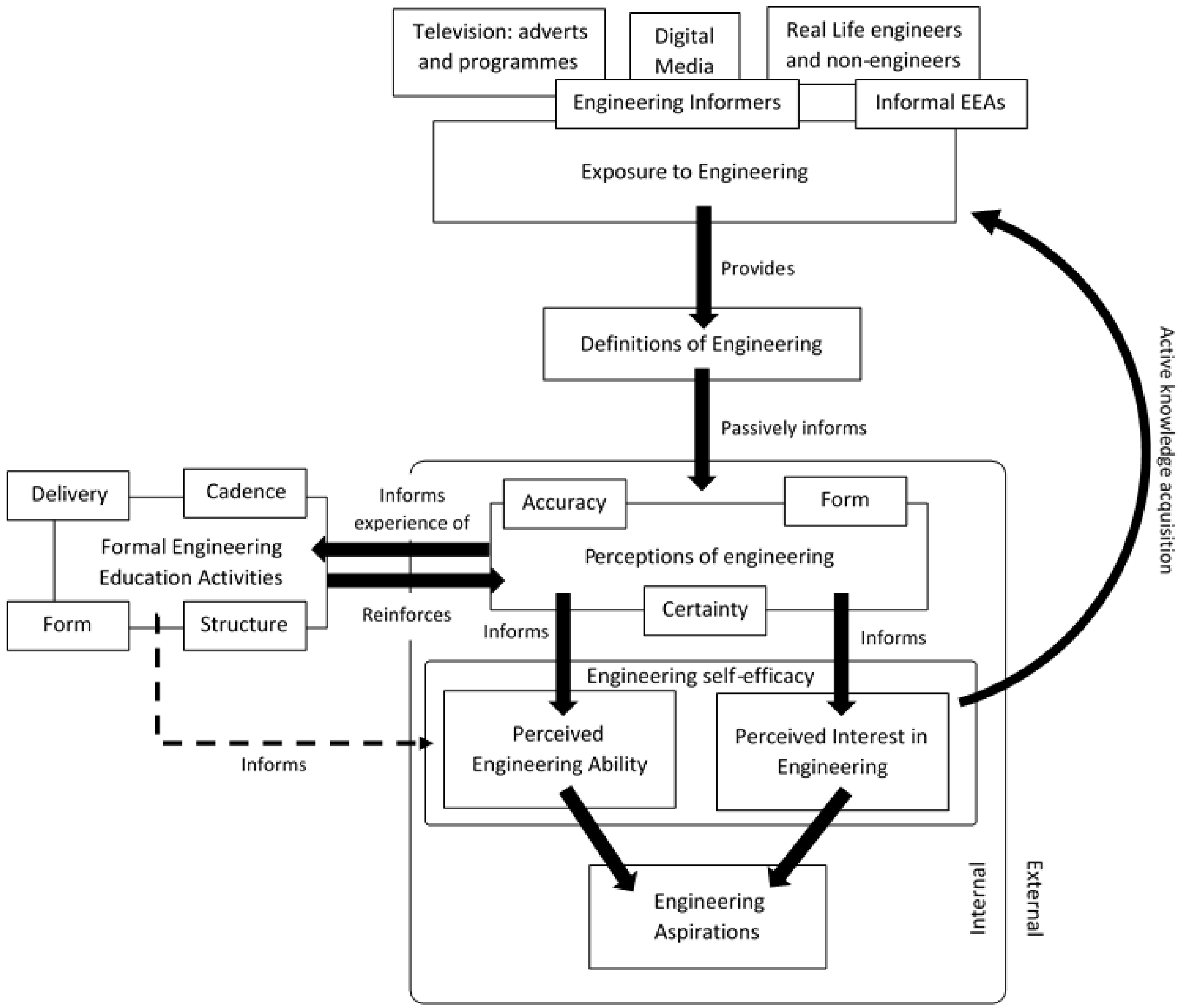

Figure 7.1: Conceptual framework defining the sub-concepts of a child's aspirations to an engineering career at age 11-12.

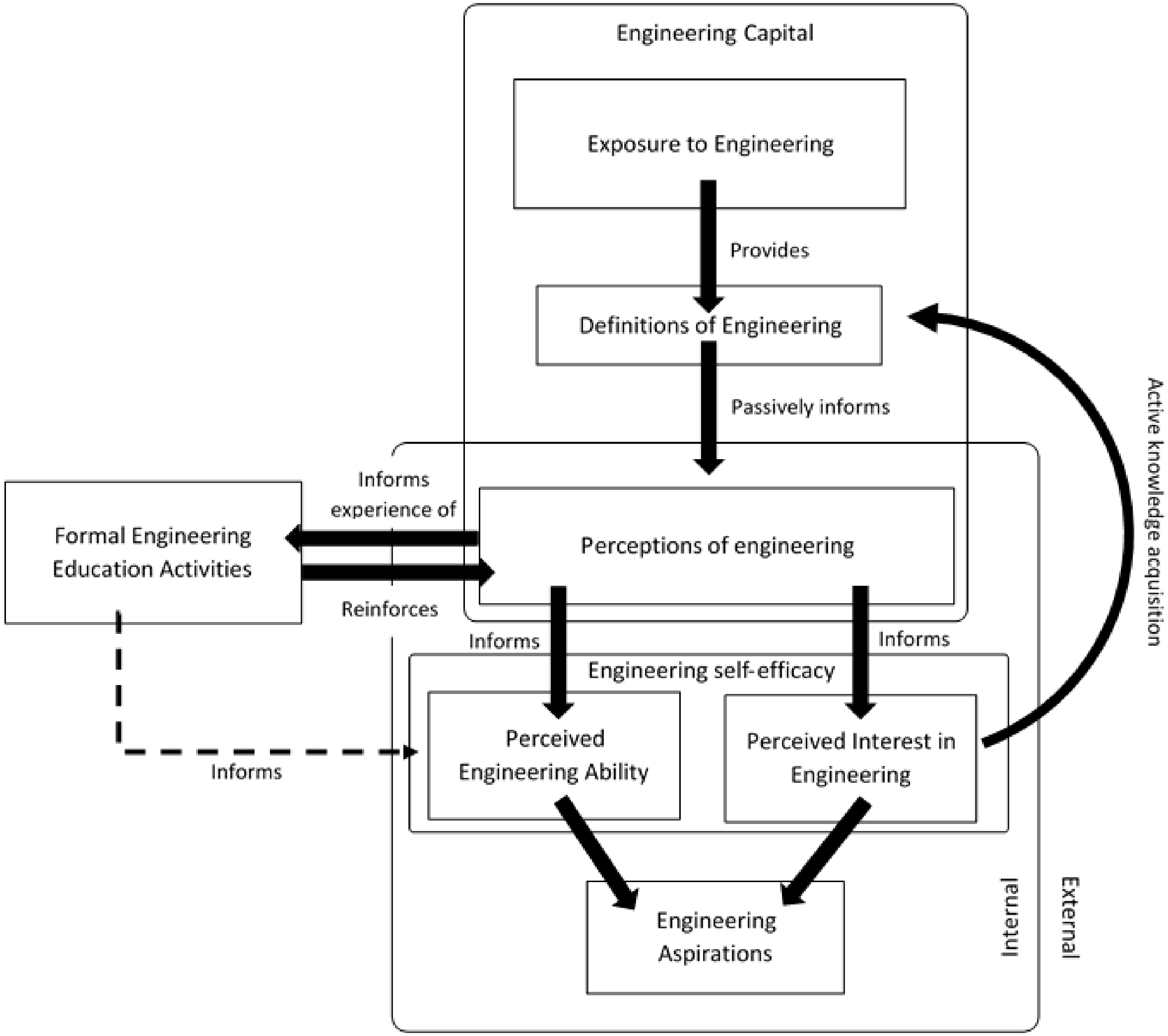

Figure 7.2: Conceptual framework defining the core domains of a child's aspirations to an engineering career at age 11-12.

In this research it has been seen that the following factors affected the children's outcomes of participation, whilst the findings are specific to the context in which this research was conducted, the conceptual framework developed provides a focus for future research.

7.4.1 Exposure to engineering: The role of Engineering Capital

As has been discussed, the children talked about a range of sources from which they drew information about engineering. This informal learning may form part of the charging station idea proposed by Master & Meltzoff (2016) (discussed in the previous chapter) and resonates with the idea of "science capital" as defined by Archer et al. (2014b), discussed in section 6.3.3.5.

Many of the dimensions of Science Capital, as presented by King's College London (2018) are visible in the findings of this research relating to the formation of engineering career aspirations; engineering literacy, engineering media consumption, participation in out-of-school engineering learning contexts, family engineering skills, knowledge and qualification, knowing people in engineering-related roles, and talking about engineering in everyday life. However, whilst these areas were seen within the data, the findings of this research suggest that there is not clear link between the total level of Engineering Capital of a child and holding an accurate perception of engineering at a young age. Although the children who did hold aspirations to engineering careers cited the use of Engineering Capital, both children who did and did not hold engineering career aspirations were seen to have access to Engineering Capital. For this reason Engineering Capital was split into two concepts, Exposure to Engineering (incorporating the majority of the dimensions of Engineering Capital) and Perceptions of Engineering (which incorporates the engineering literacy dimension of Engineering Capital). In this way the different dimensions within the concept of Engineering Capital can be explained more clearly, and their individual influences on the engineering career aspirations of the children can be examined.

Whilst the use of Engineering Capital was cited by children who aspired to engineering careers, the Exposure to Engineering experienced by the children did not appear to influence the accuracy of the perceptions about engineering held. Children who aspired to engineering careers did not appear to have a more accurate perception of engineering than those children who did not. In addition, the findings of this research suggest that the different dimensions of Engineering Capital hold different weightings of importance for the children, with media portrayal of engineering playing a large role in the perceptions of engineering that children hold at this age.

Although the children did not identify engineering focused activities that they had participated within the school environment, they did express different levels of engagement with engineering in their everyday lives. The main sub-concepts identified from the data were *Digital Media* and *Engineering Informers.*

7.4.1.1 Digital Media and definitions of engineering

For those children who expressed views about engineering, television shows and other forms of digital media were referred to as the dominant sources of information that informed their perceptions. The findings of this research suggest that before the age of 9 and up to the age of 12, digital media (see section 6.3.3.1 for the definition), plays an important role in the formation of the children's perceptions about engineering.

To investigate the definitions of engineering available to the children via digital media an internet search was conducted. The internet was mentioned by a number of children and although information about internet access was not specifically requested, many children spoke of having access to an internet enabled tablet or smart phone. Initial searches for the term 'engineering' did not return helpful results, more specific searches within the webpages of Professional Engineering Institutions (PEIs) were then used. In this way definitions of engineering were found provided by the Institution of Mechanical Engineers (IMechE), Royal Academy of Engineering (RAEng), Tomorrow's Engineers, Engineering Council, Institution of Chemical Engineers (IChemE), and the Institution of Structural Engineers (IStructE).

The Engineering Council, Tomorrow's Engineers, RAEng, IChemE, and IStructE, all provide definitions of engineer which were either stated or implied as being for a young audience who are considering engineering as a possible career. Similarities can be seen across the definitions provided by these bodies. The RAEng listed a number of bullet points on the "What is engineering?" page of their website, stating that engineers "make things, they make things work and they make things work better" before highlighting the creativity required to solve world problems, and talking about a range of engineering areas such as infrastructure, energy, medicine, and materials. (RAEng, 2018b). The sentiment of this definition was also present in the opening paragraph on the Tomorrow's Engineers "What is engineering?" webpage (Tomorrow's Engineers, 2018c), which stated that:

> *Engineering is everywhere, helping transform people's lives around the globe. The work that engineers do is creative and hands-on. It's about designing things, finding solutions and improving things.*

The Engineering Council website (2017b) also provided a broad definition of engineering, describing engineering in terms of the impact it has on society and the areas engineers are involved in, as follows:

> *Engineering is vital to our everyday lives, affecting all kinds of things we often take for granted like transport, energy, health, food and running water. Without engineers we would have to get by without television, mobile phones, hairstyling products, the internet, etc.*

Whilst these definitions provide a broad view engineering as a profession, the definitions provided on the IChemE (2018), IStructE (2018), IMechE (2016b), and ICE (2018) websites were focused on the specific discipline of engineering related to the institution whilst continuing to promote the role that engineering has in society.

> *Modern society relies on the work of chemical, biochemical and process engineers - they help manage resources, protect the environment and control health and safety procedures, while developing the processes that make the products we desire or depend on.*
> (IChemE, 2018)

> *Structural engineers make sure buildings and bridges are stable and strong enough to withstand natural forces like hurricanes and earthquakes…they're the guardians of public safety.*
> (IStructE, 2018)

> *Civil engineering is everything you see that's been built around us.*
> (ICE, 2018b)

> *Mechanical engineering is a diverse discipline that encompasses the teaching, practice and leadership of others in the development and application of scientific principles to mechanical systems.*
> (IMechE, 2016b)

Comparing these definitions of engineering to the perceptions seen to be held by the children in this study, the key characteristics of engineering as defined by the PEI's are not reflected in the definitions of engineering internalised by the children. The reason for this lack of coherence between the perceptions of the children and the definitions of engineering presented by PEIs may relate to the finding that the children were predominantly passive in their engineering knowledge acquisition, in order to engage with the definitions provided online the children would have had to seek the information actively. This behaviour was only seen when a child had an existing interest in engineering.

When exploring the use of the term ‘engineer’ in other more readily available contexts, it could be seen that the term was used by industry when referring to persons who the children may have been aware of through media advertising and daily life. For example, the British Gas website (2018) stated that “From faulty boilers to blocked drains or broken light switches, you're just a few clicks away from booking an engineer”, and the term was used in videos made by British Gas and published on YouTube for the general public to use (British Gas, 2014). The Automobile Association also used the term engineer when referring to a Home Emergency Response Engineer as someone who would “go out and rescue customers who have a home emergency or problem” (AA, 2018) and used the phrase “qualified heating engineers” in their 2011 television advert (AA, 2011).

Comparing these definitions of engineering with those held by the children in this study reveals greater alignment, indicating that the use of the term ‘engineer’ within society may have an impact on the children’s perceptions of engineering. In the UK ‘engineer’ is not a protected title, this has been a topic of debate for many years (The Guardian, 2013; IMechE, 2017) and dominates the frequently asked questions answered on the Engineering Council ‘Status of Engineering’ website (Engineering Council, 2017c). On this website, the Engineering Council state that the words engineer and engineering are not “legally defined” and that attempting to protect the words would likely “have little prospect of success”, instead the Engineering Council focuses’ on promoting specific titles which designate professional engineers. However, the children’s understanding of engineering and the role of an engineer does appear to be influenced by the message they obtain from the use of the term ‘engineer’ within the media, which is not necessarily allied with the profession of engineering.

The wider findings of this exploration into the definitions of engineering provides evidence of the broad nature of the field of engineering and the range of differing definitions that the public are presented with. Comparing the children’s perceptions of engineering with the range of definitions presented above, similarities (in terms of products and processes mentioned) can be seen, however there is a stark difference between the children’s perceptions of engineering and the holistic definitions of engineers as “the guardians of public safety” (IStructE, 2018) and engineering as “helping transform people's lives” (Tomorrow’s Engineers, 2018c).

Ultimately, this finding challenges the efficacy of our current definitions of engineering for children, and questions the ability of these definitions to build accurate perceptions of engineering. Broad definitions of engineering regarding skills and processes have been seen to lead to confusion as to the limitations of engineering (section 4.4.2.2), whereas product focused definitions lead to narrow perceptions and children failing to appreciate the breadth and reach of engineering.

7.4.1.2 Engineering Informers

The children referred to both engineers and non-engineers when they spoke of individuals whom they felt informed them about engineering. Family members were the most commonly cited individuals with teachers also mentioned, however the findings suggest that it is unlikely that the children met professional engineers in a work context. Continuing from the analysis in section 6.3.3.2 it appears that how children interact with engineering informers plays an important role in the outcomes of engagement with this network. Although there were many children who spoke of engineers whom they knew, they did not aspire to engineering and did not display perceptions of engineering that differed from those children who could not identify a known engineer. Although the children themselves appeared to place importance on their access to role models, these relationships were seen to be of limited influence to the accuracy of the children's perceptions of engineering. This correlates with a finding from a US study into the perceptions of engineering held by Gifted and Talented 3rd and 4th Grade children (Oware et al., 2007).

However, where an existing interest in engineering was present, children appeared to take an active role in gaining engineering experiences and knowledge, and parental support was seen to play a role here, not necessarily as primary informers but as facilitators of engineering knowledge through enabling access to informal engineering activities such as visits to engineering companies.

Whilst the unique information offered by personal connections to engineers appears to have little significance on the perceptions about engineering held by the children, digital media appeared to dominate the children's *Exposure to Engineering*, resulting in broadly consistent perceptions of engineering held across the two cases.

7.4.2 Perceptions of engineering

The perceptions about engineering that the children held, appeared to be formed prior to the start of this research, being influenced predominantly by the exposure to engineering that the children had through digital media, and did not appear to change over the time that this research was conducted (Year 5 to Year 7).

The forms of the children's perceptions revealed in this research are consistent with those established in previous work conducted using children's drawings to explore their perceptions of engineering, both in the UK (Silver & Rushton, 2008) and the US (Thompson & Lyons, 2008; Oware et al., 2007; Capobianco et al., 2011). The perceptions that the children held were seen to consistently centre on products (such as cars, vehicles, and machines), or processes (such as fixing, making, and designing). The less dominant sub-concepts regarding character and job attributes and the impact that engineers have on society were not seen to be present in other work conducted in the UK (Silver & Rushton, 2008). This may be explained by the difference in data collection methods used in the two studies, as questionnaires and drawings were the dominant methods utilised by Silver and Rushton, therefore the more intangible concepts of attributes and impact would have been difficult to interpret from the collected data. The concept of impact was also absent from the thematic groupings provided by Thompson and Lyons (2008) when considering the key indicators of perceptions of engineering held by African-American students in 6th Grade (UK Year 7 equivalent) using the DAET (Draw-an-Engineer-Test).

Whilst the forms of the perceptions held did not appear to alter across the period of this research, uncertainty was exhibited at each stage of the interviews. This uncertainty persisted across the research timeframe, and once the children were in Year 7 the level of certainty with which they held their views about engineering appeared to influence their perceived pathways into engineering (section 6.5.4). This is consistent with an area of Science Capital as identified by Archer et al. (2014b) who believe that a young persons "confidence in feeling that they know about science" (KCL, 2018) influences their likelihood in progressing to a science career. Translated from scientific literacy to engineering literacy in this work, children who held confident views of engineering were seen to be the children who aspired to engineering careers and had a coherent view of how they would progress to such a career once in Year 7. However, perceptions of engineering also form a fundamental element of engineering literacy as they directly relate to "a young person's knowledge and understanding" (KCL, 2018) about the subject. Whilst a link between confidently held knowledge about engineering and career aspirations did appear in this research, no link was visible between how confidently knowledge about engineering was held and how accurate perceptions of engineering were. This suggests that children are able to progress towards engineering careers whist holding a narrow or partial understanding of engineering, which may compound issues faced further along the education pipeline, especially regarding the preparedness of engineering students for engineering careers (a current topic of debate within the UK).

It is noted that negative or positive judgements were not explicitly assigned to engineering by the children when they spoke, although judgements were subsequently made when talking about engineering careers. Therefore, this area is not discussed until later in this section as it occurs within the concept of *Perceived Interest in Engineering*. However, implications of this finding are far reaching as much of the current evaluation of the efficacy of engineering education is based on tracking the negative vs. positive perceptions of engineering that different publics hold (Engineering UK 2015; 2016; 2017).

7.4.2.1 Uncertainty and accuracy

Whilst the form of perceptions of engineering were seen to persist across the interviews, the exact definitions of engineering used by individual children differed across the three stages, as expected based on existing literature (Engineering UK, 2017; Archer, 2013; ETB, 2009). This is unsurprising when the uncertainty with which definitions of engineering were held by the children is considered. For those children who did hold confident perceptions of engineering, a corresponding interest in engineering was observed from Year 5 and was seen to continue throughout the research period, and the data suggests that these children used their interest to actively increase their exposure to engineering. For children who did not exhibit an interest in engineering, the process of knowledge acquisition appeared to be predominantly passive and perceptions remained uncertain.

Whilst an interest in engineering from a young age was seen to increase the certainty with which a child held their perceptions of engineering, no relationship between this interest and accurate perceptions of engineering was seen. In the preceding chapter, the accuracy of the children's perceptions has been assessed at each interview stage, using the definition of engineering adopted by this research. This has shown that there are significant differences between the definitions of engineering that the children held and dictionary definitions given in the UK, also highlighted in section 7.4.1. This difference between children's definitions and accepted definitions of engineering is a finding that supports a conclusion drawn by Silver & Rushton (2008). However, the definition used in their research described engineering broadly as "designing and making" (p.58), concepts that were not present in the data collected and analysed by Silver and Rushton but that were present in the current study.

7.4.3 The influence of participation in the EEA

Considering the EEAs observed within this research, the findings indicate that participation in either of these one-off EEAs during Year 5 did not alter the accuracy of children's perceptions of engineering or their aspirations to engineering careers.

Although some of the children's exact definitions of engineering changed over time, the accuracy of the perceptions held by the children between Year 5 and Year 7 did not appear to improve. This finding suggests that the provision of engineering education observed during this research allows children's existing ideas about engineering to persist largely unaltered and unchallenged. However, due to the influence that the focus and structure of the EEA appears to have, altering the focus or structure of the activity is therefore likely to alter the outcomes of participation regarding perceptions of engineering and evaluation of engineering careers. This tentative statement is supported by a finding from the work of Thompson and Lyons (2008), who investigated the outcomes of exposure to engineering within the school setting on student's perceptions of engineering, using an EEA that involved graduate engineers working with teachers and classes during the latter year of elementary school (equivalent to UK Primary school). Thompson and Lyons found that this exposure influenced and increased the accuracy of the perceptions that were held by the children the following year. Although sample sizes were not vastly different (44 students who had participated in the EEA and a further 44 who had not comprised the sample in the work of Thompson and Lyons), of greater difference was the fact that the EEA considered by Thompson and Lyons was longer in duration and took a different form. More recently Archer et al. (2014a) examined the outcomes of participating in a six-week programme for Year 9 (age 13-14) students, finding that improvements in students understanding of science careers was achieved, however no increase in aspirations to study science were observed.

In addition to the duration, there are two other main differences between the EEA considered by Thompson and Lyons and the activities observed in the current study:

- The input from professional engineers (who worked with the teachers to develop activity content).
- The engagement of teachers as well as children.

Whilst the EEA considered by Archer et al. (2014a) involved professional engineers, the co-construction of content between engineers and teachers was not present.

No professional engineers were involved with the delivery of the EEA at Nant School, and although professional engineers were present to assist in delivering the EEA at Phren School it was unclear what level of input the engineers had in the design of the activities. The creation of the activity appeared to be dominated by educators rather than engineers (as alluded to by James in section 5.4.4.2). In addition, due to the interactions between the engineer and the teacher during the project discussed by Thompson and

Lyons, it is possible that the teacher's perception of engineering was altered; this was not the stated aim of either of the EEAs observed in this research.

There has been work conducted to explore teachers' perceptions of engineering, for example the annual Engineering UK report concerning perceptions of engineering held by different groups within the UK, and work conducted in the US by Hammack and Ivey (2016). However, the impact that these have on children's perceptions of engineering and the outcomes of participation in EEAs requires further research.

7.4.4 Gender and perceptions of engineering: typing and ability

No difference in the accuracy or certainty of perceptions of engineering held by the children was seen due to their gender and the concept of gender itself did not appear until Year 6, however it was then visible in both the Year 6 and Year 7 interview data. Whilst explicit stereotypes of engineers as men were not widespread in the findings of this research, there were implicit gender stereotypes that became visible during the interviews and subsequent analysis.

In Year 5 gender did not appear as a concept within the collected data, reflecting the findings of other studies that overall, images of SET are similar across the genders (Silver & Rushton, 2008). This is reinforced by the findings of the current study, where, although specific perceptions of engineering varied across the group, both boys and girls used similar terminology and imagery when talking about engineering and engineers. However, the work of Silver and Rushton (2008) also suggested that boys are more likely to hold positive perceptions of SET subjects than girls are in Year 5. This was not found to be the case in the current work, with neutral views of engineering presented in the data and with neither gender showing a more positive inclination towards engineering than the other.

In Year 6 the concept of gendered-ability appeared (section 6.4.3 and 6.4.4.1), indicating that children at this age, girls especially, may use gender within their evaluations of their own ability to succeed at engineering. During the Year 7 interviews an underlying gendering of engineering became more apparent (section 6.5.1.2), although the children stated that either gender could become an engineer if they wanted to, many children referred to engineers as male, and engineering as a male profession. Although this was seen more commonly in the narratives of the girls in the study, it was not exclusively a female trait.

There is evidence that girls may hold gendered perceptions of engineering-ability, and both girls and boys appeared to associate engineering with men by Year 7, this holds major implications for the outcomes of participation in EEA. Master & Meltzoff (2016) conducted research into the impact STEM stereotypes can have on girls and boys engagement with STEM at a young age (4 and 6 years old), leading to conclusions that “cultural fit” stereotypes may be internalised by young children. These stereotypes may result in children dismissing careers that they do not ‘fit’, and a theory proposed by Gottfredson (1981), suggested that children identify gender-appropriate careers at a young age (6-8 years) and eliminate those they regard as gender-inappropriate. The findings of the current research suggest that while the children asserted that either gender could become an engineer if they wanted to be, associations are made between engineering and males, and therefore unconsciously this may influence their career aspirations.

Although differences between the engineering aspirations held by different genders were not observed, this could have been because of the small sample of participants within this study, as larger studies have concluded that significantly more 7-11 year old boys than girls aspire to engineering careers (Chambers et al., 2018). Although the work of Chambers et al. did not fully explore the motivations for this, it was suggested that boys gravitated to “traditionally male dominated sectors and professions” (p. 19), and that “conceptions of femininity” (p. 22) drew girls to roles such as teacher or doctor. With the engineering workforce in the UK comprising of only 11% female according to WISE (2017), the view of engineering as a male dominated profession is not unreasonable. In addition, when referring to the definitions of engineering that are presented to the public through online sources (see section 6.3.3.1), it is not described as a caring or nurturing profession, both of which were associated with ideas of femininity by Chambers et al. (2018). Therefore, it is possible that the manifestations of the engineering industry, created by children using the information available to them at a young age, results in a subconsciously gendered views of engineering. This concept of identity appears to have less relation to actual ability and interest in the area of engineering, and more to do with the child’s ability to ‘see themselves’ as an engineer in the context of the industry.

Gender was not only visible in the data relating to the children’s experiences, the adult participants also spoke of gender either directly or indirectly, when talking about engineering. Although the influence that the adults approach to engineering has on the children’s perceptions and career aspirations is outside of the scope of this study, it was seen that possible unconscious favouring of boys when considering engineering may influence the gendered-identity perceptions held by some children (see 6.4.3). Engineering UK (2015) used research conducted by the Campaign for Science and Engineering (CaSE) (2014) into the diversity in STEM, to argue that parents are more likely to want their son to continue an engineering career path than their daughter, implying that adults may view engineering as a male profession. This may be passed on to children through cultural stereotypes resulting from adults words and actions, causing low engineering self-efficacy for girls at a young age.

Whilst the conceptual framework presented in Figure 7.1 presents the core domains and sub-concepts affecting each domain, it is possible that different genders will experience each of the domains differently due to the societal view of engineering and of each gender. However, further research would be required to explore this area.

7.4.5 Use of perceptions to inform engineering self-efficacy

Although neutrality regarding engineering was expressed, individual definitions were seen to be used to evaluate a child's engineering self-efficacy. At this stage it was seen that inaccurate perceptions acted as barriers to progression; the common view that engineers are people who repair and fix vehicles was seen to dissuade children from considering engineering as a career. This supports a finding from previous research with Year 5 children where it was concluded that "it is the children's stereotypical images of scientists and engineers rather than an actual dislike of science and design technology that dissuades them from becoming scientists and engineers." (Silver & Rushton, 2008, p.66).

In the case of the current study, children were seen to be deterred from considering engineering careers by the inaccurate perceptions of engineering that they held, using these inaccurate perception of engineering to evaluate their own interest and ability in engineering as a career.

Perceived interest and ability appear as important concepts in the child's decision-making process regarding engineering careers when choosing whether they want to pursue a career in engineering the relationship between these appeared in two ways:

- Positive career aspirations for children who were interested in the product or process they ascribed to engineering (and vice versa).
- Positive career aspirations for children who perceived themselves as able in the areas they associated with engineering (for example designing) (and vice versa).

7.4.5.1 Perceived ability

The apparent reasoning behind the lack of engineering career aspirations was seen to alter over time. In Year 5 the children appeared to find other jobs more appealing, in

Year 6 the children tended to focus on their personal interest and abilities, this continued into Year 7 however the children began to also use their knowledge of “the next steps” (qualifications) to define their career trajectory. This is unsurprising when we look at the literature concerning career aspirations in children, the work of Gottfredson (1981) has already been discussed in section 5.4.4, and the work of Howard and Walsh (2010) in section 6.5.4.

In addition, Bandura et al. (2001) investigated how children’s self-efficacy shapes their career trajectories based on a social cognitive theory model. Through research carried out in Italy with children aged 11-15 (average age 12), it was found that perceived self-efficacy was more important to children than their academic accomplishments. Although the education systems differ and so findings may not be transferrable, this importance of self-efficacy is reflected in the findings of the current work.

7.4.5.2 Perceived interest

The findings of this study indicate that a child’s interest in what they perceived engineering to be was influential in their career aspirations decision making, a factor also identified by research conducted by Clark and Andrews (2010a). However, in the current research, the child’s perceptions of engineering were also seen to create issues within the process of developing career aspirations as it was seen that it was inaccurate perceptions of engineering, often associated with cars or repetitive fixing tasks, which dissuaded children from considering engineering as a career (discussed in section 7.4.1).

This finding suggests that whilst focus needs to be given to increasing the accuracy of engineering perceptions held by young children, care also needs to be given to aligning accurate definitions with children’s interests.

7.4.6 Engineering Career Aspirations

Perceived interest and ability were seen to dominate the children’s decision making regarding potential careers. Those children who were seen to hold firm engineering career aspirations appeared to have held these aspirations prior to participating in the EEA, rather than them being formed during the course of the research. Those who mentioned engineering as their key career aspiration in Year 5 tended to maintain this aspiration throughout the research, although this was not always the case and the low continued participation rate at Nant School means that no firm conclusions can be drawn from this data. For those who were seen to continue to hold engineering career aspirations throughout the research, participation in the EEA did not appear to inform their views of engineering, however it was seen to provide them with confidence in their ability in the field of engineering, thus building their engineering self-efficacy.

It was seen that children were likely to continue to hold career aspirations that were not aligned to engineering, and therefore it may be argued that participation reinforced engineering as a career for those who were already focused on it, but did not encourage others to consider engineering as a career. This finding reflects work conducted by the IMechE (2014) who reported that there are ‘five tribes’ of student between the ages of 11 and 19, with those termed ‘STEM Devotees’, both enjoying STEM study and aspiring to STEM careers, being likely to progress in STEM pathways regardless of interventions such as the EEAs discussed in this work. The work of the IMechE highlighted the need to inspire and inform other groups of students who would ordinarily not consider STEM pathways, something that does not appear to have happened in either of the EEAs in this research.

7.4.6.1 The use of Engineering Capital

The findings of this research build upon and extend the finding of Archer et al. (2014b, 2015) who proposed a correlation between the Science Capital held by an individual and their likelihood of progressing to study science and the IMechE (2104) who found that STEM Devotees were most likely to have access to STEM Capital.

Whilst the findings of the current research indicate that Engineering Capital does play a role in the engineering career aspirations held by children aged 11/12, the influences of the different dimensions of Engineering Capital are complex and are not yet fully understood. It appears that interest in engineering is a crucial element in a child engaging with Engineering Capital, but that this increased exposure to engineering does not necessarily distil an accurate perception of what engineering entails. It is unclear where initial interest in engineering originates, and although those children without access to Engineering Capital may be unable to have their engineering interest nurtured, it is not known if it is the nucleus of engineering interest.

7.5 Conclusion

A conceptual framework based on the findings of this research has been presented, and the domains within the framework discussed. It is concluded that participation in an EEA that does not build engineering self-efficacy is unlikely to influence children’s engineering career aspirations, and EEAs that do not challenge existing perceptions of engineering are unlikely to result in improving children's perceptions of engineering.

The following chapter concludes the research, before the final chapter reflects on the research process as a whole.

CHAPTER 8

8 Conclusion

8.1 Introduction

This chapter concludes the project and examines whether the aims and objectives presented in Chapter 3 have been met. By drawing together the main conclusions of this research and presenting them alongside the implications for the field of engineering education research, and for the provision of engineering education in the future, the value of this research can be ascertained.

Further research opportunities following from the findings of this research are discussed briefly, and recommendations are offered for policy makers, teachers, and outreach/engagement facilitators.

8.2 Thesis synopsis

This thesis started by discussing the necessity for this research, highlighting the importance of focused engineering education research in tackling the issues in recruitment and retention of engineers within the UK. The efficacy of the current model of engineering education was questioned and the lack of research into young children's experiences of engineering education was highlighted. The link between primary school children and career aspirations was made in Chapter 2. The need for this research was justified due to scarcity of research, and thus lack of understanding, of the current outcomes of engineering education in primary school and the importance that this age has on career trajectories.

The nature of the focus of this project required the adoption of a qualitative multiple case-study methodology, in order to enable the resulting findings and knowledge to improve the understanding of this area of study and possess the greatest relevance to the field. The research design and the underlying methodology were presented in Chapter 3, drawing together the literature review to define the context for the focus of this research and developing an appropriate framework in which to carry out this study.

The data regarding each of the research cases was presented in Chapter 4 and Chapter 5, grouping the data into the emergent concepts and exploring the children's experiences of EEAs. Meta-analysis and discussion of the concepts emergent from the data at each interview stage was presented in Chapter 6, illustrating the complexity of the topic whilst focusing on the key concepts of participation as discussed by the children during the research interviews (satisfying research objective 1 as set out in Chapter 3). Through this initial coding and subsequent axial coding of the data, the main categories and their relationships were developed and a conceptual framework was created (Figure 7.1), this was discussed in Chapter 7 (satisfying research objective 2 as set out in Chapter 3). The resulting analysis chapter illustrates the social complexity of engineering education whilst weaving existing research into the discussion of the findings to advance the emergent theories formed. Coalescing the concepts in this way has meant that a relevant foundation had been provided for any further research and theory development related to this topic.

Through this research methodology and structure, the research objectives have been met and a critical investigation into the affect that engineering education activities have on children's views of engineering has been conducted, satisfying the aim of this research. During the course of the research the main concepts relating to the outcomes of participation for children have been identified and a conceptual framework of participation in an EEA (within the context of career aspiration development) has been generated, contributing new knowledge to the EER community.

It is evident from the findings of this research that the experience of participation in engineering education at primary school can be categorised into the following key concepts:

1. Perceptions: Perceptions of engineering inform the children's reflections on their experiences of an EEA and their engineering self-efficacy from the age of 9.
2. Structure and Focus of EEAs as a learning activity: The structure and focus of an EEA can affect the outcomes of participation.
3. Cadence of EEA delivery: Participation in one-off EEAs during Year 5 may not alter the accuracy of children's perceptions of engineering.
4. Definitions of engineering: Definitions of engineering for young children need to be carefully considered and provided coherently.

8.3 Perceptions

Children were seen to hold perceptions of engineering, appearing to be drawn from a range of sources, resulting in a range of inaccurate and uncertain definitions of engineering held by the children.

EEAs such as those observed here do not appear to encourage children to consider engineering as a career. However, for children who already hold an interest in engineering the activities can add to their knowledge, perceived experience of engineering, and confidence.

It is argued that the lack of sustained and effective engineering education for children during primary school results in the reinforcement of 'typical' STEM students entering the field. For the children who may not see themselves as engineers because they don't fit their narrow view of engineering, current provision of engineering education fails to inform and inspire them to consider engineering at this age.

It has been seen that the children adopted a passive approach to learning about engineering prior to developing an interest in engineering. Until this point the role of Engineering Capital should not be overemphasised.

8.4 Structure and focus of the EEA

Two potential areas of influence were identified from the findings of this research, those of the structure and focus of the EEA itself, which appear to have the potential to positively influence the gendered ability perceptions of children or reinforce engineering stereotypes.

Overall, it is argued that children's perceptions of engineering may not be challenged by the traditional 'design-and-build' model of EEAs, and that discussions about engineering are required to inform and challenge inaccurate perceptions. It is concluded that at present children do not have a clear environment for engineering discourse within the education system (or outside of it for many children who do not have access to Engineering Capital) and therefore the system is failing to build accurate perceptions of engineering or engineering self-efficacy for children.

8.5 Cadence of delivery

On the evidence available it appears that participation in an EEA (either embedded within the curriculum or facilitated by an external provider) does not alter children's perceptions of engineering. Whilst it could be argued that children may have experienced a shift in interest due to participation in an EEA, this was seen to dissipate during the timeframe of this study, highlighting the importance of sustained, focused engineering education for this age group.

It is crucial that engineering education becomes more coherent in delivery, the gap of 12 – 24 months seen in this research resulted in the loss of for children, leaving perception formation and clarification to media and role models who are not necessarily well informed or accurate in their portrayal of engineering as a profession.

Currently many outreach activities are aimed at older children (11-14 still being the prominent focus), however the findings of this research indicate that interest in engineering needs to be nurtured at a young age (9 or below) and be sustained through continued exposure to a range of engineering activities, in order for accurate perceptions of engineering to be cultivated to enable children to make informed decisions about engineering careers.

8.6 Definitions of engineering

When the definitions of engineering presented by the children during this research were compared to dictionary definitions and the definition of engineering used in this research, they were found to be largely dissimilar. Narrow perceptions were commonplace in the data and vague perceptions were seen to cause confusion for children when determining what work an engineer is involved in. However, the definitions internalised by the children at this age were seen to resemble the definitions of engineering provided by the mass media as explored in section 6.3.3.1, and that perceptions regarding engineering as a male profession aligns with the traditional view of engineering, suggesting that the societal view of engineering influences children's perceptions of engineering from a young age.

8.7 Summary of main findings

It appears that for these one-off EEAs, participation failed to inform children about engineering as a vibrant and important profession, rather participation at best confirmed engineering aspirations for those children who are already interested, and at worst reinforced stereotypes of engineering and engineers.

The current provision of formal engineering education in schools in England was seen in Chapter 2 to have limited influence on children's progression into engineering careers. Using ad-hoc school-based EEAs as the focus for promoting engineering to the next generation may not be effective, as over the long-term, participation in a one-off activity did not appear to inform children's perceptions of engineering, nor was it seen to inspire children to consider engineering careers. The findings suggest that the use of in-school engineering activities will continue to have limited influence due to their isolated nature, the timeframe in which they are conducted, and the reliance on individual schools to take the lead in facilitating them. Whilst the focus of PEI's, in particular Engineering UK, has been on school based projects, children appear to use other sources of information to inform their views on engineering at a young age. The definitions of engineering that children are presented with via the media play an important role.

There are areas where EEA delivery may be able to capitalise, especially within the context of promoting gender equality in engineering, however activities need to be monitored and evaluated to ensure sustained, meaningful, and coherent exposure to engineering for all children. Whilst engineering education in schools currently occurs on an ad-hoc basis, separate from other forms of exposure to engineering, it is highly unlikely that that goal of increasing the number of engineering graduates as required over future years will be achieved.

8.8 Limitations

General limitations of the research, relating to the underlying assumptions on which this research is based and the relatively unexplored nature of the area under consideration, are discussed in Chapter 1 and Chapter 3. This section provides a reflection on the research as a whole to acknowledge the limitations of the findings of this research.

Due to the nature of the research a small number of participants were recruited meaning that generalisations cannot be made based on the context-specific findings of this study. The sample of participants involved in this research provided gender diversity but did not represent a diversity of ethnicity, and therefore the findings may have limited applicability to other groups.

It is important to note that the two EEAs observed may not be 'outstanding' examples of the activities offered to children in England, although they are examples of two currently available activities. The findings suggest that the EEA offered may affect outcomes and so it is probable that given different EEAs the findings may differ. However, the findings of this study provide a starting point for future study, with the opportunity to extend and expand a theory of participation through research exploring different contexts.

Although perceptions emerged as an important concept, prior-perceptions were not explored and findings are based on the children's reflections explored during the interviews. Whilst perceptions appeared to have been formed prior to the EEA, further research would benefit this area of analysis. It is impossible to state with certainty that the children did not use the experience of the EEA to reflect upon their prior experiences and perceptions, giving them new meaning.

As discussed in Chapter 3, the use of group interviews means that it is possible that children updated their thoughts due to the articulated thoughts of their peers. It is also possible that as children attended the same small school in each case, conversations occurred during the course of the research based on the interviews, thus forming perceptions that may not have formed without the occurrence of the research.

Finally, it should be noted that the cases were taken as the two schools with information about the villages in which they were located given for context, however no information about medium and large engineering companies within the locality of the schools was gathered, but may be relevant to the children's exposure to engineering.

Whilst these limitations do not alter the conclusions drawn from this project, reflecting on them has allowed the researcher to identify elements of the conducted research that could be altered to mitigate certain limitations in the future. These are discussed in section 9.3.

8.9 Implications and recommendations for engineering and engineering education

Although this research was conducted with a small sample, the findings indicate that for these EEAs little influence on children's perceptions of engineering or engineering career aspirations occurred. If these EEAs are taken to be typical activities offered to children at this age, this finding suggests that the current model of formal engineering education is unlikely to instil the interest in engineering careers that the industry believes is required. The implications, for both the field of engineering and engineering education, are substantial and two key areas for action have been highlighted by this research:

1) The need to develop a coherent and consistent definition of engineering which adequately explains the role of engineering to young children.
2) The need for continuous dialogue between the engineering industry, engineering education industry, and pedagogic specialists in order to ensure engineering is understood and communicated effectively through EEAs.

In addition to the need for a critical look at the provision of EEAs as outlined above, the findings of this research suggest that there are implications regarding the diversity of children progressing to engineering based on the current provision of engineering education.

Participation in the EEAs was not seen to affect the children's positive aspirations to engineering careers, with those who were already interested in engineering persisting with this interest and vice versa. When children considered engineering as a potential career, they drew on their beliefs about what engineering entailed to evaluate an engineering career against their interests and abilities. As participation in the EEA did not influence their perceptions of engineering, they continued to use their existing perceptions in this process. Therefore, it may be concluded that those children who were already likely to become engineers are likely to continue along that path, whereas different demographics who would ordinarily not consider engineering as a career are no more likely to progress to study or work in engineering than they were prior to the EEA. Therefore, the status quo is likely to persist and it is unlikely that future engineering cohorts will be substantially diversified through this approach to engineering education.

In order to address this issue, the following recommendations are made to policy makers, teachers, and EEA providers. In order for reform of engineering education, policy makers and PEIs must lead the way in monitoring engineering education provision to ensure funding and resources are provided to projects and activities with clear aims, and measurable outcomes that improve the accuracy of children's perceptions of engineering and build engineering self-efficacy.

8.9.1 Recommendations for policy makers

- Provide a framework for provision of engineering education that enables thorough, independent evaluation of activities against their objectives.
- Create resources based around the key confusions exhibited by children regarding engineering: What is the difference between an engineer and a… building/jeweller/architect? What is the difference between fixing and repairing?
- Encourage a singular, coherent definition of engineering to be used across engineering education at primary school.

8.9.2 Recommendations for primary school teachers and senior management

- Cadence of exposure to engineering is important; this should start at a young age and be repeated throughout the school journey.
- Discuss the definitions of engineering held by staff and children at the school, as well as those held within wider society.

- Talk about engineering within the curriculum, highlight the areas where engineering is already part of the taught curriculum but is not verbalised. Work with engineers to draw out the links that already exist.
- Maintain awareness that the link created between D&T and engineering is not always useful for children and can cause confusion when definitions of engineering are unclear.

8.9.3 Recommendations for engineering education providers

- Provide a clear definition of Engineering Education Activities for the education sector.
- Review engineering education provision to ensure engagement has suitable aims and objectives relating to perceptions of engineering and perceived engineering self-efficacy and that activities achieve these.
- Create activities suitable for primary school children that contain a clear and focused narrative around engineering, and encourage discussion.
- Actively acknowledge and challenge perceptions of engineering held by children, incorporate discussion elements into engineering education activities rather than focusing on the "design and make" model alone.
- Create resources based around the key confusions exhibited by children regarding engineering, for example the difference between an engineer and a builder/architect/jeweller, and highlight the differences between fixing and repairing and creating.

8.10 Further directions and opportunities for future research

Further research potential has been identified in a number of broad areas, and the following opportunities for research have been indicated in other sections of this thesis:

- The formation of perception of engineering.
    - How and when are children introduced to engineering?
    - What role does digital media play in the formation of perceptions of engineering?
    - What role do primary school teachers' perceptions of engineering play in the formation of children's perceptions of engineering?
- Media portrayal of engineering/engineers and the effect on engineering career aspirations amongst young people. Is this the same across different areas nationally and internationally?

- Longitudinal tracking of perceptions of engineering from primary school to HE and the comparison of engineering perceptions with experience of engineering during initial stages of engineering study at HE and/or engineering career.
- Longitudinal tracking of children to develop a picture of the exposure to engineering which they receive through their educational journey (and how experience differs according to career aspirations held at a young age).
- Accuracy of perceptions of engineering held by undergraduate engineers and graduate engineers. Does accuracy of perceptions influence progression (and retention) rates at HE and in industry?
- Why do some children persist in engineering career aspirations from a young age, and others do not?
    - At what age do children learn about engineering?
    - At what age do children become interested in engineering careers?
    - What 'type' of child becomes interested in engineering at a young age?
    - Detailed case study of individual children who aspire to engineering from a young age to explore the factors common across these cases and possible comparison with cases of children who do not aspire to engineering careers. Longitudinal from entering primary school to progression into careers (engineering or not).

8.11 Summation

This work offers a snapshot of the outcomes of participation in a particular EEA for a particular group of children. Whilst not a generalisable study, it does allow an insight into an under examined area of engineering education, providing recommendations for both future research and practice, contributing new knowledge to develop the EER community's understanding of engineering education in rural primary schools in England.

In conclusion, it is clear that EEAs can be an enjoyable activity in which children in Year 5 participate, however this participation does not necessarily inform children's perceptions of engineering. It is argued that as accurate perceptions of engineering are not built whilst in primary school, many children eliminate engineering as a career prior to entering secondary education. Participation in EEAs whilst in primary school appear to have limited long term outcomes due to the discontinuity of provision, the existing perceptions held by children, and the lack of discussion regarding engineering embedded within EEAs and the curriculum as a whole. The result of this is that only a minority of children progress to engineering, and that these children may have progressed to engineering without interventions promoting the field. The resulting situation is that we are starting from a negative position in high school rather than a level playing field of perceptions, making it harder to inspire and inform students who are traditionally the focus of engineering education activities at age 11-14 years. It is therefore concluded that the current model of engineering education is unlikely to result in the big shift that is required in order to encourage the required number of students to study engineering.

It is argued that in order to improve the current progression rates and enable children to make informed career decisions, a coherent definition of engineering suitable for children is required and sustained delivery of well-narrated EEAs involving discussion as well as practical elements needs to occur. It is vitally important that EEAs be evaluated against meaningful objectives in order to ensure that participation aids children's understanding of engineering and builds their engineering self-efficacy, and that this is then nurtured.

In conclusion, the conceptual framework presented in this research thesis provides a foundation on which to develop focused research into the improved provision of engineering education for future generations, whilst also providing a clearer understanding of the processes involved in engineering career aspiration building for children and the role that EEAs play in this process. The recommendations developed from the findings of this research provide policy makers and activity providers with empirically supported information regarding the provision and delivery of engineering education, allowing resources to be focused on key areas in the future.

CHAPTER 9

9 Reflections on the research

9.1 Introduction

Having presented the key findings in the previous chapter, this chapter aims to assess critically the validity of these findings through a reflection on the research process, the scope, and the validity of the work carried out.

This research was conducted in line with the research design and methodology presented in Chapter 3. The process of research affects both the research itself and the researcher, and this chapter draws on the personal journey of the researcher within the context of the research process and what this means for the research findings.

9.2 Doing what is right: the ethics of working with children in the English education system.

The ethical issues and practicalities of research involving children have been discussed in Chapter 3. However, Graham and Fitzgerald (2010) observe that while children's status in society is being increasingly recognised, the opportunity for their voices to be heard are diminishing due to ethical frameworks of protection. Although this work focuses on Australia, the UK mirrors this trend (Morrow, & Richards, 1996) as government literature encourages school pupils' voices to be heard (DfE, 2014b) whilst simultaneously encouraging rigorous safeguarding of school students (DfE, 2016b). It has already been argued that "good" is in danger of becoming "bad" due to the steps which are taken to protect children and the research community has been urged to look beyond "protection" to a "culture of caring" (Nutbrown, 2010, p.11). However, in addition to the procedural ethics, the practicalities of fieldwork with children presented the need for the researcher to adopt a framework to ensure an ethical approach to the research throughout the process. The use of this framework during the research is now reflected upon.

9.2.1 Maintaining ethical mindfulness

The nature of the research study meant that an approach in which ethical mindfulness was central was required to guide the interactions between the researcher and the children. To ensure ethical rigour within this research, a strategy for ensuring an ethical stance was maintained throughout the research study was adhered to, and the five features of ethical mindfulness for researchers as presented by Heggen and Guillam (2011) were borne in mind.

1) Acknowledging ethically important moments

This involved the researcher being aware to ethically important moments during the research process, whilst in the field and whilst conducting analysis and disseminating the data and findings. Ethically important moments have been defined as “the difficult, often subtle, and usually unpredictable situations that arise in the practice of doing research” (Guillemin & Gillam, 2004, pg. 262). This could be, for example, the change in demeanour of a child during an interview, the reaction to a question or situation arising from participation in the research.

Group interviews created situations where children may have felt as though their voice was not heard, although rare, the following are examples of this occurring in the field: children spoke over each other, belittled others thoughts, and answered questions first effectively cutting off others’ ideas. Every effort was made to be responsive and alert to these types of situation and ensure that the children were all comfortable, and had equal opportunities to express themselves during the interview. Situations were dealt with sensitively in the field by directing questions to individual children and not condoning behaviour that was seen to impact others detrimentally

2) Give credence to feelings of discomfort

This refers to discomfort felt by the researcher herself. During this research, if the researcher felt discomfort this was not dismissed but was considered as potentially significant. The researcher acknowledged and considered feelings of discomfort at all stages throughout the research, these occurred during the transcribing of interviews, analysing of the data, and whilst writing this thesis. In some cases, these feelings were considered ethically important and so appropriate actions were taken, for example during the writing of this thesis there were times when the researcher found herself wavering over the use of certain phrasing, these moments were acknowledged and, although they were not all considered to be ethically important, some occasions led to clarification being sought from the data.

Discomfort was also felt during the initial stages of interviewing regarding the clothing worn, where a tension between appearing professional to the adults at the school and approachable to the children occurred. Personal appearance is highlighted as an important consideration when conducting interviews (Arksey & Knight, 1999) and this is an area that was given much thought before entering the research field. Conversations with colleagues suggested that smart, professional attire should be worn, however this sat uneasily with the researcher who had worked with children prior to this research project and had worn casual clothing during some of her work in schools. Whilst it was crucial to dress respectfully and appropriately, the researcher decided that casual attire was appropriate. This enabled the researcher not only to remain comfortable throughout the data collection process, but also allowed the researcher to distance herself from the image of her as a teacher.

3) Articulate what is of ethical importance

Prior to conducting this research, exploration of ethical considerations was conducted and ethical guidelines for the area of research were consulted (as described in section 3.9.1) These were invaluable in enabling the researcher to articulate what was ethically at stake should ethically important questions come up during the fieldwork. This was important when children asked about how they would be identified in the research, how the audio recordings would be used, and gave me their thoughts on how I should conduct my research. By being able to articulate the ethical implications of the children's requests, and answer their questions regarding confidentiality and anonymity, children were able to feel valued and informed during the research process.

This strategy was also useful when talking to the adults involved in the two cases, as it allowed requests for access to information gained from the children to be rebuked in a way that did not damage the relationship between the researcher and the adult 'gatekeepers' whilst upholding the confidentiality assured to the children (Christensen & Prout, 2002).

4) Be reflexive

A reflexive approach enabled ethical rigor throughout this research study. At each stage of the research the position, motivation, and actions of the researcher were considered. This time for reflection, and its consideration prior to beginning the research, meant that important decisions were not rushed. This was especially important in the field, as there was often a tension between probing to get more information and accepting that a child was unwilling to talk or that the bell had just rung for break. In these situations, the motivation to obtain the data and progress with the research had to be reflected upon in relation to the rights of the children, and the ethical guidelines that bound the research. This reflection allowed the researcher to question her own process, ensuring that ethical practice was adhered to.

5) Be courageous

Guillemin and Heggen (2009, pg. 296) state that being courageous in this context means, “opening yourself to new ways of thinking about research ethics, and taking seriously the notion of everyday ethics”. During this research, many ethically important issues were highlighted, and the continual role of ethical considerations at all stages of the research has been illustrated to the researcher during the project; from planning appropriate participant information sheets, to accurate and ethical presentation of data and analysis in reports. The process of being an ethical research has not always been easy, and ethical decisions made in practice are rarely clear, however at each ethically important moment courage was required to acknowledge, assess, and progress.

This was especially important when planning to use photographs of the children as part of the research design, as this has been seen to be a controversial issue (Nutbrown, 2010). The requirement for the photographs was questioned during the ethical review process, however they formed a crucial part of the research design and consent for the taking and use of images was to be required before photographs were taken. Although overcoming this challenge meant being courageous, it was worthwhile as the researcher was secure in the knowledge that the taking and use of photographs was ethical, and was justified in that the photographs played a key role in eliciting responses during interviews and ultimately in understanding the experience that the children had of the EEA.

9.3 Critical lessons learnt

The purpose of a PhD is not singular, whilst a research study of this nature aims to conduct an original piece of research that contributes new knowledge to the field of study, it is also a learning journey for the researcher, and therefore it is important to reflect on the educational journey that the researcher has been on.

Although I would not change the fundamental approach taken in this research, reflecting on the limitations of the research and the educational journey that I underwent during this study reveals a number of important “lessons learnt” when completing this PhD. The main of which are listed below. Although the list is not exhaustive, it does present the key advice that I would give to a researcher embarking on a study of this type based on my experiences during this project.

1. Taking control in the field: Be clear about your research approach with all involved.

I had not originally planned to be so open with the children about me being an engineer, thinking that this may influence how they answered questions regarding engineering during interviews, however in both cases, teachers introduced me as an engineer almost immediately. Reflecting on this it is perhaps not surprising given that these teachers were keen to engage their students with STEM and, hearing them talk about role models in the subsequent conversations I had with them, they were keen for children to engage with engineers. When reflecting on what I could have done differently to have prevented this, I realised that although I knew how I wanted to proceed in the field I had not been explicitly clear about this when discussing the research with the teachers involved. I learnt quickly to take time to talk to those who I was working with in the field, explaining what I wished to do, why and how. My advice to others would be, not to be afraid of taking control of your research even though you are in someone else's classroom. That is not to say that you should impose yourself on the field in a disruptive way, in this research attempts were made to reduce disruption to school timetables and lessons when organising observations and interviews, however the researcher needs to ensure that the rigour of the research is not affected by these decisions. It is important to appreciate that participants will have their own agenda, and that this will come across in conversations during the research, so you need to be clear and strong in your own approach. Have a clear process in mind and do not feel as though you need to change your time plan or approach due to advice from those who participate in your research. Plan you research carefully, have justifications for your research decision, and believe in your own ability and knowledge.

This continues into the field of ethics, and the importance of, before entering the field, being very clear about your research ethics and how you will uphold these in the field. The decisions I was required to make during my research had large impacts on the direction my research took in terms of continued participation and number of interview participants across the period of my research. In terms of longitudinal studies, considering the logistics in terms of the ethical implications of asking for continued participation are more important than I had envisaged at the outset of the research. Although I felt that I had planned for the continued participation element of the research before entering the field, once I reached the point of the transition from Year 6 to Year 7 the process of retaining participants as they transitioned schools was fraught with ethical dilemmas, which I had not fully comprehended in advance. The decision not to push children to bring in completed forms or send reminders to parents about interviews resulted in a low number of participants for my final interview with the children from Nant

School. Although in this research the views of these three children are as valid as the views of any number of children, this would have had a much larger impact on a study conducted using a different paradigm and methodology.

2. Recruitment

When developing the research design of this study I thought that the contacts that I had built up during my freelance work, and the obvious need for the research, would enable me access to the field, and that recruiting participants would therefore be straightforward. As a result, I was not fully prepared for the amount of time and effort required to recruit participants, I realised that it is important to plan for repeated periods of time at the start of a project for recruitment, and to allow time to follow up on interest shown within the research plan.

As mentioned in the previous section, the longitudinal nature of this study led to ethical decisions regarding continued participation, the impact of which were not fully realised at the outset of the project. As this was not envisaged at the outset of the research, there was not a concerted effort to "over" recruit participants within each case. In future, to ensure the continued success of longitudinal participation, I would advocate allowing time to recruit larger numbers of participants at the start of the project, and allowing time for additional recruitment during the project where the research design will allow.

3. Data collection methods

At the beginning of the project I was convinced by the literature I had read and the people I had spoken to that 20 to 30 minutes would be ample time to interview the child participants, however once in the field I realised that this was not so. In hindsight, I would have liked to have planned additional time into my first sets of interviews to allow for these taking more time than expected. I have also learnt the importance of allowing time between interviews to write notes and prepare for the next interview.

Although I would not change the methods used, my observation and interview skills have been greatly improved by conducting this study. In addition, I am now more able to accept the limitations of my data collection, starting out I was anxious to conduct "perfect" observations and interviews, however this is an unrealistic expectation and it is more important to be able to accept that there will be imperfections and to acknowledge these appropriately in the research. Accept that you will ask leading questions when you start interviewing, your practice will need to be refined and this can only really occur within the field.

Finally, I have learnt not to underestimate the time and effort required to transcribe and analyse qualitative data. This takes time and practice, and is at first a rather nebulous process, I learnt to allow myself time to think and rearrange the data and do this continually throughout the research. It is important to be continually open-minded to new ways of thinking about your data.

9.4 Scope of the research

As was discussed in Chapter 3, the aim of this research was to develop a deeper understanding of the social process of learning about engineering through participation in an EEA. In order to gain the depth of understanding required at this exploratory stage of investigation, the findings were not intended to be generalised. Rather the findings from this research inform our understanding of specific cases, enabling others within the field to map similarities and difference between the cases described here and their own situation, and providing an opportunity to inform future research projects,

Whilst the analysis of two cases allowed certain case specific concepts to be identified, this does not result in generalisable findings. However, the concepts presented here would be expected to be replicated in research conducted with similar contexts, and this has been evidenced to some extent when the findings of this research were situated within the literature, displaying similarities and reinforcing the validity of the findings drawn from this study.

It is also important to be cognisant of the temporal characteristics of any research findings, evolving over time as new data is revealed and comparative analysis continues, the published theory is only ever a snap-shot of an “ever-developing entity” (Glaser & Strauss, 1967, p.33). This can be seen in the dissemination of findings from this research project, presented in Appendix I (Broadbent, 2017; Broadbent et al., 2018).

In addition, it is important to acknowledge that the findings and conclusions drawn in any research project of this nature are a representation of reality; the concepts are grounded in the data but are devised by the researcher (Richie et al., 2013). The coding and analysis process has been made transparent throughout this study, details of the process were given in Chapter 3, the data was presented supporting the emergent concepts in Chapter 4 and 5, and the initial coding and axial analysis process was documented in Chapter 6 and 7 resulting in the formation of a conceptual framework. In this way, the validity of the findings in terms of the children’s voices being heard rather than that of the researcher has been established. However, the voice of the researcher is now reflected upon, looking at the research as a whole.

9.4.1 The role of the research in the research

As discussed in Chapter 3, the aim has not been to remove the researcher from the research, or to assume that the research has no impact on the research itself. For this reason brief reflections on the role of the researcher have been given in each of the case chapters, with the aim of enabling the reader to assess the impact that the research may have had on the research and the implications that this has for the validity of the findings.

9.4.1.1 The voice of the researcher

As discussed in Chapter 3, the findings of any research are the researcher's interpretations of the data, however it is imperative that the voice of the children be recorded during the data collection process. In order to achieve this the approach of the researcher was carefully considered with focus on adaption of language (both written and spoken) to enable comprehension (Arksey & Knight, 1999), as well as asking for clarification from the children (Docherty & Sandlowski, 1999). Awareness of maintaining the voice of the children continued throughout the research, with the conclusions drawn at each stage being checked against the raw data to ensure that the findings remained true to the data collected.

9.4.1.2 Impact on the data

Whilst every effort was taken to ensure that the data collected represented the children's view, there was also the issue of the researcher altering the field of research. This was inevitable due to the nature of the research and the researcher was sensitive and open to evidence that the children's experience had been affected by her presence, this was especially important as the research comprised a longtudinal element.

A number of occassions were recorded where the children explicitly or implicity indicated that the researcher had affected their understanding or awareness of engineering, and this was taken into consideration during the analysis of the data in order to preserve the validity of the data in answering the initial research question.

In both cases the children were aware that the researcher was an engineer, whilst this was seen to impact on the children's responses at times (visible only once where a child prefixed a statement about engineering with "*I don't want to offend you…*"), this awareness did not appear to cause the children to withhold information from the researcher. Reflecting on the research it appears that the knowledge that the researcher was an engineer meant that the children were able to ask questions about engineering and this revealed important information about the children's exposure to engineering and experience of engineering education.

Finally, it should be remembered that this research study utilised a constructivist paradigm, relating to the personal reality and beliefs of the participants but ultimately resulting in the researcher's interpretation of the participants' reality. Whilst every effort has been made to present a transparent account of the research process, the findings are ultimately bound by both the cases and the researcher.

9.5 Summary

This chapter has discussed the ways in which ethical rigour was maintained, alongside the methodological rigour presented in Chapter 3 that shows how this study was conducted, together this conveys the foundations of validity of the knowledge produced through this research and concludes this research.

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11 APPENDICES

Appendix A	Research timeline
Appendix B	Research case recruitment
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Appendix F	Interview guides
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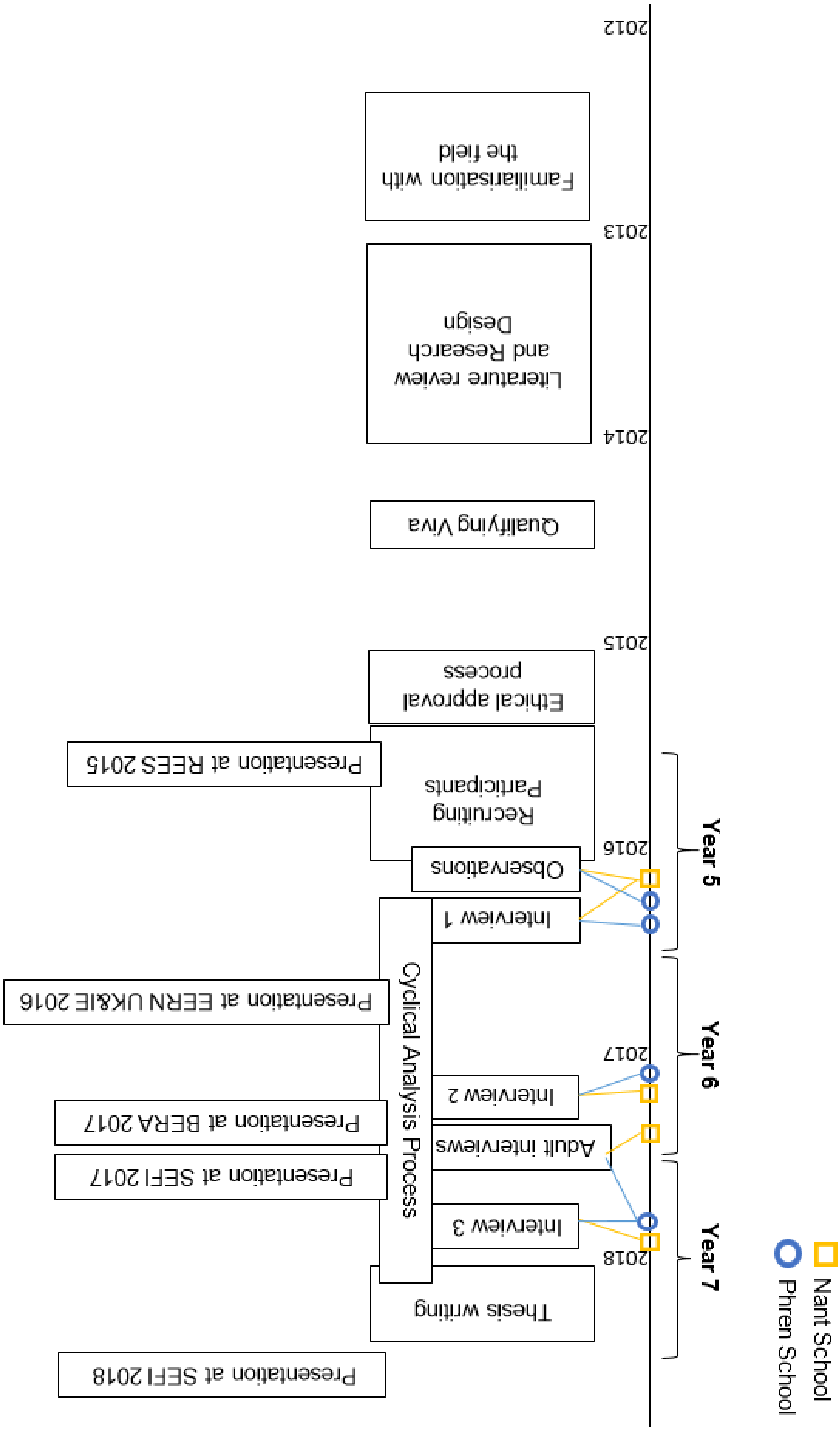
11.1 Appendix A Research timeline



11.2 Appendix B Research case recruitment

Table 11.1: Requests for participating cases in research

	Organisation Type	Contacted	Participation?	Reason
1	Professional Institution	2015	Yes but didn't happen	Did not hear back from school
2	Local Council STEM Lead	2015	No replies - Email sent to all Primary schools in area	No schools made contact
3	Museum	08/06/2015	Don't work with young enough children	Age of children
4	STEM Outreach Activity	08/06/2015	No bookings but offered dates to schools	No bookings
5	Secondary School	08/06/2015	No longer working at the school, passed my email on.	Not at school and no reply from school.
6	National Engineering Activity	08/06/2015	No reply	
7	School	08/06/2015	No reply	
8	School	08/06/2015	No reply	
9	Science activities	08/06/2015	No reply	
10	STEM Outreach Provider	08/06/2015	No reply	
11	Professional Institution	08/06/2015	Not got any bookings in 2015.	No bookings
12	STEM Outreach activity	08/06/2015	Not working in schools currently.	No working in schools
13	STEM Outreach Provider	08/06/2015	Not working with young enough children	Age of children
14	STEM Outreach Activity	08/06/2015	Yes - if possible but no dates that match (North Wales).	No schools wanted to participate
15	National Engineering Activity	08/06/2015	Yes - if possible but not until 2015/2016.	Schools not wanting to participate
16	Primary School	04/11/2015	No reply	
17	Primary School	04/11/2015	Yes – meeting in person to arrange	
18	Industry Education Centre	13/11/2015	No reply	
19	Primary School	17/11/2015	Meeting at school 3/2/16 and plan to work together in 2016.	No further response from school.
20	Prep School	17/11/2015	No	Not at school, does not want extra work.
21	Primary School	17/11/2015	No reply	
22	Primary School	17/11/2015	No reply	
23	School	17/11/2015	No reply	
24	Activity provider	16/12/2015	Sent through date of activity in 2016.	Unable to attend the activity.
25	Educational site	08/01/2016	No reply	
26	Science Museum	08/01/2016	Yes - arranged dates and contacted schools attending.	Schools either did not want to or could not provide full consent.
27	Middle School	05/02/2016	Yes – dates arranged by email	
28	Primary School	05/02/2016	No reply	
29	Primary School	05/02/2016	No reply	

11.3 Appendix C Full list of child participants

Table 11.2: Participating children information Nant School.

Case	Pseudonym	Gender	Ethnicity	Age at Y5 interview	Age at Y6 interview	Age at Y7 interview	Activity	Consent		Photography	
								Parents	Child	Child	Work
Nant School	Matthew	Male	Pakistani	9	10	N/A	Moving Toys - D&T project	Y	Y	All	All
	Bryn	Male	White British	10	11	N/A		Y	Y	All	All
	Jane	Female	White British	10	11	N/A		Y	Y	All	All
	Ella	Female	White British	10	11	N/A		Y	Y	All	All
	Becka	Female	White British	9	10	11		Y (verbal from mother)	Y	All	All
	Jack	Male	White British	9	10	N/A		Y	Y – after questions	All	All
	Jackson	Male	?	10	N/A	N/A		Y	Y – after questions	Only classroom	Only classroom
	Scott	Male	White British	10	11	N/A		Y	Y	All	All
	Paul	Male	White British	9	10	N/A		Y	Y	All	All
	Stewart	Male	Indian	?	10	N/A		Y	Y	All	All
	Billy	Male	White British	10	11	N/A		Y	Y	Only classroom	Only classroom
	Jay	Male	White British	9	10	11		Y	Y	All	All
	Will	Male	White British	9	N/A	N/A		Y	Y	All	All
	Nicky	Female	White British	10	11	N/A		Y (signed on class form)	Y	All (signed on class form)	All (signed on class form)
	Judy	Female	White British	9	10	N/A		Y	Y	All	All
	Chris	Male	White British	10	11	N/A		Y	Y	All	All
	Matty	Male	White British	9	10	11		Y	Y	All	All
	Kat	Female	White British	10	11	N/A		Y	Y - after discussing tape recording	All	All
	Jenny	Female	White British	9	10	N/A		Y	Y	All	All

Table 11.3: Participating children information Phren School.

Case	Pseudonym	Gender	Ethnicity	Age at Y7 interview	Age at Y6 interview	Age at Y7 interview	Activity	Consent		Photography	
								Parents	Child	Child	Work
Phren School	Frankie	Male	British	9	N/A	11	Balloon Cars - external provider	Y	Y - after questions	All	All
	Paul	Male	British	10	10	11		Y	Y - after questions	All	All
	George	Male	British	10	11	12		Y	Y - after questions	All	All
	Abbie	Female	British	10	10	11		Y	Y - after questions	All	All
	Ruth	Female	British	9	10	11		Y	Y	All	All
	Anne	Female	British	10	11	12		Y	Y	All	All
	Anna	Female	British	10	11	11		Y	Y	All	All
	Ellen	Female	British	10	10	11		Y	Y	All	All
	Harry	Male	British	9	10	11		Y	Y	All	All
	Sue	Female	British	10	11	12		Y	Y	Unknown	Unknown
	Den	Male	British	10	?	11		Y	Y	All	All
	Miller	Male	British	9	10	11		Y	Y	All	All
	Damon	Male	British	9	10	N/A		Y	Y	All	All
	Pete	Male	British	10	10	11		Y	Y	All	All
	Nick	Male	British	10	11	11		Y	Y	All	All
	Stephen	Male	British	9	10	11		Y	Y - after questions	Work	Work
	Diane	Female	British	10	N/A	N/A		Y – via photo form	Y	All	All
	Jackson	Male	British	9	10	11		Y	Y	All	All
	Gregory	Male	British	10	?	N/A		Y	Y	All	All
	Bryony	Female	British	10	10	11		Y	Y	All	All
	Matt	Male	British	10	10	11		Y	Y	All	All
	Ivy	Female	British	10	11	12		Y	Y	All	All
	Kat	Female	British	10	11	11		Y	Y	All	All
	Zara	Female	British	10	11	N/A		Y	Y	All	All
	Tim	Male	British	9	?	11		Y	Y	All	All
	Jessica	Female	British	9	?	11		Y	Y	All	All
	Rebecca	Female	British	9	10	N/A		Y	Y	All	All
	Gabe	Male	British	10	10	11		Y	Y	All	All

11.4 Appendix D Interview note sheet example

DG led this interview, had a lot to say, very confident.

Group 4

[redacted] [redacted]

LD, DG LP, Me

to [redacted] - not best clothes - dirty job.

JP + DG - dad - normal clothes. Not something.

LD - hand orang vest

Differing views of 'engineer' [redacted]

Family role models

YouTube Not school

Fixing

Working out what is wrong.

DG, LP } Both have eng relatives

Experience - Feedback

Building.

Lego JP - not really.

Coding [redacted] Not sure it. Not building things.

3D

Topics of interest affect view of subject.

Ability

JP - ability but not career aspiration.

Computer Game - FORZA.

Course - Education

"Challenging" Like.

Group 5

[redacted] - Involving Imagining

TRUST. confidence of others.

Money, saving, work.

LEGO - help engineering. Police set. LEGO sets relate to job ideas!

[redacted] { know how to do it - save money.

[redacted]

ER JB, Me EJ

Fixing metal

Cars

Designing - Engine.

Decisions - making.

Confidence

Ability

EJ - trip to Jag.

Emily - dad - birthday present.

Helpful person - fixing.

Understanding

DT reference - JB

DIY

Robots - same at Jag.

Family Capital

Emily

out of school activities.

Recall of if it worked or not but not of activity?

Group 6

[redacted]

TA EC, RG, Me

Building Fixing.

Engine Transport

"Hand" "Changing".

Limited responses - don't know any engineers, don't know a lot about engineering, ~~not really~~ interesting as talked about lack of continuation of activities therefore lost interest.

11.5 Appendix E Example transcript sheet with initial coding and coding guide.

H: well like it's to do, you can like in engineering you can make stuff and fix things and change things around a little bit erm say if you wanted to be a person that fixed cars you would be an engineer or something like that.	Perception - cars, fixing
I: anybody else have any ideas what engineers do?	Awareness
A and E: No idea	No awareness
J: same as what H says.	
E: I know they make things and build things and change things and stuff.	Perception - make
I: what do you think an engineer does when they go out to work?	
H: erm...	
A: would they be talking to er like people er who actually do the work as well and what they're gonna do.	Perception - leader/boss
I: and writing down things so like what they have to do for a day and if they like what they might change on a car or change on a plane or fix on a plane or add to a plane or add to a car.	Perception - planning Perception - transport
A: Maybe draw pictures as well of what they are gonna do so they know what order to do it in	Perception - planning
J: Blueprints	Perception - drawing & writing
I: so do you think they would have blueprints and they might create them? How about you E?	
E: Probably the same as what everyone else said.	
I: Is it something that you would consider, being an engineer?	
I: No	
H: if like maybe when I get a bit older like after if I am an RAF pilot I might be an engineer for the RAF or something so I can fix the planes and stuff.	Aspiration - secondary
I: Why would you want to do that?	
H: errrr it's just like quite fun to look into the insides and stuff of like things that you would never really normally see cos they are always like covered with the like metals and stuff that they use	Perception - fun
J: and you get good pay	Perception - well paid
I: You said it wasn't something that you would want to do even though you get good pay?	

Focused coding guide

The coding guide below provides the framework created through initial coding, that guided the classification of transcript data.

Code		Description	Examples
Engineering career aspiration	Ability	Child states or alludes to an aspiration or interest in a career in engineering or actively against a career in engineering.	*"cos if something don't work they've got to do it again and I'm not very good at that"* *"I don't really know much about cars and stuff"*
	Interest		*"I like cars as well so maybe engineering might be like something that I want to do."*
Awareness of engineering		Child makes a direct reference to engineering or engineers as a profession or field of study.	*"I don't know what certain jobs you could get for engineering so I'm not quite sure."* *"Depends what engineer you are […] and there's different types of I don't know like say if you fix things and you do different things…"*
		Child indicates uncertainty in their reference to engineering or engineers as a profession or field of study.	*"Building cars, isn't that engineering?"* *"I've got a toy car, a remote control one. I don't know if that is engineering or not"*
Perceptions of engineering	Processes	Child makes a direct or indirect reference to specific elements that they consider constitute engineering or the work of an engineer.	*"They don't invent stuff, no, they just build it"* *"Erm, fixing stuff, repairing and yeah everything like that."*
	Products		*"I think trains and planes are engineering…"* *"They would build the engines for vehicles"*
	Skills and job attributes		*"…it's just loads of work…"* *"I think you would definitely need to be resilient…"*
	Role		*"they help the world…"* *"…nothing in this room would have been made except for us without engineering really"*
	Personal attributes		*"I've always thought that if you were an engineer then you work in a factory"*

<table>
<tr><td rowspan="4">Knowledge Acquisition</td><td>Real life interactions</td><td rowspan="4">Child refers to influences on their perception of engineering, for example an activity, interaction, resource, or learning experience.

Child highlights areas where engineering is not discussed or mentioned, where there is an absence of information.</td><td>“Once I went to this like engineering place, I forgot what it was called and then like they were showing us like how they make cars like the diff, using different materials like really strong materials and like you know when they like go on boards that have like wheels on them, they go under the car to see…”</td></tr>
<tr><td>Media</td><td>“I like doing stuff with cars, like doing engine stuff, like I’ve never experienced it but it looks fun, the stuff I watch on telly like Top Gear”</td></tr>
<tr><td>Parental support</td><td>“The robot took a lot of time and I know that when you’re doing engineering you won’t be on your own at all cos I had my mum to help”</td></tr>
<tr><td>School</td><td>“Is assembly once Mr. S said “here I’ve got an Apple watch, imagine what your watches can do in, in like when you’re my age””
“At school we don’t really talk about it”</td></tr>
<tr><td rowspan="2">Engineering Role Models</td><td>Home</td><td rowspan="2">Child states knowing or having engaged with an engineer, either in real life or virtually through media.</td><td>“My dad used to be an engineer but he didn’t, he kind of quit like two weeks later…”
“I’m not really sure, my mum and dad do it, is it like making stuff? Cos my mum and dad do make planes”</td></tr>
<tr><td>Media</td><td>“You Tube and television programmes, there’s like big engineering programmes…”
“I just learnt it off You Tube and games”</td></tr>
<tr><td rowspan="3">Experience of engineering within the EEA</td><td>Evaluation of engineering</td><td>Child expresses uncertainty or certainty regarding the engineering content of the EEA.</td><td>“Engineering…because we were making stuff”
“…but then again it was just with like paper and stuff…”</td></tr>
<tr><td>Understanding of engineering gained</td><td>Child expresses an increase in awareness or understanding of engineering due to participation.</td><td>“It looks easier than it is”
“I didn’t realise that they had to go through many stages to get it built, like planning and designing”</td></tr>
<tr><td>Increased interest</td><td>Child expresses an increased interest in engineering due to participation.</td><td>“In Year 5 it made me more interested…”</td></tr>
<tr><td colspan="2">Gender</td><td>Child expresses a gendered view of engineering.</td><td>“It’s just for boys. Well they could, well they probably some girls probably could but I don’t want to”
“…it’s usually the men who do all the like work and the engineering and stuff like that”</td></tr>
</table>

11.6 Appendix F Semi-structured interview guide

Opening

- My name
- Who I am
- Why I am talking to you
- Can I record you?

To help me I would like you to introduce yourself and say a few words about yourself. Could you say your name, your age, your hobbies and what your ideal job would be! I'll let you start and I will go last, okay?

Theme – Play/Interests

- What do you like to do in your free time?
- What toys do you play with?

Theme - Awareness/perception of engineering

- What do you know about engineering?
- What do you think engineers do? or Could you write/draw what you think an engineer does?
- Is this something that you would like to do? Why?
- What school subjects do you think are important for engineers? Why are these important?
- What do you think of these subjects?

Theme – Engineering Role Models

- Do you know any engineers? Where did you meet them (family, school etc)?

Theme - Hands-on engineering experience

- Do you remember an activity you took part in…? *Photographs may be used*
- Why did you take part?
- What did you do?
- How did taking part make you feel? How did you feel when you were taking part?
- What do you think the aim of the activity was?
- Have you done anything like this before? Where? (school, community, with family…)

Relates to observed activity

Prompts/Probes

Could you tell me more about…? What were you thinking at the time?
Would you explain that to me? What do you mean by? Tell me about…
Take me through your experience… Could you give me an example?

Ending

I'm just going to run through the things that we have spoken about, if you think I've missed anything or got anything wrong then just let me know.
Is there anything else that anyone would like to say that I haven't asked you about?

Thank you for talking to me today.

11.7 Appendix G Samples of participant information sheets and consent forms

CHILD PARTICIPANT INFORMATION SHEET

Hello, my name is Becky. I am a student at Aston University and I am asking you to be part of my research project.

We do research studies to learn more about how the world works and why people act the way they do. In this study, I want to learn about what happens when you take part in an engineering activity.

You have been asked to take part because you are aged between 8 and 10 and you are about the take part in an engineering activity with your school. Before I am allowed to do my research it has to be checked by a group of people. They make sure that the research is fair. Your research project has been checked by the Aston University Ethics Committee.

Remember that <u>you don't have to take part if you don't want to</u>.

This sheet is yours to keep, it answers some questions about the research but if you have any other questions just ask me. The box below is for you to write or draw your questions if you would like to. On the following pages are some answers to questions you may have.

<u>My questions</u>

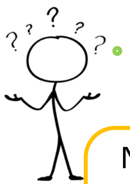
What will I need to do?

You need to take part in the engineering activity as you usually would. I will be there and will be watching the activity. You do not have to do anything special. I am just interested in what the activity is, what you are asked to do and how you do it.

I may ask you to take some photographs during the activity. After the activity I may ask you to talk to me about these photographs. You will be in a group with some of the other children who took part in the activity. I will start by asking you some questions. You don't have to answer my questions and you can ask your own questions.

I will ask you if I am okay to record this chat. I may also ask you to do some writing or draw some pictures as part of the chat.

I may want to come and see you and talk to you again in the future. This would happen about four times over the next three years. Each time you will be in a group with other people and I will always check that you are happy to take part at the start.



Do I have to be in this project?

No, you do not have to take part in this study. It is up to you. You can say no now or you can stop taking part at any time. No one will be upset with you if you decide not to be in this study.

If you do not take part in the study you can still take part in the activity just like everyone else. I will still be there but I won't be watching you and I won't ask you any questions after the activity.

You will not miss out on any activity time by not being involved in the research.

Will being in this study hurt or help me in any way?

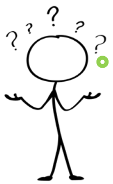
Being part of this research will not cause you any harm and there are no benefits to you for participating in this study.

What will you do with information about me?

Before and after the study we will keep all information we collect about you locked up and password protected.

We will be very careful to keep your answers to the questions we ask private.

You will be in a group of people when we are talking so we will ask you and them not to repeat what is said during the chat but it is possible that someone may accidentally repeat what is said.



What if I want to stop taking part?

That is fine. No one will be upset with you if you decide to stop taking part in the research. If at any time during the research study you don't want to take part anymore just tell your parents.

What will happen when the research finishes?

When we have finished our research project I will use all of the information that you have given me to write about engineering activities for children. I will also present the information to people around the world. I will do this to try and help more children take part in engineering activities that are enjoyable and useful.

PARTICIPANT CONSENT FORM (child)

Project title: Research into the experiences of children taking part in engineering activities and the long term impact of these experiences on career awareness and aspirations.

Researcher: Rebecca Broadbent

Read the questions below and then circle the answers that you agree with.

1)	Has someone explained this project to you?	Yes	No
2)	Do you understand what this project is about?	Yes	No
3)	Have you asked all the questions you want to?	Yes	No
4)	Have you had all your questions answered in a way you understand?	Yes	No
5)	Do you understand that it is OK to stop taking part at any time?	Yes	No
6)	Do you understand that you will be tape-recorded during interviews?	Yes	No
7)	Do you understand that you will be photographed during activities?	Yes	No
8)	Do you want to take part in this project?	Yes	No

9) How do you feel about taking part in this project? ☺ 😐 ☹

If any of your answers are 'no' or you <u>don't</u> want to take part then don't sign your name. If you <u>do</u> want to take part you can write your name below.

Your name……………………………………………………………………………………

Date ………………………………………

The person who explained this project to you needs to sign too:

Name…………………………………………………………………………………………

Signed ………………………………………………………………**Date** ……………………

SCHOOL INFORMATION SHEET FOR STUDENT AND STAFF PARTICIPATION IN RESEARCH

Study Title: Research into the experiences of children taking part in engineering activities and the long term impact on careers awareness and aspirations.
Researcher: Rebecca Broadbent
Supervisors: Prof. Robin Clark and Dr. Jane Andrews

I am a postgraduate student at Aston University working in the School of Engineering and Applied Science. I am carrying out a research study which I am asking your school to take part in. This form has important information about the reason for doing this study, what we will ask your school and children to do, and the way we would like to use the information we collect if you choose to allow your school to be in the study. Please take time to read the following information.

Why are you doing this study?

The children at your school are being asked to participate in a research study about engineering education in the UK. The purpose of the study is to explore children's experiences of engineering education activities in the UK. The outcome of this research study will further our understanding of the impact engineering education activities have and will help us to develop engineering activities in the future.

Why is our school being invited to take part?

Your school is being asked to take part in this study as you are a rural Primary school.

What will the school be asked to do if our children are in this study?

The school will be asked to allow the researcher access to the school to observe and interview the children. The children will be asked to take part in the engineering activity, their participation will be observed by the researcher and notes about how the activity engages the children and their participation in the activity will be taken.

The children may also be asked to participate in group interviews immediately following the activity and may also be invited to take part in further group interviews over the next year. The groups will include other children who are participating in the research study. The interviews will focus on the views of engineering held by the children and their career aspirations more generally as well as the engineering activity that they originally took part in. No personal or sensitive questions will be asked during the interviews at any stage of the research, the aim is not to evaluate the activity but to explore how the children have experienced it.

The interviews may involve writing and drawing activities in addition to verbal questions, depending on the group of children involved in the interview.

In addition to the initial observation, participation should take no more than an hour per interview and these will be conducted with groups of children rather than one-to-one. Interviews will take place no more than three times over the next two years.

Photography

I would like to take photographs of the children's participation in the engineering activity and I may ask the children to take photographs as well. The photographs will be used in the group interviews where the children will be asked to talk about the photographs that they and the researcher took of the activity.

Photographs will be kept for the duration of the research project and will only be published as part of the research with the consent of all parties; children, parents and school (see media release consent form).

Audio recordings

I would like to audio tape the interviews to make sure that I accurately record the children's views. The audio recordings will be transcribed and these transcriptions will be analysed as part of the research study. Both transcripts and recordings will be kept for the duration of the research project so that I may revisit the information during the study.

I will only audio record the children if they give me permission to do so. If they do not agree to audio recording during the interviews then their words will be recorded in writing by the researcher conducting the interview, in this case the views expressed will be recorded as best as possible.

What are the possible risks or discomforts to our school and the children?

To the best of our knowledge participation in this study does not involve any physical or emotional risk to your school or the children involved, beyond that of everyday life.

What are the possible benefits for the school or children?

Taking part in this research study may not benefit your school or the children personally, but we may learn new things that will help others in the future.

Does our school or all of our children have to take part?

No. Participation in this study is voluntary, if you or any of the children in your school don't want to take part then you don't have to. If a child decides to take part now but changes their mind during the research that is fine. They may stop taking part in this study at any time, neither you nor the child will be penalised in any way for deciding not to participate in the study.

If a child decides to withdraw from this research during the project then the researcher will need to be informed. Depending on the point at which the child withdraws information collected during previous interviews and observations may already have been used in the research and it may not be possible to remove this data from the research study.

How will you protect the information you collect about our school and the children, and how will that information be shared?

All of the data collected as part of the research will be stored either as a hardcopy in a locked cupboard or digitally in a password protected folder, a back-up will also be kept on a password protected external hard drive which will be kept in a locked cupboard. Only the researcher (myself) will have a key to the cupboard and know the passwords.

The photographs and audio recordings will be digital and will be stored in a password protected folder, a back-up will also be kept on a password protected external hard drive which will be kept in a locked cupboard. The audio recordings will only be used to enable the researcher (myself) to transcribe the interviews. Once transcribed the information will be anonymised and no personal information will be stored alongside the photographs, recordings or the transcriptions.

Results of this study will be used in publications and presentations however your school name or the name of any child will never be published. The audio recordings of the interviews will never be published however the anonymised transcriptions may be published in whole or part. It may be necessary to publish photographs in which your staff or a child's face is visible, this will only occur if the photograph is vital to understanding the research when published and will only occur with the consent of the staff member and child (as well as the child's parent/guardian) (see media release consent form).

<u>Has this study been reviewed?</u>

Yes, this research study has been reviewed by the University Ethics Committee.

<u>Who do I contact to withdraw my child from the study?</u>

If your school or an individual child wants to stop participating in the study, contact Rebecca Broadbent on [redacted] or [redacted]. If you choose to stop before the research project is finished, information already collected may be used in the research.

<u>Who can I contact if I have questions or concerns about this research study?</u>

If you or your child have any questions, you may contact the researchers at:

Rebecca Broadbent

PhD Researcher

Email: [redacted]

Phone: [redacted]

Prof. Robin Clark

Project Supervisor

Email: [redacted]

Phone: [redacted]

<u>Who do I contact if I wish to make a complaint about the way in which the research is conducted?</u>

If you have any concerns about your child's participant in this research, please contact the Secretary of the University Ethics Committee at:

John Walter

Phone: [redacted]

Email: [redacted]

PARENT INFORMATION SHEET FOR CHILD'S PARTICIPATION IN RESEARCH

Study Title: Research into the experiences of children taking part in engineering activities and the long term impact on careers awareness and aspirations.
Researcher: Rebecca Broadbent
Supervisors: Prof. Robin Clark and Dr. Jane Andrews

I am a postgraduate student at Aston University working in the School of Engineering and Applied Science. I am carrying out a research study which I am asking your child to take part in. This form has important information about the reason for doing this study, what we will ask your child to do, and the way we would like to use information about your child if you choose to allow your child to be in the study. Please take time to read the following information.

Why are you doing this study?

Your child is being asked to participate in a research study about engineering education in the UK. The purpose of the study is to explore children's experiences of engineering education activities in the UK. The outcome of this research study will further our understanding of the impact engineering education activities have and will help us to develop engineering activities in the future.

Why is my child being invited to take part?

Your child is being asked to take part in this study as they are aged between 8 and 10 years old and are about to participate in an engineering activity.

What will my child be asked to do if my child is in this study?

Your child will be asked to take part in the engineering activity as normal, their participation will be observed by the researcher and notes about how the activity engages your child and their participation in the activity will be taken.

Your child may also be asked to participate in group interviews immediately following the activity. Your child may also be invited to take part in further group interviews over the next three years. The groups will include other children who are participating in the research study. The interviews will focus on your child's views of engineering and career aspirations more generally as well as the engineering activity that they originally took part in. No personal or sensitive questions will be asked during the interviews at any stage of the research.

In addition to the initial observation, participation should take no more than an hour per interview. Interviews will take place no more than four times over the three years.

Photography

I would like to take photographs of your child's participation in the engineering activity and I may ask your child (and others participating in the activity) to take photographs as well. The photographs will be used in the group interviews where the children will be asked to talk about the photographs that they and the researcher took of the activity.

Photographs will be kept for the duration of the research project and will only be published as part of the research if you and your child consent (see media release consent form).

Audio recordings

I would like to audio tape your child during the interviews to make sure that I accurately record their views. The audio recordings will be transcribed and these transcriptions will be analysed as part of the research study. Both transcripts and recordings will be kept for the duration of the research project so that I may revisit the information during the study.

I will only audio record your child if they give us permission to do so. If they do not agree to audio recording during the interviews then their words will be recorded in writing by the research conducting the interview, in this case the views expressed will be recorded as best as possible.

<u>What are the possible risks or discomforts to my child?</u>

To the best of our knowledge, your child's participation in this study does not involve any physical or emotional risk to your child beyond that of everyday life.

<u>What are the possible benefits for my child or others?</u>

Taking part in this research study may not benefit your child personally, but we may learn new things that will help others in the future.

<u>Does my child have to take part?</u>

No. Participation in this study is voluntary, if you or your child don't want to take part then you don't have to. If your child decides to take part now but changes their mind during the research that is fine. They may stop taking part in this study at any time, neither you nor your child will be penalised in any way for deciding not to participate in the study.

If your child decides to withdraw from this research during the project then the researcher will ask if the information already collected from your child can be used. Depending on the point at which your child withdraws information collected during previous interviews and observations may already have been used in the research and it may not be possible to remove this data from the research study.

<u>How will you protect the information you collect about my child, and how will that information be shared?</u>

All of the data collected as part of the research will be stored either as a hardcopy in a locked cupboard or digitally in a password protected folder, a back-up will also be kept on a password protected external hard drive which will be kept in a locked cupboard. Only the researcher (myself) will have a key to the draw and know the passwords.

The photographs and audio recordings will be digital and will be stored in a password protected folder, a back-up will also be kept on a password protected external hard drive which will be kept in a locked cupboard. The audio recordings will only be used to enable the researcher (myself) to transcribe the interviews. Once transcribed the information will be anonymized and no personal information will be stored alongside the photographs, recordings or the transcriptions.

Results of this study will be used in publications and presentations however your child's name will never be published. The audio recordings of the interviews will never be published however the anonymised transcriptions may be published in whole or part. It may be necessary to publish photographs in which your child's face is visible, this will only occur if the photograph is vital to understanding the research when published and will only occur if your and your child's consent is given (see media release consent form).

Has this study been reviewed?
Yes, this research study has been reviewed by the University Ethics Committee.

Who do I contact to withdraw my child from the study?

If you or your child wants to stop participating in the study, contact Rebecca Broadbent on [redacted] or [redacted]. If you choose to stop before the research project is finished, information already collected may be used in the research.

Who can I contact if I have questions or concerns about this research study?

If you or your child have any questions, you may contact the researchers at:

Rebecca Broadbent
PhD Researcher
Email: [redacted]
Phone: [redacted]

Prof. Robin Clark
Project Supervisor
Email: [redacted]
Phone: [redacted]

Who do I contact if I wish to make a complaint about the way in which the research is conducted?

If you have any concerns about your child's participant in this research, please contact the Secretary of the University Ethics Committee at:

John Walter
Phone: [redacted]
Email: [redacted]

11.8 Appendix H Work booklets used in the EEA

These booklets are provided for reference only and should not be reproduced.

(Illustrations removed for copyright restrictions)

11.8.1 Nant School

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

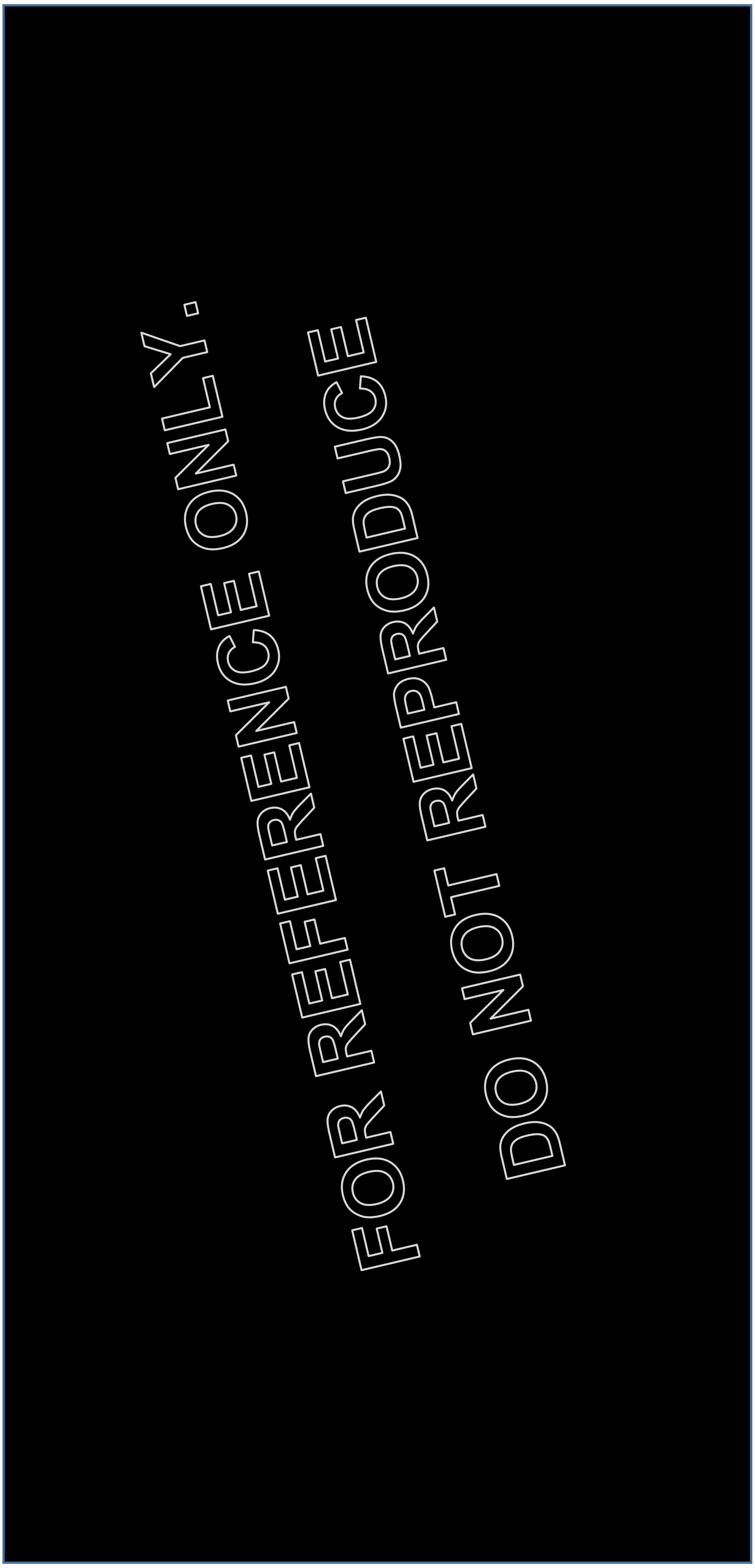
[redacted]

[redacted]

[redacted]

[redacted]

11.8.2 Phren School



11.9 Appendix I Published work and presentations

11.9.1 Conference presentations and papers

Cottrell (now Broadbent), R., Andrews, J., and Clark, R. (2015). The future of engineering - Do primary school engineering education interventions leave a lasting impression*?* In Proceedings of the *6th Research in Engineering Education Symposium: Translating Research into Practice, REES 2015.* Dublin Institute of Technology.

Cottrell (now Broadbent), R. (2016). Talking to children: experiences of engineering education. Presented at the *UK and Ireland Engineering Education Research Network Annual Symposium 2016*, 3^{rd} – 4^{th} November 2016, York University, York.

Broadbent, R. (2017) Listening to Children – Experiences of engineering education in UK Primary Schools. Presented at the *British Educational Research Association (BERA) Annual Conference 2017*, 5^{th} – 7^{th} September 2017, University of Sussex, Brighton, UK.

Broadbent, R. (2017). What can a child's experiences tell us about engineering education activities? In Proceedings of the *45th European Society for Engineering Education (SEFI) Annual Conference 2017 - Education Excellence for Sustainability*. Azores, Portugal. 18^{th} – 21^{st} September 2017. p. 1292-1299.

Broadbent, R., Andrews, J., and Phull, S. (2018). The future of engineering: Children's perceptions of engineering following participation in an engineering education activity. Accepted for inclusion in the *46^{th} European Society for Engineering Education (SEFI) Annual Conference 2018*. Copenhagen, Denmark. 18^{th} – 22^{nd} September 2018.

11.9.2 Invited presentations

Our role in inspiring the next generation of engineering: engaging children with engineering. MERI Seminar Series, Sheffield Hallam University, United Kingdom, February 2018.

What influences children and young people to study STEM and aspire to STEM careers? Seminar on "Developing STEM-B education for high school students". VNUK, DaNang University, Vietnam, 17^{th} July 2018.