Impact of Academic Research through Northumbria's Physical Sciences, Technology and Engineering Outreach Activities on Improving the Uptake of STEM Disciplines by Young People

I C EMEMBOLU

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ITORO CHARLES EMEMBOLU

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ABSTRACT

Previous research highlights that children from an early age should have learning experiences on real world applications and careers to widen their horizons and open up future opportunities. In parallel, there is a growing emphasis especially in the UK, to ensure academic research impacts on wider society. This research brings these two elements together and contributes to the challenge of improving the uptake of STEM (Science, Technology, Engineering and Mathematics) disciplines by young people. Although there have been considerable numbers of STEM interventions (past and current) with young people and substantial funds invested in these, there is still little evidence on the effectiveness of those interventions. The aim of this study is to develop an effective evaluation framework and provide a process whereby academics and practitioners can plan, develop, implement and assess the impact of a range of intervention activities in primary schools, on children's interest in STEM across many disciplines. The intervention activities under evaluation were targeted at children aged 7 – 11 years. The focus of these interventions combined research work done by academic researchers with practical/career applications to bring STEM subjects to life for children. Adopting an action research approach and a Theory of Change process, an innovative impact evaluation framework was designed to provide a set of pathways for widening aspirations and help children appreciate that STEM professionals are just 'people like me'. Evaluation of the impact of STEM intervention activities on young people was achieved using a collection of instrumental case studies from intervention outreach activities across three STEM disciplines: computer science, materials science and geography. Data was collected from 343 children across the different case studies using a pre and post quasi-experimental design. Data was collected on the children's aspirations, career knowledge and understanding, subject knowledge and inclination towards introduced career. Data analysis provides evidence to suggest that children are gendered in their career aspirations from an early age. Post intervention, the data shows there was an increase in career knowledge of the children across the different case studies and an increase in vocabulary used to describe subject specific concepts. The impact evaluation framework designed was successful in providing an iterative model and pathway for change that academics and outreach practitioners can use to design and refine research based STEM outreach activities for children.

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DECLARATION

I declare that the work contained in this thesis has not been submitted for any other award and that it is all my own work. I also confirm that this work fully acknowledges opinions, ideas and contributions from the work of others as cited in this thesis.

The ethical clearance for the research presented in this thesis has been approved. Approval has been sought and granted by the Faculty of Engineering and Environment Ethics Committee.

I declare that the word count of this thesis is: **63,337**

Name: **Itoro Charles Emembolu**

Signature:

Date: **24th June, 2020**

CHAPTER ONE – INTRODUCTION

Literature studies highlight the importance of children's learning experiences from an early age (Tanenbaum, 2016; Harrington et al., 2014; McClure et al., 2017; English et al 2017), real world applications (Wu, 2013; Hwang, 2014; ACARA, 2016; Mildenhall et al., 2018) and careers information (Brott, 1993; Helwig, 2001; Reiss and Mujtaba, 2016; Chambers et al., 2018; Gatsby, 2019), to widen children's horizons and open up future opportunities. In parallel, there is a growing emphasis especially in the UK, to ensure academic research impacts on wider society (REF2014; Given et al., 2015; Chikoore et al., 2016; Darby, 2017; Gunn & Mintrom, 2017; Phillips et al., 2018; Watermeyer and Chubb, 2018; Wilkinson, 2019; REF2021). This research brings these two elements together and contributes to the challenge of improving the uptake of STEM (Science, Technology, Engineering and Mathematics) disciplines by young people. This chapter provides the background to the study. It outlines the aim and objectives of the research. It also presents the scope of the research, followed by a summary of the research design and methodology. The rationale for this study and the structure of this thesis are also described in this chapter.

1.1 Background to study

The importance of STEM to the competitiveness, growth and future of an economy is well documented internationally in reports and literature studies (Krishnamurthi et al., 2013; Saxton et al., 2014; Archer, L., Dawson, E., DeWitt, J., Seakins, A., & Wong, B. 2015; ACARA, 2016; Duodu et al., 2017; UNESCO, 2017; Dare et al., 2018; House of Commons, 2018; National Audit Office; 2018). The STEM workforce of the future is dependent on having more young people encouraged and taking up STEM careers and remaining in the STEM pathways (House of Commons, 2018).

In the UK, the government is committed to supporting STEM interventions or initiatives to encourage more young people into STEM careers. In the decade between 2007 and 2017, the UK government has invested about £990 million funding on STEM interventions or initiatives (National Audit Office, 2018), excluding funding to Higher Education Institutions. Apart from economic importance of STEM, the rapid technological advancements in the world currently has made it important or maybe even necessary that individuals including children have some understanding of STEM (McClure et al., 2017) and acquire some STEM skills. STEM skills are valued for their higher order thinking, solving complex problems and advancing new knowledge (Saxton et al., 2014). STEM education, irrespective of a young person’s future career aspirations, promotes critical thinking that can be useful to all (Volmert et al., 2013; Tanenbaum, 2016). The UK government has departments actively involved in promoting and encouraging STEM activities and acquisition of STEM skills. The two main departments are the Department for Education (DfE) and the Department for Business, Energy & Industrial Strategy (BEIS). The DfE is in charge of STEM interventions for skills acquisition and also STEM careers while BEIS promotes and supports STEM inspiration initiatives (House of Commons, 2018; National Audit Office, 2018). Other departments involved in STEM can be seen in Table 1.

Table 1: UK Government departments involved in funding and managing STEM activities

Government Departments	**Responsibility regarding STEM**
Department for Education (DfE)	Working with schools Higher Education Institutions and in charge of the government career strategy
Department for Business, Energy & Industrial Strategy (BEIS)	Manages the government industrial strategy and STEM inspiration initiatives
Department for Transport	STEM apprenticeship programmes
Ministry of Defence	STEM apprenticeship programmes and defence related STEM programmes
Department of Digital culture, media and sports	Digital skills and digital strategy
HM Treasury	
Home Office	Provide support/funding
Cabinet Office	

Source: National Audit Office (NAO), 2018

In parallel to the drive to get more young people into STEM degrees and pathways, there are also moves to ensure academic research particularly in the UK, has societal impact (Phillips et al., 2018; Watermeyer and Chubb, 2018; Wilkinson, 2019). The relevance of this is shown by the level of importance associated with societal impact in the Research Excellence Framework (REF) in the UK (REF2014; REF2021). Research into societal impact is still relatively new (Given et al., 2015) but gradually gaining traction. Many STEM related initiatives based on academic research were identified in the last REF 2014 case studies (this is discussed further in the next chapter), but these were mainly targeted at young people in secondary schools and above with less efforts or focus on children in primary schools (11years old and below).

Research studies suggest starting STEM interventions or education early in a child's life (Tanenbaum, 2016, McClure et al., 2017). The UK government's careers strategy (DfE, 2017) indicated findings that children in primary school already thought STEM subjects were difficult and not for them. If many of these young children feel that way, they may not take on the STEM subjects when given the options, which further diminishes possibilities of them ending up in STEM career pathways. This also reinforces the reason why targeting STEM education and STEM careers awareness at an early age is important (Brott, 1993). McClure et al. (2017) argued that not only should STEM education and career information start early in a child's life but the engagement should also be sustained.

Gottfredson's theory on circumscription and compromise (Gottfredson 1981; Gottfredson & Lapan 1997) describes how the range of career options children consider for themselves narrow, as they grow older. Children grow within nested systems of influences (McClure et al., 2017). They start picking up nuances about social behaviors, gender roles and occupations from their environment which they use to form perceptions about the roles and occupations, even when those perceptions might be based on incorrect information. Gottfredson's theory (1981) refers to circumscription of career options as situations where young people discard career options (even if these career options are accessible) because they think these career options are unsuitable or least suitable for them, while compromise of careers is described as when young people discard career options due to its inaccessibility (Gottfredson & Lapan, 1997).

Reigle-Crumb et al (2011) argued for more research studies to explore how to prevent young people from prematurely shutting themselves out to possible future careers (including STEM careers). One way to do this, is by providing authentic experiences that children can relate with (Lombardi, 2007; Harrington et al., 2014; English et al 2017). Aspirations could be made more realistic by providing children with experiences of STEM careers and more information on the accessibility and pathways towards such careers (Gottfredson & Lapan

1997; Helwig, 2001). Hands-on experience has been shown to play an important part in learning subject or discipline specific content (Volmert et al., 2013; Tanenbaum, 2016).

Substantial investments have been made towards interventions and STEM education to encourage more young people to take on STEM subjects and careers, and remain within its pathways (Archer et al., 2014; 2015; Sinatra et al., 2015; National Audit Office, 2016). Despite these investments, there is still a dearth of evidence on the effectiveness of these STEM interventions (*Engineering Skills for the Future, the 2013 Perkins Review revisited*, 2019). The National Audit Office (2018) report identified and recommended the need for robust impact evaluations of STEM interventions to identify what works and what is effective. There is a need for more innovative and accessible ways to measure STEM processes of learning that indicates what works, how it works, its contexts, materials and tools for implementation and evaluation (Tanenbaum, 2016). Saxton et al. (2014) argued that information necessary to improve teaching and learning in STEM are a function of the quality of measurement and evaluation systems of relevant STEM constructs. Evaluation of STEM constructs are useful in helping teachers, schools, funders, outreach groups and practitioners by providing meaningful information necessary to direct effort and resources for improvement in STEM education (Saxton et al., 2014).

This study develops an evaluation framework to evaluate the impact of a range of intervention activities in primary schools, on children's knowledge, understanding and perceptions of STEM and its related careers. The research also responds to the need for further research into social impact, particularly looking at social impact on younger children.

1.2 Research aims and objectives

The aim of this study is to develop an effective evaluation framework to assess the impact of STEM interventions, based on research work by academics on primary school children's career interests. Also, the research provides an end-to-end process whereby academics and practitioners can plan, develop, implement and assess the impact of a range of intervention activities, on children's interest in STEM across multiple disciplines. This is carried out through Northumbria's physical sciences, technology and engineering outreach activities, on young people's interest in the STEM disciplines. The focus is on the interface between outreach activities developed from the works of academic researchers and practical applications that would bring to life STEM subjects for young people. The objectives of the research are stated below:

1. To review the existing state of the field, industry and literature and other intervention engagements on effective and innovative impact evaluation metrics, measures and available frameworks.
2. To design and develop a plan to monitor, collect data and analyse intervention(s) on young people's interest in STEM disciplines.
3. Use the designed and developed plan to establish an impact evaluation framework and evaluate the impact of academic and research outreach engagements on young people's STEM interests.

1.3 Scope of the study

This study is concerned with young people but with particular focus on children aged 11 years and under. The sample is drawn from NUSTEM's partner and linked schools in the North East of England. NUSTEM[1] is a STEM outreach group that works with young people and their circle of influence.

Within this study, academics are engaged and collaborate with STEM outreach specialists, to co-design and co-create new intervention activities in their various disciplines by combining aspects of their research work with practical/career applications, to bring STEM subjects to life for children.

This research explores some of the pathways that can been used to mitigate some of the factors affecting uptake in STEM disciplines by young people. By evaluating academic research-based STEM workshops with children, this research outlines four pathways for widening aspirations and make young people appreciate that scientist and wider STEM professionals are just 'people like me'. These pathways are used as short-term outcomes in the Theory of Change model developed in this research. They are:

- Provide/increase basic knowledge of some STEM related concepts
- Provide/increase knowledge of some STEM related application
- Increase knowledge of a wider range of STEM careers

[1] https://nustem.uk/

- Improve or increase science practical skills

1.4 Research design & methodology

The study adopts an action research and Theory of Change process using a multiple case study approach.

Theory of Change and action research approach

The evaluation framework is designed using a Theory of Change process. It is derived from NUSTEM's over-arching model. Theory of Change is useful in the understanding of which interventions or initiatives works, how and under what circumstances they work (or not) in a specific, or different contexts (Prinsen & Nijhof 2015; Allen et al. 2017; Davies 2018). It also accommodates different research methods and instruments (Davies, 2018; Guarneros-Meza et al., 2018). While the evaluation framework is derived from NUSTEM's over-arching model working with children, schools, families and carers, this research focuses on work with children and provides an innovative theory of change model and approach that extends the NUSTEM model and shows how the process can be applied across disciplinesEach of the discipline workshop's design and implementation were underpinned by the action research iterative cycle (Kemmis & McTaggart, 1988; MacIsaac, 1995; Gabel 1995):

Case study approach

The study takes on a multiple case study approach with case studies from three different disciplines; computer science, materials science and geography (the third case study is a series of mini case studies). Use of a multidisciplinary approach allows for across case analysis and comparisons (Yin, 2003; Stubbs & Myers, 2015), helps to provide insight into applications of research knowledge (in this case through intervention activities) and how new knowledge is gained by the learner in different contexts (Tanenbaum, 2016). Also, a strength of the case study approach is that it can accommodate multiple data collection methods and evidence for triangulation (Yin, 2003).

Data collection and analysis

The Theory of Change model guided the measures used to collect data. Data on discipline specific research were collected from academic researchers through informal interviews. Variables of interest to this study include children's aspirations, discipline specific STEM knowledge, understanding, and inclination towards STEM disciplines.

Data was collected from 170 children for the pilot studies across the different case studies and 343 children for the main intervention (73 children in phase one and 270 children in phase two). Using a pre and post quasi-experimental design, data was collected on the children's aspirations, career knowledge and understanding, subject knowledge and inclination towards introduced career.

The instruments used to obtain data from the children include pre- and post-workshop questionnaires, pre- and post-knowledge maps, activity sheets, and the output of activities within a workshop (for example, the games the children designed). The design of the knowledge map used in collecting data evolved as the different workshop pilots were implemented because findings from each pilot study was used to improve the knowledge map design for subsequent pilot studies.

Qualitative data was analysed using thematic analysis, themes generated from the data were categorised for convergence. Quantitative data was analysed using descriptive statistics, chi-squared tests and Fisher's exact tests. Each case was analysed individually and similar measures were compared across case studies.

1.5 Significance of study

There is a substantial amount of literature on evaluations of STEM intervention programs, where many evaluations highlight the benefits of evaluations and the implementation of the intervention, describe the processes used (George-Jackson & Rincon 2012) and/or highlight what the STEM intervention achieved (Malyn-Smith 2014). In spite of this, there is still a lack of evidence or empirical based literature to suggest the effectiveness or impact of STEM interventions (George-Jackson & Rincon 2012; Malyn-Smith 2014; Archer et al 2014; 2015; Chalmer & Gardiner 2015) particularly on young people. Are they really doing what they set out to do, is there an effect? Current research thus advocates for more evidence-based studies (Chalmer & Gardiner 2015) on the outcomes of STEM engagements; if there is an impact and if so why, or why not. This study provides a systematic, evidence-based impact evaluation of STEM interventions.

Also, several studies on impact evaluations concentrate on effects of individual intervention activity or project (Archer et al 2014; Scott 2015). Evaluation has also been concentrated on interventions in secondary schools, particularly for young people aged 14-19 years (Tripney et al 2010; Archer et al 2012; 2014; 2015; Scott 2015). This study develops an evaluation framework to assess impact for primary intervention engagements across multiple intervention workshops.

This research contributes extensive review on current trends in STEM literature and a framework for impact evaluation of academic research on children regarding STEM intervention activities. While the aim of the study is to evaluate impact of academia on young people as mentioned above, the research also presents the design and implementation of STEM intervention activities that could be useful to support other innovative and customized activities and applications to aid improved support to young people's STEM pathways.

1.6 Outline of thesis

This thesis consists of eight chapters which are all interlinked. The first chapter provides an introduction, it presents the background to the study, the research aim and objectives, its scope and the relevance of the study. It also provides a summary of the methodology adopted for the study.

The second chapter presents a detailed literature review. The history of STEM is discussed and also current conversations and as related to STEM. This includes discussions on widening participation, investments into STEM programmes, interventions and the focus on older children. Factors influencing young people's aspirations and approaches to improve uptake are discussed. Intervention activities for young people based on academic research are also discussed. The chapter also looks into types of evaluations particularly impact evaluations and the use of a Theory of Change model.

The third chapter builds on chapter two and describes the methodology adopted in the study. It outlines the theoretical and methodological approach through which the study is undertaken. The steps taken to design an impact evaluation framework and measures and indicators used to assess impact of the intervention workshops are presented. Ethical considerations are also discussed in this chapter.

The fourth chapter presents the case studies used in this research study from three STEM disciplines. Objectives of the workshops from the different disciplines are outlined. The structure of the workshops, design considerations and evaluation tools are also presented.

The fifth chapter presents the findings from the pilot studies across all the different workshops.

The sixth chapter presents findings from the main intervention phases and for the different intervention workshops.

The seventh chapter provides a discussion around the findings from this research. It discusses the impact on the children and the on the academics. Reflections on the evaluation and pedagogical approach are made.

The eighth and final chapter provides a summary of the research. It summarises the contribution of the research to the body of knowledge. It presents the limitations of the research and discusses avenues for further work. The chapter also presents the researcher's interaction with the research community during the course of this study.

Chapter 1 provides a background for chapter 2. Chapter 2 informs chapter 3 and chapter 4. Chapter 3 and 4 are iteratively used to inform findings in chapter 5 and 6. Chapter 7 discusses the outcomes of chapters 5 and 6. Chapter 8 reflects on all the chapters and brings the thesis to a conclusion.

CHAPTER TWO – LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of the literature on Science, Technology, Engineering and Mathematics (STEM) intervention programmes and current conversations regarding the evaluation of the effectiveness of those programmes. The chapter discusses the shortage of STEM professionals and the investments that have been made to increase participation in Higher Education particularly in the STEM disciplines. A review is presented of young people's interests in terms of aspirations and academic research that has been geared towards promoting higher participation of young people within the STEM disciplines. The chapter also discusses the importance of evaluating the impact of academic research on young people's uptake of the STEM disciplines. Firstly, the principles of evaluation are explained: highlighting the different components of an evaluation and when those components are adopted. Utilizing New Philanthropy Capital's (NPC) four-pillar approach to planning an effective impact evaluation framework, there follows an extensive discussion on the Theory of Change and how the Theory of Change can be mapped towards generating young people's interest and uptake of STEM disciplines. This is followed by a recap of the existing gaps in literature and a chapter summary.

2.2 Science Technology Engineering and Mathematics (STEM)

STEM is widely used to refer to Science, Technology, Engineering, and Mathematics (Moore et al., 2013; Kloser et al., 2018). The acronym can be traced back to the National Science Foundation (Sanders, 2008; Bybee, 2010; Ostler, 2012) in the United States in the 1990s where combining science, technology, engineering and mathematics disciplines was seen as an important move by professionals in those disciplines to gain a louder collective voice. Initially the acronym was known as SMET but was later rearranged to the much more popular STEM in 2001 (Kloser et al., 2018). There is currently no agreed definition for the disciplines or subject areas included in STEM in the literature (Byars-Winston, 2014; Kloser et al., 2018; van den Hurk et al., 2019). Whilst some research studies confine their study of STEM to one discipline, others combine more than one discipline and include related subject areas (Rottinghaus et al., 2018). The range of field and subject areas included in the categorization of STEM is constantly evolving particularly with current technological developments and its influences across nearly all sectors of an economy (Zollman, 2012; Rottinghaus et al., 2018) including sectors that previously did not have much need for technology. Over the past few years, interest in STEM, the debates and dilemmas surrounding STEM employment shortages, and STEM education have increased. For the purpose of this research, STEM includes health, physical and applied sciences, technology, engineering and related subject areas. This wider definition of STEM is useful because the research involves working with children and their experience includes health professionals such as doctors and nurses.

2.3 Shortage of STEM workforce

There are researchers who argue that the claimed shortages of STEM professionals are a myth and reports of skill shortages are over exaggerated (Charette, 2013; Smith & Gorard, 2011; Cappelli, 2015; Mendick & Danielsson, 2017). It has been argued (Xue & Larson, 2015) that the shortage or surplus depends on which sector is looked at. On the other hand, and more commonly, there are many reports from a range of countries conveying concerns that there is indeed a shortage of STEM professionals in several sectors. In 2015, the United Kingdom (UK) Commission for Employment and Skills reported that 43% of positions in STEM roles were difficult to fill due to not enough applicants with the necessary skills (UKCES, 2015). It is projected that 2.65 million jobs will be needed in the engineering field in the UK by 2024 (Engineering UK, 2017), whilst at the same time the figures project that 2.42 million people will be leaving the field. This means an additional 234,000 new engineering jobs is needed by 2024 (Engineering UK, 2017). There is also a prediction of 157,000 new jobs being required in big data alone by 2020 (Engineering UK, 2018). The STEM workforce shortage is also evidenced by the numerous efforts, across governments of different countries, to boost the involvement of young people in the STEM disciplines (Tripney et al., 2010; Marginson et al., 2013; Archer et al., 2014; 2015; Sinatra et al., 2015; DeCoito, 2016).

Independent of the debate on STEM shortages, the quest to enhance STEM education is beneficial because STEM education and disciplines remain important for national productivity and competitiveness (Marginson et al., 2013; Mildenhall et al., 2018) and STEM expertise can be applied to various aspects of daily life. Australia's Chief Scientist referred to STEM as being "at the core of almost every agenda" and Chubb (2014) states that STEM is "the almost universal preoccupation now shaping the world's plans". Given the relevance of the STEM workforce and its critical role to economies, there have been numerous conversations regarding the promotion of STEM disciplines and acquisition of STEM related skills in literature (DeWitt et al., 2013; Byars-Winston, 2014; MacDonald, 2014; van den Hurk et al., 2019). Governments have invested substantial funds towards interventions that encourage young people's interests, aspirations, participation and achievement in STEM disciplines (Tripney et al., 2010; Archer et al., 2014; 2015; Sinatra et al., 2015). Although the majority of the evidence in literature are around interventions in Higher Education and secondary schools, there has been a gradual shift in widening participation to involve the younger age groups (Cotabish et al., 2013; Hughes et al. 2016; Kim, 2018; Castro et al., 2018).

2.4 Widening participation (WP)

Widening participation in the context of education has been referred to in the literature as the means by which people regardless of background or status are able to have access and support to education opportunities, especially those individuals who usually might not have participated if those opportunities did not exist (Grout et al., 2015; Smith & White, 2011). The idea is that as more people participate in Higher Education, the diversity of who participates should also widen.

Groups of individuals that are usually targeted for widening participation are under-represented groups. They are selected based on certain characteristics such as socio-economic status (SES), ethnicity, disability, gender, and type of study such as part time, mature students (Moore et al., 2013; Bernaschina, 2015, Grout et al., 2015, DeWitt et al., 2016; McCulloch, 2017). Under-representation in STEM disciplines has been attributed to some of the key barriers to STEM participation. These include lack of access and experience of STEM content by young people from under-represented groups (Avendano et al., 2018), stereotypes attributed to specific disciplines (Smith, 2011), and parental, peer and cultural influences (Saucerman & Vasquez, 2014). There have been moves to improve equity in STEM from under-represented groups through improved access and positive experiences (Lynch et al., 2018).

Widening participation research is concerned with bridging differences and inequalities in participation (Wardrop et al., 2016) by bringing about a social or cultural change. In education, those differences could be in terms of aspirations, enrolments, experiences and attainments, which cut across different subjects and disciplines. Substantial funds have been invested with the aim of bridging the participation gap. In the United Kingdom, the Office for Students (OfS), previously known as the Higher Education Funding Council for England (HEFCE) and the Higher Education Funding Council for Wales (HEFCW) are committed to increasing participation in Higher Education and provide funds for that purpose. In the 2016/17 academic year, the total funds disbursed by HEFCE was £3.6 billion of which £54 million was for widening participation of students from disadvantaged backgrounds (HEFCE, 2016). HEFCW budgeted £99 million for Higher Institutions in Wales for the 2017/18 academic year (HEFCW, 2017) and provided funding to a collaborative body, the Wales Institute of Social and Economic Research, Data & Methods (WISERD), to evaluate progress on widening participation (HEFCW, 2016).

In Scotland, the Government annually invests about £51 million to widen participation and access (Scottish Government, 2018). Using a recently established Framework for Fair Access (Scottish Government, 2019a), consisting of a toolkit for best practices in intervention evaluations, Scotland is aiming to have 20% of students from disadvantaged backgrounds constituting 20% of students entering Higher institutions by 2030 (Higher Education Policy Institute, 2017). Ireland has the Higher Education Access Route (HEAR) and the Disability Education Access Route (DEAR) which are both national initiatives to widen participation from under-represented groups (Higher Education Policy Institute, 2017). Northern Ireland has the ‘Access to Success’ strategy developed in 2012 (European Commission, 2018) and the Widening Access and Participation Plan (WAPP) provided annually by Higher Institutions funded by DEL (Department for Employment & Learning, 2015).

United States has the Federal TRiO programme (US Department of Education, 2019) consisting of eight (8) national government-funded programmes that has supported over 800,000 students. TRiO annual funding in 2016 was about $900million (Higher Education Policy Institute, 2017). Australia has the Higher Education Participation and Partnership Programme for citizens from low SES backgrounds. Funding between 2018/19 academic year and 2021/22 is projected to be $650.4 million (Australian Government Department of Education, 2019).

2.5 Uptake of STEM disciplines

Attaining parity or balance in participation is ideal because it promotes equality, fairness, reduces stereotypes and improves diversity (World Economic Forum, 2019). Diversity reduces 'group think' which in turn improves problem-solving and is significant for economic growth over time (Gibbs, 2016; Strachan et al., 2018). Group-think refers to when people within a group have similar ways of doing things.

Although attaining parity in participation is ideal, it is harder to achieve in practice across disciplines. For instance, differences in number of students' uptake of STEM programmes between 2007/08 and 2016/17 academic year, varied across disciplines in the UK (see table 2).

Table 2: Participation of students in some STEM subjects between 2007/08 and 2016/17 in UK Universities

Subject of study/Disciplines	2007/08 (Numbers)	2016/17 Numbers)	% Change
Veterinary Science	4,850	7,145	47.3
Biological Sciences	161,600	226,370	40.1
Engineering & Technology	139, 435	165,090	18.4
Physical Sciences	82,130	95,170	15.9
Computer Science	95,575	101,045	5.7
Architecture, Building and Planning	63,085	51,185	-18.9

(Source: Universities UK, 2018)

While some disciplines have greatly improved uptake within the last decade (veterinary science by 47% and biological sciences by 40%), others have not had as much increase in uptake. Engineering showed an increase of 18%, physical sciences about 16% and computing around 6%. Architecture, building and planning on the other hand, showed a decline by about 19% (Universities UK, 2018).

Research studies further show large gender imbalances in some of these STEM disciplines. Data using the gender parity index by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) shows more females participate in Higher Education in general compared to males in many countries (World Bank, 2019). However, in comparison, female participation lags behind males in STEM subject areas (Global Education Monitoring Report Team and UNESCO, 2018). Another example: in 2016/17, over 70% of students in medical and veterinary sciences were from female participation (UK Universities, 2018). Within the same period, computing, engineering and technology subjects had less than 20% female participation.

Byars-Winston (2014) argued that under-representation of any group is not an issue in itself if there are no limiting barriers or influences affecting the choice of disciplines or subject areas. Ideally, this implies a level playing field of equal opportunities and freewill for any group of participants. However in reality, there are many systematic barriers and influences impacting on an individual's choice (Kao & Tienda; Bandura et al., 2001; Tripney et al., 2010; Riegle-Crumb et al., 2011; Gomez 2014; Uka, 2015). Research suggests that individual uptake of careers are not necessarily by chance but as an outcome of a combination of influences; individual, environmental and social influences (Byars-Winston, 2014; Reiss & Mujtaba, 2017). Van den Hurk (2019) categorises the influences into three types. The first is environmental-level factors, which include cultural and social factors such as stereotypes, parental (carer) influences and scarcity of role models in the disciplines. The second is school-level factors, which include curriculum focus, instructional approach of the teachers and participants' unconscious bias. The third are individual-level factors such as ability, self-efficacy and background, gender and socio-economic status. Intervention activities to increase uptake of STEM have focused on the different factors as evidenced in research studies.

2.6 Interventions

For the purpose of this study, intervention refers to a purposeful action to create change (Midgley, 2006). The objectives of many higher education intervention activities can widely be classified into two groups; raising attainment and raising aspirations (Crawford et al., 2017). The gap between aspirations and attainment can be likened to a continuum where there are a range of influencing factors and milestones that need to be reached before getting to successful attainment. For example, before a young person can aspire to a particular career, they have to have knowledge of possible careers/pathways, and then they can aspire towards these pathways. They have to then participate and remain on one of the pathways before they can successfully reach attainment.

Several interventions for young people have been aimed at increasing participation in Higher Education, especially from under-represented groups, through raising aspirations. Gale et al. (2010) suggested classifying aspiration-raising interventions into three categories. The first category is raising aspiration through stimulating knowledge. This can be done by presenting or exposing young people to courses required to get into programmes of interest in a higher institution. The idea is to increase their knowledge about those programmes and related occupations and vocations. The assumption behind this argument is that a person cannot aspire to a career they do not know about (Hildago, 2015); their aspirations are constrained by what they know (Gale et al 2010). This assumption, while not explicitly stated in many research studies or education policies, can be inferred (Gale et al., 2010; Chambers et al., 2018).

The second category is by raising aspirations through experiential knowledge where young people are given a glimpse of the subject area, vocation or occupation, through an experience-based intervention programme. The main difference between the first and second category is that the first category focuses more on expanding knowledge and the second category focuses on providing experiences such as spending some time with a person in the profession of interest and getting involved in activities within that profession.

The third category is a combination of the two aforementioned categories. Interventions that involve collaborations between different stakeholders tend to adopt the third category (Gale et al., 2010) such as collaborative interventions funded by the OfS (2019) and HEFCW (Afon, 2018). While policies have been geared towards raising aspirations (HM Government, 2009; 2011; Communities and Local Government, 2011), concerns have been raised regarding the narrative of ‘raising aspirations’ particularly in terms of class or socioeconomic status (SES) (Archer et al., 2014c; Spohrer et al., 2018). Much of the rhetoric around ‘raising aspirations’ is based on the premise that young people from low SES or disadvantaged backgrounds have ‘low aspirations’, therefore, the need to ‘raise aspirations’. However, research studies suggest young people have high aspirations irrespective of background (Croll, 2008; Kintrea et al., 2011; Chambers et al., 2018). Archer et al (2014c) argued for a change from mainly ‘raising aspiration’ to a more diversified and informed approach to aspirations; in essence, ‘widening aspirations’.

2.7 Aspirations

Aspirations have been described in literature as the desires, hopes and dreams a person has for their future. (Gorard et al., 2012; Uka, 2015). Aspirations are formed in the early years of life and are susceptible to change or can be influenced by experience or environment (Uka, 2015; Gottfredson, 1981). Although decision points on subject choices that could determine career paths are usually between age groups 14 – 18 years (Tripney et al., 2010), aspirations and attitudes towards possible career paths are developed at much younger ages (Reiss & Mujtaba, 2017; Castro et al., 2018; Kitchen et al., 2018). Gorard et al. (2012) argued that altering aspirations on their own might not lead to a change in educational outcomes. Aspirations are also influenced by the young people's expectations and other enabling or inhibiting environmental or societal conditions.

Many studies have distinctly separated the two concepts; aspirations and expectations (Stephenson, 1957; Marjoribanks, 1998; Reynolds and Pemberton, 2001; Gorard et al. 2012; Khattab, 2015; Crawford et al. 2017). Expectation has been defined as perception on thoughts of future occurrences while aspiration is defined as perceptions on hope of future occurrences (Gorard et al. 2012). Using the theory of possible selves (Markus & Nurius, 1986), Perry et al. (2009) described aspiration as 'hoped-for-self' (what I wish to be) and expectation as 'expected self' (who I will likely become). For example, even though a young person might hope or aspire towards a specific career such as being a volcanologist, they might not actually believe or expect that they will be a volcanologist depending on their environment or circumstances around them. There is a gap between the young person's hope (aspiration) and belief about what might actually happen (expectation).This gap has been referred to in literature as the aspiration-expectation gap (Hellenga et al., 2002; Perry et al., 2009; Boxer et al.,2011).

The connections between aspirations, expectations and educational attainment appear quite complex. Gorard et al. (2012) argue that aspiration could be both a predictor and outcome of educational attainment. Khattab (2015) used the Longitudinal Study of Young People in England (LSYPE) to investigate the various ways that aspirations, achievement and expectations impact a young person's educational pathway and results found that an alignment of all three was a relevant predictor of educational pathways of the young people. Several research studies have investigated the causal relationship between aspirations and achievement and found little evidence to support a causal link (Gorard et al., 2012; Khattab, 2015; Gutman & Schoon, 2012)

Other studies have, however, argued that the causal link between aspirations and achievement are better analysed by also investigating the expectations of the young persons. This is because the aspirations of a person might be disassociated from reality; social, environmental and economic factors while expectations are more in tune with perceived reality (Khattab, 2015). In order to understand and bridge gaps within the aspiration, expectation and attainment continuum, it is important to consider the factors influencing young people. While it may be difficult for an individual research study to address all the different factors influencing young people, different studies have concentrated on exploring specific factors.

2.7.1 Key factors influencing aspirations

Some key factors that have been shown to influence aspirations, particularly concerning STEM, are included in table 3:

Table 3: Some factors that influence career aspirations

	Influence	**Supporting Reference(s)**
1	Gender	Ojeda & Flores, 2008; Tripney et al., 2010; Riegle-Crumb et al., 2011; Koul et al., 2011; Archer et al., 2014
2	Attitude to Science	Evans & Herr, 1994; Riegle-Crumb et al., 2011: Bennett et al., 2014
3	Individual Characteristics such as academic achievement	Majoribanks, 2002; Uka, 2015
4	Knowledge of STEM career option/pathways	Gomez, 2014
5	Self-Efficacy/Concept (Perception of self)	Bandura et al., 2001, Archer et al., 2013
6	Family Context	Ojeda & Flores, 2008; Kao & Tienda, 1998; Tripney et al., 2010; Archer et al., 2012; 2013; 2014; Reiss & Mujtaba, 2017
7	Teacher/ School environment	Kao & Tienda, 1998; Tripney et al., 2010; Riegle-Crumb et al., 2011; Archer et al., 2013
8	Media/ Role Models	Kao & Tienda, 1998; Archer et a.,2013
9	Motivation	Wentzel, 1998
10	Friends & Peers	Antonio, 2004

Gender roles have been described extensively in literature as a key factor influencing young people's occupational aspiration choices (Bigler & Liben 1990; Gottfredson & Lapan, 1997; Helwig, 2001; Tripney et al., 2010). Children are aware of gender differences by the age of

3 years (Helwig, 2001) and start characterizing career roles by gender from about the age of 6 years. (Gottfredson & Lapan, 1997). Young people are also largely influenced by role models and the media (Kao & Tienda, 1998; Archer et a.,l 2013). The images and notions individuals are frequently exposed to, affects their perceptions, beliefs and behaviors (Handelsman & Sakraney, 2015; Tanenbaum, 2016). Many other research studies highlight the influences of parental and family attitude to a young person's attitude and aspirations (Archer et al., 2012; DeWitt et al., 2013; Reiss & Mujtaba, 2017). Positive school experiences and teacher support have also been suggested to encourage inclinations towards science aspirations (Lyon, 2006; Aschbacher et al., 2010; Dewitt & Archer 2015).

2.8 Approaches to improve uptake in STEM

A number of studies have sought to address some of these factors. Mildenhall et al. (2018) addressed the STEM learning experience from an equity and social justice perspective using resources available in a refugee camp to design shoes. Students aged 8-9 were involved in designing shoes through an interdisciplinary approach of combining mathematics and materials science. Research studies suggest that young people who participated in a STEM summer intervention were 1.4 times more likely to report a STEM career aspiration post-high school compared to young people that did not participate (Kitchen et al. 2018). Some of the approaches recommended in the literature (Banerjee, 2017; Kitchen et al., 2018) to improve STEM uptake and persistence in its pathways include:

- ***Improving interest and attitude towards STEM*** (Archer, 2013; Kitchen et al 2018; van den Hurk et al., 2019).
- ***Improving self-efficacy regarding STEM*** (Hurtado et al., 2010; MacPhee et al., 2013).
- ***Acquiring STEM subject specific knowledge*** (Mildenhall et al., 2018; Cotabish et al., 2013; Wooten et al., 2013).
- ***Using Real world applications* of STEM** (Riegle-Crumb et al., 2011; Krishnamurthi et al., 2014).
- ***Addressing stereotypes regarding STEM disciplines and associated careers*** (Narayan, Park & Peker, 2007; Schinske et al., 2016; Dele-Ajayi et al., 2018).

- ***Embedding career information in STEM subject teaching (***Reiss & Mujtaba, 2017; Archer et al., 2013).

2.8.1 Improving interest and attitude towards STEM

There is increasing evidence on links between interest in STEM (for example, STEM activities) and STEM career considerations (Archer, 2003; Tai et al. 2006; Dabney et al., 2012; Kitchen et al., 2018; van den Hurk et al., 2019). The concept of interest and its implication for learning has been discussed in literature studies (Thorndike, 1935; Schiefele, 1992; Renninger 2014). It has been referred to as preferences derived from learning experience (Thorndike, 1935; Gottfredson, 2002) and as a phenomenon born out of a person's interaction with his/her environment (Renninger et al., 2014). Young people are more likely to pursue careers they are interested in (Nugent et al., 2015). Also, research studies suggest that it is difficult regain interest in science in young people over the age of 14, particularly when such interests have not been nurtured earlier in the young person's life (Kim, 2018). For young children, many of the interventions start with capturing their interest.

Generating, sustaining and improving interest have been described as outcomes of STEM engagement (Krishnamurthi et al., 2014) and interest could be inspired or increased by engaging with STEM based activities (Kitchen et al., 2018). Other examples of STEM-related research studies include Dabney et al. (2012) who found association between out-of-School (informal) science activities and interest in STEM careers. Tai et al. (2006) identified correlations between young people's interest within a formal setting and future career expectation and Nugent et al. (2015) suggested interest as a predictor of performance. Many of the research studies related to STEM interests focus on older children with fewer working with children below the age of 11 years (Archer et al., 2015; Scott, 2016; Hughes et al., 2016).

2.8.2 Improving self-efficacy regarding STEM

Self-efficacy is a factor that has been evidenced in literature to influence interest, participation in STEM activities and performance across age groups. (Nugent et al., 2015). Aspirations can be altered or mediated by self-efficacy or self-concept, individual characteristics, personal experiences, and family contexts (Gutman & Akerman, 2008). For young people particularly, their aspirations and expectations are usually not constant but alter as they advance in age with respect to the influencing factors (Gorard et al. 2012). Young people reflect on their performance in different subjects and activities they participate in and develop a self-perception or self-concept based on external feedback from their environment; exams, grades activities and experiences (Schneider & Stevenson, 1999; Riegle-Crumb et al., 2011; Boaler, 2016). An example STEM intervention is the use of robotics to improve young people's learning and their self-efficacy (Castro et al., 2018).

Saxton et al. (2014) identified factors that consisted of a young person's perception of themselves and the likelihood of aspiring and pursuing a STEM career. They describe them as psychological needs and precursors for achievement in STEM. These components are understanding the usefulness or value of the STEM activities in everyday life, a sense of relatedness that 'people like them' belong (MacDonald, 2014) or are welcome in the specific STEM professions of interest and a sense of competence or perceived ability to succeed in the STEM related activities often described in literature as self-efficacy. The factors together have been called academic identity (Saxton et al., 2014) or even STEM identity (Archer et al., 2013; Krishnamurthi et al., 2014) which are necessary but might not be sufficient conditions individually, for engagement with STEM (Saxton et al., 2014). This is because these factors are mutually reinforcing and together, they are part of a motivational drive consistent with Ford & Smith's (2007) thriving with social purpose framework. Young people may understand the usefulness of STEM skills but might not feel competent enough or that 'people like me' pursue such STEM careers. This could make them more inclined to careers or activities where they feel more competent or welcome. Similarly, young people could be confident in their abilities regarding STEM subjects and feel STEM careers can be for people like them but might not understand the usefulness or why it should be worth investing their effort and time.

Young people's construction of their self-identity is patterned in line with, or generally influenced by their environment (Riegle-Crumb et al., 2011; DeWitt & Archer2015). They are influenced by what is considered in their environment as acceptable or unacceptable, desirable or undesirable, prestigious or not, which in turn influences what might seem normal for 'people like me' (MacDonald, 2014; DeWitt & Archer2015). Gottfredson (1981) describes this as a child's zone of acceptable alternatives. This also impacts on the career aspirations or 'possible selves' (Markus & Nurius, 1986) they can imagine themselves in. Providing young people with activities they can relate to, enhances their understanding of the usefulness of the STEM subject area involved (Tanenbaum, 2016) and allows them to envision possible fits with what they self-identify with.

2.8.3 Acquiring STEM subject specific knowledge

Formal education is one of the main ways of acquiring subject specific knowledge, although teachers in schools are challenged with finding a balance between subject content and the context they situate the content in particularly for STEM disciplines (Dare et al., 2018; Mildenhall et al., 2018). Studies suggest that an in-depth understanding of STEM concepts help develop young people's motivation to engage with STEM and make connections with real life situations (Cotabish et al., 2013; Wooten et al., 2013) particularly if the learning engagement is practical based. English & King (2015) argue for the need of teacher or facilitator scaffolding to introduce young people to new STEM subject concepts or processes. Once new knowledge is acquired, teacher or facilitator scaffolding could help young people understand and apply STEM subject knowledge (English & King 2015). An example of a project that that showcases children acquiring STEM specific subject knowledge, is an engineering project where year six children in primary school (10-11 years old) made use of engineering processes, to plan and design a building that was resistant to earthquakes (English et al., 2017). Saxton et al. (2014) highlights the challenge of measuring content knowledge due to its reliance on specific context.

2.8.4 Real world applications of STEM

Previous research highlights the impact of early experiences and achievement in young people's lives on their future career paths (Riegle-Crumb et al., 2011; Reiss & Mujtaba, 2017; Kitchen et al., 2018; Kloser et al., 2018). The use of experiences based on real world contexts has been suggested to improve understanding of the value of STEM in everyday life. (Wu, 2013; Hwang, 2014; English et al., 2017). The 2016 Australian STEM connections report suggested that STEM content knowledge and practical skills are reinforced and enhanced when situated in authentic learning opportunities (ACARA, 2016; Mildenhall et al., 2018). Authentic learning refers to learning centred on real life experiences where participants are able to connect concepts they learn and application of those concepts to the real world (Lombardi, 2007; Harrington et al., 2014).

Real world has been defined in Webster's Dictionary (2014) as "in, from, or having to do with actual experience or practice, rather than being theoretical, idealistic, or impractical".

By applying content taught using hands-on activities, young people are able to understand the value, connections and contribution of STEM to participants' everyday life and society as a whole (Krishnamurthi et al., 2014; Tanenbaum, 2016). Other studies suggest emphasizing the usefulness of STEM in activities or interventions promotes more STEM inclined aspirations (Murphy & Whitelegg, 2006; Kitchen et al., 2018). While experiences of STEM are currently being introduced in schools, it is still under-utilised in primary schools particularly with regards to engineering disciplines (English et al., 2017; Mildenhall et al., 2018).

2.8.5 Addressing stereotypes regarding STEM disciplines and associated careers

Stereotypes have been described in a research study as blanket simplistic assumptions, attitude or opinions that generalise a particular group of people, place or things, using certain characteristics. Such generalisations are based on little information, might not be true and are usually not positive (Narayan, Park, & Peker (2007). Stereotypes are difficult to change (Lake & Kelly, 2014).

Young people are largely influenced by the culture they are embedded in and form perceptions based on what they see, hear or their environment (Christensen et al., 2014, Gottfredson, 1981; Gottfredson & Lapan, 1997). There are different types of stereotypes such as gender stereotypes (Bigler & Liben 1990), racial stereotypes (Wheeler et al., 2001); culture stereotypes (Christensen et al., 2014) and career related stereotypes (Kinnunen, Butler, Morgan, Nylen, Peters, Sinclair & Pesonen, 2016). Studies have been done to examine perceptions of young people through stereotypes of scientists displayed in drawings (Narayan, Park, & Peker 2007). For example, the stereotype that scientists are old, male, possibly with white hair and laboratory coats has remained over time. Another example is the stereotype that computer science disciplines in higher education are concerned primarily with programming (Kinnunen et al., 2016).

Regarding the STEM disciplines, reducing stereotypes could reduce the STEM gender gap and ultimately increase attainment in the STEM disciplines (Reinking & Martin, 2018; Makarova et al., 2019). One way of addressing stereotypes of STEM disciplines and their associated careers, is by bridging the divide between perceptions of those STEM disciplines and real career engagement (Dele-Ajayi et al., 2018). Bourdieu (2001) suggested that young people unconsciously learn or assimilate knowledge or information from their environment and therefore develop a perceived expectation constrained by the social structure. This might be one possible explanation for the aspiration-expectation gap. It has been suggested that aspiration-expectation gap is larger for those from lower socio-economic backgrounds (Stephenson, 1957; Murayama et al., 2016). Tackling career stereotypes helps ensure that young people do not rule out possible career options due to stereotypical perceptions they might have previously had about those careers (Gottfredson, 1981).

2.8.6 Embedding career information in STEM subject teaching

Gottfredson's (1981) theory on circumscription and compromise of occupational aspirations describes the developmental path of career choices as an individual grows up and how aspirations are nurtured or sacrificed through socialization and cultural learning. This highlights how young people might needlessly start limiting their options or ruling out careers they might have otherwise found interesting and possibly excelled in (Gottfredson & Lapan, 1997). Targeting career awareness of an individual at an early age is therefore important (Brott, 1993). Reiss and Mujtaba (2016) promote embedding careers information into STEM education. Making a connection between STEM subject teaching and possible careers could broaden a young person's horizon (Chambers et al., 2018). There is an increasing focus on careers by the UK government. This is shown by one of the objectives of the career strategy by the Department for Education (DfE, 2017) to ensure young people are provided with good career advice and guidance. Aspects of the government's career strategy are built around the Gatsby benchmarks framework. Gatsby provides eight benchmarks for good career guidance which include linking careers to learning curriculum, workplace experiences and encounters with Higher Education.

The importance of good career provision is emphasized for raising and widening aspirations of young people and making them open to career opportunities obtainable by them (DfE, 2017; Gatsby, 2019). It allows young people to be able to make more informed decisions about future career pathways to adopt (Gatsby, 2019). While private organisations and governments are gradually pushing for careers to be embedded in learning from a young age, Higher Institutions are not left out in promoting career messages because concrete steps are taken towards specific careers at this point in a young person's life.

2.9 Academic research and young people's interests

There have also been efforts in the past few years to extend academic research beyond academia to impact the economy, society and wider environment (Given et al., 2015; Chikoore et al., 2016; Darby, 2017; Gunn & Mintrom, 2017; Phillips et al., 2018; Watermeyer and Chubb, 2018; Wilkinson, 2019). Research impact can be divided into academic, economic and societal impact (Phillips et al., 2018). This thesis focuses mainly on societal impact.

Societal impact has been described as impact that is useful, relevant and beneficial to the society. It includes knowledge transfer; positive changes in societal attitudes, culture & lifestyles; and improved opportunities and value to society (Bornmann, 2012; REF, 2014; Phillips et al., 2018). Evaluation of academic research for societal relevance is still in its early stages (Given et al., 2015) with a growing call for more research on bridging the rigour-relevance gap. The rigour-relevance gap refers to differences in language, style and approach to solving issues, which exist in translating scholarly research work to practice (Kieser & Leiner, 2009). One suggestion to bridge this gap is to modify existing research to be relevant or useful for practice (Wolf & Rosenberg, 2012) and the wider society. While this line of research is prevalent in management literature (Kieser & Nicolai, 2005; Gulati, 2007; Kieser & Leiner 2007; 2009; Hodgkinson & Rousseau 2009; Wolf & Rosenberg, 2012), it is applicable to all types of research irrespective of subject discipline**.** Bridging the rigour-relevance gap is a means of showing how research can effectively be translated to practice with societal relevance (Phillips et al., 2018). This is evidenced by the weight the Research Excellence Framework (REF) attributes to the impact of research to the wider society across all disciplines in the UK.

REF is a system that evaluates the quality of research in Higher Education Institutions in the UK. The 2014 REF assessment included an impact measure for the first time with a 20% assessment allocation to measure the impact of research beyond academia. This was increased to 25% in the next round of assessments for REF 2021. Watermeyer and Chubb (2018) referred to the inclusion of impact in the REF as a game-changer that would impact on how academics will conduct and make known their research. Gunn & Mintrom (2017) suggested that a great potential of the impact agenda is clarification of what works that is relevant for practitioners and to guide policy and future investments.

Some research studies have examined the impact of academic research. Phillips et al. (2018) used the Academic Rigour & Relevance Index (AR2I) as a tool to evaluate societal impact of research articles in academic journals. Given et al. (2015) explored the use of qualitative approaches to evaluate societal impacts of academic research in Business and Management. Darby (2017) argued for collaboration with research partners for ethically co-produced relevant impacts. Chikoore et al. (2016) examined public audiences that academics could potentially engage with and possible engagement activities. Brooke (2018) examined the structure of evidence used in some REF 2014 case studies in Arts & Design unit of assessment. Watermeyer and Chubb (2018) explored the viewpoints of academics and assessors in humanities and social sciences. Wilkinson (2019) investigated the seeming value and challenges of evidencing research impact across different subject areas. Eilam et al. (2018) provides a framework of engagement within the university structure without necessarily going into the structure of the engagement with the programme beneficiaries.

Due to the increased concerns regarding STEM professional shortages, there have been case studies of interventions using academic research to address the STEM shortage and increase uptake within those disciplines. This section of the study refers mainly to REF impact case studies because of the difficulty in identifying STEM intervention studies in literature based on academic research, despite the vast number of STEM intervention studies available in literature. A review of case studies from REF 2014 by the thesis researcher showed a total number of 6,637 case studies and a search of the word 'STEM' produced 204 cases whilst a search of 'aspirations' produced 136 cases. Of these groups of cases, only cases that involved young people up to the age they enter university were reviewed and also only cases that are within the STEM disciplines (excluding medical sciences) were included. This exclusion criteria resulted in 22 cases (summarized in appendix A1).

Of the 22 case studies, only 5 of the cases concentrated on children in primary schools under the age of 11 years. These are: (1) An education research study from Nottingham Trent University showing increased engagement with science and technology in 4-6 year old children, using multi-sensory and multi texture artefacts to understand concepts about space and planets. (2) The National Space Centre (NSC) in conjunction with University of Leicester, explored engagement with space science for 8 – 14 year old children, through museum galleries and planetarium experiences. (3) University of Sussex's use of fundamentals of physics in enhancing teaching and young people's interest (from primary school to A-levels) in science, through talks, tours, lab days and hands-on physics activities. (4) The National School's Observatory in Liverpool John Moores University engage young people aged 8 -18 years in science, through the educational potential of its Liverpool Telescope. (5) Physics research from Oxford University that utilised graphic capabilities within a smartphone app to engage people in the Large Hadron Collider (a particle accelerator). Although only 10% of the participants were under the age of 18 in this particular case study, the research evidenced widening aspiration for further science engagement.

Four (4) of the cases studies focused on physics and one in education. All of the case studies were concerned with either exploring engagement or increasing interest in science with one providing evidence of raised aspirations in young children. This further reinforces the argument that much of the focus is on young people 11 years above with less on younger children. Efforts to widen participation and sustain engagement should target early years of a young person's education and engage the individuals at intervals throughout the course of their education.

2.10 STEM interventions and young people

Apart from REF case studies, many studies have also focussed on working with older children and young adults particularly the 14-18 years age group, with relatively few studies targeting younger children (Archer et al., 2015; Scott, 2016; English et al., 2017). Many STEM related evaluations for programmes regarding participation, achievement and attainment also focus on young people between the ages of 11-19 (Tripney et al. 2010; Archer 2013; 2015; Scott, 2015; DeWitt et al, 2016; Banerjee 2016; 2017; McCulloch, 2016; Kitchen et al 2018). One of the few examples of an intervention targeting children below 11 years used a combination of STEM and social justice to frame its activities. In this example, young people in year 3 designed shoes for refugees from recycled materials (Mildenhall et al., 2018).

Cotabish et al. (2013) identified that one of the issues of STEM education which could be associated with the persistence STEM interventions' that seem not to be working, is that many intervention programs seem to focus on a single factor rather than multiple factors.

Another issue identified is limitations of measurement systems (Saxton et al., 2014). Good measurement systems help to identify why, how and in what context something happens.

Saxton et al., (2014) argue that improving STEM facilitation and learning are dependent on the quality of its measurement and evaluation systems. If these systems are not in useful and meaningful formats, they would fail to uncover or provide important information necessary for improving or innovating. For interventions carried out in primary schools, studies suggest difficulty in finding instruments that are age-appropriate to evaluate STEM subject knowledge (Castro et al., 2018).

Evaluations have been used to investigate if STEM interventions have made any change in young people's engagement with STEM and evidence if such a change was achieved but given the large amounts of time, human resources and funding invested in STEM interventions (past and ongoing), there is still little evidence of the effectiveness of those interventions (Archer et al, 2014; *Engineering Skills for the Future, the 2013 Perkins Review revisited*, 2019). That is, the extent to which observed changes at the end of the intervention(s) can be attributed to the intervention(s). Are these interventions successfully achieving their goals and objectives? Is impact being demonstrated? The UK government Magenta book guide for evaluation (HM Treasury, 2011) suggests difficulty in showing the impact of an intervention arises mainly because of the difficulty in isolating the effects of the intervention from effects of other factors.

2.11 Evaluations

All intervention programmes are designed to bring about change. It is therefore important to funders, programme implementers and all stakeholders that these interventions function the way they are meant to. This is one of the major reasons why evaluations of intervention programmes are important.

Evaluations are assessments that enable understanding of interventions, their processes, implementation and impacts on their recipients. They enable enhancement of intervention processes and provide a justification for current and future funding (HM, Treasury, 2011). Other reasons why evaluations are good practice include, provision of accountability, change advocacy based on what works and what does not, for strategic planning of intervention activities, and for knowledge sharing. Thus, evaluations not only to investigate if a change was achieved but are also to explain or understand how and why the change was (or not) achieved which could aid learning and improvement (Allen et al., 2017). Evaluation of an intervention programme involves understanding the intended aims and objectives of the programme in order to create measurable indicators in line with the objectives to assess the impact of the programme on participants. Evaluations could aid effective allocation of resources best aligned with the programme(s) objectives therefore should be incorporated in the design stage of the intervention programme (Crawford et al., 2017).

There is an increasing call in literature for intervention programme evaluations that are flexible or more aware of complexities (Douthwaite & Hoffecker 2017; Douthwaite et al., 2003; Arkesteijn et al., 2015). Action research and adaptive collaborative approaches are some of the approaches that have been suggested (Cook, 2006; Smith, 2010, Jolley, 2014). Despite the awareness of the need, there are still few research studies that show explicit evidence-based Theories of Change with flexibility to accommodate complexities except for research in the medical sciences.

Earlier evaluations in literature were focused on the implementation of intervention programmes or projects and thus used a method-based evaluation that evaluates the process of implementation. This evaluation type came under criticism (Maru et al. 2016) because of its inability to determine the utility or mechanisms by which specific intervention programmes succeed or fail. The response to these criticisms in some fields (for example agriculture and sports) was a move from method-based evaluations to theory-based evaluation that was informed by a clearly expressed theory and could incorporate a process evaluation (Douthwaite et al. 2003; Maru et al. 2018, Richards et al 2016; Bolton et al 2018).

2.11.1 Components of an evaluation for an intervention programme

An evaluation for an intervention programme can be divided into five main components (Gertler et al., 2016) that address different types of questions regarding the intervention:

1. ***Needs Assessment*** (Identifying the problem): This component verifies the existence of a problem(s), possible sources of the problem, proposed solutions and intended recipients
2. ***Theory of Change*** (Blueprint for Change): This aspect addresses how the intervention intends to meet identified needs and bring about a change, the requirements for change and proposed alternatives
3. ***Process Evaluation*** (Making the programme work): This aspect looks at whether the intervention worked as planned in terms of delivery, timeliness and reach to intended recipients or beneficiaries

4. ***Impact Evaluation*** (Measuring how well it worked): This component is directed at uncovering if a change occurred, and if it did, the magnitude of the change
5. ***Cost-Effectiveness Analysis*** (Evidence-Based Policymaking): This aspect focuses on the cost-effectiveness of an intervention, which can be relative to other interventions or possible alternatives. This is quite useful for policy making because it provides evidence by which decisions could be made.

The type of evaluation utilized is dependent on the type of questions being asked. An evaluation framework refers to the approaches adopted in undertaking an evaluation. Different evaluation frameworks can concentrate on particular components or a combination of components. For example, an evaluation framework can focus on just the needs assessment, a combination of needs assessment and a theory of change, a combination of a process and an impact evaluation or even just a cost effectiveness analysis.

This literature review is concerned with the effectiveness of STEM interventions, and so the component of evaluation that is focused on primarily in this chapter is the impact evaluation. Crawford, Dytham & Naylor (2017) suggest a five-stage impact evaluation design consisting of review-reflect-plan-implement-evaluate stages. The review and reflect stages are concerned with understanding the aims and objectives of the intervention and reflection on how the objectives are to be achieved. The plan stage is concerned with the evaluation method(s) and data collection techniques to be adopted. The implement stage relates to the logistics of data collection; when, where and how the data would be collected, and the evaluation involves analysis of the data collected.

2.11.2 Impact evaluations

One major concern with impact evaluations is the difficulty in establishing causality due to the difficulty in isolating the effects of the intervention from other effects; which could have happened anyway with or without the intervention (HM Treasury, 2011). Impact evaluations are evaluations that attempts to answer questions with a causal dimension or effect. This type of evaluation involves outcomes and attribution (HM Treasury 2012b). The outcomes are concerned with what actually happens (effects) from an intervention while attribution refers to the ability to show if such an intervention was/is responsible for the observed outcomes. Causality is not always necessarily linear or unidirectional (Rogers 2008). Gorard, See & Davies (2012) suggested four elements of evidence relevant to establish causality. These elements are ‘association’ (cause and effect) where a measurable indicator of a cause can be clearly linked to an outcome usually through correlation. The second element ‘sequence’ (cause to effect) describes a situation where a cause can be established and can be shown to exist before an effect and can also be used to predict the effect, usually through longitudinal research. The next element ‘intervention’ (effect from cause) highlights evidence that an effect could be explained by a particular cause. Research points to the difficulty in isolating a cause as the only possible explanation to an observed effect but suggests a possible way of achieving effect from cause through Randomised Control Trials (RCTs). The last element of evidence for causality suggested by Gorard et al. (2012) is ‘explanation’ (how the effect is caused) which consists of a logical and credible account of the measurable indicators of the cause influenced the observed effect.

Van den Hurk (2019) conducted a review of literature assessing the effectiveness of STEM interventions from 538 studies, findings suggested no agreement on interventions that successfully raised interest in STEM and suggested need for more research on the effectiveness of STEM interventions.

Impact evaluations alone might have reduced usefulness for decision making because such an evaluation is only able to assess if a change occurred as a result of the intervention but might not be able to explain why (or why not) such changes were observed. Some researchers have suggested that the combined use of process evaluation and impact evaluations provide an effective evaluation framework. The combination provides a systematic evidence base of what works (or does not work) and under what conditions the interventions work; as the process evaluation is able to explain the results of the impact evaluation (HM Treasury, 2011). Process evaluation is also carried out to understand why (why not) an intervention is successful and is relevant for insights necessary for enhancing the impact of an intervention (Crawford, Dytham & Naylor, 2017).

An impact evaluation framework refers to an evaluation framework primarily focused on the impact or effectiveness of a programme; it explains how the impact evaluation is done. New Philanthropy Capital[2](NPC) suggested a four-pillar approach to establishing an effective

[2] NPC is a charity organization that works with funders and organizations to try and achieve the most impact from activities or interventions they fund or undertake.

impact evaluation framework (Kazimirski & Pritchard, 2014). The four pillars are outlined below but are further discussed in the next chapter (section 3.6).

- Mapping a Theory of Change
- Determining the most relevant outcomes and how they would be measured
- Deciding on the level of evidence to adopt and finally
- Determining sources of data and required tools

A Theory of Change is a visual representation of a causal framework of how and why a change would occur in a specific context (Davies 2018); it is a pathway of change that shows the links between various sections or components (Prinsen & Nijhof 2015). Different programmes might have their own different Theory of Change, which can link to an overarching Theory of Change. By outlining the objectives and outcomes desired clearly, a Theory of Change aids understanding of what works, how and under what circumstances or situations they work (or not). It also helps planning and identification of adequate indicators of each outcome in order to assess the level of impact(s) achieved (Allen et al. 2017).

2.12 Theory of Change

A Theory of Change provides statements explaining how specific interventions are to bring about change and justifications of why the change(s) are expected. It is a visual representation of the achievement wanted, how the achievement will be attained and why this approach should work. It shows the link between various sections or components with justification for the rationale.

The use of 'Theory of Change' in the field of evaluation can be traced back to the 1990s (Stein & Valters, 2012; Archibald et al., 2016; De Buck et al., 2018). It has been used largely in agricultural programmes (Maru et al., 2016, Douthwaite & Hoffecker, 2017), international development (Prinsen & Nijhof, 2015; Archibald et al., 2016; Davies, 2018), and medical research (Maclean & Vannet, 2016; Mackenzie & Blamey, 2005). Some other areas where Theory of Change has been used include leadership development (Watkins et al., 2011), organizational research (Richards et al., 2016); sports (Bolton et al., 2018) and environmental health (De Buck et al., 2018).

Theory of Change helps explain why and how particular intervention programmes work (Davies, 2018); under which conditions or contexts the intervention programmes work and its beneficiaries (Maru et al., 2016; Connell & Kubisch, 1998; Pawson & Tilley, 1997;

Rogers et al., 2000; Douthwaite & Hoffecker, 2017). This is necessary for translation of research into practice and to aid accurate replication of the successes of an intervention programme beyond the test locations and into other possible contexts. It provides clarity of goals and objectives that aid understanding and makes it easy to communicate an intervention's message (Bolton et al., 2018; Richards et al., 2016; Guarneros-Meza et al., 2018; De Buck et al., 2018). It also aligns activities to goals and as such sets realistic expectations. A laid out Theory of Change helps the evaluation process because inputs, outputs and outcomes are clearly specified with measurable indicators.

Theory of Change is a useful model that is robust enough to accommodate learning and collaboration; its flexibility can accommodate uncertainties and allows for multiple iterations during the design (Davies, 2018; Guarneros-Meza et al., 2018). It is cost-effective and flexible such that it could work with other evaluation techniques or instruments. It has also been described in the literature as a process as well as a product (Vogel, 2012). The iterative process of outlining the objectives and linking the activities to the outcome is an example of Theory of Change as a process and the framework as the product consisting of the different logic models (Anderson, 2005; Taplin et al., 2013; Allen et al., 2017). The process evaluation would help investigate if the intervention worked in the way intended, also uncover unintended consequences, constraints, or other change dynamics.

An explicit Theory of Change is also useful for funders to aid transparency and to hold the implementers accountable for what they have set out to do (Plimmer & Kail, 2014). It also helps frame specific intervention programmes within a wider context. It helps highlight how specific programme interventions contribute to short-term or long-term goals. The transparency and clarity of the Theory of Change can inform learning by highlighting aspects of the programme intervention that contributes the most to the observed outcome effects. The process evaluation would help to track and highlight discrepancies between the intervention(s) as designed and as implemented.

Developing an explicit Theory of Change enables all stakeholders and possible funders to understand the change process and examine the extent to which those processes align with the programme theory by specifying the underlying logic, short- and long-term outcomes, possible causal linkages and any assumptions made. It helps by framing the intervention(s) for evaluation. It also helps refocus attention from current activities being undertaken to outcomes that need to be achieved. It lets programme implementers know where it might be necessary to make mid-programme alterations through the learning process.

Research studies suggest that while Theory of Change models should ideally be developed and utilized from the beginning of an intervention, most models are designed ex-post (after the intervention has finished) (Bolton et al. 2018; Guarneros-Meza et al. 2018). This limits reflection of intended beneficiaries' voice or viewpoint which should be one of the strong points of using a Theory of Change framework.

In developing a Theory of Change, backward mapping has been suggested (Anderson, 2005) starting from the main objective to outcomes necessary to achieve the main objective. It is also important that all stakeholders clearly agree on the final goal or outcome desired because research has shown that different stakeholders tend to have diverse viewpoints on what the main or final objective is (Anderson, 2005).

It is also a way that stakeholders could examine the level of influence that could be achieved and if those goals or objectives could be realistically attained within the set timelines with respect to available resources.

2.12.1 Components of a Theory of Change

Theory of Change takes into consideration stakeholder involvement to build links between the intervention process, the evaluation, decision making and policy by clearly defining the logic that leads from the goals to the results. A Theory of Change has some main components with some variations about these components in the literature (Bolton et al., 2018; Richards et al., 2016; Guarneros-Meza et al., 2018; De Buck et al., 2018). The components used in this study are summarised below:

Ultimate Goal: The main effect(s) or impact expected from the programme as a whole: what one hopes to achieve at the end of the programme. For example, since STEM workforce in the next few years is projected to be inadequate to meet demand, some possible goals could be to increase uptake in STEM fields, and reduce attrition in those fields.

Intermediate Outcomes: Refers to what changes should occur within the target group to achieve the intended goal and specification of which of the outcomes the project is targeting. For example, intermediate outcomes could be to improve interest in STEM subjects, widen aspirations, improve self-efficacy, reduce gender gap, etc.

Some of the intermediate outcomes might lead to other intermediate outcomes and it is important to state clearly the rationale behind proposed causal linkages. Also, outcomes should be specific, measurable, attainable, relevant and time-bound- SMART (Jones et al., 2012; Allen et al., 2017).

Preconditions: These refer to what has to happen for the main goal to be achieved. They are conditions which need to be in place regarding the programme for specific outcomes to be successful. Preconditions are not necessarily addressed by the programme but such information might be included because it helps identify future areas to address, or areas that have been addressed, or potential for collaborations.

Causal Links: Arrows that show which interventions lead to which outcomes and how they link to the ultimate goal, and the links identified can be used to explain the rationale. For example, exposing young people to female role models in a profession that is predominantly male dominated might make some of the young females consider a career in that profession, which in the long term might lead to a reduction in the gender gap in such a field. This causal link could be inferred because research shows that role models in such fields can influence young people's decisions or interests (Gamse, Martinez & Bozzi, 2017). The causal links also need to be feasible (Getz 2019). The extent to which the logic of the model can be followed to achieve the desired outcome is useful in validating the theory with respect to effectiveness and sustainability (Richards et al. 2018; Getz 2019).

Indicators: These are measures to provide evidence to show that a component of the Theory of Change has been achieved. For every indicator, there should be thoughts towards what is being measured, who the target population is, how much change is expected, when these changes are expected to work and how one can identify that the goal has been reached. Usually the measures being used are identified and chosen before indicators for such measures are selected; the measures should inform the selection of suitable indicators.

Assumptions: These refer to assumptions made regarding the causal links in order to identify possible arguments as to why that causal link may not hold true. The assumptions identify links that are less convincing or contestable. For example, young people have to see the role models as role models, or there is an intent to increase science knowledge of families because it is assumed that family members will talk to the child(ren) about science or not.

It is very important in a Theory of Change to articulate the assumptions because they form the backbone on the causal linkages to the outcomes. Assumptions refer to the fundamental beliefs that inform or drive the intervention programme perspective. Anderson (2005) suggests that the articulation of assumptions is the most relevant part of the Theory of Change because it allows stakeholders to challenge each other's viewpoints on what assumptions must hold for the interventions to be successful. It will also help identify assumptions that might not be easy to defend and which of the assumptions are testable. Archibald et al. (2016, pg. 119) refer to assumptions as the '*Achilles heel of intervention programmes'* and the extent to which the assumption can function as a useful resource or a risk is dependent on how clearly articulated it is. Archibald et al. (2016) describe two types of assumptions: the first type are assumptions regarding precondition(s) that are necessary and/or sufficient for outcomes to be achieved, while the second type of assumptions are those regarding external factors beyond the control of the programme but which significantly impacts on the outcome of the programme.

External factors refer to conditions beyond the control of intervention programme or evaluation that could influence the extent the intended effects are accomplished (Hansen et al., 2013). The consequences or effects of the programme refer to the intended or unintended changes that occur as a result of the programme; they are a function of the programme activities and the external factors.

The group of linked outcomes is referred to as the '*pathway to change'*, which forms the backbone of the Theory of Change as a representation of the process of change as visualized by the programme initiators. The challenge with explicating the assumptions of a Theory of Change is determining which of the assumptions are essential for successful outcomes. The Theory of Change framework provides a method of understanding actual barriers and enablers for successful attainment of set objectives or main goal (Bolton et al., 2018). Many Theory of Change models can be complicated and may require extensive discussions to explain the different aspects of the model. One way to address this is the use of 'nested' models that break up an over-arching theory of change model into smaller sections.

2.12.2 Nested Theory of Change

Some research studies (Hansen et al., 2013; Mayne, 2015; Douthwaite & Hoffecker 2017; Bolton et al., 2018) have discussed or made use of a nested Theory of Change that is derived from an over-arching Theory of Change Model. The nested model offers an in-depth narrative on a subset of the over-arching model in terms of specific beneficiaries, stakeholders and intervention programmes. Nesting also helps to keep the over-arching Theory of Change from getting too complicated which might make the model less coherent (Douthwaite & Hoffecker, 2017). A nested Theory of Change could be derived from one of the objectives of an over-arching Theory of Change, have its own set of objectives but be working towards achieving or contributing to the final goal of the over-arching Theory of Change.

Bolton et al. (2018) highlight some cautionary notes in using a Theory of Change. Researchers should ensure that in the process of concentrating on intended outcomes they should be aware of the possibility that unintended outcomes or consequences that might occur. For example, a STEM intervention that is geared towards encouraging more females to aspire to careers within a specific STEM discipline should not end up dissuading boys from aspiring to that discipline. A Theory of Change model (over-arching or in its nested form) also makes use of logic models to communicate how specific programmes are implemented and aids evaluation of the programme to ensure its achieving its intended objectives (Bolton et al., 2018).

2.12.3 Difference between Theory of Change and logic models

A logic model helps to ensure effective implementation of a program. The logic model describes the components of an intervention by identifying the inputs, activities, outputs and outcomes (both intermediate and long term) while Theory of Change links the activities to the outcomes by articulating the assumptions held and explaining why and how what is being done in an intervention would bring about a particular change (Mayne 2015; Davies 2018; Dhillon & Vaca, 2018; Getz, 2019). The logic model is about a particular intervention while the Theory of Change starts with a goal and links back to one or more intervention or activities. The logic model does not say why something should lead to an outcome but Theory of Change gives justification at every stage for any proposed casual link. The logic model (Kellogg, 2004) provides extensive detail regarding scope, context and process of an intervention programme outlining the different activities relevant to contribute to the specified outcomes intended. Some components of a logic model as mentioned earlier, include the intervention activities, inputs and outputs.

Intervention Activities: These are the activities that are directed at effecting those changes with brief information explaining what the activities within an intervention entails for example specifying the number and length of sessions of the programmes.

Inputs: These refer to all the various resources that are needed to be able to carry out the interventions or activities for example the amount of human capital required to run the activities.

Outputs: These are just measurable descriptions of the results of the intervention, for example, the number of people that attended the activity. Examining the outputs can reveal or uncover unintended consequences.

A logic model complements a Theory of change. They work together to help programme implementers and organizers make explicit how the intervention is meant to make a social impact. Theory of Change describes how the programme is meant to achieve or lead to a desired outcome by linking the inputs, activities and outputs from a logic model to the outcomes. Together, they aid assessment of the implementation of the intervention: to evaluate if the intervention was implemented well and if the right group in need were targeted. It helps to focus on whether the inputs lead to the outputs and also uncover assumptions made across the whole process. The use of a Theory of Change and logic model(s) together ensures alignment of activities to the objective(s) of the intervention and that those objectives are achieved.

2.13 Learning theories

To further understand how and why changes occur with young people in an intervention, it is necessary to look into learning theories. Learning involves change, obtaining and adapting knowledge and ability (skills) sets (Schunk, 2012). For example, learning involves ability or capacity to change skills, behaviour and attitude. Learning is not always directly observable, for example, when individuals are being taught, learning could be inferred though outcomes or products of activities these individuals engage with. While learning focuses on the individuals and what they learn, pedagogy focuses on the process of learning. Pedagogy refers to teaching techniques, processes and practice (Robinson, 2016).

Pedagogical learning theories provide understanding of how people learn (Harasim, 2017). They help researchers think about why and how change in learning occurs (Bell, 2012). Three popular learning theories are behaviourism, cognitivism and constructivism. These three learning theories have been discussed extensively in literature (Roy & Novotny, 2001; Bell 2011; Schunk, 2012; Harasim, 2017; Castro et al., 2018). With the wide spread use of technology in learning, another learning theory emerged; connectivism (Siemens, 2017).

2.13.1 Behavioral learning theory

Behaviourism as a learning theory emerged in the 1900s (Doolittle & Camp, 1999) and suggests that learning is based on prompts or signals from the environment (Roy & Novotny, 1999). Perceived positive or desired responses and behaviour are encouraged, supported and repeated. Behaviourist learning theory relies mainly on an instructional design with distinct learning steps that are empirical, observable and can be measurable and replicable (Harasim, 2017). Knowledge is conveyed from the teacher to the learner in objective forms (Bell, 2011). Learners play a more passive role using this approach.

Direct Instruction is a learning approach derived from behaviourism which highlights the importance of explicit guided instruction for better learning outcomes (Charles, 2014) considering the limited working memory capabilities of learners. Working memory refers to the short term memory that is used to hold information for processing in human consciousness, it has limited capacity.

One of the main criticisms of behaviourism is its inability to explain social behaviours (Harasim, 2017). Another limitation of this learning theory is the consideration of the human mind as a blackbox, therefore whatever happens in the mind is not taken into account (Harasim, 2017). Cognitive learning theory on the other hand, considers what happens in the mind.

2.13.2 Cognitive learning theory

Cognitivism is centred around mental processes necessary for cognitive development. Learning is described in this theory as a process with more emphasis on context than environment (Roy & Novotny, 2001). It focuses on what happens inside the mind and represents or replicates the human mind computationally. The human mind creates mental representations and during learning, new information or knowledge is integrated into the mental representations using a set of processes for manoeuvring through pre-existing and new knowledge. The learner could be viewed as an information processor (Bell, 2011) while the educator or teachers helps the learner to organise and categorise the information (Roy & Novotny, 2001). Criticisms of this learning theory are around some of the assumptions of this learning approach. One of such assumption is that learning through thinking is a function of the mind alone rather than a combination of interactions between the mind, other people and the environment (Schunk, 2012). Also the approach focus on learnings in formal instructional scenarios rather than incorporating learning from experiences and distinctive abilities. Constructivism addresses these criticisms by emphasizing the interaction between a learner's experiences, their abilities and the environment (Dolittle & Camp, 1999).

2.13.3 Constructivist learning theory

Constructivism is described in literature studies not only as a learning theory (how people learn) but also as a research epistemology (Doolittle & Camp, 1999). As a learning theory, constructivism highlights the significance of social influences; learners socially construct meaning based on their experiences and the environment (Doolittle & Camp, 1999; Harasim, 2017). Constructivism has been widely explored in literature (Schunk, 2012; Harasim, 2017; Castro et al., 2018) with different developed research streams. The different streams have been described along a continuum (Dolittle & Camp, 1999) between cognitive constructivism and radical constructivism at both ends. Another stream, social constructivism, lies somewhere in-between both ends. Cognitive constructivism, with some roots in cognitive learning theories, focuses on how learners develop their cognitive abilities. It is associated with Information processing. Building on the foundation of prior knowledge, people are able to construct new knowledge (Robinson, 2016). Social constructivism highlights social interactions influencing how a person generates or acquires knowledge (Bell, 2011). Unlike in behaviourism, learners using a constructivist approach play an active role, with their independence emphasized (Charles, 2014). This approach suggests that limiting guided instruction and increasing creative constructed thinking will develop higher order thinking in learners. A criticism of this approach is the assumption of all knowledge being constructed by the learner for understanding to occur disregarding knowledge gained through guided instruction, explanation or by discovery.

2.13.4 Connectivism learning theory

Connectivism, focuses on the learning environment in a technological age. It is a well-known network learning theory for e-learning (Siemens 2004; Goldie, 2016) with wide applications in massive open online learning (MOOC). Some of the major principles of this approach is that learning resides in the differences of opinions, it is a process of linking different information sources and could exist in non-human objects or applications (Bell, 2011). While cognitive theory views learning changes in a person's mental construction, learning in connectivism is as a result of interactions between different information connections and their structures rather than from a single source (Goldie, 2016). One of the main criticisms of this approach is that many of its fundamental principles are drawn from other theories particularly constructivism. Also, the approach on its own is not sufficient to inform learning but dependent on other theories of learning (Bell, 2011).

2.13.5 Case for combining learning theories

Although each of the learning theories have distinct research streams, there have been calls in research studies to explore complementary aspects of the different theories (Hung, 2001, James-Gordon, 2003; Charles, 2014). A reason for this is that, decisions on which theory of to use is dependent on the scope and objectives of an intervention (Bell, 2011) where a single theory might not be sufficient to accommodate the learning requirements needed. Roy and Novotny (2001) argued that due to the complexity of human behaviour, it is difficult for a single theory to sufficiently explain or accommodate all types of learning situations, therefore the need to combine theories.

For example, while constructivism and direct instruction diverge on different issues particularly around the level of guidance required by a learner, they both agree on the need for some scaffolding (learner support) with the level of scaffolding reducing as learning occurs (Charles, 2014).This shows common ground from which integration of the two theories could be explored.

2.14 Limitations of research studies to date

Despite substantial investments in STEM interventions, many of the interventions have focused their STEM activities on the science and mathematics aspects compared to the technology and engineering aspects (Castro et al., 2018), particularly for the younger age group.

As mentioned earlier in the chapter, many of the interventions have focused on young people in secondary schools and above (11-19 years) with less focus on the younger age group (below 11 years). Research suggests that it is difficult to find instruments that are age appropriate to evaluate STEM subject knowledge, particularly for the younger age group

(Castro et al., 2018). Castro et al. (2018) argues for the need of explicit evaluation of STEM knowledge for younger children.

When translated into practice, intervention programmes do not usually follow linear pathways as described in a method-based system but actually consist of unpredictable factors in a complex system (Douthwaite & Hoffecker 2017). The Theory of Change approach is able to incorporate the flexibility that is required for a complex and dynamic system or context (Prinsen & Nijhof 2015; De Buck et al. 2018). The Theory of Change model is currently being used in different fields, but has not been used as widely in engineering and education.

There is scarcity of research regarding the process of evaluating societal impact of academic research, with most studies concentrating on pathways to impact with less evidence of experiences and evaluation of the impact (Watermeyer and Chubb 2018). Measurements of the impact of university-led STEM activities or interventions to society are still in its early phases (Eilam et al., 2018). Gunn & Mintrom (2017) referred to the state of academic research evaluation currently being at a critical juncture. There is increasing interest in evidencing the societal impact of academic research. Despite this interest, many of the studies have focused on the stakeholders, with less focus on the application of research. A report by the National Co-ordinating Centre for Public Engagement (NCCPE) shows that evidence of impact of academic research on public awareness and understanding has been mainly centred on either the number of people or the list of organisations or groups engaged (Duncan et al., 2017; NCCPE, 2019). NCCPE is an initiative hosted by University of Bristol and University of the West of England. NCCPE is aimed at improving practice of public engagement including providing support for universities' public engagement. NCCPE is funded by UK Research and Innovation (UKRI), Wellcome (a leading charity in UK) and other Higher Education funding organisations including Scottish Funding Council (SFC), Department for Employment Learning (DEL) in Northern Ireland and HEFCW.

The focus of this study is to develop an evaluation framework that is useful to academics to assess and aid the implementation and maximization of impact for intervention engagements with primary school aged children across multiple engagement activities. The framework developed in this study is aimed at providing a systematic evidence base to influence interests (aspirations) of young people that provides users access to information on intervention processes, impact that could aid understanding of what works (or does not work) and under what context or circumstances such changes can be observed to inform future interventions in this area.

2.15 Summary

This chapter reviews literature on STEM intervention programmes intended to address the shortage of STEM professionals and how effective those interventions have been. It also discusses evaluation and its components, Theory of Change, young people's interests and academic research as related to STEM. The chapter highlights the limited number of interventions that focus on a younger age group and their aspirations, and the limited evidence of the impact or effectiveness of those interventions.

CHAPTER THREE - METHODOLOGY

3.1 Introduction

This chapter details the methodology adopted for this research study. It discusses the different philosophical paradigms and why realism and constructivism were adopted in this study using a multiple worldview approach. The three theoretical lenses from which the study is approached are then discussed. These are the Theory of Change process, two learning theories (Direct Instruction and Cognitive Constructivism) integrated together to provide an effective learning experience for the participants, and logic models. The action research approach using multiple case studies from three different STEM disciplines (computing, materials science and geography) is explained. The steps used for the impact evaluation are outlined using NPC's 4-pillar approach to evaluation. This is followed by a thorough description on how the intervention workshops were developed and the logic models created. The evaluation tools used in the design and implementation of the workshops are also discussed. The study was carried out in two phases, the pilot and main intervention workshops across each of the different disciplines. A clear description on how the research data was collected, analysed and underlined by the iterative action research cycle is presented and finally the ethical considerations in undertaking this study are discussed.

3.2 The research process

The research process discusses the considerations and processes in which research is conducted. It discusses the philosophical, theoretical and methodological approach underpinning a research study. Figure 1 below provides an overview of the research process adopted for this study.

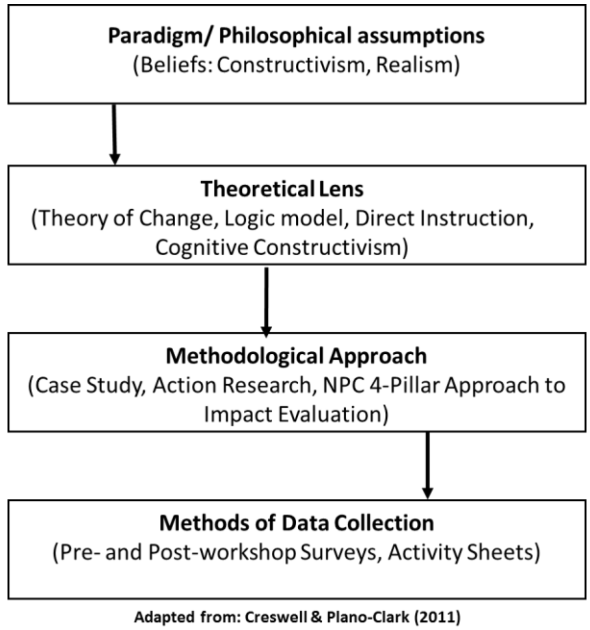

Figure 1: Graphical representation of the research process adopted

3.3 Worldviews

Worldviews, also known as philosophical assumptions or paradigms (Lincoln, Lynham & Guba 2011; Mertens, 2010), are beliefs that impact researchers and how researchers go about their research (Creswell, 2009). These paradigms or philosophical backgrounds are the foundations from which research process(es) are built, and drive the methodological approach and research methods to be adopted. According to the literature, world views differ depending on the **ontology** (belief about reality), **epistemology** (how the researcher acquires knowledge of what is being studied; the rationality of belief), **axiology** (the value system of the researcher that guides what they do), and **methodology** (the research process) (Lincoln & Guba, 2000; Creswell & Plano Clark, 2011). Researchers can have a particular worldview or adopt a combination of paradigms (also known as multiple worldviews). Some of the well-known worldviews in the literature are positivism, constructivism, pragmatism and realism.

3.3.1 Positivism

Positivism is a belief position deeply rooted in science and is based on scientific rationalism or empiricism (Henderson, 2011). This is a very traditional position that depends on a world or reality that is objective, stable and predictable (Sharp et al., 2011). A post-positivism perspective, developed after positivism, queries the claim of an absolute truth. A post-positivist adopts a deductive approach with a deterministic philosophy of cause and effect that are mostly identified with quantitative research. This paradigm has been referred to as the scientific method of research (Creswell, 2014). One of the major assumptions of this paradigm is that there is no absolute truth and that is why no hypothesis can be proven. Other assumptions are that empirical evidence shapes knowledge and the paradigm adopts an objectivity epistemology where researchers work to get rid of bias. Some proponents of this worldview are Durkhiem, Newton & Locke (Smith, 1983) and Phillips & Burbules (2000). Many core engineering research studies adopt a positivist or post positivist stance particularly those that do not involve collecting data from human participants. One of the issues with the positivist and post positivist stances is that many of the factors used in the field, especially when working with human beings, cannot be or are not easily measurable directly – essentially, they are 'unobservable' (Durand & Vaara, 2009). This perspective does not take into consideration the role of the observer (Umpleby, 2007).

3.3.2 Constructivism

This position adopts an inductive approach to research and therefore is usually qualitative. Constructivists believe in multiple realities, which are socially constructed. One of the major assumption of this paradigm are that subjective meanings are generated from interaction with one's community. In addition, interpreting reality depends on historical and social viewpoints. Constructivism uses an epistemology of proximity and a subjective perspective; where researchers are in direct contact with their respondents. Some initial proponents of this perspective are Berger and Luekmann (1967), Lincoln and Guba (1985) and more recently Mertens (2010).

3.3.3 Pragmatism

Unlike positivism that focuses on strict structures of reality, and constructivism with many subjective realities and no particular claim to truth, pragmatism utilizes an epistemology of practicality. It can adopt either a single reality or multiple realities depending on what works to resolve the research question. The main objective of this perspective is problem solving (Dewey, 1988) and it provides a link between theory and practice. Some other proponents for this paradigm are Patton (1990) and Creswell (2014). This paradigm allows for a combination of different research methods depending on what is being studied. Proponents of this perspective argue that there is a continuum between positivists and constructivists and the direction adopted should be dependent on the research or problem being addressed

(Creswell, 2003; Giacobbi et al., 2005). This perspective highlights the importance of the observer and actions taken with less focus on describing context (Umpleby, 2007).

3.3.4 Realism

Another paradigm that developed in criticism of the positivist view is realism. Proponents of this perspective believe that reality exists outside of and independent from, our awareness and understanding of it and that falsification and verification is necessary for the advancement of theory (Miller & Tsang, 2011). This paradigm is common in the field of evaluation (Pawson & Tilley, 1997; Maxwell & Mittapalli, 2010) and has been integrated with the constructivism epistemology of reality being understood from one's own perspective, and highlights the importance of descriptive construction. Practical application of realism regarding causality is by means of logical inferences to explain observed phenomena or events. This can be carried out by identifying mechanisms that can cause or produce those events (Zachariadis et al., 2013). This approach is consistent with the Theory of Change process.

3.3.5 This study's worldview

This research adopts a multiple worldview approach making use of both constructivism and realism paradigms. Since the research relies on the socially constructed subjective perspective of children regarding their aspirations, perceived understanding of occupational knowledge or subject specific concept knowledge, this is consistent with the constructivism paradigm and its ontology of different individuals having different interpretations of reality. In addition, due to the multidisciplinary nature of the research, different aspects of the research may not fit into the same structure across the different disciplines or workshops and thus need adaptations specific to the discipline or workshop. This is consistent with the realist paradigm; its epistemology is compatible with the other paradigm's nature, which accommodates different perspectives about reality without necessarily agreeing to multiple realities. It also accommodates multiple research methods.

3.4 Theoretical underpinnings and scope of the research

The theoretical underpinnings refer to the theoretical lenses that can be used as guides to the structure of a research study. This section describes the scope of this research using three theoretical lenses. (1) The Theory of Change process (as discussed in the literature review section) which is the over-arching theoretical process underlying the design of this research; (2) an integrated framework of elements from two learning theories; Direct lnstruction and Cognitive Constructivism which serves as a guide in engaging the participants and facilitating learning; (3) logic models which guide workshop implementation.

3.4.1 Theory of Change

The Theory of Change model adopted is drawn from the over-arching Theory of Change for NUSTEM at Northumbria University. The NUSTEM team works with young people and their circle of influence to cultivate interest in the STEM disciplines and reduce the gender gap in those fields. The main Goal or objective of NUSTEM is having **'more young people choose a career in STEM post-18*''.***

In order to achieve this goal, NUSTEM identified the key stakeholders that are necessary to achieve the aim as outlined below:

- ***Young people***
- ***Teachers and school community***
- ***Families and carers***

The scope of this research study does not extend to cover all of these. It is focused on work with young people with the intention of increasing the diversity of young people choosing a STEM career by opening up their aspirations and helping young people see people in STEM careers as being for 'people like me'. Although NUSTEM works with young people from pre-school to sixth form, this research focuses only on work with primary schools, particularly young people in Year 3 up to Year 6 (aged 7 – 11 years). The literature suggests the need to intervene at an early age to impact on young people's future career paths (Archer et al 2014c; Chambers et al., 2018) and evidence shows that children as young as 6 years have already started having conceptions of what they would like to be when they grow up (Hughes et al., 2016). This research provides an innovative Theory of Change model that builds on a section of the over-arching NUSTEM Theory of Change model. It also focuses primarily on intervention workshops that are based on the research work of academics, particularly with the current focus on extending academic research beyond academia to impact society and the environment.

3.4.2 An integrated framework from two learning theories

The two learning theories integrated in this study are 'Direct Instruction' drawn from Behaviourism learning theory and 'Cognitive Constructivism' which is drawn from Constructivism learning theory with some roots in Cognitive learning theory.

Direct Instruction highlights the role of the environment and importance of explicit instruction with less focus on individual differences of participants. Guided instruction is used to promote learning using a step by step approach to develop proficiency. This learning approach was adopted because children participating in the workshops may not have prior knowledge with the concepts being taught. This approach accommodates for low or no level of previous knowledge. Cognitive Constructivism on the other hand highlights the role of the participant and knowledge creation. This learning approach was adopted because the research is concerned with children's representations and perceptions which are socially constructed based on prior knowledge and experiences. An issue with this cognitive constructivist approach has been raised in the literature. This is the assumption of prior knowledge of the participants with regards to the subject content being taught. Since prior knowledge might be required to effectively construct new knowledge, depending on the level of expertise required, cognitive constructivism might not be sufficient for participants with no prior knowledge (low expertise or novice level).

Combining elements of both pedagogical learning theories enable the workshop designs to benefit from the strengths of both theories, and integrating them also compensates for the weaknesses of each. While Direct Instruction will accommodate learners with little or no prior knowledge about the subject content, Cognitive Constructivism will accommodate the individual differences of the participants thereby enabling participants to work independently and creatively. Four elements from Direct Instruction are adopted in this study which are (1) conceptual mapping, (2) structured instruction, (3) seatwork and (4) interactive questioning. Four Elements of cognitive constructivism are also adopted for this study to enable effective learning which are (1) triggering prior knowledge, (2) eliciting a surprise moment from participants, (3) application of new knowledge and (4) feedback.

3.4.3 Logic models

The logic model guides the implementation of an intervention by describing the components of each individual workshop, by identifying the inputs (all the various resources needed to make the workshop work), activities (the activities directed at effecting expected changes), outputs (measurable description of result sources) and outcomes (short or medium term results expected such as changes in behavior, attitudes or knowledge). Each individual workshop had a logic model designed for it with each workshop having its objectives aligned to the overall theory of change intended outcomes. These workshops are discussed as case studies in chapter 4.

3.5 Methodological approach

This study adopts an action research methodology consisting of multiple case studies from the different intervention workshops based on research work by academics from different STEM disciplines. The case studies from the following subject areas were considered for this research study: Engineering & Technology, Physical and Environmental Sciences, Computer Science and Architecture, Building and Planning. These subject areas were selected due to the reduced uptake in those disciplines within the past 10 years in the UK (Universities UK, 2018). This is shown in Table 2.1, participation of students in some STEM subjects, in the previous chapter. The following sections describe the methodological approach adopted in this study.

3.5.1 Action research approach

Action research is a method of inquiry grounded primarily in qualitative research. It is phenomenological and hermeneutic because it is centered around specific experiences and/or events and how such events or experiences are interpreted and/or socially constructed respectively (Stringer, 2014). It is also consistent with the constructivist and realist paradigms. Denzin and Lincoln (1994) refer to action research as a localized action based approach to providing customized solutions in specific contexts. Other researchers have referred to action research as a life enhancing, collective and a community based approach (Whitehead et al., 2003; Lingard et al., 2008; Stringer, 2014).

One of the main advantages action research is used in this study, is that innovative solutions can be created and identified for a specific situation by a combination of varying sources of knowledge, expertise and experiences. This is due to the agreement, collaboration and collective vision of participants and stakeholders that should occur by using this research approach. In this study, action research supports an in-depth understanding of the outreach activities of the NUSTEM and gives room to reveal new insights that might not be straightforward or clear-cut. This provides avenues for creating innovative solutions to significant issues or circumstances. All the workshops were designed using the cyclical four stages of action research (Kemmis & McTaggart, 1988; MacIsaac, 1995; Gabel 1995): reflect, plan, act and observe. The *reflection stage* includes identifying and engaging stakeholders, identifying aspects of the academic(s) research that should be incorporated in the workshop and the main objectives of the workshop. The *planning stage* includes creating/designing the actual workshop; identifying and designing the activities to be used, designing the evaluation tools, engaging the schools that will be involved and identifying beneficiary cohorts of young people. The *acting stage* consists of the implementation/delivery of the workshop, evaluation of the workshop, observation of the workshops and analysis of data collected. The *observe stage* includes using the findings from the acting stage to identify what worked well, what did not work well, key lessons learnt from the workshop and its findings.

3.5.2 Case study approach

This study adopts a case study method (Yin, 2003). Research studies that have used Theory of Change (Maru et al., 2016) have often used case studies as a method to describe the pathways to impact of intervention programmes. Some of these studies use a single case study (Boyce, 2017) while others use multiple studies (Watkins et al., 2011; Douthwaite & Hoffecker, 2017). This study adopts multiple cases studies to showcase the different intervention workshops, highlight their similarities and differences and map the individual workshop's logic model to the overall Theory of Change model, to evaluate the impact of the workshops. A cases study was selected in engineering because of the reduced uptake in Higher Education (Universities UK, 2018) and the ease with which engineering can be integrated with other subjects. For example, integration with mathematics and English to teach learners (Roger & Portsmore, 2004). Material science was chosen for this study because while still under engineering, it provides a variety of practical real life examples that could be used to teach concepts (David & Wilcock, 2003). Within the physical and environmental sciences, geography was chosen because research suggests that awareness of geography as a discipline tends to get lost within the physical sciences (LeVasseur, 1999) and knowledge about the wide range of careers with respect to geography is limited. Review of studies by Bednarz et al. (2013) showed that geography education, particularly physical geography, is not taken up by schools, with teachers in primary education having little subject content knowledge. Subjects in architecture and building planning were considered because of the huge decline in uptake within the past ten years (Universities UK, 2018). Computer science also showed a slow growth in the number of students taking up the discipline in universities within the past few years as shown in Table 2.1 in the previous chapter. Also, there are some negative and unflattering stereotypes attached to computer science discipline (Christensen et al., 2014).

3.6 NPC 4-Pillar approach to impact evaluation

The study adopts the NPC 4-Pillar approach to designing an effective impact evaluation framework. This is outlined in the following sections in 4 steps.

3.6.1 Step 1 - Mapping a Theory of Change

As discussed in section 3.4.1, the Theory of Change model is drawn from the over-arching NUSTEM Theory of Change. The Theory of Change model in this research is a nested model of NUSTEM's model, focusing on work with young children. The outcomes for the nested model are derived from approaches as previously discussed in the literature review chapter to improve uptake in STEM (section 2.8). The model is designed through backwards mapping to understand the pathway of change required to achieve the main goal: increasing the uptake of STEM disciplines. A major prerequisite for uptake into the STEM disciplines is choosing the right set of subjects in secondary school to enable entry to those disciplines at further and higher education. Many interventions in secondary schools have provided programmes or workshops to sustain engagement with subjects. Since this research is concerned with children that have not yet entered secondary school, one of the assumptions of this model is that there is continued sustained engagement with the young people after their primary education in STEM subjects. Using backward mapping (see Fig. 2), for these children to take up the required subjects, they need to see people that take up such subjects or pursue a career in those subjects as 'people like me'. In order to see people that study or pursue careers in those disciplines as 'people like them', the young children need to know about the careers (it is assumed that one cannot aspire to a career one does not know about). The increase in knowledge of STEM careers is achieved through participation in the workshop activities.

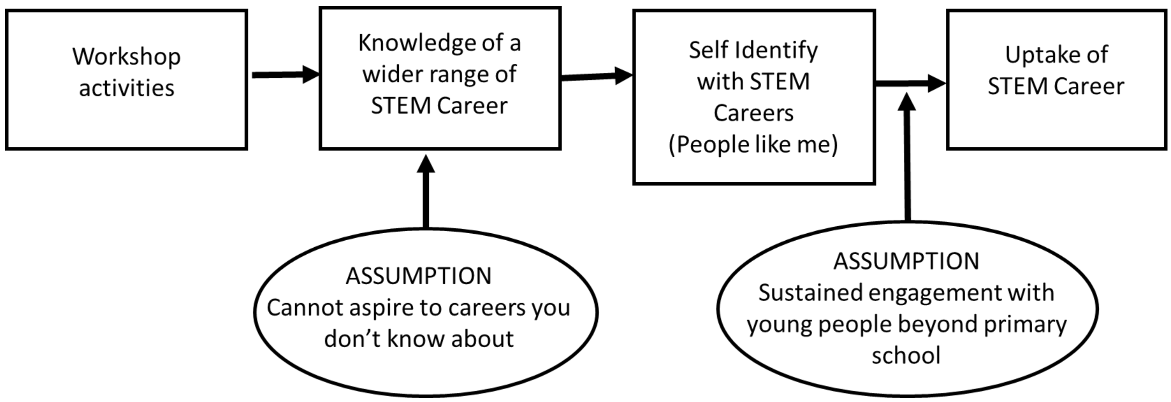

Figure 2: Example of a pathway of change to improve STEM uptake

This flowchart shows increasing knowledge of STEM careers as one of the pathways to generating interest of young people in STEM careers. Their interests can be further engaged if these young people understand what people in those career do (applications) and how they do things, they are then able to reflect on how people in those careers are like them, and if it is something they would like to do.

Personal experience has been shown to be a major influence on an individual's perception about something (Gomez, 2014). Children in primary schools do not have direct experience of careers so they depend on their environment (culture, media, family etc.) to form perceptions about those careers. If these children can be given direct experience of what it is like to be a person in such a career, they will be able to relate and make a more informed decision about whether they would like to pursue such a career.

The framework in Figure 3 shows the Theory of Change model for improving uptake of STEM disciplines by young people through bringing academic research into primary school classrooms.

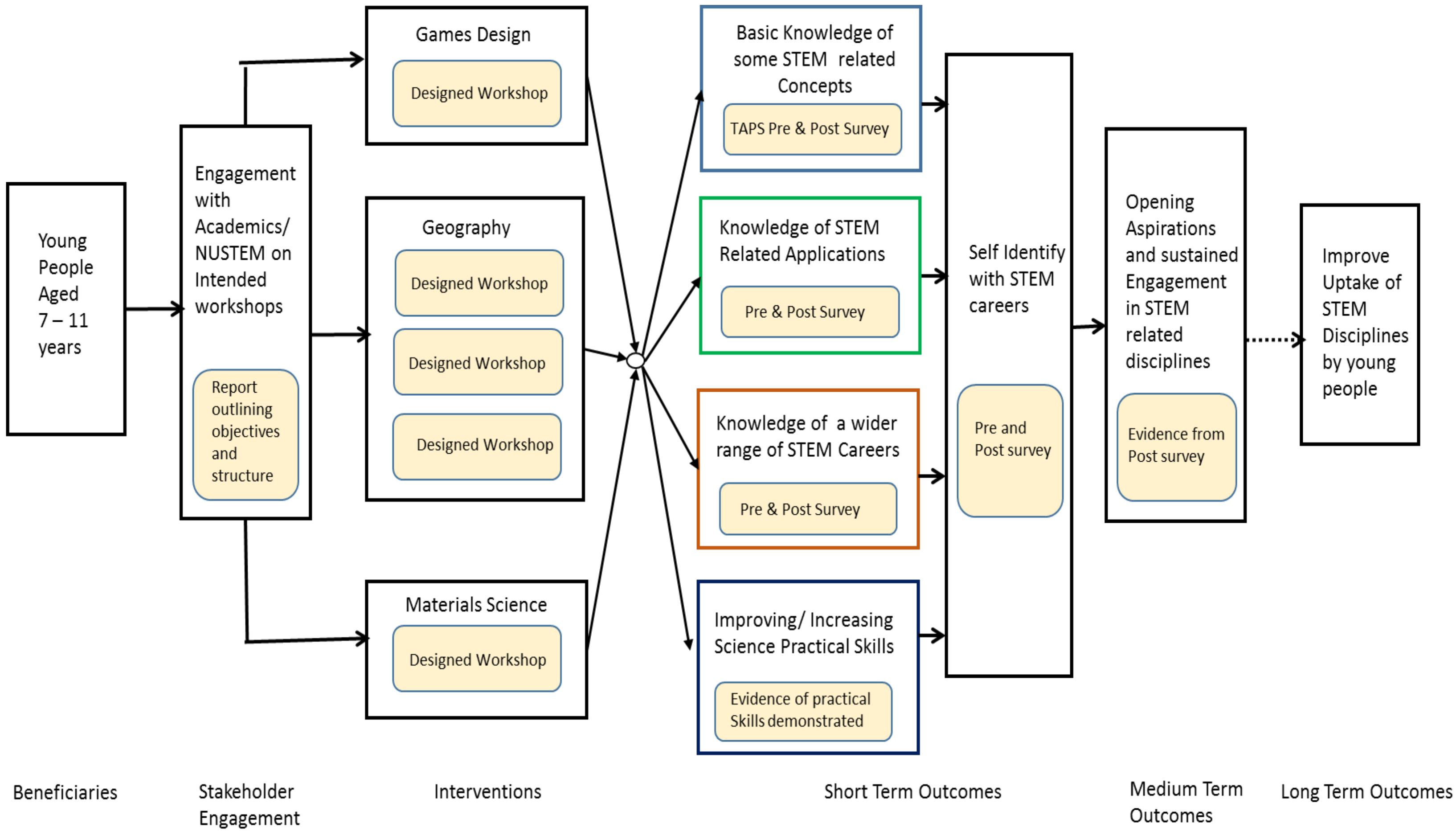

Figure 3: Theory of Change to improve uptake of STEM disciplines by young people through bringing academic research into the classrooms

3.6.2 Step 2 – Prioritizing what to measure

The measures used in this study were drawn from the Theory of Change model (Fig. 4). Indicators were selected for each of the short term and medium term outcomes based on the outcome objectives and how they have been measured in other research studies. Table 4 shows the measures selected for outcome objective.

Table 4: Measures for Theory of Change outcome objectives

Outcome Objective	Indicators
Widening Aspirations	Aspiration
Self-identify with STEM careers	Inclination towards STEM career
Basic Knowledge of STEM concept	STEM subject Specific Knowledge
Knowledge of STEM related application	Knowledge of related STEM application
Knowledge of wider range of STEM careers	Knowledge of STEM career
Improved Science practical skills	Participation in hands-on activity

- **Aspiration measure**

  Widening of aspirations is measured using young children's aspirations. Liben & Coyle (2014) argue that predictions of future science based choices could be inferred from temporal behaviour measures of children that undertake an intervention. This could be carried out by comparing respondents' disposition pre and post intervention and problem solving abilities regarding topics or materials covered during the programme or intervention.

  In line with the Office of Fair Access[3] (OFFA), most evidence on aspirations is usually qualitative because they are based on perceptions. Across different research studies on aspiration, questions on aspiration were collected mostly through a survey

[3] OFFA is a self-governing body in England that oversees and monitors fair access to higher education particularly from groups that are not adequately represented.

instrument and consist of a question where children were asked about careers they could see themselves in the future. An example of an aspiration question asked in studies is, '*What do you want to be when you grow up?'* (Auger et al., 2005; Flouri & Panourgia, 2012; Gomez, 2014). This question for aspiration examines children's perception of what they wish to be. Using findings and understanding about aspirations, researches are able to explore and investigate further factors that influence aspirations. This study adopts the aspiration question used in many research studies, what would you like to be when you grow up?

- **Inclination towards STEM career**

  Studies have adopted different measures to evaluate if children self-identify with STEM careers. Examples are the most like me/most like a scientist tool; the sorting job affinity tool (Padwick et al., 2016) and survey tools asking children if they were interested in becoming engineers before an intervention workshop started (Anderson & Gilbride, 2007).

- **Knowledge of STEM career**

  Anderson and Gilbride (2007) used questionnaires to ask learners what they thought engineers did. Children were given the options of indicating 'not sure'. The study (Anderson & Gilbride, 2007) also used qualitative measures to collect data on children's perceptions.

- **STEM subject specific knowledge/ knowledge of STEM concepts**

  Cotabish et al. (2013) measured learners knowledge of science concepts using a pre and post assessment. Some studies have measured STEM content knowledge using scans from surveys or workbooks of written children's responses, sketches or reflections (English & King, 2015; English et al., 2017). STEM subject knowledge has also been measured through children's responses, for example through interviews where responses are coded, categorised and themes are identified (Stubbs & Myers, 2015).

- **Knowledge of related STEM application**

  Highlighting the usefulness and applications of STEM concepts and careers (Macdonald, 2014) help children better engage with STEM**.** Young people's application of knowledge has been measured in a research study using their explanation of their responses either verbal, written or through drawings (English & King, 2015; English et al., 2017). English et al. (2017) asked children where they would apply new STEM knowledge acquired.

3.6.3 Step 3 – Choosing type and level of evidence

OFFA provides standards of evaluation practice to guide project evaluations of Higher Education outreach programmes on three different levels; the higher the level, the stronger the evidence (Crawford et al. 2017)**.** Level one standard is attained when there is a logical narrative on why the selected intervention or programme is relevant, and there is evidence in the literature on the effectiveness of such interventions. Level two standard is attained when there is evidence of more of the desired outcome(s) in programme participants post-intervention when compared to outcomes pre-intervention. This second level does not establish direct causality. The third level, which is usually referred to as the 'gold standard', provides evidence of direct effect. This level of evidence is often obtained through intervention programmes that involve more than one interaction with the participants, long-term engagement and with an adequate control group.

OFFA guidelines for acceptable evidence in Level 2 evaluations include; teacher's assessment of participants performance, participants results in public exams, data from participant's university application, pre- and post- intervention surveys of participant perceptions of their aspirations, expectations and intentions (Crawford, Dytham & Naylor 2017). Since this study is interested in young people's aspiration and interests, pre and post evaluation surveys were used in line with Level 2 evidence.

3.6.4 Step 4 – Selecting research sources

In selecting the research sources, some considerations where taken into account such as identifying the disciplines, identifying the stakeholders, schools and year group to engage.

STEM disciplines

Some STEM disciplines had already been earlier identified as possible case studies for this research (see Section 3.5.2), namely, material science (from engineering), computer science, geography (from environmental sciences) and architecture and building planning. In order to select the case studies used in this research, another condition had to be satisfied; availability of willing academics ready to commit their time to co-create an intervention program based on their research work. Academics in Northumbria University were approached from the different disciplines who were willing and available, except academics in Architecture and Building planning, who were unavailable due to other commitments. Cases were chosen across the different disciplines to enable comparisons across disciplines but cases were also chosen within a particular discipline (geography) to enable across and within discipline(s) comparisons.

Stakeholders

Stakeholders for this research were identified, and include academics from three disciplines within the Faculty of Engineering and Environment at Northumbria University, NUSTEM primary outreach specialist, evaluation researcher, primary schools in the North East of England and the young people aged (7-11 years). There were a series of stakeholder meetings held to design and plan the structure of each program. These meetings were attended mainly by the three first aforementioned stakeholders. The Primary schools were involved in providing access to the young people and in ensuring the logistics necessary for the workshop to occur where adhered to. The young people were the beneficiaries of the workshops.

Participants

Participants were young people aged between 7 -11 years old in Years 3 -6 of Primary Schools in England. Participants were chosen from this age group because there is evidence from research that aspirations and attitudes towards possible career paths are developed at an early age (Reiss & Mujtaba, 2017; Castro et al., 2018; Kitchen et al., 2018). Also, more STEM intervention programs should focus on younger children, rather than those in secondary schools and above (Archer et al, 2013; Kang & Keinonen, 2017; Sainz & Muller, 2018). A third reason this age group was selected is that children, those below the age of 7 years may not yet have the reading and writing levels/skills needed to take part in both workshop activities and evaluation activities. There was also the possible lack of robustness and reliability of results from very young children particularly concerning their level of knowledge and understanding of future aspirations. Participants were drawn from primary schools within the NUSTEM group of partner schools in the North East of England. Schools within the NUSTEM partner schools were selected based on their Socio Economic Status (SES). Free School Meals (FSM) pupil eligibility was used as a proxy for SES of children from deprived or disadvantaged background. It has been used as a means of identifying communities with high need or disadvantaged groups (Krishnamurthi et al., 2014). Although not an accurate measure of a young person' background, the percentage of FSMs in a school can provide an indication on the socio-economic area the school is situated in (Chambers et al., 2018).

Pilot studies

Pilot studies were carried out across the five intervention workshops one after the other to test the content and structure of the workshops with the selected age groups. It was also used to evaluate the evaluation tools in terms of ease of use, age appropriateness, non-intrusive characteristic and time constraints. The pilot studies were also part of the iterative nature of the action research cycle. Since the workshop pilots were carried out consecutively, findings from earlier workshop pilots were used to further improve subsequent pilot workshops using the reflection lessons learnt from each workshop.

Main intervention workshops

The main intervention studies were carried out across the five intervention workshops. While some workshops were carried out once, others were carried out twice. A reason for this was related to the willingness and availability of the stakeholders including the academic staff and partner schools. Also to explore the robustness and flexibility of the intervention workshops. The timing across the school year was also a factor. The set of geography workshops were carried out once in each category (all single sessions), while the materials science and games design workshops were both carried out twice (both single sessions for the materials science workshop and one single and a 5-weeks session for the games design workshop).

3.7 Intervention workshops development

Across the different workshops, each stakeholder group was involved in the co-design and co-creation process. Darby (2017) argues for collaboration with research partners for ethically co-produced relevant impacts.

3.7.1 Workshop design engagement

The stakeholders involved in this research are the people involved in designing and delivering the intervention activities (workshops) that will help to achieve the main goal of the study. The stakeholders include the researcher, academics from Northumbria University who have developed workshops based on aspects of their research and members of the NUSTEM team, particularly the primary outreach specialist who worked with academics to bring to life aspects of the academic's research into age-appropriate workshops.

3.7.2 Workshop objectives

During the stakeholder meetings, academics were asked to talk about their research and the interesting things about their research, by the NUSTEM team. They were then asked to mention the objectives of the intended programs to be created and to list at least three subject specific outcomes they wanted the workshop participants to take away or remember long after they had participated in the workshop. The objectives were then checked to see alignment with expected outcomes in the Theory of Change model. Academics then collaborated with NUSTEM outreach specialists to co-create age-appropriate workshop and activities based on the academic research.

3.7.3 Intervention characteristics

The different intervention programs were designed to follow a general structure

- **Introduction:** The workshops usually start with a general introduction of the facilitating team and given a brief background on why the research was being carried out. The children were asked about their (1) aspirations, (2) prior knowledge of the career, and (3) what they thought the career might involve even if they had not heard about it before. The children would then be introduced to a specific career and the facilitator would have discussions on what the career was about.
- **Subject specific content:** The children are then introduced to subject specific concepts and discussions are had around the concepts with examples provided either by the facilitators or the children.
- **Practical activities:** Children participate in at least two practical activities to test out some of the new concepts learnt.
- **Application of knowledge:** Children are then asked to suggest other practical applications of some of the subject specific content learnt. Inclusion of applications of STEM knowledge highlights the usefulness of STEM that participants can find relatable (Padwick et al., 2017).

- **Recap of lessons learnt:** A summary is provided of the lessons learnt and examples of people that do the kind of careers linked to the research are provided.
- **Evaluation of inclination towards career:** Children are then asked if they would like to do such careers and provide explanation or reason(s) for their choice. Questions are intended to evaluate the impact of the STEM workshops on the children particularly if they are inclined to engage with the promoted career given the opportunity.

3.8 Data collection

The approach for data collection comprised of semi-structured expert interviews, surveys (Strachan et al 2012, Archer et al 2014; 2015) and activity sheets to enhance the richness of the study. Data was collected in two stages, the design stage and the evaluation stage.

3.8.1 Data collection during the design stage

During the design stage, in-depth interviews/engagements were conducted with the core NUSTEM team and the academic team of the different intervention workshops. This was necessary, to understand the kind of activities for children, that can be drawn from research, with regards to the STEM disciplines. Expert interviews facilitate discussions and are used to obtain subject knowledge (Robson, 2002; Creswell, 2007; Bagiya, 2016). In each interview with academics, the same open ended questions (Robson, 2002). These were (1) Tell us about your research (2) What three main points do you want the children to take away at the end of the workshop? Response to these questions were used to shape the objectives of the workshop and align the objectives to the intended outcomes of the Theory of Change model. The questions also allowed for free expression and set the groundwork for co-creation. Findings from the design stage informed the workshop structure and the data collection during the evaluation stage. This design stage is consistent with the ‘reflect’ and ‘plan’ stage of the action research cycle.

3.8.2 Data collection during the evaluation stage

During the evaluation stage, a pre and post survey was used for comparisons before and after the children engaged with the intervention workshop activities. This is consistent with OFFA guidelines of using pre and post as level two evidence for analysis of aspirations and perceptions on subject content (Crawford, Dytham & Naylor 2017). Data was collected from the children using a mix of open-ended and close-ended questions. The questions were asked during the course of the workshop and children were asked to write down their responses or thoughts before discussions were had about the question responses. The researcher returned a month later to obtain post-workshop data from the same participants. This evaluation stage is consistent with the ‘act’ stage of the action research cycle where data collection is implemented.

3.9 Evaluation tools

This section refers to the tools adopted across the workshops and what informed the choices made. There are a number evaluation tools used in STEM education and STEM intervention workshops. For example, Cotabish et al. (2013) measured learner’s knowledge of science concepts using a pre and post assessment. The ASPIRES project (Archer et al., 2013) from Kings College, London used a survey instrument to explore young people’s aspirations and which related influences could impact on their aspirations towards a science related career. Examples of other evaluation tools are shown in Table 5.

Many of the instruments mentioned are tailored for young people in secondary schools and above (aged 11 years and above). Despite this, even the ones tailored to accommodate younger children are stand-alone surveys (administered on their own) with many questions and the questions do not assess STEM content knowledge. For example, S-STEM survey has a version for children aged 8-11 years (Wiebe et al., 2013; Unfried et al., 2015), SMTSL has been used for young people 10 – 13 years and CIQ for ages 10 -13 year olds.

Some other types of assessment include the Trends in International Mathematics and Science Studies (TIMSS). TIMSS is an international assessment of the effectiveness of mathematics and science teaching in young people in Grade 4 and 8 respectively. This assessment is carried out every four years by the International Association for the Evaluation of Educational Achievement (IEA, 2019). Another International assessment is the Programme for International Student Assessment (PISA). This evaluates competence in mathematics, science and reading and is administered by the Organisation for Economic Cooperation and Development (OECD, 2019). TIMSS and PISA both use an examination style approach to evaluating young people.

Table 5: Examples of STEM evaluation instruments

Evaluation instrument	Description	References
Affective elements of science learning questionnaire	Measures young people's attitude to science learning	Williams, Kurtek, & Sampson, 2011
Student STEM (or sometimes referred to as S-STEM) survey	Measures young people's confidence and self-efficacy towards STEM	Wiebe et al., 2013; Unfried et al., 2015; Luo et al., 2019
Test of Science Related Attitude (TOSRA)	Measures young people's attitude to science	Fraser, 1978; Schibeci & McGaw, 1981; Khalili, 1987
STEM Career Interest Survey (STEM-CIS)	Measures interest in STEM activities and careers	Kier et al., 2014; UNLU et al., 2016
Career Interest Questionnaire (CIQ)	Measures young people's perceived importance of science and interest in Science careers	Tyler-Wood et al., 2010; Peterman et al., 2016
The Student Interest in Technology and Science (SITS)	Explores career interest	Romine et al., 2014
STEM semantics survey	Measures perceptions of STEM disciplines	Tyler-Wood et al., 2010
Students' Motivation toward Science Learning (SMTSL) questionnaire	Identifies children's motivation to learn science	Tuan et al., 2005; Yilmaz & Cavas, 2007; Caves, 2011
Attitude toward mathematics survey	Explores learning and performance goals	Miller et al., 1996

Despite research studies highlighting the importance of starting STEM interventions early in primary schools (Archer et al., 2013), there are few published evaluation tools appropriate for use with young children (Padwick et al., 2016). Some appropriate tools are detailed in Padwick et al., (2016) which explored young children's attitude and aspirations towards Science related careers using a combination of tools. Chambers (1983) investigated the age at which young children start developing distinct images of a scientist. While these tools are appropriate for young children, they are designed as stand-alone tools and are not easily embedded in intervention workshops, particularly for workshops with limited time for delivery.

Some of the considerations required for this study's evaluation instruments were that the:

- Workshops content and evaluation tools that are easy to use with language that is appropriate for children aged 7 – 11.
- Evaluation tools that are able to be embedded or incorporated into the delivery of the workshop so that there is no disruption to the flow of the program.
- Tools that do not take up much time in administration with each workshops length about 60 – 75 mins long. This length of time was chosen because it is the length of a lesson within primary schools in the North East of England.

The research tools identified from previous studies were unable to satisfy the mentioned requirements. This led to the decision to create a new evaluation tool. Reviewing assessment systems used by teachers in primary school classrooms, The Teaching Assessment in Primary Science (TAPS)[4] project was identified. TAPS is an assessment tool from Bath Spa University and funded by the Primary Science Teaching Trust (PSTT)[5]. The tool has been used in over 24 schools in England and aspects of the tool were adapted to create the knowledge map.

The main evaluation tool used in this research is the knowledge map. The knowledge map captures the aspirations of the young people, their knowledge of the career promoted, what they think people in that career do, if the young people would like to do the career and subject specific understanding of particular STEM concepts. The knowledge map is discussed in more detail in the next chapter. The knowledge map also benefited from the different iterations of the action research cycle. With each iteration of the knowledge map created in a workshop, how the lessons learnt is used to improve on further iterations of the map, is discussed in the case study chapter of this thesis. The second tool used were activity sheets that were customized to the individual intervention workshops. The activity sheets were used to evidence practical skills gained from the participation.

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[4] Bath Spa University. (2017). Introducing the TAPS Pyramid model [pdf]. Retrieved from https://pstt.org.uk/application/files/6314/5761/9877/taps-pyramid-final.pdf

[5] Primary Science Teaching Trust - PSTT. (2019). Retrieved 15 November 2019, from https://pstt.org.uk/

3.10 Data analysis

Qualitative data collected were analysed using thematic analysis. Thematic analysis is a technique for identifying patterns or themes within text-based data (Bryman, 2012; Bayiga, 2016). The researcher's role in the analysis was that of a sense maker to identify themes and present the information extracted from the data in a sensible way. Themes extracted from the data were coded and were used to investigate relationships and patterns in the data.

The quantitative data collected was entered into excel and exported to IBM's SPSS 24 (IBM Corp., 2016) and 25 (IBM Corp., 2019) statistical software packages. The software packages were used descriptive and inferential statistical analysis (Field, 2013; Bayiga, 2016). Descriptive statistics was used for frequency counts on gender, aspirations, knowledge of STEM job introduced, and inclination to STEM job introduced. Chi-squared tests were used to establish relationships and test for differences within variable groups. This test was used because the data collected included categorical variables. In order to use this test, 80% of the cells in a dataset for those variables should have an expected count of at least 5 (Robson, 2002). For situations where the expected count was less than 5, an alternate test was carried out using Fisher Exact test, which is appropriate for datasets with small sample sizes.

3.11 Ethical considerations

Consideration of ethics is essential as research suggests that participants or data sources could unintentionally be harmed or put at risk if adequate measures or procedures are not deliberately taken (Stringer, 2014). This study is committed to minimising harm or any negative consequences that may arise from this study. As such, this research has been approved in line with Northumbria University risk guide and Ethical approval process (Northumbria University, 2019). The study was coded **RED** according to Northumbria University's risk categorisation because the research involved collecting data from human participants, including children, that are classed as vulnerable individuals. Ethical approval for the study was granted by Northumbria University with reference number RE-EE-16-170221-58ac5eacbfbcf. The key ethical considerations taken into account for this study include consent, safeguarding of everyone involved in the study, data management and quality assurance of the research.

3.11.1 Consent

The acquisition of informed consent is an important consideration in conducting research (Crow et al., 2006) and also a mean of respecting the autonomy (Ferrer et al., 2016) of participants or people in charge of making decisions on their behalf.

Consent was sought from the school authorities that can legally act in the best interest of the children in school environments using 'in loco parentis' which means in lieu of parental consent (Rumel, 2013; Tenenbaum & Hogh, 2016). The use of 'in loco parentis' is common in primary and secondary school settings (Rumel, 2013). The 'in loco parentis' consent form used in this study were the consent forms (with minimal adaptation) utilised by NUSTEM for head-teachers in their partner schools (see appendix B1 for a sample).

To ensure adequate information was provided to the children and their family or carers, to aid their understanding and give consent, an information sheet (see appendix B2) was sent home with the children (Wolfenden et al., 2009). The information sheet contained necessary information regarding the research. Participants and their parents or carers were informed about the objectives and purpose of the study with clear information about what the study entailed and any possible consequence of taking part in the study (Tisdall et al., 2008a; Stringer, 2014). In line with the ethical obligation to ensure that participation in research is voluntary (Ferrer et al., 2016); children' family, carers and legal guardians were also informed that allowing children in their care to take part in the study, was purely voluntary and they could give their consent or not. They were given the option of opting out of the study through letters attached to the information sheet. Parents or legal guardians were to sign the opt-out sheet and return to the school, if they did not wish a child in their care participate in the study, otherwise the study assumed '*in loco parentis'* via the consent of the school. If parents or carers opted out their child from the research study, those children still took part in the intervention activities but no data was collected from them. This means the children were not disadvantaged by opting out.

Verbal assent was also sought from the pupils. Consent was sought from the children before commencement of any data collection exercise. Children were told again, that they were free to opt out of the study and would not be made to participate should they choose not to.

3.11.2 Safeguarding participants and researchers

Since the study involved acquiring data from vulnerable individuals, and in line with Northumbria University ethics guidebook, the principal researcher undertook the required Disclosure Barring Service (DBS) check. This complies with rules and regulations in the United Kingdom regarding working with vulnerable individuals including children. The DBS clearance certificate number for the researcher is 001562237110. DBS is a part of the Home Office in the United Kingdom that identifies individuals that should not work with vulnerable people. The primary researcher has also participated in the Faculty of Engineering research Ethics training, General Data Protection Regulation (GDPR) and other trainings at Northumbria University.

'Safeguarding' training was also undertaken by the researcher to ensure researcher's awareness and compliance with keeping self and participants safe at all times throughout the course of the study, understand the Department of Education's guidance on safeguarding and obtaining knowledge of what to do if the researcher is concerned about a child or stakeholder. The safeguarding training was organised by an independent consultant (which is recognised in about 200 schools in the North East of England). There was no anticipated or observed physical discomfort or danger associated with this research to either researcher or participants.

3.11.3 Data management

The risk factors of the study were assessed in terms of collection of personal data from participants and how the data would be protected and stored.

- ***Personal data of participants:*** Sensitive personal data was not requested from children. Only demographic data such as age and gender were requested and was be used strictly for monitoring purposes.
- ***Data protection and storage:*** Physical confidential information was stored in locked cabinets within Northumbria University premises. Data in electronic or digital format including personal or confidential information were only accessed via password protected computer systems. Only the researcher and supervising team associated with the study had access to the data collected. In cases where anonymity and confidentiality was needed, identifier codes were created and stored separately from the coded data. Also care was taken to ensure confidential information was not

included within any written document made available. Data collected has been stored in accordance with Northumbria University Retention policy.

3.11.4 Quality assurance of research

The quality of this research process was guided by some fundamental research principles (HM Treasury, 2012a) which include contribution to knowledge in theory and/or practice; defensibility of research through a sound logic model that links the objectives of the study to the outcomes of the research and rigor of research through methodical and transparent collection, documentation, analysis of data and reporting of findings.

3.12 Chapter summary

A key objective of this study was designing an evaluation framework that could be used to assess the impact of academic research based programs on young people’s interests and inclination towards STEM careers. This chapter outlines the philosophical positions this research study sits within. It discusses the research process and steps taken in designing an impact evaluation framework using NPC’s four pillar approach. The Theory of Change model is explained and considerations that informed different aspects of the research are also discussed. The workshop structure, data collection and evaluation is explained and the chapter ends with an outline of the ethical procedures taken to safeguard, participants and researcher. The next chapter delves into the case studies adopted in this research.

CHAPTER FOUR – CASE STUDIES

4.1 Introduction

This chapter presents and describes the case studies used in this research. The study adopts a multiple case study approach with case studies from three different disciplines; computer science, materials science and geography. The case studies from the first two disciplines are single case studies, while the geography case study consists of a series of mini case studies based on environmental planning, environmental modelling and paleontology. Each case study is presented in a similar format. The chapter outlines the action research cycle put into practice and how the cycles underpins the workshop design and implementation across the different case studies. The structure of the workshop incorporates elements from two pedagogical learning theories: Cognitive Constructivism and Direct Instruction. The academic research that underlies each case study is discussed, together with the key objectives for the workshops associated with each case study. This is followed by a discussion of the features and other elements considered during the planning and design stages. The structure of each workshops is explained together with the logic model, which helped guide the implementation. The evaluation tools adopted to assess understanding of the intended concepts from the workshops are explained. Finally, the data collected for the research from both the pilot and main intervention workshops for each case study is described.

4.2 Process of design and implementation across case studies

The design and implementation of the workshops across each of the case studies are underpinned by the *'action research'* process. The action research stages *'reflect'*, *'plan'* and *'act'* are described in this chapter while the fourth stage 'observe' will be discussed in the next chapter

1. **Reflect stage:** Each of the case studies started with a *reflection* of the underlying academic research that the workshops were based on. The 'reflect' stage was concerned with identifying aspects of the discipline-specific research that could be incorporated in the workshop. It also involved a reflection on the intended outcomes from the Theory of Change model and how the objectives of each case study

workshop aligned with those intended outcomes. The Theory of Change outcomes, as described in the previous chapter, are increasing/improving:

- Knowledge of some STEM related concepts (Outcome 1)
- Knowledge of STEM –related applications (Outcome 2)
- Knowledge of a wider range of STEM careers (Outcome 3)
- Science Practical Skills (Outcome 4)

The outcomes would hereafter be referred to, in terms of their associated numbers in this chapter.

2. **Plan stage:** Across the different case studies' workshops, the plan stage involved identifying subject-specific concepts and activities, based on the underlying academic research, which aligned to the objectives of the workshops. The focus of this stage across the case studies was on co-designing and co-creating workshops through a consideration of the design options, the workshop structure and the evaluation tools for each workshop. Different aspects of workshops structure are also underpinned by elements from pedagogical learning theories.
3. **Act stage:** This stage focused on the implementation of the workshop across the case studies; the use of logic models to aid organisation and delivery of workshop activities in line with the workshop objectives. The 'act' stage describes how each workshop was carried out during the pilot and main intervention phases.

4.3 Background to case study 1: Games design

The academic research underlying the games design workshop was drawn from academics in computer science whose research interests include integration of digital technologies to improve lives in the classrooms to support student learning, professional development and provide technological solutions (Liyanage et al., 2013; Strachan et al., 2016; Padwick et al., 2016; Dele-Ajayi et al., 2018; Dele-Ajayi et al., 2019). This workshop was designed for children aged 7 – 11 years (Key stage 2) with the intention of raising awareness of careers in the digital sector, and challenging stereotypes. The specific focus was on the following areas; increasing or improving knowledge of careers in the digital industry, an appreciation and better understanding of how games can be diverse (diversity and equality in online gaming), and an exploration of stereotypes in the games sector. Two workshops were designed, one to work as a single session (2- hour) workshop and the other as a series of five sessions that occurred over the course of 5 weeks (cumulative time of about 6.5 hours) to explore the robustness and flexibility of a games design workshop. Children are introduced to games design, and the process of building games using a games design engine. They then go on to create, play, test and evaluate their own digital games.

4.3.1 Objectives of the games design project

The objectives of the games design workshops are to increase/ improve among children:

- Awareness of careers in the games design industry (aligns with outcome 3)
- Understanding of stereotypes (aligns with outcome 3)
- Use of online games for learning (aligns with outcome 1)
- Applications and practical skills in games design (aligns with outcomes 2 and 4)

Careers in the games Industry

During the reflection stage for this case study, findings in literature suggests that thoughts about careers and aspirations begin in young people as early as 5 year of age (Hughes et al., 2016; Gottfredson & Lapan, 1997). Also, given the dynamic technological landscape, and the importance of computing skills, recommendations have highlighted the importance of raising and increasing awareness of careers within computing fields (Shadbolt, 2016). For example, there is a projection of 157,000 new jobs in big data alone by 2020 in the UK (Engineering UK, 2018). These reports, research findings and personal experiences of the academic team informed the objective of 'increasing or improving awareness of careers in the games design industry'. This objective is also consistent with the overall Theory of Change Outcome 3's objective of increasing or improving knowledge of a wider range of STEM careers.

Understanding stereotypes

Young people are largely influenced by the culture they are embedded in and form perceptions based on what they see, hear or their environment (Christensen et al., 2014). Research studies suggests that stereotypical influences start affecting children consciously or unconsciously from the age of six (Biglar & Liben, 1990; Bian et al., 2017). At a young age, children may not have had direct experience with some STEM disciplines or its related content, therefore they rely on their environment and their ciricle of influence to form perceptions. If there are already stereotypes about the STEM disciplines or people that work in those disciplines, held within their circle of influence, the children will be influenced by those strerotypes. For example, a stereotype that people who study or work in computer science related jobs are socially awkward (Cheryan et al., 2013) and mostly males (Biglar & Liben, 1990; Cheryan et al., 2015).The game design industry has also primarily reflected male dominance in the games and roles (Bian et al., 2017), reinforcing the stereotype perception that this industry might not be for females. By including an objective of 'improving understanding of stereotypes', this objective aims to break down stereotypical perceptions that would help bridge the gender gap and improve diversity in the field. While this objective does not have direct links with the overall Theory of Change outcomes, by breaking down stereotypes, under-represented groups interested in the computer science field begin to see careers in the field as careers for 'people like them' which is consistent with the model's outcome 3 of increasing or improving knowledge of a wider range of STEM careers.

Use of Online games for learning

Online educational gaming has been shown to have positive influences on young people's learning experiences (Benton et al., 2014; Heredotou, 2017). As such, games have been used to encourage more exploration and engagement with computer science, computing and digital technologies (Lieberman et al., 2009). Although many research studies have engaged young people in games for learning, the majority of those studies have included young people in playing the games (Su & Cheng, 2015; Heredotou 2017) rather than having them create the games. A few of the studies that have included young people in game creation (Ong & Tzuo, 2011; Fisher & Jenson, 2017) have focused on older children in secondary schools rather than the younger ones in primary schools. By using online gaming for learning, where children create their own games, children would learn new games design concepts during the games creation process. This aligns with the Theory of Change model's outcome 1 of increasing, and improving knowledge of STEM related concepts.

Application and practical skills in games design

Findings from research studies suggest that providing or increasing practical skills within a discipline could help break down stereotypical perceptions about a field and careers within that field (Cheryan et al., 2015). By providing hands on experience, which young people can relate to, young people are able to readjust initial perceptions based on personal experiences. Exposure and experience to careers and practical skills at an early age, have also been suggested to influence career knowledge and understanding and later association with related disciplines (Ferrari et al., 2015; Kang & Keinonen, 2017). By making young people create their own games, this case study objective aligns with outcomes 2 and 4 of the overall Theory of Change objectives: young people are able to gain more knowledge applications in the games industry and also gain practical skills.

4.3.2 Workshop design considerations and outcomes

After the objectives were chosen, the research moved to the planning stage of the action research cycle where features and considerations necessary for the design of the workshop were discussed. These include:

- The use of a games engine that was web based, for ease of use in school IT facilities. This was important because many of the primary schools could not permit installations or downloads on the school system. A game that could work offline was explored to enable the children work on their games even if there was no network connection.
- A tool that was easy for children to use for building their game and was age appropriate. Overmars (2004) suggested the use of object based platforms that are more age and classroom friendly, particularly for younger children.
- A game engine that offered variability such that children had choices in the type of game they wanted to design: where they could decide on the type of background, character, music and objects within the game, and the main theme of the game.
- Due to the possibility that children in the target group might have limited or non-existent exposure to the usual writing of programming codes, simple drag and drop tools were preferred over more complicated user interfaces.
- Consideration was given to design a workshop that the children would be attracted to, that could keep them playing and possibly immerse themselves in. This is important because traditional educational games can be boring (Bellotti et al., 2009) and can lose the engagement and enjoyment factors normally associated with gaming (Dele-Ajayi et al., 2016).
- Another consideration was to highlight the importance of diversity and equality in the games sector and the wider digital and IT industry. This was necessary in order to

bridge the divide between children's perception of an industry or field and their actual engagement with the field (Yardi & Bruckman 2007).

- A workshop that explored and possibly demonstrated stereotypes in games (particularly through allowing children to create their own characters).
- The game design and development needed to be enjoyable to sustain the children's interest and at the same time, enable game character development for practical skills building.
- The game engine platform also needed to be robust enough to allow the children to save and be able to return at a later time. The use of usernames (individual logins) was also useful in accessing saved work and tracking progress.
- A game engine that provided the option of sharing built games with others. This enabled other children access games built by their peers by clicking on the designed games to critique and provide peer feedback useful for improvements to created games.
- A tool that allowed for children to work individually or in pairs. Learning is more active and collaborative when children work in pairs or groups (Baines et al., 2003). By having individual or pair-work ability in the tool, children are able to work autonomously and collaboratively.
- Consideration of zero or minimum costs attached to using a games engine (the extent to which use was free or minimum charges associated with use). This was necessary in case of scalability or situations of limited funds where available funds could be re-allocated to other aspects of the workshop delivery.

Four main games engines were considered. These were GameSalad, Stencyl, Cocos2d and Gamefroot. Following further examination of these four engines, Gamefroot[6], was chosen as this allowed for online use with no installation needed and could support use by a whole class of children. The platform also had built-in tutorials that were useful for participants with little or no prior contact with the engine.

4.3.3 Structure of the games design workshop(s)

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[6] Gamefroot (2017) game creator social and mobile gaming. [Online]. Available: https://make.gamefroot.com/ [Accessed: 17 Nov. 2019]

Still within the planning stage of the action research cycle, there were two types of structures designed; the single session workshop or the 5-sessions workshop. The two structures were chosen to explore the flexibility of the games design workshop by having the workshop in a single session and exploring how it could be extended by a couple of sessions or possibly over a half term period within the primary school calendar. While the structure of the individual and multiple session formats were different, both structures consisted of a similar games design process; design and story development, game creation and evaluation. Different aspects of the workshop structure use elements from either Direct Instruction, Cognitive Constructivism or integrated both learning theories.

Below, is the structure for a single session workshop:

1. **Introduction:** The workshop starts with a general introduction of the workshop delivery team. The children are asked about previous knowledge of the games industry. The aim of this activity is to *trigger prior knowledge,* which is an element of Cognitive Constructivism pedagogical learning theory. Acquisition of new knowledge has been shown to be more effectively attained when it builds on prior knowledge and understanding (Nuttal, 2007; Hartle et al., 2012; Fletcher-Wood, 2019), allowing children to construct new meaning based on previous knowledge.
2. **Overview of the games Industry:** The children are shown slides giving an overview of games and the games industry. These actions are intended to create '*elements of surprise'* particularly for participants whose pre-existing knowledge is inaccurate or misconstrued (Hartle et al., 2012; Stanny, 2019). Surprise is another element from the Cognitive Constructivism learning theory. By eliciting those moments of surprise, children are made aware of the gap in their pre-existing knowledge with the intent to elicit a change or motivation to bridge the knowledge gaps (Zull, 2002). A set of accounts or workgroups are created from the Gamefroot home screen under which each individual student account is created.
3. **Games story and design:** Children are asked to think about and plan the game they intended creating. They are introduced to 'conceptual mapping' using the game overview sheet and the games design planning sheet. The games overview sheet allowed children create the story of their game using story points while the design planning sheet allows them to create a visual representation of what they wanted their

games to look like. Conceptual mapping is an element of the pedagogical learning theory by Direct Instruction, which provides structure to concepts from children minds.

4. **Introduction to game engine:** The children are required to log into the Gamefroot webpage (make.gamefroot.com) using pre-provided usernames and password from the workgroup administrator and can begin creating their game from a blank game (a game that has nothing inside that could be customised). Using *structured instruction*, another element of Direct Instruction, they are provided with a game building document guide that contains a step-by-step guide to creating a new game. Structured instruction enables children work at their individual paces while gaining new knowledge (Roy & Novotny, 2011; Muijs & Reynolds, 2017).
5. **Making the game activity:** Children are able to apply new knowledge gained by building their own games. *Application of new knowledge* (an element of Cognitive Constructivism) allows the children to put into practice new knowledge learnt through repeated actions or tasks through which learning is reinforced (Hartle et al., 2012). Gamefroot allows choices in making a playable game. Since the children are building the game from scratch, there are no assets in the game they could work with therefore, they need to import some assets from online. Assets refer to all the different things that can be in a game. These include characters, designs, backgrounds, objects, and sound effects. Gamefroot provides a variety of art assets that could be imported to build a game. The Gamefroot classic pack is utilised for these workshops. Using the Gamefroot classic packs, children are provided with a variety of options from which they could customise their work. These include the type of background they want, how they want their story points within the game to look like and other distinctive features desired in the game (collectables, death points, damage points check points and end points). Tile map layers are used for add-ons into the backgrounds of the game platform such as the platform terrains within the game and even characters. Example of how the children access tile map layers is shown in Fig. 4. The characters within the game are built using the character creator that is accessed by 'adding a game object' from the on screen menu. From the character studio, the participants are able to customise their character from a range of options to a very

high level of detail such as their head (face, eyes, mouth, hair and accessories), body, legs etc.

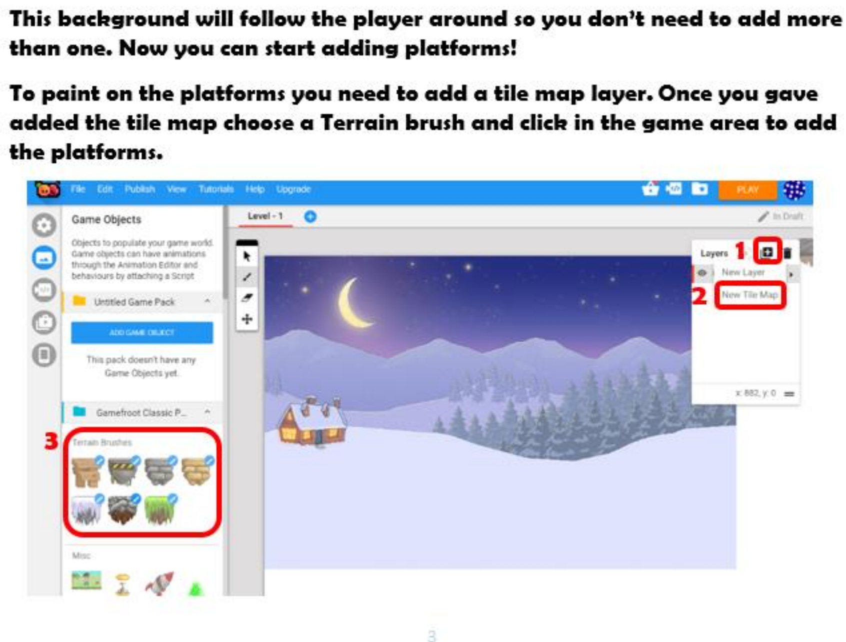

Figure 4: Example of how children access tile map layers

Character(s) are animated in the game using the 'scripts tab' in the menu and the 'classic platform player selection', which allows the player to move. Children could also add moving parts to their game using the moving tiles menu and edit the properties of this to provide the desired movement. The menu also provides an eraser tool that is very useful in case there is a need to make changes or corrections as the game is being built.

6. **Saving and publishing created games:** Children are shown how to save their games. They are also able to work at individual paces during *seatwork* time for individual practice (an element of Direct Instruction). With enough support materials and instruction sheets, this element of Direct Instruction is able to accommodate a range of working speed and ability differences (Fisher et al., 2012). Children are also shown how to publish their games so that others can test their games. Throughout the activities in the workshop, participants can interactively question what they learn during individual seatwork time. Interactive questioning is also an element of Direct Instruction learning approach.

The structure of the 5 weeks (5-sessions) workshop is as shown below:

- **Session 1**
  - The first session in week 1 (2hrs session) is a face-to-face delivery session with the academic(s). The session is similar in structure to the one day structure consisting of the six steps described where there is an introduction to games design and careers in the industry (with images carefully selected to portray the diversity within the career roles). This is followed by a storytelling session where participants plan out the story of their game and are encouraged to include others or multiple characters apart from their main character. Then, children are introduced to the game engine they will use to build their games (Gamefroot). This session equally integrates elements from both Direct Instruction and Cognitive Constuctivism learning theories. It incorporates conceptual mapping, structured instruction, seatwork and direct questioning from the Direct Instruction approach and triggering of prior knowledge, eliciting elements of surprise and application of knowledge from cognitive constructivism
- **Session 2**

  The second session in week 2, is a follow up session (1hr session) where more *seatwork* is carried out, which can be supported by the teachers or postgraduates. The children continue to work on their games design at their pace in school with the knowledge they could work on their games at home if they have internet access and have access to a laptop or desktop.
- **Session 3**
  - The third session (an hour and the half session in week 3) is the second intended face to face delivery session with the academic(s). Initial results of evaluation of the games created by the children are shared with the children. Feedback provides avenues for reflections and discussions on learning and experiences (Nicholson, 2012). Feedback is also an element of learning from cognitive constructivism. The children are introduced to some game engagement factors (Dele-Ajayi et al., 2015) after which, they are allowed to play each other's games and evaluate against the engagement factors

discussed using an evaluation sheet. The engagement factors are visual appeal, game theme, goal clarity, challenge of the game, rewards, feedback and game creativity. Children are introduced to diversity in games with a focus on gender to convey why diversity is important in order to make the games more accessible and appeal to a wider audience.

- **Session 4**
  - The fourth session (a 1-hour session in week 4), is the second support session where participants spent more time on *seatwork*, adjusting and improving the game in school and possibly at home based on reflections from feedback.
- **Session 5**

  The final session in week 5 (1 hour session) is a celebration session that starts with an analysis of the second evaluation of results. It was also an interactive questioning session where a role model that fitted with the theme of the workshop from the games industry was introduced to the children. This role model talked about the job they do, why and what about the job they enjoy or find interesting. A post workshop evaluation questionnaire was then completed by the children and this brought the workshop to a close.

4.3.4 Games design evaluation tool

A set of tools were designed and developed to capture data in order to evaluate the impact of the workshop on the children. These comprised of a pre- and post-questionnaire, sorting activity, planning sheets for designing the game, game overview sheet, engagement factors sheet and the games created online. The set of tools are shown in Fig 5.

Figure 5: Evaluation tools for the games design workshop

Pre and Post Questionnaire: A pre and post quasi-experimental design was used for the evaluation of the workshop, which is consistent with OFFA guidelines on adequate level of required evidence as mentioned in the previous chapter. This evaluation tool (see appendix C1) provides some indicators for the first objective of this workshop; raising or improving awareness of careers in the games design industry. One of such indicator is a question regarding children's aspirations; what they would like to be when they grow up. While not a direct indicator of awareness of STEM careers, the question provides a glimpse of aspirations towards STEM careers. Other survey questions included are demographic questions (gender, year group, school attended) and questions regarding children's expectations regarding attaining the jobs they aspired to, and their previous engagement with computer games.

Sorting activity (Terraria): This tool provides indicators for the workshop's first and second objectives; improving awareness of careers in the games design industry and understanding of stereotypes respectively. The sorting activity involves using a 2-dimensional action game called Terraria to examine stereotypes. A set of 20 characters of different ethnic backgrounds and gender are provided to the children. They are asked to name some job roles they know in the gaming industry to evaluate their knowledge of related STEM careers. Children are asked to identify three of the characters from the list shown to them and assign each one of these characters to a different role. This activity explores stereotypes. The children also have to choose a role for themselves assuming they were involved in the games industry; this activity explored the children's inclination towards related STEM careers.

Game overview sheet: This tool is one of the means of presenting children's' process of game creation. The children plan the game they want to make using story points to help describe in more detail the games they intend to build and the kind of characters they want to create. The games overview sheet helps them create a narrative (tell a story). It provides a framework for participants to use online games for learning.

Planning sheets for designing the game: The planning sheet (see Fig 6) is the second means of presenting children's process of game creation. Children are able to provide a visual representation of what their games would look like by drawing and including details in their planning sheet. The planning sheets contains a legend key so that the children could keep track of what each item means.

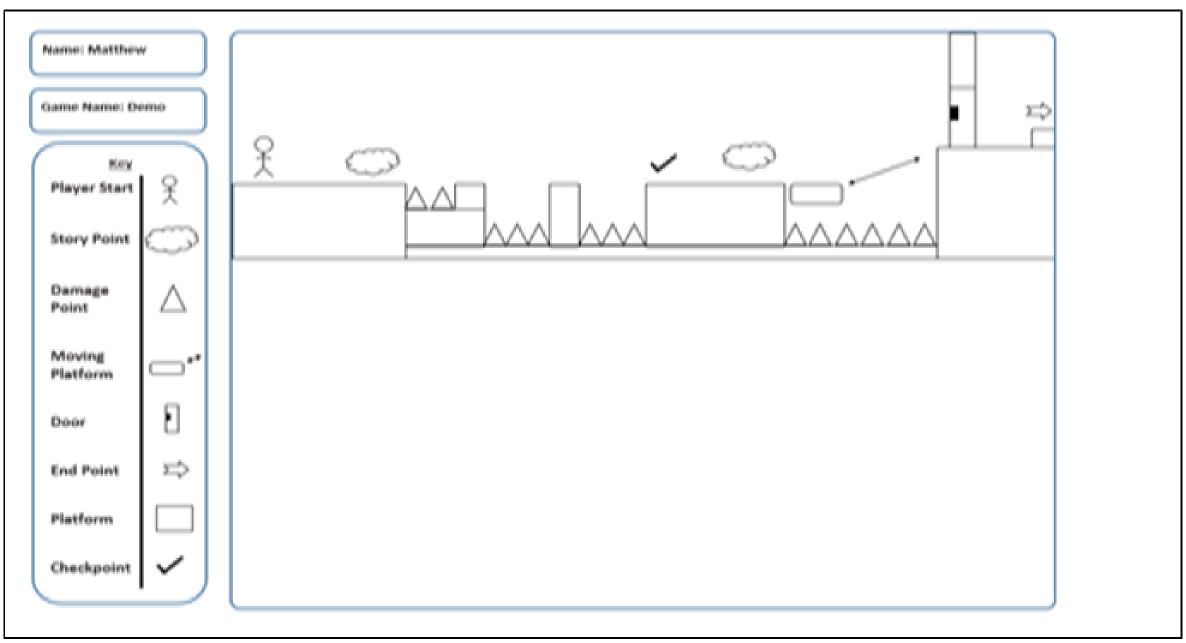

Figure 6: Planning sheet for designing game

Created games online: Using the story points and visual representations of the games children plan to build, they go online to create the game they want using the Gamefroot engine. As all the games are saved online, the characters that participants design and use in their game can be reviewed and evaluated after the workshop sessions. The created game is an indicator for the fourth objective of the workshop, improving or increasing application and practical skills.

Engagement factors: A set of engagement factors were used to help children evaluate each other's games and to further develop their own games. The engagement factors were visual appeal, theme of the game, clarity of the goal of the game, how challenging the game was, rewards in the game, feedback in the game and creativity of the game. These engagement factors questions were from already developed factors (Dele Ajayi et al., 2015). The children evaluated each other's games and also suggested which factors might need improving, which also provides evidence for application and practical skills.

4.3.5 Games design logic map

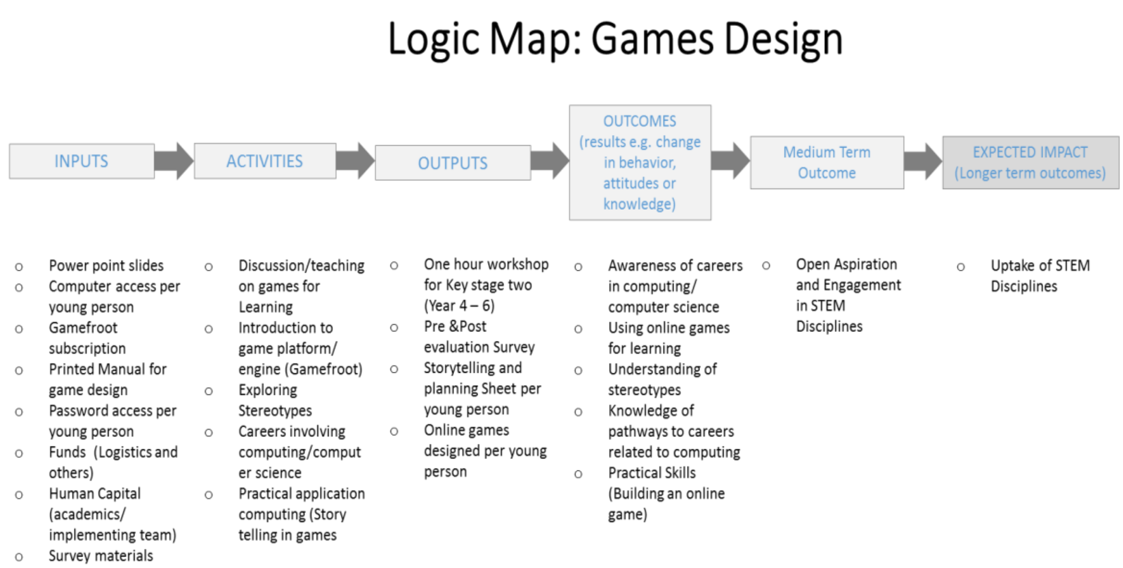

Figure 7: Games design workshop logic map

The logic map (Fig.7) provides provide a guide to the implementation of the workshop in terms of providing a structure of required inputs, outputs and expected outcomes. This stage of the research ushers in the 'acting' stage of the action research cycle. Using the logic map, a facilitator is provided with a checklist of requirements (inputs) through which children are introduced to games for learning, the Gamefroot engine, how design and build their own games and actually creating the games (activities). At the end of the workshop, the children should have completed 2hours (for the single session structure) or 6.5 hours (for the 5 session structure) of activity, have a pre and post questionnaire completed by all the children, compilation of background stories for planned games using the overview and planning sheets and also created games on Gamefroot (outputs). Analysis of the output can then indicate if the objectives of the workshop (outcomes) have resulted in a change in order to infer to widening aspiration and engagement in STEM disciplines (medium term outcome).

4.3.6 Games design workshop pilot

The pilot phase was mainly to explore the game engine to be used in the workshops and test out its usability. During the pilot phase, feedback was gathered from each of the children to help improve the workshop for future deliveries. The pilot games workshops were delivered in two sessions to 40 children aged 8-12 years. The children were from 20 different primary schools from the North East of England. Each session lasted two hours.

4.3.7 Games design main intervention(s)

The main workshop was an extension of the pilot workshop and consisted of 5 sessions over the course of 5 weeks with three of the sessions involving face-to-face delivery with academics. This allowed it to be scheduled over one half-term within the primary school setting. The other two sessions were for the children to have time developing their games with support from the academics, teachers or post graduates working with the academics.

The second main workshop was run in a similar format to the pilot workshop to test if the workshop would also work as a single session rather than as a series of workshop sessions. The Terraria sorting activity and the use of engagement factors were excluded from this workshop due to time limitations and a specific career was promoted (Games designer in this workshop).

4.4 Case study 2: Materials Science workshop

The academic research underlying the material science workshop is drawn from an academic in mechanical engineering whose research interests include smart materials and surfaces, shape memory metallic alloys and their properties. Other research interest areas include microalloying technologies and metallurgy (Hynowska et al 2012; Gonzalez & Sort, 2014;

Gonzalez, 2016; Nnamchi et al., 2019). This intervention explores material science, properties of different materials with particular focus on smart materials. The 1-hour workshop involved children in primary school (Key stage 2) exploring seven different materials; predicting and testing the properties of the materials. The smart material the children were introduced to is Nitinol which is a memory metal that remembers its shape when immersed in hot water.

4.4.1 Objectives of the materials science workshop

The objectives of this workshop are to:

- Create an awareness of materials scientist as a potential career (aligns with outcome 3).
- Understand the properties of materials (aligns with outcome 1).
- Understand the uses of prediction and testing (aligns with outcomes 2 and 4).
- Apply and use knowledge of materials and their properties (aligns with outcome 2 and 4).

4.4.2 Workshop design considerations and outcomes

During the planning stage using an action research cycle, some of the main features and considerations that were discussed in designing the material science workshop include:

- Activities that could fit into a 1-hour session consistent with the average teaching time for a subject within primary schools in the North East of England.
- Suitable materials to introduce to the children at the workshop. This was an important consideration because the materials had to have some physical differences that can be easily observed or felt. For example, materials with different colors, textures and densities. They also needed to be materials that children have encountered or heard about previously. This was necessary to ensure that children are able to relate or are at least familiar with. Seven different materials were selected due to their commercial availability as a set of materials; Brass, Aluminum, Copper, Steel, Stone, Perspex and Lead.
- Different properties of materials that children can investigate. Some of the properties considered were; test of mass, electrical conductivity, thermal conductivity, strength of materials and magnetism. Choice of the type of properties were constrained by ease of implementation, level of risk involved and availability of materials. Due to

the possibility of damage to materials during strength testing which might increase cost and affect sustainability of the workshop, strength testing was discarded.

- Possible methods children should use to investigate and test properties of the different materials.
- Considerations on location of workshop delivery. Suggestions were raised to deliver the workshop in the university lab space rather than in the school due to freezing logistics (ice cubes needed) for the thermal conductivity tests.
- Risk assessment of activities in the workshop. One of the risks identified was the scalding temperature of the water required for the memory metal to return to initial shape. It was decided that facilitators could handle the water at all times and the children were only allowed to drop in the memory metals while facilitators retrieved the metals.
- Evaluation tools that were not disruptive to the learning process were considered. This was necessary given the time constraint for the workshop themselves and that the evaluation tools needed to be easily embedded in the workshop delivery. Also, there were discussions on where to incorporate evaluation questions within the presentation slides.

4.4.3 Structure of the materials science workshop(s)

Similar to the structure of the games design workshop, aspects of the material science workshop are underpinned by Direct Instruction or Cognitive Constructivism OR an integration of the two learning theories. Elements of the learning theories are identified in the structure description by words in *(italics).*

Structure of the workshop

1. **Introduction:** The workshop starts with a general introduction and a safety information session. The children are asked questions regarding their knowledge of material scientists, what they thought material scientists do, what materials are and their thoughts on what materials, other things are made of (*triggering Prior Knowledge*). At the end of this activity, the children are shown slides and introduced to concepts in materials science and what materials scientists do because there can be misconceptions or wrong perceptions of what people do in this career *(eliciting elements of surprise)*.

2. **Investigating materials activity**: Children are asked to walk around the lab space or classroom, identify objects and suggest what materials the objects are made from, and why they think the objects are made from these materials. This activity is carried out to make children more conscious about materials around them and consider their properties. This activity can also *trigger prior knowledge*. Children are provided with examples by the facilitators and shown how to record their findings *(*use of *structured instruction).* Responses from the children are captured in an activity booklet

3. **Prediction and testing:** Children are introduced to the different materials. They identify similarities and differences between the materials *(seatwork).* They are also asked to discuss between themselves and provide some responses to the class. The children sort the materials based on their thoughts and predict: (1) Which materials are the heaviest and lightest, (2) Which are magnetic and non-magnetic, (3) Which did or did not conduct heat and (4) Which did or did not conduct electricity (*application of new knowledge*). The concept of prediction and testing is discussed following the activity. Fig. 8 shows some of the materials and tools used in the materials science workshop.

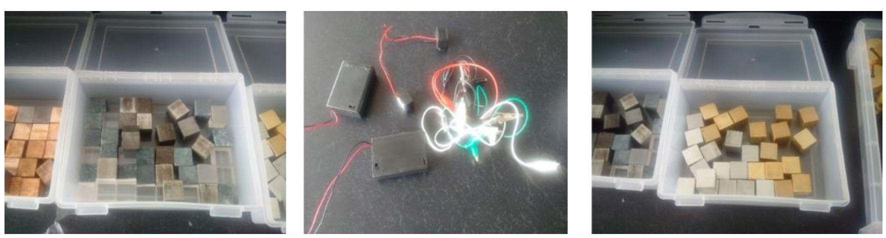

Figure 8: Some materials and tools used in the materials science workshop

4. **Independent activities completed by children:** The children are provided with magnets to test if the materials are magnetic, a balance to get the mass of the materials, and a buzzing electric circuit to test for electrical conductivity. By testing to find out if initial prediction were right or wrong, children are provided with *feedback* and can reflect on initial choices and why they could have been wrong.

5. **Activity that needed facilitator supervision:** The thermal conductivity testing is conducted with the facilitator who takes the ice blocks round each table to test materials in groups.

6. **Application of materials:** The children are then given a list of objects (for example a chair, boat anchor and walking frame for elderly people) and asked to identify which

materials they felt could be used to make the objects from the list of materials introduced to them. This is just to reinforce learning and make the children *apply new knowledge.*

7. **Smart Material:** The final activity is an introduction to memory metal where the children are asked to twist a Nitinol paper clip out of shape and then drop the deformed metal into a beaker of hot water. The memory properties of the metal are then discussed and the children asked to identify a possible use for Nitinol (*application of new knowledge*). They are then given opportunity to *interactively engage and question* facilitator(s) on concepts and topics learnt during the workshop. Fig. 9 shows samples of the smart material, Nitinol.

Figure 9: Image of samples of the smart material Nitinol used in the study

4.4.4 Materials science evaluation tool

The tool is designed as an activity book to reduce the amount of loose sheets of paper the children would have to work with which could cause distractions during workshop delivery. The activity book consists of the knowledge concept map/sheet, an identifying of materials sheet, a testing samples sheet and a materials application sheet.

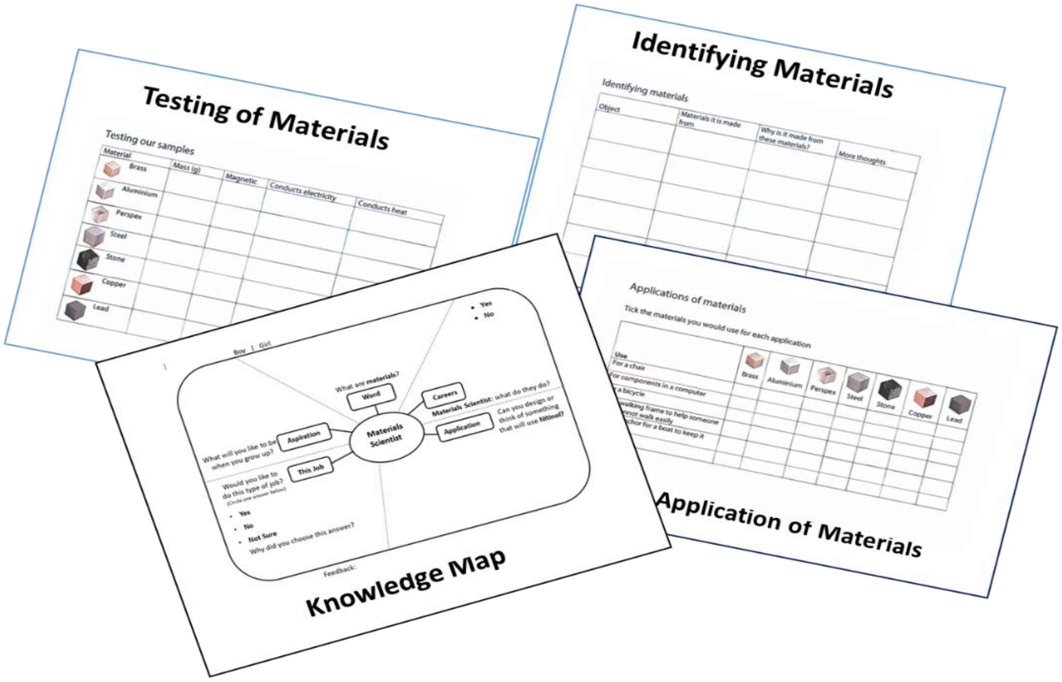

Figure 10: Evaluation tools for the materials science workshop

Knowledge/Concept map: This evaluation tool provides indicators for assessing the workshop's objective of creating awareness of materials science as a potential career through the pre- and post-experimental design. The knowledge map captures the aspirations of the children, their knowledge of the career 'materials scientist' and what they think people in that career do, their inclination towards the career and subject specific understanding of particular concepts (see appendix C2).

Materials identification sheet: The materials identification sheet provides indication of children's understanding of the properties of materials; second objective in the materials science workshop. This sheet captures children's responses to objects they are able to identify from their surroundings, their perception on what materials those objects are made from and why they feel those objects are made from those materials.

Testing samples sheet: This activity sheet provides evidence on applications of concepts learnt from the workshop. For example, application of prediction and testing which aligns with the third objective. The activity sheet captures the findings of the children's investigation when they find the mass of the metals, test for magnetism, electrical and heat conductivity.

Materials application sheet: This sheet evaluated the responses of the children to which materials (from the seven materials discussed in the workshop) they would use for specific applications. Items they were to suggest materials for include a chair, a bicycle, components of a computer, a walking frame and an anchor. This sheet provides evidence of application materials taking into consideration its properties which aligns with the fourth objective of applying and using knowledge of materials.

4.4.5 Materials science logic map

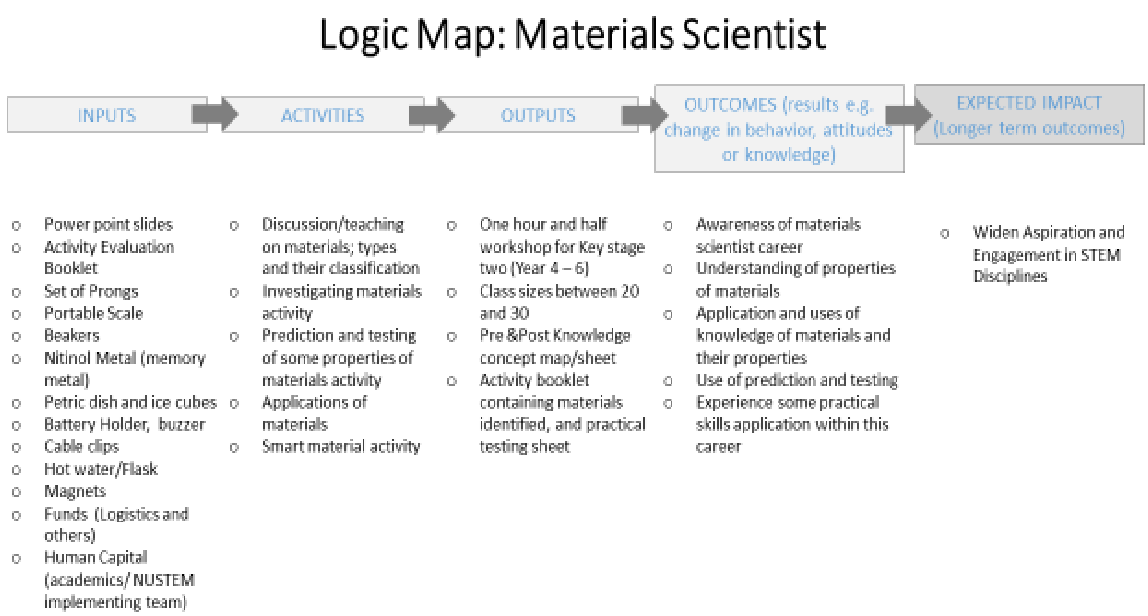

Figure 11: Materials science workshop's logic map

Similar to the games design logic map, Fig.11 presents the material science workshop's logic map used in the acting stage of the action research cycle to guide delivery of the workshop. The input section lists out the required components needed to deliver the activities through identifying properties, testing, predicting and application of materials. Evaluation of the workshop are carried out using output indicators from the pre and post knowledge map sheets and the activity booklet to assess effects on the outcomes (objectives of the workshop).

4.4.6 Materials science workshop pilot

Data for the pilot phase were collected from 54 children from 2 primary schools in the North East of England. The children selected were within the target age group specified for the scope of this study as discussed in the previous chapter. The workshop was delivered twice on Northumbria University premises. The pilot phase explored the evaluation tools and the implementation of the workshop. Data was collected during the delivery of the workshop.

4.4.7 Materials science main intervention(s)

The first run of the workshop was carried out in a primary school with 58 participants from two year 3 classes. A pre- and post- quasi-experimental design was also used for the evaluation of the workshop. Pre-evaluation data was collected during the workshop and the post-evaluation data was collected a month later.

4.5 Case study 3: Geography workshops

The geography intervention comprises series of three (3) separate workshops stemming from a collaboration between multiple academics within geography research areas to promote geography as a science career and explore links between different geography careers. Three different careers were promoted: *palaeontologist*, *environmental modeller and environmental planner*. Each of those careers themes are used to inform the design of a workshop. Each 1-hour workshops involved children in primary school (aged 8-11 years) learning about the past and how to look back in time using microfossils for the palaeontology workshop; learning about maps and their uses in predicting the future in the environmental planner workshop; and the third workshop, environmental modeller highlighted the importance and application of using models to make predictions. Each of the geography workshop is presented as a mini-case study and similarities are discussed across the group because they share the same justifications for the reasoning behind the design decisions.

4.5.1 Mini case study 1: Paleontology

The academic research underlying the palaeontology workshop are drawn from academics in geography whose research interests include studies in paleoclimate, modern and prehistoric environments, Artic and Antarctica sites (Strother et al., 2015; Strother et al., 2017; Salabarnada et al., 2018). The 1-hour workshop involved children in primary school (aged 8-9 years) exploring microfossils and how these are used to look back in time through core sample analysis.

4.5.1.1 Objectives of the paleontology workshop

During the reflection stage of this project, the following objectives were developed. Children will know or have an understanding of:

- Paleontology as a career and what people in this career do (aligns with outcome 3)
- What fossils are (aligns with outcome 1)
- Why we want to know about the past (aligns with outcome 2)
- Microfossils, which are used to understand climate in the past testing (aligns with outcomes 1 and 4)
- Core samples, and their uses in understanding past climate (aligns with outcome 2)

4.5.1.2 Workshop design considerations and outcomes

Some features and considerations discussed during the planning stage of the action research cycle of this project include:

- The types of fossils to introduce to the children. The type of fossils introduced needed to be portable for logistics purposes and be available in sufficient quantity so that every child could have a hands-on experience and study fossil specimens either individually or in pairs. A collection of fossil specimens were provided by the academic team associated with the project.
- The types of microfossils to introduce children to, and how to indicate their size. Since microfossils are not visible to the naked eye, suggestions were made to provide images of the microfossils and an image of a microfossil, going through the eye of a needle to indicate how tiny it is.
- What analogy to use to show how paleontologists look back in time, and how sediment layers build up in the environment. Suggestions were made to show an image of a room with a build-up of worn clothing. The type of clothing an indication of the season such clothing are worn. For example mittens in winter and sun hats in summer. The mittens and sun hats are an analogy for microfossils which are markers to indicate the season or environmental conditions at the time.

4.5.1.3 Structure of the paleontology workshop(s)

Structure of the workshop

1. **Introduction:** The introduction section is similar to the materials science workshop in structure and making use of elements two elements from cognitive constructivism; *triggering prior knowledge* and *element of surprise*. The workshop starts with a general introduction. The children are then asked questions regarding their knowledge of the career paleontologist, what they think paleontologists do, what fossils are and their thoughts on how we could look back in time. Children are showed slides and have a discussion with the facilitator on what paleontologists actually do
2. **Fossil drawing activity:** The children are given sample and images of fossils and asked to draw what they see (see Fig. 12). This is to engage children to observe and explore with sight and touch. This activity incorporates *seatwork* where the children work at their own individual pace. They are then introduced to microfossils and provided with sand from the sea-floor and asked to look through microscopes to draw what they see *(application of new knowledge).*

Figure 12: Samples of fossils shown to the children

3. **Introduction to a core sampler:** The children are shown a core sampler and how it is used to take core samples. The usefulness of microfossils from core samples is discussed; how corers let us look back in time.
4. **Fossil Identification and counting activity:** This activity incorporates more *seatwork*. Using a fossil sheet, the number of fossils present in a particular period are

used to show what type of environment existed in that or previous periods. The importance of looking back in time is highlighted. Children are given an activity to identify specific fossils and using a key, predict the vegetation of the area from years back *(application of new knowledge)*. They are also allowed to *engage and interact* with the facilitator(s).

5. **Past-future link activity:** After the children have identified fossils and predicted the vegetation in specific time periods, they start linking the past to the future by looking at what has happened in the past 30 million years with regards to the climate and what they think would happen to potential future climate.

4.5.1.4 Paleontology evaluation tool

The two tools used in this workshop are the knowledge concept map/sheet and the fossil identification sheet.

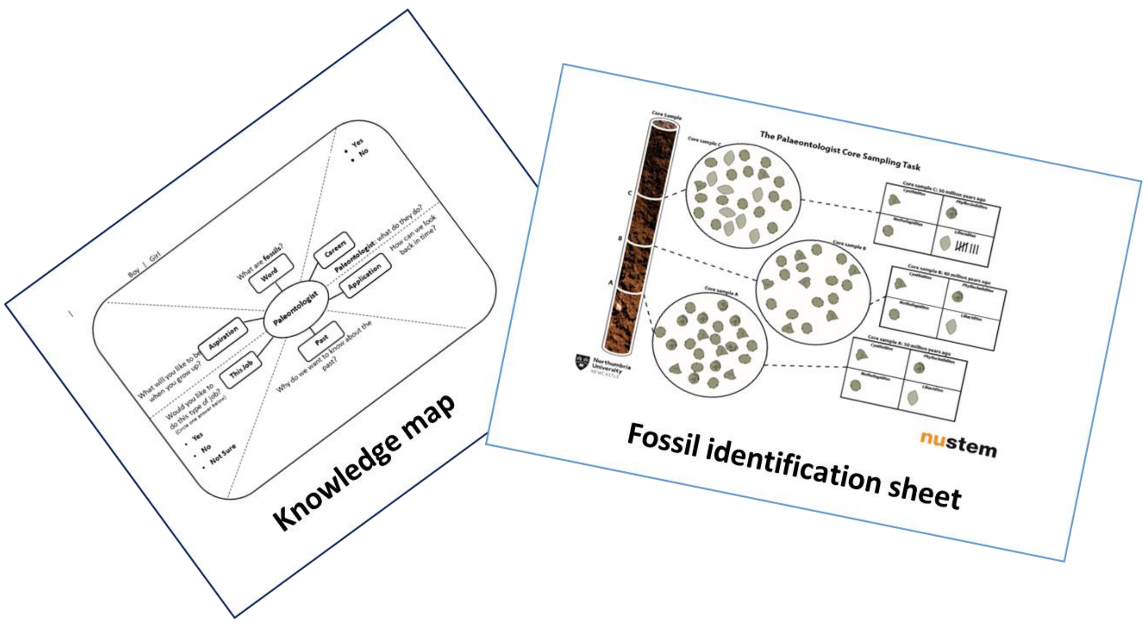

Figure 13: Evaluation tools for the paleontology workshop

Knowledge/Concept map: The knowledge concept map is the main tool used to provide indicators to assess all the objectives from the paleontology workshop**.** This activity sheet captures the aspirations of the children, their knowledge of the career paleontologist and what they think people in that career do, young people’s inclination towards a paleontology career, understanding of fossils and how to look back in time (see appendix C3).

Fossil identification sheet: This sheet provides evidence of understanding and application of taught concepts. This activity sheet is used by the children to identify different type of fossils used to represent different environments. The children count the number of each type of fossils from core sample representations dated 30, 40 and 50 million years ago.

4.5.1.5 Paleontology logic map

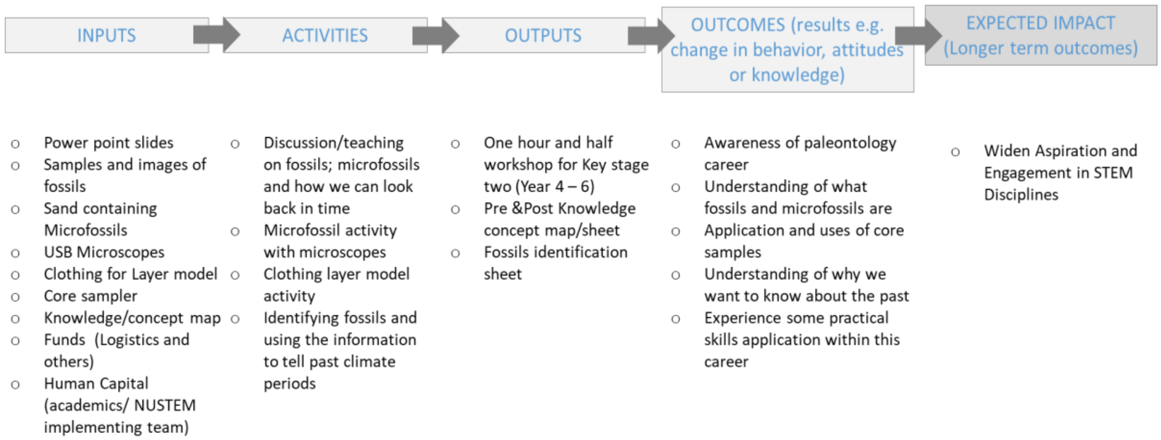

Figure 14: Paleontology workshop's logic map

Consistent with previously shown logic maps, Fig. 14 presents the paleontology workshop's logic map to guide delivery of the workshop activities. The fossil drawings, microscopic observations, use of microfossils to look back in time and other activities are carried out through, input of necessary components, such as human capital, microscopes, fossil samples and slides, for the delivery of workshop. Evaluation of the pre- and post-intervention knowledge map sheets outputs are used to assess effects on the workshop's outcomes.

4.5.1.6 Paleontology workshop pilot

The recipients of this workshop were 27 children in year 4, aged 8- 9 years old, consistent with the targeted age group for this research from a primary school in Newcastle, North of England.

4.5.1.7 Paleontology main intervention(s)

The workshop was carried out in a primary school in the summer term with 65 children from two classes of year 4.

4.5.2 Mini case study 2: environmental modelling

The academic research underlying the environmental modelling workshop are drawn from academics in geography whose research interests include the hydrology of icy environments, snow measurements to limit uncertainties in created models, glaciology and climate modelling (Rutter, 2005; Essery et al., 2009; Sandells et al., 2014; Watts et al., 2015; Maslanka et al., 2019). The workshop involved children in primary school (aged 9-10 years) exploring models and concepts of prediction and uncertainties.

4.5.2.1 Objectives of the environmental modelling workshop

The objectives of the workshop are aimed at children knowing or having an understanding of:

- Environmental Modelling as a career and what people in this career do (aligns with outcome 3)
- Prediction and its uses (aligns with outcome 2)
- The concept of uncertainty (aligns with outcome 1)
- What models are and their importance (aligns with outcomes 1, 2, & 4)
- The difference between weather and climate (aligns with Outcome 1)

4.5.2.2 Workshop design considerations and Outcomes

Some of the design considerations and features taken into account in designing the workshop during the planning stage of the action research cycle include:

- How to present concepts in a logical manner such that children are able to relate activities they know or understand to more abstract concepts such as prediction and uncertainty. Sequencing of concept introduction during the workshop, took place.
- How to introduce the concept of prediction and explore children understanding of the concept, in an age appropriate and easy to understand manner. An example of the weather was used where children described the weather of the day and expressed their thoughts on what they thought the weather would be some days in the future. They were then asked to explain the rationale behind their expressed thoughts on future weather conditions.
- How to introduce the concept of a model in an easy to understand manner, and possible examples to represent a model. Activities were considered that were easy to implement but still offered enough variability in design. For example, modelling a

'house' with more design considerations than a 'cup' with limited design considerations.

- Activities that could explain the differences between weather and climate. Considerations included using a bucket and bean bags at different distances to indicate the differences in time between weather and climate.
- Activities to introduce climate change, including use of graphs, and maps

4.5.2.3 Structure of the environmental modelling workshop

In line with other case studies previously described, the structure of this workshop is also underpinned by elements from Direct Instruction and Cognitive Constructivism learning theories.

Structure of the workshop

1. **Introduction:** The workshop starts with a general introduction. The children are then asked questions regarding their knowledge of the career environmental modelling, what they think environmental modellers do, what models are, the difference between weather and climate and their thoughts on what prediction means *(trigger prior knowledge).* Children are shown slides describing what environmental modelling entails and what people in those careers do (*eliciting elements of surprise).*
2. **Prediction activities:** There are two prediction activities. In the first activity, the children are given an example of how someone can predict the weather tomorrow based on some information they may have. The children are then asked to make predictions about the weather next week and weather on their 20th birthday (*triggering prior knowledge* and *application of new knowledge*). The second activity involves using bean bags and throwing into a bucket. The bucket is placed at different distances for the children to throw in bean bags. The activity incorporates elements of *structured instruction* and *application of new knowledge* through explanations on how to use the activity to understand the concept of uncertainty and the activity itself respectively. The closer the bucket is to the individual, the more accurate the prediction of the thrown bean bags entering the bucket and vice versa. The further the bucket is from the individual, the more uncertainty is introduced
3. **Modelling activity:** The children discuss their thoughts on what a model is after which they engage in some *seatwork* designing a model of a house using modelling

plasticine. Some of the children are asked to explain their design to the whole class and application of models are also discussed

4. **Climate Change Modelling Activity:** this activity involved checking the temperature for different countries at different time periods. Children are provided with activity sheets to record their findings *(application of new knowledge).*
5. **Climate change:** This aspect of the workshop was an *interactive discussion* on climate change, its effects and how climate change will affect temperature was also discussed.

4.5.2.4 Environmental modelling evaluation tool

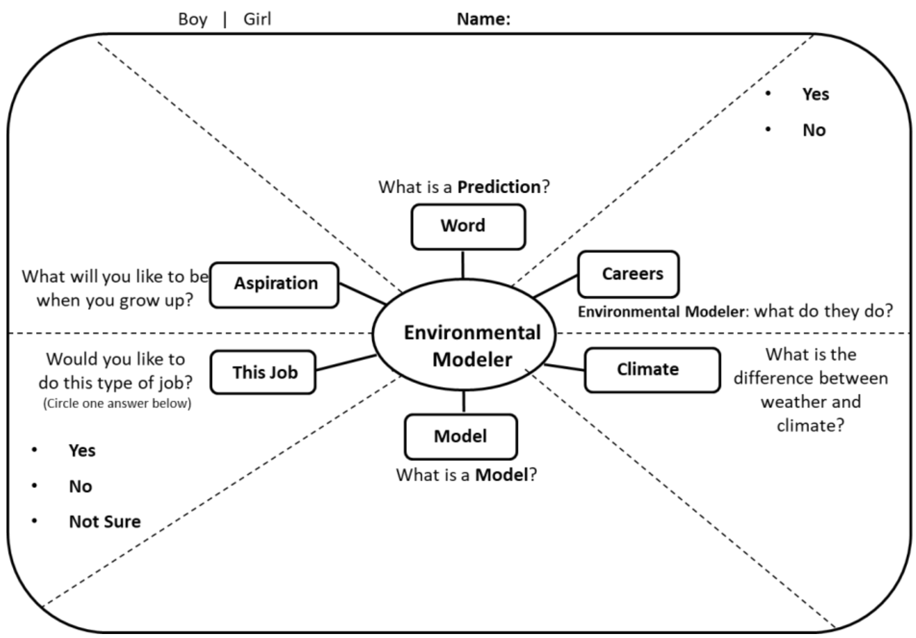

Figure 15: Knowledge map evaluation sheet for environmental modelling workshop

Knowledge/Concept map: This is the main evaluation tool used to provide indicators to assess the objectives of this workshop. This activity sheet captures the aspirations of the children, their knowledge of the career paleontologist and what they think people in that career do, if the young people would like to do the career and subject specific understanding of particular concepts.

4.5.2.5 Environmental modelling logic map

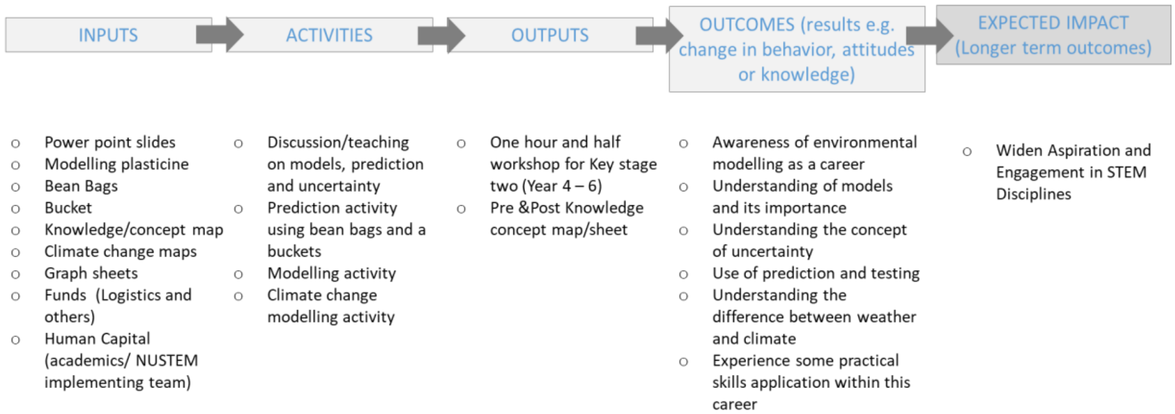

Figure 16: Environmental modelling workshop's logic map

Fig 16 presents the environmental modelling workshop's logic map. Input materials such as slides, modelling plasticine, bean bags and buckets are used in delivering activities to the children. For example the prediction and modelling activity. Again, evaluation of the pre- and post-intervention knowledge map sheets outputs are used to assess effects on the workshop's outcomes.

4.5.2.6 Environmental modelling workshop pilot

The recipients of this workshop were 27 children in year 5, aged 9-10 from an NUSTEM partner primary school in Newcastle, North of England.

4.5.2.7 Environmental modelling main intervention(s)

The workshop was carried out in a primary school with 63 children from two classes of year 5 aged 9-10 years.

4.5.3 Mini case study 3: environmental planning

The academic research underlying the environmental planning workshop are drawn from academics in geography whose research interests include coastal risk mapping, sea level trends, application of geospatial approaches and interests in palaeoenvironments (Perry et al., 2015; East, 2017; East et al., 2018; Liang et al., 2019). The 1-hour workshop involved children in primary school (Key stage 2) exploring maps from different time periods and changes in the coastlines over time with possible responses to changing situations of the coastlines.

4.5.3.1 Objectives of the environmental planning workshop

The objectives of the workshop are aimed at children knowing or having an understanding of:

- Environmental Planning as a career and what people in this career do (aligns with outcome 3)
- What maps are and their uses (aligns with outcome 2)
- That maps change over time and space (aligns with outcome 1)
- That maps are used for prediction about the future (aligns with outcome 4)

4.5.3.2 Workshop design considerations and outcomes

During the planning stage using an action research cycle, some of the main features and considerations that were discussed in designing the environmental planning work workshop include:

- The type of mapping activity to showcase to the children. Google earth was initially considered but was discarder because it required internet connection to search for specific locations which might be unavailable in primary schools on the workshop delivery date. Printed maps were selected instead.
- Suitable locations on the map to use for workshop activities. It was suggested to use areas where the school taking part in the workshop is located. This is because children will be familiar with the area and will be able to relate to it. One thing to note is that maps might require reprinting of new areas if the workshops would be delivered in new schools outside the area printed in a previous workshop, to reflect the location of the new school.
- The historical nature of the maps used. It was important to find a set of time periods for which the maps of an area existed to enable children make comparisons on similarities and differences in the map area within the time periods used. The time periods chosen were 1856, 1955 and 2018.
- Suitable activity to use to explain some practical activities and applications of environmental planning. The use of actions required around the coastlines was suggested since children might be familiar with the North Tyneside, Northumberland coastlines around them. Although the North East was not chosen at the end to depict

the issues around the coastline because it might have felt too close to home for the children and also because the issues around the coastline in the North East is not as severe as some other areas in England for example, Mappleton.

4.5.3.3 Structure of the environmental planning workshop(s)

Structure of the workshop

1. **Introduction:** Utilising the same structure as other geography workshops in this research study, this section also incorporates elements of *triggering prior knowledge* and *eliciting surprise*. The workshop started with a general introduction. The children were then asked questions regarding their knowledge of the career environmental planning, what they thought environmental planners did, what maps are and their uses.
2. **Similarities and Differences:** Children are provided with two maps from different time periods and asked to identify similarities and differences in features on the map by putting tracing paper over the maps and highlighting those differences or similarities using coloring pens/pencils. The children are given the 2018 map first to look at to explore current landscape and infrastructure and then they are given a tracing of a historical map, either 1856 or 1955. This allows the children to *apply new knowledge* acquired.
3. **Discussion and tracing of coastlines:** The children were asked what environmental planners could learn from maps of coastlines. There is an *interactive discussion* between children and facilitator on how coastlines change over time. The children are provided with *seatwork* time to map out changes in the coastlines which are documented by tracing the receding coastlines from the different maps in different periods.
4. **Managing of coastlines:** Children are taught about the methods for managing coastlines using *structured instruction*. Children are provided with a seatwork activity where they have to apply the new knowledge learnt on managing coastlines. The activity explores strategies used in managing coastlines such as holding the line, managing retreat, doing nothing or advance the line. Children use tracing paper and coloring pens to indicate their choices.

4.5.3.4 Environmental planning evaluation tool

Two tools are used in this workshop to assess children's perceptions and understanding which are the knowledge concept map/sheet and tracing sheet.

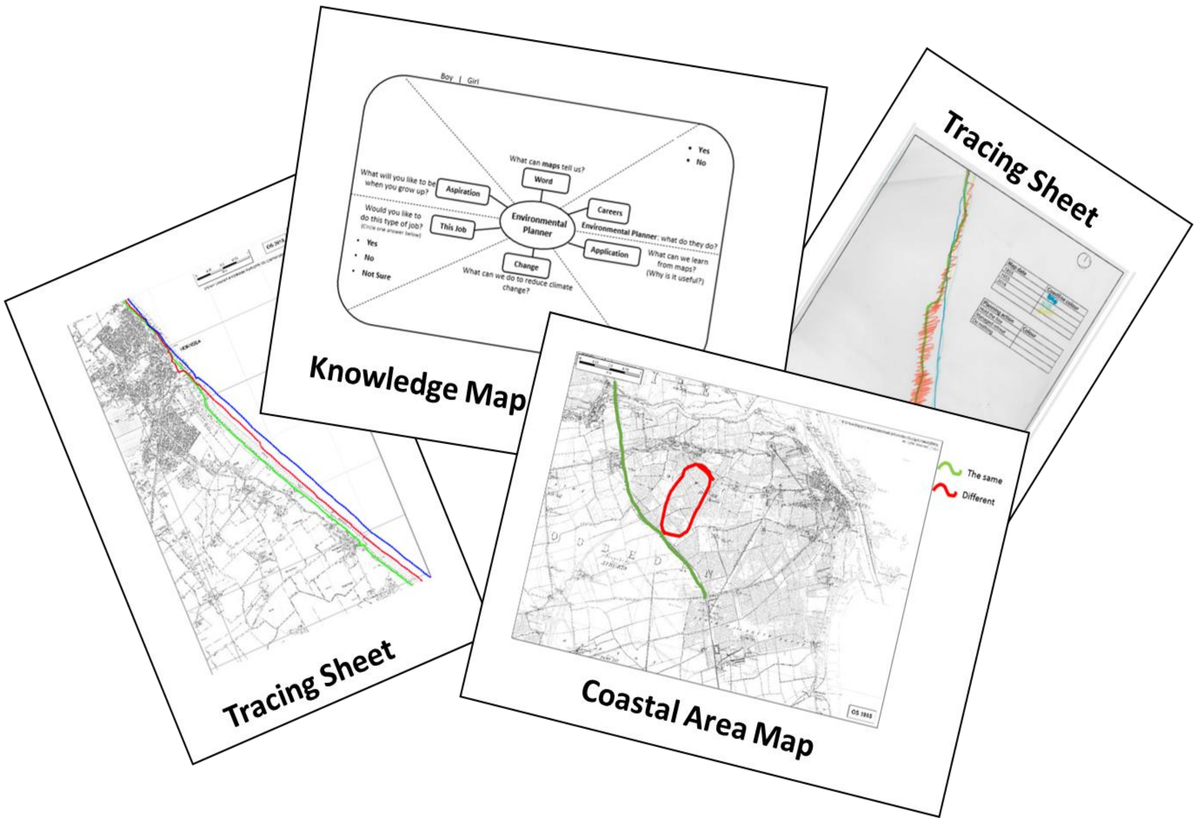

Figure 17: Evaluation tools for the environmental planning workshop

Knowledge/Concept map: This activity sheet captures the aspirations of the children, their knowledge of the career paleontologist and what they think people in that career do, if they would like to do the career, perceptions of what fossils are, why we want to look back into the past, and how to look back in time. Similar to other knowledge maps used in this research, this map provides indicators to assess the objectives of the workshop (see appendix C4).

Tracing sheets: The tracing sheet was used to trace coastlines and allow participants see similarities, differences and shifts that happen on the coastline over time. This sheets provide evidence on the application of maps and aligns with the workshop's fourth objectives of understanding uses of maps to predict the future.

4.5.3.5 Environmental planning logic map

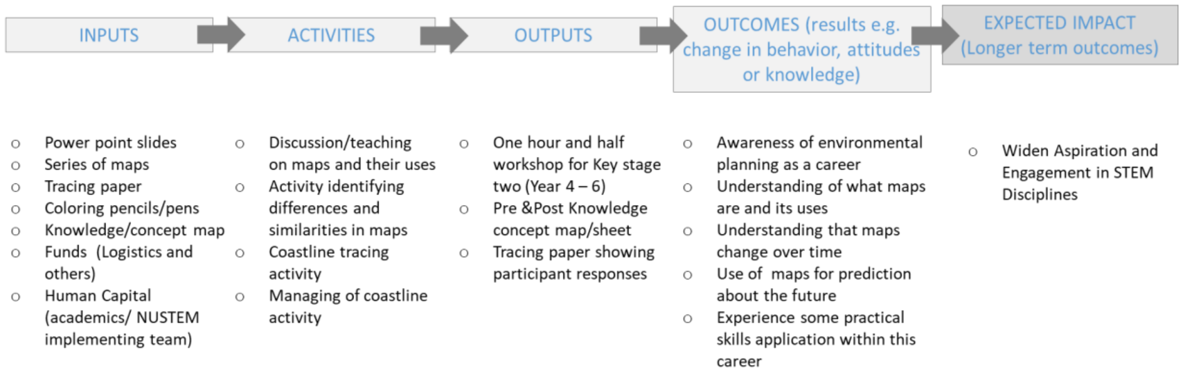

Figure 18: Environmental planning workshop's logic map

The logic map shown in Fig. 18 can be used to guide the implementation. Using an input of a series of maps, tracing papers, knowledge maps, children are able to engage in activities that explore changes in environments and coastlines over time. Using the responses from the concept map (outputs), changes in the workshop outcomes can be assessed.

4.5.3.6 Environmental planning workshop pilot

The recipients of this workshop are 22 children in year 6, aged 10-11 from a primary school in Newcastle, North of England.

4.5.3.7 Environmental planning main intervention(s)

The main intervention workshop was carried out in a primary school with 61 children from two classes of year 6 (aged 10-11).

4.6 Summary

The chapter outlines the sets of case studies from three disciplines. It describes the design and considerations required to create the workshops, the various evaluation tools used and the implementation of the workshops. The chapter shows how each of the workshop's design structure is underpinned by elements from two pedagogical learning theories, Direct Instruction and cognitive constructivism. All the case studies make use of the action research cycle in the design and implementation of the workshops. The chapter describes how the evaluation tools in each of the workshops are used to achieve the objectives of the workshops, which are in turn linked to the overall Theory of Change model's outcomes. The chapter also summarizes how data was collected in each workshop from the pilot and main intervention phases.

CHAPTER FIVE – ANALYSIS AND FINDINGS OF PILOT STUDIES

5.1 Introduction

This chapter presents findings from the pilot phases of the workshops. It is concerned with the fourth stage of the action research cycle, the observe stage. Findings from this analysis of the pilot stage were used to assess the implementation and effectiveness of both the workshop delivery and the evaluation tools. The evaluation tools were designed to assess the children in terms of their gender distribution, STEM aspiration, knowledge and understanding of career promoted, subject specific knowledge, understanding of applications of subject content and inclination towards the career promoted in the workshop.

This chapter discusses the implementation of the workshops. They are presented in the same order as they were delivered and the findings from one workshop informed the delivery of the subsequent workshops. The chapter also presents descriptive statistics data for the common components across the different workshops. After this, subject specific findings are presented for each of the discipline based workshops.

5.2 Pilot phase

The first pilot was the games design workshop. Data collected from this workshop was used to assess the evaluation tools, workshop implementation and the impact on the children. The evaluation tools used to collect the data included a pre- and post-questionnaire, sorting activity sheet, planning sheet, games overview sheet and engagement factor sheet (refer to section 4.3.4 for more details). The second pilot was the materials science workshop. The main evaluation tool used for the materials science workshop is the activity booklet consisting of the knowledge map sheet, materials identification sheet, testing samples sheet and materials application sheet (refer to section 4.4.4 for more details).. Data collected during this workshop was mainly used to assess the evaluation tool. This was necessary because the materials science workshop format and structure was different from the games design format and structure. The games design workshop was practical and application based and the children's learning could be assessed by examining the final games that were created. The materials science workshop explored different materials but the children did not produce an end product such as a game so evaluation was mainly through the results from completion of a carefully designed evaluation sheet by each child. Findings from the pilot of the materials science workshop were then used to improve the evaluation tools used in the pilot of the geography workshops (paleontology, environmental modelling and environmental planning workshops). These geography workshops had a similar structure to the materials science workshop. The main evaluation tool used across the geography workshops was the pre- and post-knowledge maps (refer to sections 4.5.1.4, 4.5.2.4 and 4.5.3.4 for more details).

5.3 Descriptive statistics of pilot studies

Analysis of the survey data was carried out using the SPSS statistical package (IBM, 2016). Descriptive statistics were used to summarize the characteristics of the data collected across the different disciplines in terms of gender distribution, aspirations in general and STEM aspiration. An alpha level of .05 was used for all statistical tests.

5.3.1 Gender distribution of children in pilot studies

Table 6 below shows the gender distribution across the dataset from the different discipline workshops collected during the pilot study phase.

Table 6: Gender distribution of children across intervention workshops (Pilot Studies)

Workshop	Male Freq. (%)	Female Freq. (%)	No response Freq. (%)	Total Freq. (%)
Games Designer	18 (45%)	22 (55%)	0	40 (100%)
Materials Scientist	24 (44.4%)	24 (44.4%)	6 (11.1%)	54 (100%)
Paleontologist	5 (18.5%)	2 (7.4%)	20 (74.1%)	27 (100%)
Environmental Planner	8 (36.4%)	6 (27.3%)	8 (36.4%)	22 (100%)
Environmental Modeller	14 (51.9%)	13 (48.1%)	0	27 (100%)

Children completed the gender question across all the different workshops except for the paleontology workshop which had a large percentage of no response (74%) from the children. This was due to an error on the response sheet that did not include the section indicating gender, therefore the children were not asked to fill in their gender during the workshop.

5.3.2 Aspiration findings

At the start of each workshop, children were asked the question "What would you like to be when you grow up?''. Their variety responses are shown in the word cloud in Fig. 19.

Figure 19: Participants aspirations from pilot studies

Children responses across all the workshops show that they already have particular careers they are considering at a young age given the variety in their responses. The most common career aspirations were 'footballer' and 'vet'. This is shown in Table 7 and presented graphically in Fig. 20. The table and figure present the frequency and distribution of children's aspirations that were mentioned more than once (frequency count of at least two).

Table 7: Aspirations of children with the highest frequency count (pilot studies)

Child Aspiration	Freq.
Footballer	12
Vet	12
Paleontologist	6
Youtuber	6
No Response	5
Scientist	4
Gymnast	3
Police Officer	3
Architect	2
Astrophysicist	2
Doctor	2
Engineer	2
Soldier	2

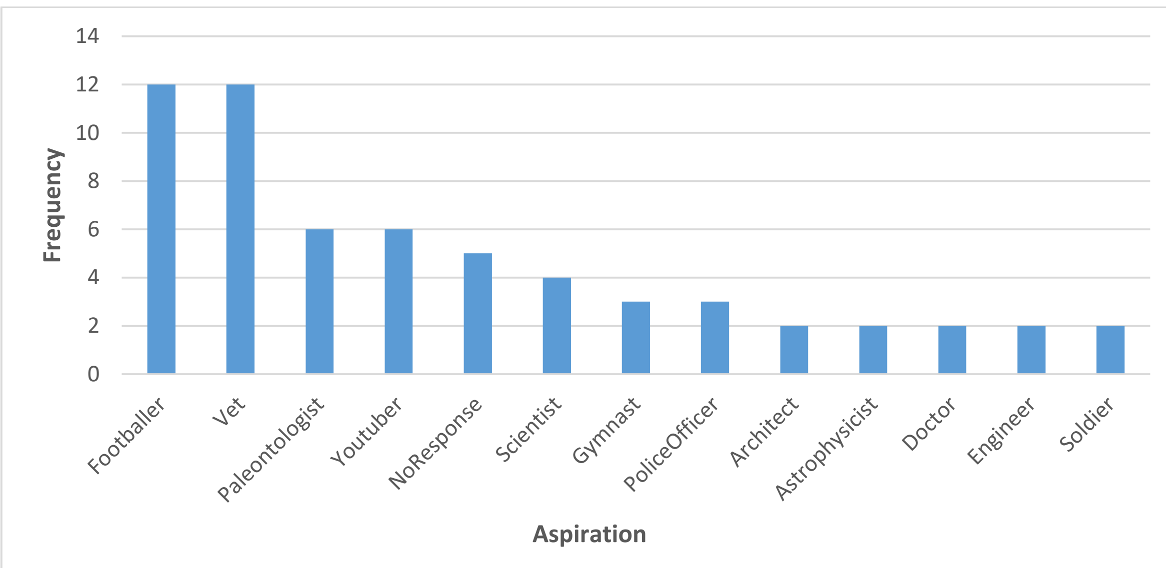

Figure 20: Aspirations of children with the highest frequency count (pilot studies)

5.3.3 STEM aspiration distribution in pilot studies

Responses of children to the question ‘’what would you like to be when you grow up?’’, were coded into STEM aspirations, non-STEM aspirations, and null response. Occupational aspirations were classified into STEM and non-STEM occupations using the UK Standard Occupational Classification (SOC) system (Office of National Statistics, 2019). Occupations were checked using the occupation code search tool. Many of the STEM occupations mentioned by the participants fell within two groups; the professional occupations (group 2) and the associate professional and technical occupations (group 3) hierarchies of the SOC system. Summary of children's responses are shown in Table 8.

Table 8: STEM and non-STEM aspiration distribution of children across intervention workshops (pilot studies)

Workshop	STEM Freq. (%)	Non-STEM Freq. (%)	No response Freq. (%)	Total Freq. (%)
Games designer	26 (65%)	14 (35%)	0	40 (100%)
Paleontologist	14 (51.9%)	11 (40.7%)	2 (7.4%)	27 (100%)
Environmental planner	5 (22.7%)	15 (68.2%)	2 (9.1%)	22 (100%)
Environmental modeller	7 (25.9%)	19 (70.4%)	1 (3.7%)	27 (100%)

Aspiration data was not collected in the pilot of the materials science workshop because the workshop was mainly to assess the workshop implementation and the evaluation tools used. From the games design workshop, results indicate:

- 65% of children aspire to a STEM Career of which 73% (19) are female and 27% (7) male. A chi- square test of independence was performed and results suggests an association between gender and STEM career aspirations, X^2 (1, N = 40) = 9.808, p =.002. Whilst these results initially suggest more females likely to aspire to STEM careers than males, more females are likely to aspire to health sciences related careers.
- 28% of the children aspire to a career in the health sciences; all of which are female (no male from this dataset aspire to a career in health sciences. The data also suggests evidence of an association between Gender and STEM career aspirations in the Health Sciences (p=.000, Fisher's Exact test).
- Of the children that aspire to a STEM career, only 5% (2) aspire to a career associated with computer science. Both participants are male and both aspired to be game designers.

Results from the geography workshops:

- From the paleontology workshop before the intervention, results indicate that 51.9% of children aspire to a STEM career of which 22.2% (6) want to be paleontologists.

- From the environmental modelling workshop before the intervention, 25.9% of children aspire to a STEM career of which 71.4% (5) are females who all aspire to careers in health sciences and 28.5% (2) are male.
- Results from the environmental planning workshop before the intervention show 22.7% of children aspire to a STEM career, none of who indicated their gender.
- STEM careers aspirations seemed to decline as the children got older. From 51.9% among 8-9 years old children (paleontology workshop), to 25.9% among 9-10 year olds (environmental modelling workshop) and 22.7% among 10-11 year olds (environmental planning workshop).
- Fisher's Exact tests were carried out and there was no significant association between gender and aspiring to a STEM career in data from all of the geography workshops

5.4 Digital games workshop pilot phase findings

While the previous section presented statistics across the different workshops, the following sections will present findings from the individual discipline workshops starting with the digital games workshop. The questionnaire used in the pilot study for the games design workshop can be found in appendix C1. Findings from this pilot study indicate:

- 68% (27) of children play online games regularly of which 52% (14) are male and 48% (13) female. There is no evidence from the dataset of an association between gender and playing online games regularly, X^2 (1, N = 40) = 1.576, p =.209
- The job roles most identified in the gaming industry are games designer, Programmer, games artist and games tester
- Children identified some job roles that they would like to do if there were in the gaming industry. The following job roles had the highest frequency: 15% (6) chose games tester, 10% (4) programmer, 8% (3) games designer and 8% (3) games artist. Of all the roles, only females selected games artist, games author and Illustrator. More males than females chose programmer as a career. An equal mix of males and females chose to be games testers when asked to pick a role in the gaming industry
- Fisher's Exact tests were carried out and there was no significant association between gender and the role children would like to do if they were in the gaming industry.

- In the sorting activity, participants were requested to assign roles to characters. The three characters selected most often for a job role in the gaming industry were male while the three characters selected the least often/commonly for a job role were all female.

5.4.1 Lessons learnt from the implementation of games design pilot workshop

The main lessons learnt from the implementation of the pilot phase of the games design workshop are:

- The game engine worked better using chrome rather than internet explorer (version 11). Use of internet explorer to run the Gamefroot engine had the internet browser freezing or not responding and the children were unable to access the Gamefroot engine at times.
- The story sheets required a lot of explaining and prompts for participants to further develop their intended game aim and story which was time-consuming. Facilitators had to go round the groups prompting the participants using questions such as '*what is your game about?', 'who is or are your main character(s)?',* and *'what is/are your character(s) supposed to do to achieve the goal of the game?'*
- Aspects of the workshop that did not work well was the creation of more than one level in the game. Some participants spent time making many levels for their game without developing a particular level in detail.

5.4.2 Lessons learnt from the evaluation of the games design pilot workshop

The main lessons learnt from the evaluation of the games design pilot workshop are:

- The pre- and post-data collection survey worked well. The children showed no difficulties in completing the questionnaires and it did not take them much time.
- There was difficulty assessing individual stereotypes during the games creation process because many of the participants created single characters in their games and many of the characters created were non-human (including animals and zombies). These made it difficult to determine gender of the characters.

5.4.3 Reflections on the pilot phase of the games design workshop

Observations from the implementation and evaluation of the games design workshop identified recommendations for improving subsequent games workshops. Even though the children were provided with an instruction guide on games creation, frequent requests for explanation on 'story points' required a further investigation into how to provide more age appropriate solutions. There were suggestions to include more visual representations (such as GIFs) on the story points, and directions on how to perform some actions in building games. Other suggestions were to put up these representations during the game creation stage online or on a screen so that different participants could follow the procedure at the same time rather than through one on one explanations.

Discussions with the academics and primary outreach specialists provided recommendations that there was a need to spend more time at the beginning to talk the children through the story telling drawing process. It was also recommended that the story point sheet should include prompt sentences or lines to guide the participant using bullet points rather than facilitators asking the children individually. This required adapting the games overview sheet to include these questions: *'What is the game about?'*; *'Who are the characters?'*, and '*What does one need to do to win?'*

In order to further explore stereotypes, it was suggested that facilitators highlight the need for participants to include more than one character in the games they designed to provide a clearer picture of their perspective regarding stereotypes. This also necessitated the inclusion of the question *'which other characters are in your game?*' in the storyline prompts in the games overview sheet.

5.5 Materials science workshop pilot phase findings

As previously mentioned at the beginning of the chapter, this workshop had a different structure to the games design workshop. Thus the data collected during this pilot phase was used to assess the implementation of the workshop and the evaluation tools. In addition to the hands on activity of testing and predicting different material properties, subject specific knowledge was also evaluated. Participants were asked about their perception on what materials were and their thoughts on what people in such careers do.

5.5.1 Perception of what materials are

When children were asked about their perception of what materials were, many of the children mentioned items or objects with few children providing descriptive explanation of their perceptions of materials. Table 9 shows sample responses of children's description of materials by gender. Table 10 shows the list of objects and frequency count of participants that mentioned the objects. Total frequency count is more that the sample size because some participants mentioned more than one item or object.

Table 9: Sample responses of children's description of materials and gender

Description of what materials are	Gender (M/F)
They are things you can feel around you	F
I think materials are fabrics that can be used for different things	F
Materials are a type of clothing	F
It is fabric and clothing	M
Everything to use to build stuff	M
Objects with different strengths	M

Findings suggest that males seem to describe materials in terms of building materials while females seem to describe them in terms of clothing.

Table 10: List of objects and frequency count of participants that mentioned the objects

Materials	Freq.			% Total
	Male	Female	Total	
Fabric/cotton	10	16	26	48.1
Metal	11	11	22	40.7
Wood	6	10	16	29.6
Rock/stone	7	5	12	22.2
Plastic	3	8	11	20.4
Objects	4	4	8	14.8
String	1	5	6	11.1
Everything	2	4	6	11.1
Substances	0	1	1	1.9
Glass	0	1	1	1.9
Living things	0	1	1	1.9

Again, while males identify objects that could be structural, for example, things that are used to build (metals, rocks, and stones), females identify objects that are more personal to them for example, clothing and strings.

5.5.2 Perception of what people in a materials science career do

Children were asked what they thought materials scientists did in their jobs. Table 11 shows children's by gender.

Table 11: Participants responses to 'what materials scientists do' (pilot study)

What do material scientists do?	Male (Freq.)	Female (Freq.)	Total (%)
Studies/researches materials	5	4	16.7
Suggests what we need for clothes/ designs clothes	3	4	13
Test materials	3	4	13
Build/collect resources	6		11.1
Uses/works with different materials	3	2	9.3
Invent/experiment with materials		4	7.4
Looks at different objects and finds out which is flammable and what they are made of		3	5.6
They make things	2	1	5.6
Makes materials	2		3.7
Makes 3D models with 3D printers	1		1.9
Fix materials	1		1.9
Binding	1		1.9
Finds things and researches how to make more		1	1.9

Many of the participants across gender describe the job material scientists do as using, working with, studying and testing materials. While only males describe the job in terms of building and collecting resources, females describe the job in terms of inventing and experimenting with resources.

5.5.3 Lessons learnt from the implementation of the materials science pilot

Testing thermal conductivity involved the use of ice block cubes and required a facilitator to demonstrate the activity to each group. This would prove difficult to do in practice for large groups given time constraints of a workshop. Also, this activity could potentially provide logistical issues in environments without access to freezers to keep the ice from melting, for example, in schools. It should be noted that the pilot workshop was delivered on University grounds.

5.5.4 Lessons learnt using evaluation tools for the materials science pilot

The initial evaluation tool used in the pilot study did not have the gender on the evaluation sheet but required the facilitator, at the beginning of the workshop, to ask the children to it include on the sheet. Many participants wrote their names and indicated their gender on the evaluation sheets, although they were not asked to include their names. This might be due to the common routine of putting their name on their work in schools.

After the pilot workshop was completed, it was realised that the researcher assumed the children had previously heard about the career promoted during the workshop. Even though there was a survey question on children's perception of what people do in the promoted career, the question 'Materials scientists: what do they do?' did not adequately capture children's previous knowledge of the career.

5.5.5 Reflections on the pilot phase of the materials science workshop

Findings from the evaluation tools influenced the suggested inclusion of a question in the survey on the children's prior perceived knowledge of the career. This was necessary in order to differentiate between participants that feel they know about the careers and those that feel they do not know about the career, irrespective of their responses to what people in those careers do in their jobs. The recommended question included in the survey to assess perceived knowledge was 'Do you know who a material scientist is?'

5.6 Paleontology workshop pilot phase findings

The pilots of the geography workshops followed a similar structure to the material science workshops, therefore the results of the pilots for the paleontology, environmental modelling and environmental planning workshops are presented without describing the structure again.

5.6.1 Perception of what people in a paleontology career do

Young people were asked before the start of the workshop what they thought paleontologists did. Below is a summary of responses from the workshop in Table 12

Table 12: Participants perceptions of what paleontologists do (pilot study)

What does a Paleontologist do?	Freq.	%
Dig up fossils	12	44.4
No response	5	18.5
Investigate fossils/ things from the past	4	14.8
Work with animal fossils	2	7.4
Build stuff/make things	2	7.4
Search for important stuff	1	3.7
Study dinosaur fossils	1	3.7
Total	27	100

The majority of participants think that paleontologists dig up fossils. The responses of the young people to this question as seen in the table above suggests possible prior engagement with the concept of paleontology. The researcher was unable to investigate responses from the paleontology pilot in terms of gender, due to the high, no response percentage indicating gender as explained in section 5.3.1

5.6.2 Knowledge or understanding of subject specific concepts in paleontology pilot study

Three subject specific questions were asked to assess children's understanding of specific concepts before the start of the workshop. These were:

- What are fossils?
- How can we look back in time?
- Why do we want to know about the past?

Tables 13 -15 presented, show a summary of participants' responses. Actual list of children's responses can be seen in appendices D1-D3.

Table 13: Children's responses to what fossils are (pilot study)

What are Fossils?	Freq.	%
Type of bone	12	44.4
Bodies/remains of all sorts of creatures including plants	5	18.5
Rocks/ shapes	3	11.1
Things from the past	2	7.4
A big thing people can find	1	3.7
Bolls	1	3.7
No response	1	3.7
A type of animal	1	3.7
Things that have hardened up through time	1	3.7
Total	27	100

The majority of the participants described fossils as a type of bone.

Table 14: Participants responses to 'how to look back in time' (pilot study)

How can we look back in Time?	Freq.	%
No response	7	25.9
Microscope	7	25.9
By using fossils	5	18.5
Study of dinosaur bones/fossils	3	11.1
Use images/stuff	3	11.1
Use a time machine to study fossils	1	3.7
They look back in time because of the fossils they find	1	3.7
Total	27	100

The use of microscopes was the response with the highest frequency count as a means of looking back in time. This is consistent with knowledge gained from use of microscope in one of the workshop activities.

Table 15: Participants' responses to 'why we want to know about the past' (Pilot studies)

Why do we want to know about the past?	**Freq.**	**%**
No response	7	25.9
To see what the world was like in the past	6	22.2
We could find out how much oxygen there was in the past	3	11.1
It is interesting to learn about	3	11.1
For information	2	7.4
To save the world by getting fruit and money off trees	2	7.4
It is a great thing to do	1	3.7
So we can find more fossils	1	3.7
So we know that things exist	1	3.7
Because they are okay	1	3.7
Total	**27**	**100**

5.6.3 Lessons learnt from the implementation of the Paleontology pilot

The fossils, microscope and sand activities kept the children engaged and many of them seemed fascinated when they were shown where the sands they handled came from. The children also seemed to enjoy sketching the fossils. Suggestions were made by the academics and NUSTEM outreach specialist on exploring 3D printing of larger versions of pollen grains and microfossils so that the young people could look at and handle those. Children were quite attentive during the activity involving assisting with the core sampler. Suggestions were made on providing more demonstration with that or allocating more time to it. The academic involved in the delivery of the workshop, enjoyed the engagement in the classroom particularly the question sessions where the children provided their own responses to questions on subject concepts, to understand their thoughts on the subject before the academic provided explanation on the concepts.

5.6.4 Lessons learnt using evaluation tools for the paleontology pilot

While the evaluation tools captured the perception of participants as intended, there seemed to be a learning curve required for the facilitators to use the knowledge maps effectively. Facilitators require practice in using the knowledge maps in order to ask the evaluation questions at the appropriate time during the delivery of the workshop.

5.6.5 Reflections on the pilot phase of the paleontology workshop

The children seemed to be aware of paleontology as a career and concepts relating to the career as shown from the aspiration responses and 'what are fossils' responses. It might be worthwhile engaging the class teacher prior to the workshops to understand the level of engagement the participants have had with the concepts to be discussed in the workshop.

The implementation of the evaluation tool highlighted the need for practice using the tool. Academics or persons delivering the workshop(s) should have a trial run delivery of the workshop to familiarize themselves with the tools and its positioning within the workshop delivery before going into schools.

5.7 Environmental Planning Workshop Pilot Phase Findings

Using a similar design as other workshops, children were asked what they thought people in environmental planning careers did. Table 16 presents a summary of their responses.

Table 16: Children's responses to 'what environmental planners do' (pilot studies)

What does an Environmental Planner do?	**Male (Freq.)**	**Female (Freq.)**	**Didn't say (Freq.)**	**Total (%)**
A person who plans out the environment	5	0	4	41
No response	2	1	1	18.2
Help the world/environment	0	3	0	13.6
Somebody that looks after the environment	1	1	0	9.1
Give the environment a better place	0	0	1	4.6
Might predict what happens to the environment	0	1	0	4.6
They want to run their own things like look after the environment	0	0	1	4.6
When they want a fountain placed down and have to plan it	0	0	1	4.6
Total	**8**	**6**	**8**	**100**

5.7.1 Knowledge or understanding of subject specific concepts in environmental planning pilot study

Three subject specific questions were asked to assess the children's understanding of specific concepts before the start of the workshops. These were:

- What is a map?

- What can we learn from maps?
- What can environmental planners learn from maps of coastlines?

Tables 17 - 19 present summaries of children's responses to these questions respectively. Full list of children responses can be seen in appendices D4-D6.

Table 17: Summary of children's responses to 'what a map is' (pilot study)

What is a map?	Freq.	%
A map is a piece of paper that has locations in it to show you where to go	4	18.0
A map is a plaque that tells you where a location is	1	4.5
A thing that helps you get to places that you don't know where they are	3	13.5
An object which shows you places	3	13.5
It is just a map/ map of the world	3	13.5
Something that helps you get around and find things	5	22.5
Tells you where you need to go and helps you find places	3	13.5
Total	22	100.0

From the responses, children seemed to have understanding of what a map is.

Table 18: Summary of participants' responses to 'what we can learn from maps' (pilot study)

What can we learn from maps?	Freq.	%
No response	1	4.5
Because they tell you where to go	1	4.5
Some maps show you difference and they change over the years/ things change over time	13	58.5
They are useful when lost to help find way home	2	9
We can learn how our land area was years before now	1	4.5
We can learn whereabouts the place you need to be is	3	13.5
House, school	1	4.5

Table 19: Summary of participants' responses to 'what environmental planners can learn from maps of coastlines' (pilot study)

What can environmental planners learn from maps of coastlines	**Freq.**	**%**
No response /do not know	6	27
So that the sea does not fill the sea beach	1	4.5
That they cannot build their stuff	1	4.5
You can get higher or lower water levels	2	9
To see how big the coast is	5	22.5
Where the land meets the sea and how tsunamis are created and when they might happen	1	4.5
Whereabouts the land meets, changes position over the years	4	18
To see what can go where on the beaches	1	4.5
To see where the sea is and which colour that is different to the coastline	1	4.5

5.7.2 Lessons learnt from the implementation of the Environmental Planning pilot

The exploration of maps and the activities were well received by the young people. Highlighting similarities and differences from the different maps also worked well, it kept the young people really engaged and produced very interesting discussions amongst them. Making use of participants local area map seemed to be appreciated particularly because it was where they lived and they enjoyed seeing what used to be where their house was.

While the general structure of the workshop seemed well received by the participants, the academic participating in the workshop delivery was not convinced that the young people completely understood the prediction and management aspects of the coastal exercise. The academic felt the quality of discussions had with the children did not allow them think deeply about the challenges and benefits of decisions an environmental planner made on the job. Given the time constraints, there wasn't really enough time to explain/break it down further. Some examples of engineering solutions were proposed to be incorporated for future workshops. It was also suggested that in subsequent workshops to choose to either management or prediction (rather than both).

5.7.3 Lessons learnt using evaluation tools for the environmental planning pilot

To uniquely identify children, they were asked to write on their survey response and activity sheets, a three item code: their favorite pet, number and colour. The use of the combination of identifiers (pet, number and colour) for the young people worked really well because the possibility of having two children or more having the same combination of animal, number and colour was low. This made it easy to link the different response sheets for a particular individual. However, each child required a minimum of six different colors to complete the required tasks, so there were not enough coloring pencils/pens for different tracings required. This posed a challenge during analysis of the responses on the tracing paper because the young people used the same colors to represent different aspects of their responses

5.7.4 Reflections on the pilot phase of the Environmental Planning workshop (Pilot Phase)

Aspects of the workshop needed to be reviewed to improve understanding of specific concepts by the participants. Reflections on the workshop highlighted differences that can occur with implementation compared to the designed plan. It showcases what worked and what did not work well during implementation and the evaluation process, to improve and achieve the intended outcomes of the workshop. Also exclusion of some of the questions for evaluation reinforced the need for practice of delivery as previously identified in the other geography workshop.

5.8 Environmental modelling workshop pilot phase findings

The young children were asked if they had previously heard about the career 'an environmental modeller'. Responses can be seen in the Table 20.

Table 20: Distribution of participants' responses on previous knowledge of the career environmental modeller (pilot study)

Have you heard of an Environmental Modeller before?			
Response	**Male**	**Female**	**Total**
Yes	1 (50%)	1 (50%)	2 (100%)
No	13 (52%)	12 (48%)	25 (100)

Results indicated that only 7.4% (2) of children in the class had previously heard about the career environmental modeler.

Table 21: Participants responses to 'what environmental modellers do' (pilot study)

What does an environmental modeler do?	Freq.	%
No response	20	74.1
Environmental	1	3.7
Heard about it but forgotten	1	3.7
Not sure	1	3.7
Someone who helps the environment	1	3.7
They create models	1	3.7
They create stuff in the environment	1	3.7
They help the environment, predict the future	1	3.7
Total	27	100.0

Participants were asked what they thought people in environmental modelling careers did, 20 (74.1%) of the young people had no response for the question on what an environmental modeler does. Results indicate that the children did not have much prior knowledge about the career 'environment modelling'.

5.8.1 Knowledge or understanding of subject specific concepts in environmental modelling pilot study

Three subject specific questions were asked to assess the children's understanding of specific concepts. These were:

- What is a prediction?
- What is the difference between weather and climate?
- What is a model?

Summary of responses to these three questions are shown in Tables 22, 23 and 24 respectively.

Tables 5.17: Summary of children's responses to 'what a prediction is' (Pilot studies)

Table 22: Summary of children's responses to 'what a prediction is' (pilot studies)

What is a prediction?	Freq.	%
A guess	14	51.8
Opinion	5	18.5
Something you think will happen	5	18.5
Predict	2	7.4
When you talk about something or someone	1	3.7
Total	27	100

The majority of children described a prediction as a guess (51.8%), as an opinion (18.5%) or something that is likely to happen (18.5%). Results suggest that children seemed to have some prior knowledge on the concept of prediction (see appendix D7 for full list).

Table 23: Summary of children's responses to 'the difference between weather and climate' (pilot study)

What is the difference between climate and weather?	Freq.
Climate is night, weather is day	2
They are the same thing	2
Not sure/ I do not know	2
Climate is how the weather affects the environment	1
Weather is the temperature and climate is the wind and things	1
Weather is the sun, rain and climate is the temperature	1
Weather is like snow, rain, sleet and climate is the temperature	1
Weather is for days, climate is for years	1
The difference is the word, they are not the same	1
The weather is like rain, snow, sleet, sun and hail while the climate are the degrees of the weather	1
Climate is the temperature and weather is the type of climate. weather is snow, rain and sun while climate is the degrees like 32deg	1
Weather means sunny and hot while weather is cold and bad	1
A climate could be a season and weather is when it rains and stuff	1
Weather is rain and sun while climate is hot and windy	1
Climate is the degrees and weather snow	1
Climate is everything but the weather is just a little bit	1
Weather is snow, sun and sleet while climate is the river, water and what makes it	1
Weather is like when it is sunny and climate is like the temperature	1

Children provided a wide variety of responses to the difference between weather and climate. Results suggest the children did not understand or know the difference.

Table 24: Summary of children's responses to 'what a model is' (pilot study)

What is a model?	**Freq.**
Something like a sculpture of another thing	4
Looks the same but it is not	3
Something that looks like the same but it is not and could be an example	2
A thing you make	2
Someone who models for a job and does really well or a statue	1
Someone who creates something	1
It is a special device	1
A structure of a kind	1
A structure someone makes or a person who shows off clothes	1
An example	1
It's like a face	1
It is a type of equipment lie the computer	1
Not sure	1
A person who sets a good example, it is a thing you can make	1
Not sure	1
A thing for show	1

5.8.2 Inclination towards environmental modelling career (Pilot studies)

At the end of the workshop, the young children were asked if they would like to do the career that was the topic of the workshop. See Table 25 for distribution responses

Table 25: Distribution of participants' inclination towards an environmental modelling career (pilot studies)

Career	**Would you like to do career being promoted?**	**Male (Freq.)**	**Female (Freq.)**	**Total**
Environmental Modeller	Yes	9	2	11
	No	4	7	11
	Not sure	1	4	5
	No response	0	0	0
	Total	**14**	**13**	**27**

Findings indicated

- 40.7% of children say they would like to do the career promoted of which 81.8% (9) are males and 18.2% (2) are females.
- 40.7% of children say they would not like to do the career promoted of which 36.4% (4) are males and 63.6% (7) are females.
- 8.5% of children say they are not sure if they would like to do the career promoted of which 20% (1) is male and 80% (4) females.
- Results suggest an association between gender and children that would like to do an environmental modelling job, (p= .048, Fisher's Exact test)

5.8.3 Lessons learnt from the implementation of the environmental modelling pilot

The academic involved in the facilitating and delivery of the workshop felt the complexity of the message was pitched at the correct level. The children seemed to enjoy the activities as well as the topics raised. The building of house models generated good discussions between the children. They seemed to understand the link between distance of throwing the bean bag (one of the activities) and the concept(s) of uncertainty/predictive capacity.

There were suggestions to allocate more time for Q&A about doing fieldwork (especially fieldwork in the arctic) because the young people were particularly interested in asking questions about that. This required reducing aspects of the workshop for example, the individual throwing bean bags activity.

5.8.4 Lessons learnt using evaluation tools for the environmental modelling pilot

The evaluation tool was mainly the knowledge map, similar in structure to the map in other geography workshops excluding the questions to evaluate subject specific knowledge. Embedding the knowledge map into the workshop presented no issues and participants were able use it and insert their responses as the workshop delivery progressed.

5.8.5 Reflections on the pilot phase of the Environmental Modelling workshop (Pilot Phase)

Post workshop results indicated a large gender difference in the number of young people that would like to do a career in environmental modelling (81.8% males and 18.2% females). This raised the question if having males deliver the workshop, affected the gender of participants that would like to do the job. It highlights the importance of the consideration of controlling for different facilitators delivering workshops. While in practice, it is intended for different facilitators to deliver the workshops, for this research, it was important to control for differences that might arise from different facilitators by having the same facilitator deliver the evaluated workshops used in the main study across the different disciplines.

5.9 Chapter Summary

This chapter presents the findings from the pilot studies of the different workshops. The results of the analysis are presented. Combined descriptive statistics are presented for ease of comparisons in terms of gender distribution and STEM career aspirations. Discipline specific findings are presented along with a reflection on the lessons learnt in terms of implementation and the evaluation for each of the workshops which is important for accessing the adequacy of the evaluation tools used in the individual workshops.

Summary of findings from the pilot studies:

- Children responses across all the workshops show that they already have particular careers they are considering at a young age.
- The most common career aspirations across all the workshops were ‘footballer’ and ‘vet’.
- In the games workshop, 65% of children aspire to a STEM career, 51% from the paleontology workshop, 25% from the environmental modelling workshop and 22% from the environmental planning workshop
- Results from the games workshop suggests an association between gender and aspiring to a STEM career.
- Results from the games workshop also suggests an association between gender and aspiring to a STEM career in the health sciences, with females more likely to aspire to health sciences related careers compared to males.

- The job roles most identified by the children in the gaming industry are games designer, programmer, games artist and games tester.
- When the children were requested to assign roles to characters in the games design workshop, the three characters selected the most for a job role in the gaming industry were male while the three characters selected the least for a job role were all female.
- From the materials science workshop, males seem to describe materials scientist job in terms of building and collecting resources while females describe the job in terms of inventing and experimenting with resources.
- Majority of participants think that paleontologists dig up fossils
- Almost half of the participants from the paleontology workshop describe fossils as a type of bone
- Children seemed to have an understanding of what a map is, in the environmental planning workshop
- Results indicate that the children did not have much prior knowledge about the career 'environment modelling'.
- Children seemed to have some prior knowledge on the concept of prediction in the environmental modelling workshop
- Children did not seem to understand or know the difference between weather and climate.
- 40% of the children say they would like to do an environmental modelling career (82% males and 18% females).
- Results suggest an association between gender and children that would like to do an environmental modelling job.

CHAPTER SIX – ANALYSIS AND FINDINGS FROM MAIN INTERVENTION

6.1 Introduction

The previous chapter focused on the analysis and findings in the pilot stage which were mainly used to assess the workshop delivery and evaluation tools across the different workshops. In this chapter, analysis and findings for the main workshops are presented. The main intervention was carried out in two phases. Phase one consist of the games workshop that was delivered in five sessions and the materials science workshop incorporating all the feedback from the pilot session and delivered in a single session. The second phase consist of all five workshops delivered once each.

Results are presented in line with the time sequence in which the workshops were implemented: games design, material science, geography. Then comparisons are presented across the different disciplines. This is followed by subject specific findings for the different individual comparison workshops in the second phase.

6.2 Digital games main workshop (phase 1) findings

The evaluation from the games design workshop took place over the course of the five sessions and explored both the robustness of the workshop and whether it provided opportunities for participants to have a deeper engagement with games design. The results from this evaluation are presented below.

6.2.1 Gender distribution in game design workshop (phase 1)

The games design workshop was delivered over 5 sessions to a class of 20 children comprising 12 males (60%) and 8 females (40%) pre- and post-workshop. The higher number of males compared to females was not pre-selected but rather the normal class distribution from the school used in the study. Children attendance varied during course of the workshop sessions due to pupil absence, so 20 represents the number that attended the 5 workshop sessions.

6.2.2 Findings on aspirations of young people in game design workshop (Phase 1)

The participants were asked what job they would like to do in the future, before the workshop sessions and post the workshop sessions. Their responses are provided in Table 6.1. This table shows the pre- and post-intervention response for the same child. Each child was individually tracked using the unique codes used in log-in for the game engine. Consistent with the pilot studies, aspiration responses were classified into STEM and non-STEM occupations using the UK Standard Occupational Classification (SOC) system as described in section 5.3.3. The summary of participants' responses are shown in Table 26.

Table 26: Pre and post aspiration of young people in games design workshop (phase 1)

Gender	**Pre - workshop aspiration**	**Pre STEM**	**Pre CS**	**Post - workshop aspiration**	**Post STEM**	**Post CS**
Male	Baker	No	No	Chef	No	No
Male	Teacher	No	No	Teacher	No	No
Male	**Pilot**	**Yes**	No	**Pilot**	**Yes**	No
Female	Builder	No	No	**Game tester**	**Yes**	**Yes**
Male	Teacher	No	No	Teacher	No	No
Female	**Pilot**	**Yes**	No	**Pilot**	**Yes**	No
Female	Teacher	No	No	Teacher	No	No
Female	Ice hockey player	No	No	Ice hockey player	No	No
Female	Footballer	No	No	Footballer	No	No
Female	Train driver	No	No	Musician	No	No
Female	**Computer developer**	**Yes**	**Yes**	**Gamer**	**Yes**	**Yes**
Female	Footballer	No	No	**Games developer**	**Yes**	**Yes**
Male	Artist	No	No	Hairdresser	No	No
Female	Builder	No	No	Miner	No	No
Male	**Nurse**	**Yes**	No	**Midwife**	**Yes**	No
Male	Gymnast	No	No	**Computer programmer**	**Yes**	**Yes**
Female	RA	No	No	Foster carer	No	No
Female	**Engineer**	**Yes**	No	**Games designer**	**Yes**	**Yes**
Male	Care worker	No	No	Care worker	No	No
Female	**Palaeontologist**	**Yes**	No	**Palaeontologist**	**Yes**	No

From Table 6.1, the variables are categorized according to gender (1 = male, 2 = female), aspiration, STEM aspiration (yes or no), aspiration related to computer science (CS). Results indicate:

- Almost half (9) of the children have the same aspiration pre- and post-intervention.
- Shows an increase in the number of children's aspirations to a STEM job from 30% (n=6) pre workshop to 45% (n=9) post-intervention workshop.

- One child (5%) aspired to a computer science related career pre- intervention. This percentage increased to 25% (n=5) post-intervention.
- No association was found between gender and STEM career aspiration pre-workshop (p = 1.000; Fisher's Exact Test).
- No association was found between gender and STEM career aspiration post-workshop (p = .670; Fisher's Exact Test).
- No association was found between gender and computer science aspiration pre-workshop (p = .603; Fisher's Exact Test).
- No association was found between gender and computer science aspiration post-workshop (p = 1.000; Fisher's Exact Test).

6.2.3 Findings on choice of game characters (phase 1)

When the children created their games, they were given a free choice on which type and gender of character they chose (within the boundaries of GameFroot). These characters were analysed with the following results:

- The data suggests evidence of an association between gender of children and choice of lead character in the game (p=.021; Fisher's Exact Test).
- Females created a diverse set of lead characters including females, males, animals and non-human, while the males created male characters.
- 10% of children chose a female lead character (n= 2, both females).
- 65% of the children chose a male lead (n= 13; 3 females and 10 males).
- 15% of children chose more than one lead character (n=3; 1 female and 2 males).
- 10% of the children chose an animal as their lead character (n= 2, both females).

When the children created additional characters, the following distribution was observed:

- There was no evidence from this dataset of an association between gender and choice of additional character in the game (Fisher's Exact Test).
- 80% of children included additional characters in their plan (n= 16).
- 6% of the children chose just females as additional character(s) (n= 1 female).
- 19% of the children chose only male as additional character(s) (n= 3, all male). No females chose just male additional character(s).

- 13% of children chose a mixture of male and female additional characters (n=2, both females). No male chose a mixture of male and female additional characters.
- 19% of the children chose zombies as their additional characters (n= 3, 1 female and 2 males).
- 25% of the children chose monsters as their additional characters (n= 4; 1 female and 3 males).

6.2.4 Findings on evaluation of each other's games using engagement factors (phase 1)

The children were introduced to some game engagement factors (Dele-Ajayi et al., 2015) which they used to evaluate each other's created games. The results of the children's evaluation of each other's games did not result in any significant findings in five of the six engagement factors used (visual appeal, theme, clarity of goals, challenge, and reward). Findings from the dataset however suggested an association between gender and the engagement factor 'feedback' (p= .027; Fisher's Exact Test). Feedback from the engagement factors refers to notifications in the game. For example, notifications informing the player about progress, tasks and actions during game play.

- 32% of children felt they did not get feedback from the game they evaluated (n=7; 4 females, 2 males, 1 person gender unknown).
- 32% of children felt they got feedback from the games they evaluated (n=7; 6 males and 1 person gender unknown).

Results of the other engagement factors can be found in appendix E1.

6.2.5 Changes in number of jobs known in gaming industry (phase 1)

Children were asked to list out the jobs they knew in the gaming industry pre- and post-intervention. While there was no evidence from the data to suggest an association between gender and number of jobs known, the following was observed:

- 45% of the children named more jobs post-workshop compared to their pre-workshop survey responses (n=9; 6 females and 3 males).
- 30% of the children identified fewer jobs post-workshop compared to their pre-workshop responses (n=6; 2 females and 4 males).

- 25% of the children knew equal number of jobs pre- and post-workshop (n=5, all males).

6.3 Materials science workshop (phase 1) findings

The materials science workshop was carried out in phase 1 to incorporate the learning and reflections from the pilot studies across the different discipline workshops. The findings from the materials science workshop are presented below.

6.3.1 Gender distribution in materials science workshop (phase 1)

The gender distribution pre and post workshop for the materials science workshop carried out in phase 1 consist of data from 53 children pre-intervention of which 54.7% (29) are males and 45.3% (24) females. Post-intervention data collected consist of 54 children of which 51.9% (28) are males and 48.1% (26) are females.

6.3.2 Findings on aspirations of children in materials science workshop (phase 1)

The children were asked what they would like to be when they grew up. The aspirations of the young people pre and post workshop were similar but the post workshop data show a more descriptive expression of aspirations. For example, rather than saying they would like to be an ‘engineer’, careers such as ‘mechanical or chemical engineers’ were mentioned in the post-workshop data. Other examples of more descriptive responses of the participants’ pre and post workshop include changes of ‘work with bones’ to ‘archaeologist’ and ‘carer’ to ‘working with children’. Full list of responses pre and post workshop can be seen in appendix E2 and how they were classified into STEM and non-STEM.

- Data collected from the children show that more than half of the children (54.7%, n =29) have the same aspiration pre- and post-workshop.
- Results from the pre- and post-workshop data show an association between gender and career aspired to, ($p= .000$, Fisher’s Exact test) and ($p= .001$, Fisher’s Exact test) respectively.

The distribution of participants’ STEM aspirations pre and post the workshop are presented in Table 27.

Table 27: STEM aspiration of children in materials science pre- and post-workshop (phase 1)

STEM Aspiration				
Response	**Pre workshop**		**Post workshop**	
	Male	**Female**	**Male**	**Female**
STEM aspiration	10	10	9	12
Non-STEM aspiration	19	13	18	11
No response	0	1	1	3
Total	29	24	28	26

- The distribution of children aspiring to a STEM career as shown in Table 6.2 indicates more females aspired to a STEM career post workshop compared to pre-workshop.
- Results from the pre-workshop data showed an association between gender and aspiring to a career in the health sciences (p= .002, Fisher's Exact test), with females more likely to aspire to careers in the health sciences.
- Post-workshop data indicated no association between gender and aspiring to a career in the health sciences (p = .064, Fisher's Exact Test).

6.3.3 Findings on knowledge of materials science as a career (phase 1)

Children were asked if they knew what a material scientist is. Distribution of responses is shown in Table 28.

Table 28: Pre- and post-workshop distribution on knowledge of materials science as a career (phase 1)

Do you know what a material scientist is?				
Response	**Pre workshop**		**Post workshop**	
	Male (Freq.)	**Female (Freq.)**	**Male (Freq.)**	**Female (Freq.)**
Yes	1	1	17	18
No	28	22	11	8
No response	0	1	0	0
Total	29	24	28	26

Before the start of the workshop, only 2 people (3.8%) from the cohort responded that they knew who a material scientist was. There was a large increase in the number to 35 (64.8%) following the workshop.

- A chi-square test of independence was carried out pre- and post-workshop and no association was found between gender and if the children knew what a material scientist is, (p = .723, Fisher's Exact Test) and X^2 (1, N = 54) = .429, p =.577 respectively.

6.3.4 Children's perception of what materials science career do (phase 1)

Children were asked what they thought materials scientists do in their jobs. Even though many of the children pre-workshop said they did not know who a material scientist is, many of the participants were able to describe what a material scientist does (such as study materials, work with materials and design materials).

The post-workshop data shows a more descriptive or expressive response about material scientists do compared to pre-workshop data. There was more subject specific vocabulary used in the post data. For example, when asked the question, rather than say 'study materials' (as shown in the pre workshop data in Table 29), young people said 'study materials and their properties'. Again, rather than 'build with materials' there was 'use materials in their job and find new materials and find out what they are made of'.

Table 29: Participants responses to 'what material scientists do' (phase 1)

What do you think material scientists do? (Pre-workshop)	Freq.	What do you think material scientists do? (Post-workshop)	Freq.
Study materials	15	Study materials and their properties	14
No response	8	No response	1
Works with materials	10	Works with materials and find their properties	7
Experiment on/with materials	3	Investigate and experiment on/with materials	11
Design materials	2	Design materials to see their uses	2
Investigate materials	2	Investigate materials	1
No idea	2		
Build with materials	1	Uses materials in their job and they find new materials and find out what they are made of	1
Building stuff like cars	1		
Determine what materials are	1	Discover/explore materials	5
Find materials in most objects	1	Find materials and find their properties	2
Make building supplies	1	Make stuff/ build stuff	1
Make weird and magical materials	1	Mix materials to create new ones	1
Put materials in the lab	1		
Study rocks and minerals	2	Compare and observe different materials	1
Test materials	1	Test materials and find their properties	7
Work with nature	1		
Total	53	Total	54

6.3.5 Findings from activities in the materials science workshop (phase 1)

Object identification

Children were asked at the beginning of the workshop to look around the room and identify and write down objects made from materials. Objects most frequently identified include windows (by 19 males and 14 females), doors (16 males and 10 females), tables /desks (12 males and 11 females), water bottles (7 males and 8 females) and chairs/stools (8 males and

6 females). The full list of objects and gender distribution is in appendix E3. The results indicate a gender difference in the choice of particular objects. Findings indicate

- An association between gender and the choice of book as an object (p= .004; Fisher's Exact Test). This include 3 males and 11 females.
- An association between gender and the choice of whiteboard as an object (p= .014; Fisher's Exact Test). This include 2 males and 8 females.
- An association between gender and the choice of glasses as an object (p= .022; Fisher's Exact Test). This include 0 males and 4 females.

Properties of materials identified

When children were asked to write down the materials that the objects were made from and why the objects were made with those materials. The question was asked to get the children thinking about properties of materials and to identify which properties the children were able to identify from the objects they mentioned.

The material properties identified by the children include strength/sturdy/strong (n= 53), transparency (n= 31), flexibility (n= 9), hardness/does not break easily (n= 11), waterproof (n= 3), weight/lightness (n= 12), fire resistant (n= 1) and rut resistant (n= 1).

The frequency count (n) in this section refers to the number of times children mentioned a property of material across the different objects listed. This implies that some children mentioned the same property for different objects identified.

Other aspects highlighted by the participants were

- How secure the object was (other words/phrases grouped within this property include 'protection', 'holds it together 'and 'holds stuff in'); n= 55.
- The cost of the object (cheap); n= 11.
- How comfortable the object was (ease of use was also mentioned); n=19.

For full list of objects and corresponding properties identified, see appendix E4

Nitinol Use

Children were asked to think about applications of the smart material Nitinol[7]. Two of the main uses children thought Nitinol could be used for are jewellery (26.6%, n =14) and a car (24.7%, n =13). An example of a child's use as jewllery was

Child: '*if jewelry snaps, put in hot water to make it come back or if you bend it by accident, it will go back'*.

Majority of the children that mentioned a car as a use for Nitinol referred to its use as the bodywork of the car in cases of accidents, breakdowns and dents. See appendix E5 for summary of uses of Nitinol and the percentage distribution of children responses.

6.3.6 Findings on inclination towards a materials science career (phase 1)

Children were asked if they would consider a career as a materials scientist immediately after the workshop and a month later. Distribution of children's responses are shown in Table 30

Table 30: Distribution of children's inclination towards a materials science career (phase 1)

Would you like to consider a career as a materials scientist?				
Response	**Post Workshop**		**One month Later**	
	Male	**Female**	**Male**	**Female**
Yes	1	1	0	0
No	12	10	21	19
Not sure	14	12	7	7
No response	2	1	0	0
Total	29	24	28	26

- When asked at the end of the workshop if they would like to do the career (material scientist), 2 children (3.8%) said they would like to do the career. When asked a month later, no child said they wanted to do the career.

[7] Nitinol is a memory metal that reverts to its original shape when immersed in hot water at a particular temperature.

- 22 children (41.5%) did not want to do this career when asked immediately after the workshop. This number increased to 40 children (74.1%) when the question was asked a month after the workshop.
- 26 children (49.1%) were not sure if they would like to do the career (material scientist) immediately after the workshop. This number decreased to 14 people (25.9%) when the question was asked a month after the workshop.
- There was a shift in children saying they were not sure if they wanted to do this career (after the workshop) to they did not want to do the job (a month later).
- No evidence of an association was found between gender and considering a materials science career in the pre-workshop (p = 1.000; Fisher's Exact test) and Post-workshop data X^2 (1, N = 54) = .026, p = .872.

6.3.7 Post-workshop feedback findings on the materials science career (Phase 1)

The children were asked a month after the workshop what they liked, did not like or would change about the workshop. The feedback on the workshop was generally positive with most young people saying they enjoyed the workshop and 4 people (7.4%) saying they could not remember the workshop. The summary of their responses can be seen in appendix E6.

6.3.8 Reflections on the design and delivery of the materials science workshop (phase 1)

Consistent with the pilot study, the structure of the workshop worked well and the children enjoyed the activities, particularly the Nitinol activity. The children were able to relate the concepts in the workshop with objects they saw around themselves. During implementation, participants kept testing the electrical conductivity of materials which had a loud buzzer even after the activity was supposed to have ended. Considerations were made to change the buzzer to a light bulb by the outreach specialist.

It was interesting how the feedback on the workshop by the children was generally positive but their consideration of a career in material science shifted from a 'not sure if they would like to do the job' to 'they did not want to do the job'. This prompted an adaptation to the survey in subsequent workshops across the disciplines to include a question on why participants chose the option they did to gain better understanding of the young people's choices.

6.4 Combined findings across disciplines (phase 2)

This section presents findings across the different discipline workshops for comparisons. Descriptive statistics are used to summarize the characteristics of the data collected in terms of gender distribution, STEM aspiration, knowledge of career being promoted and inclination towards the STEM career promoted.

6.4.1 Gender distribution of intervention workshops (phase 2)

Table 31 shows the gender distribution across the dataset from the different disciplines collected pre and post intervention.

Table 31: Gender distribution of children across intervention pre- and post-workshops

Workshop	PRE			POST		
	Male	**Female**	**No response**	**Male**	**Female**	**No response**
Environmental modeller	34 (54.0%)	29 (46.0%)	0	26 (44.1%)	32 (54.2%)	1 (1.7%)
Paleontologist	34 (52.3%)	30 (46.2%)	1 (1.5%)	31 (49.2%)	32 (49.2%)	1 (1.6%)
Environmental planner	33 (54.1)	27 (44.3%)	1 (1.6%)	28 (53.8%)	24 (46.2%)	0
Materials scientist	35 (60.3)	22 (37.9)	1 (1.7%)	38 (65.5%)	20 (34.5%)	0
Games designer	12 (52.2)	11 (47.8)	0	11 (57.9%)	8 (42.1)	0

6.4.2 Combined aspiration findings (phase 2)

Aspiration data was also collected across the different workshops pre and post the workshops. The aspiration data were combined based on the children responses from each of the five workshops pre- and post-intervention and presented in a word cloud format. This is shown in Fig. 21. Full breakdown of children's aspiration pre- and post-intervention can be seen in appendices E7 and E8

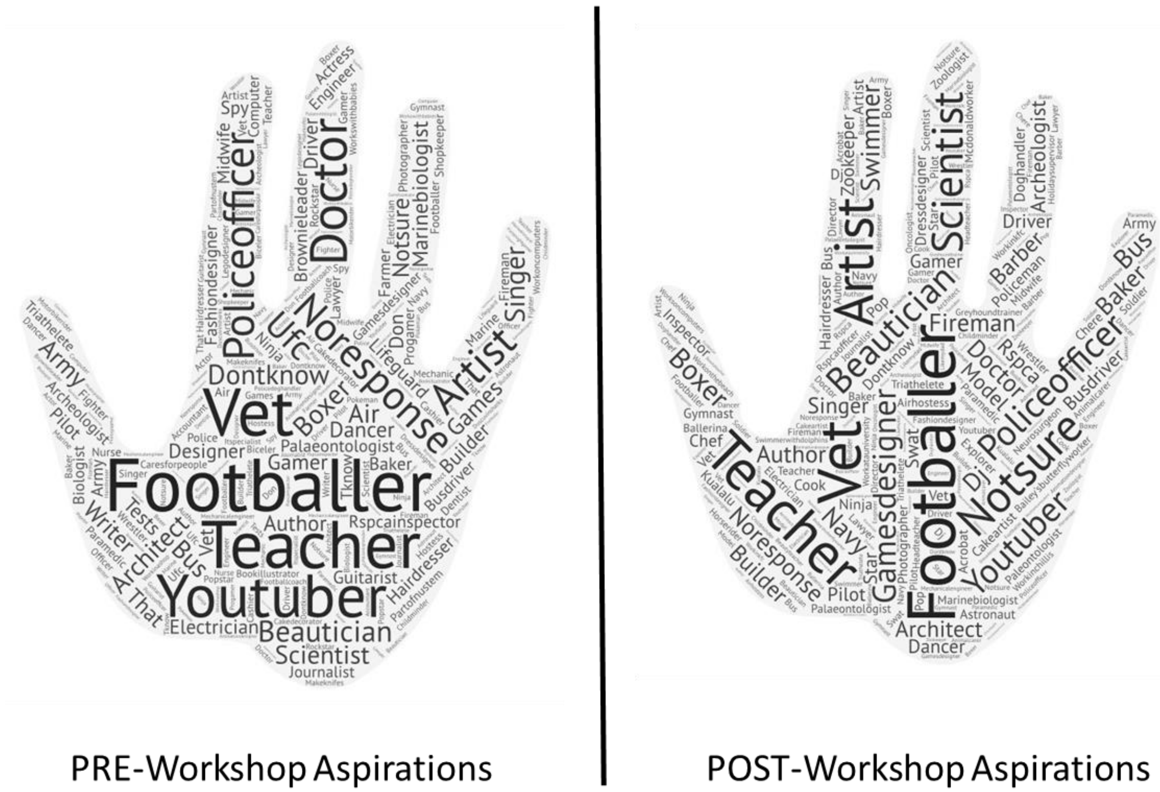

Figure 21: Word cloud of children's pre- and post-workshop aspirations

Similar career aspirations were seen which did not change pre- or post-intervention. These occupations are shown in Fig 22

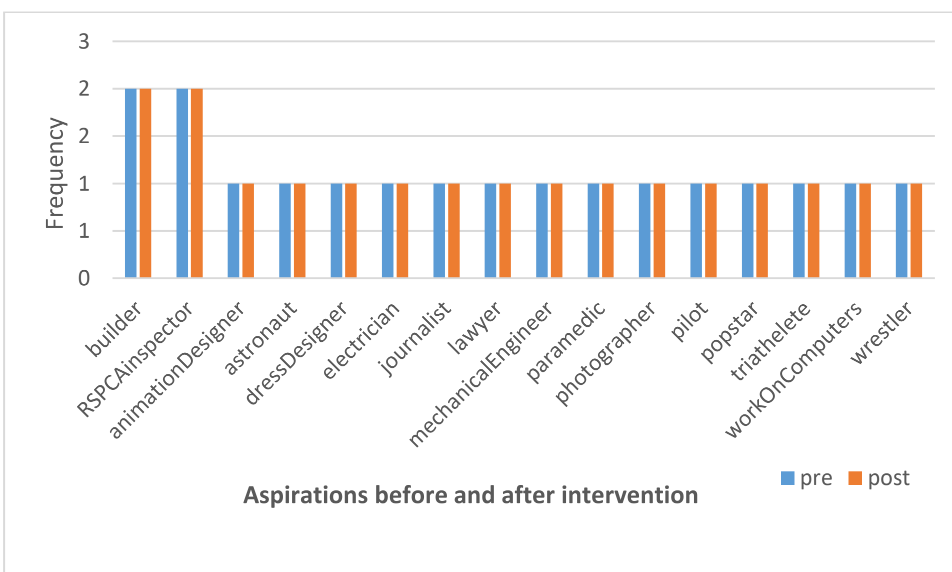

Figure 22: Overall aspirations that stayed the same pre- and post-intervention

Across the different discipline workshops. ‘Footballer’ ranked the highest pre (17%, n=46) and post workshop (19%, n=48) as shown in Fig 23. Aspirations to paleontologist increased from 1.8% (5) to 2.4% (6). Children that were undecided in what they would like to be when they grew up increased from 3.3% (n=9) to 4.8% (n=12).

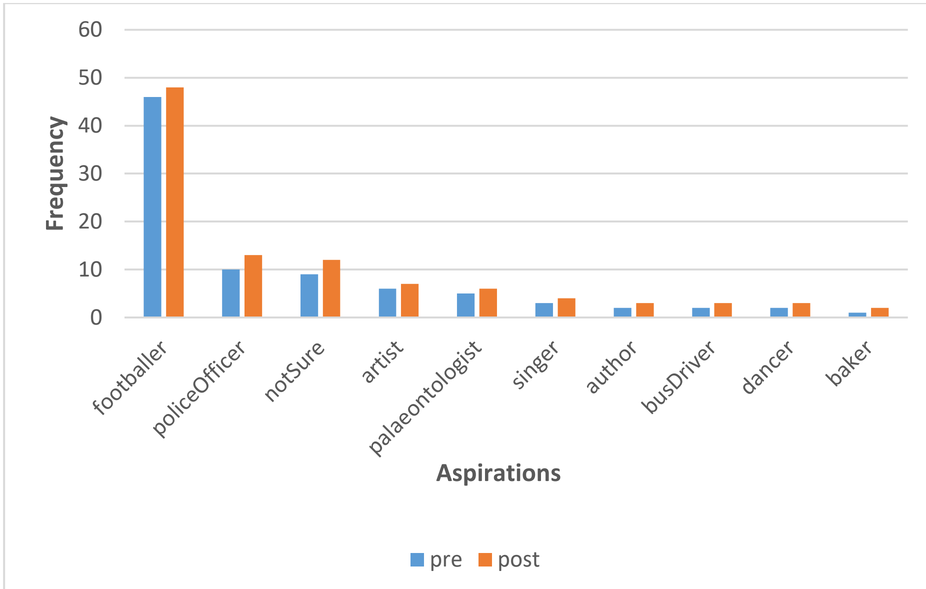

Figure 23: Overall increase in jobs children aspired to (pre- and post-intervention)

Children that aspired to be teachers reduced from 6.6% (n=18) to 4.8% (n=12, non-response in the dataset reduced from 6.8% (n=17 pre) to 4% (n=10; post workshop) and games designer dropped from 2.2% (n=6) to 2% (n=5) as shown in Fig. 24.

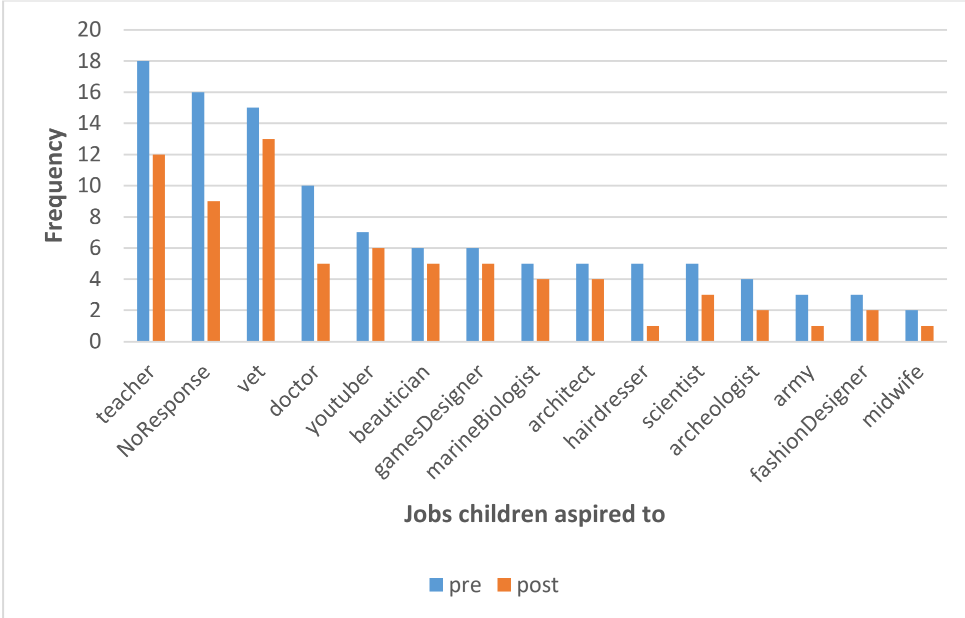

Figure 24: Overall decrease in jobs children aspired to (pre and post-intervention)

The findings regarding aspirations for the individual workshops are discussed below:

Games design: Slightly more children completed the pre-workshop questionnaire (n=23) compared to the post-workshop questionnaires (n=19). The number distribution for children that wanted to be an architect, artist, engineer, games designer, police officer and vet did not change. (See appendix E9 for the full list).

- Fewer number of children at the post data collection compared to the pre data wanted to be footballers (from 17.39%, n=4 to 10.53, n=2), designers (from 8.7%, n=2 to nil), youtuber (from 4.35%, n=1 to nil) and scientist (from 4.35%, n=1 to nil).
- The number of young people that indicated that they did not know what they wanted to be when they grew up also decreased (from 8.7%, n=2 to nil).
- There was a slight increase in the number of young people that did not respond to the question during the post compared to the pre data collection (from 13.04%, n=3 to 21.05, n=4).
- More young people after the workshop compared to before workshop, wanted to be doctors (from 8.7%, n=2 to 15.79, n=3), games maker (from nil% to 5.26%, n=1) and teacher (from nil% to 5.26%, n=1).

- Fisher's Exact tests were carried out on the children's responses pre- and post-workshop, and the association between gender and children's aspirations were not significant in both datasets.

Geography workshops: data from environmental modelling, environmental planning and paleontology workshops indicated an association between gender and the type of careers children aspire to (p= .036, Fisher's Exact Test), (p= .002, Fisher's Exact Test), and (p= .030, Fisher's Exact Test) respectively.

When the test was carried out using the post-workshop data, no association was identified between gender and the type of careers children aspire to in all three geography workshops.

Materials science: The association between gender and the type of careers children aspire to was significant in responses from the pre-workshop data (p= .003 Fisher's Exact Test). Association between gender and children's aspiration was still evident post-workshop (p= .009, Fisher's Exact Test).

6.4.3 STEM aspiration distribution (phase 2)

Consistent with the pilot studies and the phase 1 of the main intervention, aspiration responses were classified into STEM and non-STEM occupations using the UK Standard Occupational Classification (SOC) system from the Office of National Statistics ("ONS Standard Occupational Classification (SOC) Hierarchy", 2019). Refer to sections 5.3.3 and 6.2.2 for previous description. The summary of participants' responses are shown in Table 32.

Table 32: STEM and non-STEM aspiration distribution of children (pre- and post-intervention), phase 2

Workshop	Aspiration	PRE		POST	
		Freq.	**%**	**Freq.**	**%**
Environmental modeller	STEM	19	30.2	17	28.8
	Non-STEM	36	57.1	36	61.0
	Undecided	3	4.8	4	6.8
	No response	3	4.8	1	1.7
	Total	61	96.8	58	98.3
Paleontologist	STEM	28	43.1	19	30.2
	Non-STEM	27	41.4	40	63.5
	Undecided	0	0	0	0
	No response	10	15.4	4	6.3
	Total	**65**	**100**	63	100
Environmental planner	STEM	16	26.2	7	13.5
	Non-STEM	40	65.6	42	80.8
	Undecided	0	0.0	2	3.8
	No response	5	8.2	1	1.9
	Total	61	100.0	52	100.0
Material scientist	STEM	18	31.0	10	17.2
	Non-STEM	33	56.9	38	65.5
	Undecided	0	0	6	10.3
	No response	7	12.1	4	6.9
	Total	**58**	**100**	**58**	**100**
Games designer	STEM	8	35	10	53
	Non-STEM	8	35	4	21
	Undecided	2	9	0	0
	No response	5	22	5	26
	Total	23	100	19	100

Across the range of workshops, only the games design workshop showed an increase in STEM aspirations post-workshop compared to pre-workshop aspirations. Even though, slightly fewer of the children completed the post workshop questionnaire compared to the pre questionnaire in the games design workshop, there were more young people in the post survey results (10 people; 52.6%) that aspired to STEM careers than from the pre workshop survey (8 people; 34.8%).

6.4.4 *Knowledge of individual STEM careers (Phase 2)*

Children were asked about their knowledge of the career promoted in each of the different workshops. Using an example from the material science workshop, the question is ''Do you know who a material scientist is?'' Table 33 shows the results for each workshop.

Table 33: Children's knowledge of the specific STEM career pre- and post-workshops

Workshop	Response	PRE		POST	
		Freq.	%	Freq.	%
Environmental modeller	No	53	84.1	22	37.3
	Yes	8	12.7	33	55.9
	No response	2	3.2	4	6.8
	Total	63	100.0	59	100.0
Paleontologist	No	33	50.8	11	17.5
	Yes	31	47.7	52	82.5
	No response	1	1.5	0	0
	Total	**65**	**100**	63	100
Environmental planner	No	60	98.4	8	15.4
	Yes	0	0.0	41	78.8
	No response	1	1.6	3	5.1
	Total	61	100.0	52	100.0
Material scientist	No	47	81.0	39	67.2
	Yes	8	13.8	18	31.0
	No response	3	5.1	1	1.7
	Total	**58**	**100**	**58**	**100**
Games designer	No	10	43.5	6	31.6
	Yes	13	56.5	13	68.4
	No response	0	0.0	0	0
	Total	23	100.0	19	100.0

Responses were coded into the number of participants who indicated that they knew about the career (*yes*), participants who indicated they did not know about the career (*No*) and participants who did not provide a response (*No response*). There was a positive change (increase) across all the different disciplines in the percentages of children that knew the career being promoted from the post-workshop responses compared to the pre-workshop responses

6.4.5 Inclination towards the specific STEM career (Phase 2)

Table 34: Children's inclination towards the specific STEM career pre- and post-workshop

Workshop	Response	PRE		POST	
		Freq.	**%**	**Freq.**	**%**
Environmental modeller	Yes	2	3.2	1	1.7
	No	32	50.8	39	66.1
	Not sure	24	38.1	18	30.5
	No response	5	7.9	1	1.7
	Total	**63**	**100.0**	**59**	**100.0**
Paleontologist	Yes	16	24.6	16	25.4
	No	13	20	25	39.7
	Not sure	32	49.2	21	33.3
	No response	4	6.2	1	1.6
	Total	**65**	**100**	**63**	**100**
Environmental planner	Yes	5	8.2	3	5.8
	No	32	52.5	26	50.0
	Not sure	24	39.3	22	42.3
	No response	0	0.0	1	1.9
	Total	61	100.0	52	100.0
Material scientist	Yes	15	25.9	6	10.3
	No	21	36.2	28	48.3
	Not sure	19	32.8	22	37.9
	No response	3	5.1	1	1.7
	Total	**58**	**100**	**58**	**100**
Games designer	Yes	4	17.4	3	15.8
	No	4	17.4	3	15.8
	Not sure	8	34.8	10	52.6
	No response	7	30.4	1	5.3
	Total	23	100	19	100

At the end of each workshop, after participants had experienced, participated in and been provided information about the STEM career promoted, they were asked 'would you like to do this type of job when you grow up? The summary of responses is provided in Table 34. Across the various discipline responses, only the paleontology workshop showed a minimal increase (from 24.6% to 25.4%) in children's positive (yes) responses towards the proposed STEM career. The material science and games design workshops both showed an increase in the percentage of participants that were not sure if they wanted to do the careers promoted, from 32.8% to 37.9% and 34.8% to 52.9% respectively.

6.5 Subject specific findings from the digital games workshop (phase 2)

Findings from Phase 2 of the research that are specific to the games design workshop are indicated in this section

6.5.1 Playing online computer games

In the pre-workshop, children were asked if they played games online. Table 35 shows the distribution on online game playing.

Table 35: Gender distribution of children that play online games (phase 2)

Do you play online games regularly?			
	Gender		Total ((Freq. (%))
	Male ((Freq. (%))	Female ((Freq. (%))	
Yes	12 (52.2%)	9 (39.1%)	21 (91.3%)
No	0 (0%)	2 (8.7%)	2 (8.7%)
Total	**12 (52.2%)**	**11 (47.8%)**	**23 (100%)**

- Only two (about 9%) of all the young people do not play online games and those two were females
- Statistical test carried out indicated no evidence of an association between gender and playing games regularly online (p= .217, Fisher's Exact test).

The children were also asked to indicate how often they played the computer games. Summary of responses are shown in Table 36.

Table 36: Gender distribution of how often participants play computer games (phase 2)

How often do you play computer games?			
Description	**Gender**		**Total ((Freq. (%))**
	Male **((Freq. (%))**	Female **((Freq. (%))**	
No response	0	2 (8.7%)	2 (8.7%)
Every day/night	3 (13%)	3 (13%)	6 (26.1%)
Not often	3 (13%)	2 (8.7%)	5 (21.7%)
A lot	6 (26.1%)	4 (17.4%)	10 (43.5%)
Total	**12 (52.2%)**	**11 (47.8%)**	**23 (100%)**

- The 'not often' response included responses of 'sometimes', 'Less than three times a week', and 'only on weekends'.
- The 'a lot' response included responses of 'more than 3 times a week', 'every other day', 'often' and 'really often'.

Responses from this dataset suggests that the children regularly play computer games.

6.5.2 Children's perception of the games designer job (phase 2)

Pre- and post-workshop, the children were asked about their perception of what a games designer does. The results (see appendix E10) indicate that

- 43.5% (n=10; 7 females and 3 males) participants pre-workshop thought that games designers 'designs games', with a slight decrease to 42.1% (n=8; 5 females and 3 males) post workshop.
- 21.7% (n=5; 2 females and 3 males) participants pre-workshop thought that games designers not only 'designs games' but also makes the games with an increase to 31.6% (n=6; 5 males and 1 female) post workshop.

6.5.3 Feedback from games design workshop (phase 2)

Children were asked to provide feedback on the workshop and summary of responses are shown below (see appendix E11):

- There was generally positive feedback from the participants. Examples of some of the feedback are shown in responses from males and females below

- Feedback from male participants include '*liked creating the actual game*', '*yes, everything'*, *'the programming was complex', 'really good but I did not want to do it'* and '*loved everything'*.
- Feedback from female participants included '*I don't know,* '*I liked making the robot play the instrument'* and 'I *liked everything but not the chairs*'.
- 31.6% (n=6; 2 females and 4 males) did not respond (did not provide feedback).
- One child did not seem to enjoy the workshop. Her feedback *'it was great deleting, the stuff was annoying'.*

6.6 Subject specific findings from the materials science workshop (phase 2)

Findings from Phase 2 of the research that are specific to the materials science workshop are indicated in this section

6.6.1 Children's perceptions of the materials scientists career (phase 2)

Children were asked what they thought materials scientists do in their career. Table 37 presents a summary of their responses (see appendices E12 and E13 for the full list).

Table 37: Children's perception of what materials scientists do, pre- and post-workshop (phase 2)

What do people in this career do?	Pre		Post	
	Freq.	**%**	**Freq.**	**%**
No response	10	17	9	15.3
Make materials	16	27.2	5	8.5
Look at/into materials	9	15.3	2	3.4
Make stuff/do things with materials	8	13.6	3	5.1
Discover/study/explore materials	4	6.8	6	10.2
Experiment/investigate/test materials	5	8.5	26	44.2
Do portions	2	3.4	1	1.7
Designs materials	1	1.7	0	0
Make metals	1	1.7	0	0
Make reports	1	1.7	0	0
Move stuff out of materials	1	1.7	0	0
I do not know	0	0	1	1.7
Estimate materials and buildings	0	0	1	1.7
Measuring materials	0	0	1	1.7
Check that materials are safe	0	0	1	1.7
Total	58	99	56	95

Before the workshop, many of the participants (27%; n=16) described material scientists as people who made materials. Post workshop results show 44.2% (n=26) describe the role of material scientists in terms of experimenting, investigating and testing of materials

6.6.2 Children's reason for inclination choice towards a material science career (phase 2)

Children were asked to provide reasons for their choice of either wanting to do a material science career, not wanting to do the career or not sure if they would like to do the career. The summary of participants responses are shown in the Table 38

Table 38: Summary of children's reasons for preferred choice in 'Inclination to materials science career' question (phase 1)

Reason response on Inclination to Material Science career was chosen?	**Pre**	
	Freq.	**%**
Want to be something else	12	20.4
No response	9	15.3
Not Sure what they do	5	8.5
It does not sound fun/boring	5	8.5
Cannot remember	4	6.8
Do not like it/ Do not like science	3	5.1
It seems complicated/hard	3	5.1
I don't know	3	5.1
It sounds fun	2	3.4

Many of the children (20.4%) in the materials science workshop, already had a career in mind and this career was the reason given for a 'no' or 'not sure' response to the question.

6.6.3 Children's perception of what materials are (phase 2)

Children's responses to what materials are pre and post the material science workshop is shown in Table 39. Before the workshop, about 22% of the children described the materials as fabrics and clothing. Other descriptions include metals (13.6%) and something you use to make things with (11.9%). After the workshop, many children described materials as something you make things with and as wood (both at 20.4% each).

Table 39: Participants perception of what materials are pre- and post-workshop (phase 2)

What are materials?	**Pre**		**Post**	
	Freq.	**%**	**Freq.**	**%**
No response	5	8.5	1	1.7
Fabric/ clothing	13	22.1	6	10.2
Build stuff/things with	0	0	11	18.7
Wood	5	8.5	12	20.4
Metals	8	13.6	6	10.2
Make things with them	7	11.9	12	20.4
Paper	2	3.4	0	0
Leather	2	3.4	0	0

6.6.4 Feedback from materials science workshop (phase 2)

A month after the material science workshop, children were asked to provide feedback on the workshop. A summary of the responses are shown in Table 40.

Table 6.15: Feedback from the materials science workshop (phase 2)

Table 40: Feedback from the materials science workshop (phase 2)

Feedback from materials science workshop (phase 2)	Freq.	%
No response	14	23.8
Cannot remember the workshop	31	52.7
I don't know a lot/thing	2	3.4
I don't know	1	1.7
Liked testing Nitinol	4	6.8
Not sure	2	3.4
Liked testing materials	4	6.8

- More than half of the participants (52.7%) indicated that they did not remember the workshop when asked to provide feedback.
- 13.6% mentioned that they enjoyed the workshop.

6.7 Subject specific findings from the paleontology workshop (phase 2)

Findings from Phase 2 research for the paleontology workshop are presented in this section.

6.7.1 Children's perception of what paleontologists do (phase 2)

Children were asked what they thought paleontologists do. Table 41 presents a summary of the children's responses (see appendices E14 and E15 for detailed list).

Table 41: Children's perception of what paleontologists do pre- and post-workshop (Phase 2)

What do paleontologists do?	Pre		Post	
	Freq.	%	Freq.	%
I don't know	17	25.5	2	3.2
No response	9	13.5	6	9.6
Find/search/study fossils	17	25.5	46	73.6
Find/search/study dinosaur bones	3	4.5		0
Look at rocks/ ores	4	6		0
Look into the past		0	3	4.8
Science stuff	3	4.5	1	1.6

- Pre-workshop, 25% (n=17) of the participants indicated that they do not know what paleontologists do, this percentage dropped to 3.2% (n=2) post-workshop
- 25% (n=17) of participants pre-workshop described the role of paleontologists as people who find, search or study fossils. This increased to 73.6% (n=46) post-workshop

6.7.2 Children's perception of what fossils are (Phase 2)

Children were asked the subject specific question 'what are fossils?' to assess their subject specific knowledge and understanding, in this case through paleontology concepts. Results are presented in Table 42 for children's responses pre-and post-workshops

Table 42: Participants perception of what fossils are pre and post workshop (phase 2)

What are fossils?	Pre		Post		
	Freq.	%	Freq.	%	
Dinosaur bones	24	36	5	8	
Rocks/stones	16	24	18	28.8	
Bones	13	19.5	15	24	
Dead animals from long ago	6	9	12	19.2	
No response/I do not know	4	6	5	8	
Dead plants from long ago	1	1.5	2	3.2	
Thing from long ago	1	1.5	3	4.8	

- While a large percentage of participants described fossils as bones (55.5%, n=37), 36% (n=24) of participants referred to fossils as dinosaur bones pre workshop. This percentage dropped to 32% post workshop.
- There was an increase post workshop in the percentage of participants that referred to fossils as rocks from 24% (n=16) to 28.8% (n=18), when compared to pre workshop responses.
- There was also an increase post workshop, in the percentage of participants that referred to fossils as dead animals from long ago from 9% (n=6) to 19.2% (n=12), when compared to pre workshop responses.

6.7.3 Feedback from paleontology workshop (phase 2)

When asked to provide feedback on the workshop a month after the workshop, 35% of the children did not respond, 17.6% did not remember the workshop and 24% of participants enjoyed the workshop (as shown in Table 43).

Table 43: Feedback from paleontology workshop (phase 2)

Feedback from the paleontology workshop (phase 2)	Freq	%
No response	22	35.2
I cannot remember	11	17.6
I have /know nothing	2	3.2
I liked feeling/holding the fossils	10	16
I liked looking through the microscope	6	9.6
I liked using the different tools	4	6.4
I liked it	2	3.2
It was fun	2	3.2

6.8 Subject specific findings from the environmental modelling workshop (phase 2)

Findings from Phase 2 of the research for the environmental modelling workshop are shown in this section

6.8.1 Children's perception of what environmental modellers do (phase 2)

The children were asked about their thoughts on what environmental modellers do. Responses are shown in Table 44 (see appendices E16 and E17 for the full list).

- Results indicate a reduction in percentage of non-response post workshop at 22.1% (n=13) compared to pre workshop at 24% (n=15)
- There was an increase in the percentage of children (13.6%, n=8) post-workshop, who described environmental modellers as people who predict the future when compared pre-workshop (at 1.6%, n=1)

Table 44: Participants perception of what environmental modellers do pre- and post-workshop (Phase 2)

What do environmental modellers do?	PRE		POST	
	Freq.	**%**	**Freq.**	**%**
No response	15	24.0	13	22.1
Makes models for/in the environment/ designs a model	10	16.0	9.0	15.3
Not sure/ no idea	3	4.8	7.0	11.9
Can't remember			2.0	3.4
A person who models and crafts	5	8.0		
Draw or makes things/something in the environment/ design for the environment/build stuff	5	8.0	5.0	8.5
Help the environment/involve the environment	2	3.2		
It makes plants grow in the garden/ stuff we plant	2	3.2		
Make better ways/ make environment better/ specialized in the environment	2	3.2	3.0	5.1
Protects the environment/ protect nature/ protects animals	4	6.4	3.0	5.1
They clear the environment/ they help keep the environment clean	2	3.2	2.0	3.4
They predict the future	1	1.6	8.0	13.6
Do prediction or a model about a climate/ weather			4.0	6.8

6.8.2 Children's reason for inclination choice towards an environmental modelling career (phase 2)

Children were asked to explain the reason behind their choice about whether they would, would not or were not sure if they would like to pursue an environmental modelling career. A summary of responses are presented in Table 45.

Table 45: Summary of children's reasons for preferred choice in 'inclination to environmental modelling as a career' question (Phase 2)

Reason	**Freq.**	**%**
No response	6	10.2
Because I don't want to/ I don't want to build models	3	5.1
I don't know, I just might get another job if I don't/I am not sure if I want this job or a you tuber	7	11.9
Because of what I already said I want to be	15	25.5
Because I am into animals and know lots	2	3.4
Because I am not good at it/ because I just don't think it's me, I am not clever	2	3.4
Because I am not interested/ I don't really want to do this kind of job	2	3.4
Because I don't feel like it is my type of job/ I don't think it's me/ is not my thing	4	6.8
It sounds a bit boring/ because I don't know what to do and I think it's boring	3	5.1
Because I don't really like it that much, sorry	2	3.4
Because I love to design and make videos	1	1.7
Because it sounds engineering and hardworking/ it sounds too hard for me	3	5.1
Because it's a big responsibility/ because lots of work and I want to be a hair/nail artist	2	3.4
Because predicting the future can be telling people what will happen	1	1.7
Don't know if it's in my ratings	1	1.7
Don't know much about it	1	1.7
I like it but not that much	1	1.7
I would more likely be bossy	1	1.7
It looks like a good job for people to do	1	1.7
Total	59	100.0

Just like the material science (Phase 2) findings, a quarter of the participants (25.5%, n =15) already indicated other career aspirations they were interested in as their reason for not choosing or being unsure of choosing environmental modelling as a career.

6.8.3 Participants perception of the concept 'Prediction'

Children were asked the subject specific question 'what is a prediction?' to assess their subject specific knowledge and understanding, in this case through environmental modelling concepts. Results are presented in Table 46 for children's responses pre-and post-workshops

Table 46: Summary of children's perception of the concept prediction pre- and post-workshop (phase 2)

What is a Prediction	PRE		POST	
	Freq.	**%**	**Freq.**	**%**
Scientific guess	7	11.2	8.0	13.6
No response	4	6.4	6	10.2
A guess/good guess/close guess/ hard guess/average guess	18	28.8	12.0	20.4
A guess for something	2	3.2		0.0
I don't know		0.0	2.0	3.4
A guess of what will happen/ know what is going to happen/ predict something going to happen	13	20.8	9.0	15.3
A guess that is in the future/ guess the future/going to happen in the future	8	12.8	16.0	27.2
Something that is your opinion	1	1.6	2.0	3.4

Children's pre-workshop responses show about 28% of children describe prediction as a guess and about 33% being more descriptive in what a prediction. When asked the question post-workshop, 20% of the children described a prediction as a guess and about 42.5% of children more descriptive in their definition of prediction.

6.8.4 Perception regarding the difference between 'weather' and 'climate'

Children were asked another question 'what is the difference between weather and climate?' to assess their knowledge and understanding, of some useful environmental modelling concepts. Results are presented in Table 47 for children's responses pre-and post-workshops

Table 47: Summary of children's perception of the difference between weather and climate pre- and post-workshop (phase 2)

What is the difference between weather and climate?	PRE		POST	
	Freq.	%	Freq.	%
Do not know/ not sure/ no idea	18	28.8	14	23.8
No response	7	11.2	11.0	18.7
I cannot remember			5.0	8.5
Climate is heat	2	3.2		
Climate is hot and cold, weather is like what is happening outside	7	11.2	1.0	1.7
Climate is degree while weather is sunny, cloudy o rainy/ climate is degrees warmer	5	8.0	7.0	11.9
Climate is 30 years of what the weather is going to be then/ 30 years ahead what you would predict now			6.0	10.2
Climate is more far away in time and sums up a whole month, but weather is just tomorrow			6.0	10.2
Is about the weather and temperature			2.0	3.4

While some children seem to have some understanding about the difference between weather and climate (20%) post-workshop, it would seem majority of the children still had difficulty understanding the difference as shown in Table 47.

6.8.5 Feedback from environmental modelling workshop (phase 2)

Children were asked to provide feedback on the workshop a month after the workshop, summary of their responses is shown in Table 48.

Table 48: Feedback from environmental modelling workshop (phase 2)

Feedback from environmental modelling workshop (Phase 2)	Freq.	%
No response	10	17
I don't remember	11	18.7
It was fun/cool	9	15.3
Enjoyed the bean bag throwing	5	8.5
Enjoyed making the sculpture/ modelling	13	22.1
I liked it/ loved it	2	3.4
It was ok	2	3.4
It was really good what they did because it had loads of prediction	2	3.4
I like art a little bit so I loved it	1	1.7
No, I did not like it because I do not like that stuff	1	1.7
I like that it was a challenge and we got to share our ideas with other people	1	1.7
I liked everything but I don't want to be it	1	1.7
No, I did not like it because I do not like that stuff	1	1.7
I liked the workshop because it helped me learn more what models are and what weather is like	1	1.7

- Over 50% of the children indicated that they enjoyed the workshop.
- 17% (n=10) of the children could not remember the workshop.

6.9 Subject specific findings from the environmental planning workshop (phase 2)

Findings from phase 2 of the study specific to the environmental planning workshop are presented here.

6.9.1 Children's perception of what environmental planners do (phase 2)

Children's thoughts were sought regarding the roles of environmental planners (what they do in their jobs). Table 49 presents a summary of their responses (see appendices E18 and E19 for the full list).

Table 49: Participants perception of what environmental planners do pre-- and post-workshop (phase 2)

What Environmental Planners Do?	Pre		Post	
	Freq.	%	Freq.	%
I don't know	12	19.2	7	11.2
Plan the environment	19	30.4	18	34.2
Keeps the environment clean/ litter free	6	9.6		0
Protect/ help the environment	15	24		0
No response	2	3.2	3	5.7
Eco war/warrior	2	3.2		0
Keeping the world a better place/ changing the world	2	3.2		0
Growing up at graft	1	1.6		0
Helps the animals, uses a map	1	1.6		0
Global warming	1	1.6		0
I think it can help people who are new to uni	1	1.6		0
Not sure	1	1.6	3	5.7
Robot planner/book	1	1.6		0
Work with maps	1	1.6	9	17.1
Decides where coastlines or which Piece to keep		0	2	3.8
Predict the future/ what is going to happen		0	3	5.7
Things to do with the environment		0	3	5.7

- Over 30% of the children pre- and post-workshop describe what environmental planners do as planning the environment.
- There is a decline in the number of children that indicate that they do not know what environmental planners do from 19.2% pre-workshop to 11.2 % post workshop.

6.9.2 Children's reason for inclination choice towards an environmental planning career (phase 2)

Table 50 presents a summary of children's responses when asked to explain the reason behind their choice on whether they would, would not or were not sure if they would like to pursue an environmental planning career (see appendices E20 and E21 for full list)

Table 50: Summary of some of the children's reasons for preferred choice in 'inclination to environmental planning as a career' question (phase 2)

Reason	Freq.	%
I don't want to break /destroy houses	7.0	11.2
Not my thing/not interested	9.0	14.4
Not sure	2	3.2
Boring	1	1.6
Hard job/ hard decisions	15.0	24.0
Complicated/ tricky	5.0	8.0
I don't want to make a mistake/ not good at choices	3.0	4.8
You could save lives or destroy lives	4.0	6.4

- 17.6% of children indicated that their choice was because they did not want to break or destroy houses or lives
- 24% of children felt the career involved making hard decisions
- 14.4% of children indicated that their choice made was because they were not interested in environmental planning as a career.
- Examples of children's feedback indicating their concern *include 'I could destroy people's houses and they would not have a home'*, *'I have a job in mind already and I am unsure if I would make the wrong decision'*, '*I will not want to pick any bit of land'* and *'I would like to save homes and people but it would be hard'.*

6.9.3 Children's responses to what are maps (phase 2)

Children were asked a question 'what are maps?' to assess their knowledge and understanding, of environmental planning concepts. Results are presented in Table 51 for children's responses pre-and post-workshops

Table 51: Summary of children's perception of what maps are, pre- and post-workshop (phase 2)

What is a map?	Pre		Post	
	Freq.	**%**	**Freq.**	**%**
A guide to show you where to go	18	28.8	22	41.8
A map is a paper that shows places for example cities, towns etc	16	25.6	2	3.8
A map is a picture/ text of an area (photograph) to show you where to go (key)	4	6.4	0	0
Where we are/ where things are	4	6.4	5	9.5
Useful guide to give directions	7	11.2	6	11.4
Tells us how things/places have changed	0	0	7	13.3

Pre workshop, 25% (n=16) of children described maps as a paper that showed a person where places are. This percentage decreased to 3.8% (n=2) post workshop. Meanwhile, the description of 'maps as guides to show a person where to go' increased from 28.8% (n=18) pre-workshop to 41.8% (n=22) post workshop.

6.9.4 Participants responses to what we can learn from maps (phase 2)

Children were asked a question 'what can we learn from maps?' to explore their understanding of environmental planning applications. Results are presented in Table 52 for children's responses pre-and post-workshops

Table 52: Summary of children's perception of what we can learn from maps, pre- and post-workshop (phase 2)

What can you learn from maps?	Pre		Post	
	Freq.	**%**	**Freq.**	**%**
Gives Direction	11	17.6	3	5.7
No response	2	3.2	2	3.8
Tells you where to go	2	3.2	10	19
If you are lost, they tell you where to go	13	20.8	18	34.2
Where places/things are	12	19.2	9	17.1
How places have changed over time	1	1.6	6	11.4

6.9.5 Feedback from environmental planning workshop (phase 2)

Children were asked to provide feedback on the workshop a month after the workshop, summary of their responses is shown in Table 53.

Table 53: Feedback from environmental modelling workshop (phase 2)

Feedback from the Environmental Planning Workshop (Phase 2)	Freq.	%
No response	9	17.1
I can't remember/ not sure	5	9.5
I enjoyed it/liked it	5	9.5
I liked working with the maps	11	20.9
We looked at a map of our area	3	5.7
I liked how we used the tracing paper to see how the coast had changed over time	7	13.3
It was fun/ exciting	3	5.7
Liked seeing how places change over time	4	7.6
I didn't like how I killed people	1	1.9

- Results indicate a non-response of 17.1% (n=9)
- 57% (n=30) of participants indicated that they liked the workshop

6.10 Summary

This chapter presents findings for the phase 1 and phase 2 of this research. Results of the material science and games design workshops are presented in phase one while a comparison is carried out across the five discipline workshops.

Summary of findings from phase 1 of the main intervention workshops:

- Almost half of the children in the games design workshop have the same aspiration pre- and post-intervention.
- More than half of the children from the materials science workshop have the same aspirations pre- and post-intervention.
- Results from the games design workshop shows an increase in the number of children's aspirations to a STEM career from 30% pre- workshop to 45% post-intervention workshop.
- In the games design workshop, 5% of the children aspire to a computer science related career pre- intervention. This percentage increased to 25% post-intervention.

- Data from the games design workshop suggests an association between gender of children and choice of lead character in the game.
- Females created a diverse set of lead characters including females, males, animals and non-human, while the males created male characters in their created games from the games design workshop.
- Findings from the games design dataset suggest an association between gender and the engagement factor 'feedback'. Results suggest female are more interested in getting feedback compared to males.
- Results from the materials science pre- and post-workshop data show an association between gender and career aspired to.
- Results from the materials science pre-workshop data show an association between gender and aspiring to a career in the health sciences, with females more likely to aspire to careers in the health sciences. This association was not identified in the post workshop data.
- Before the start of the workshop, only 2 people (3.8%) from the cohort responded that they knew who a material scientist was. There was a large increase in the number to 35 (64.8%) following the workshop.
- Before the start of the materials science workshop, 3.8% of the children responded that they knew who a material scientist is, this increased to 64.8% post-workshop.
- The materials science post-workshop data shows a more descriptive or expressive response about what material scientists do, compared to pre-workshop responses. There was more subject specific vocabulary used in the post data.

Summary of findings from the second phase of the main intervention workshops:

- Across all the different discipline workshops. 'Footballer' ranks the highest pre-and post-workshop.
- Across the geography workshops, an association between gender and the type of careers children aspire to, are indicated from children's pre-workshop responses. When the test was carried out using the post-workshop data, no association was identified between gender and the type of careers children aspire to in all three geography workshops.

- In the materials science workshop, the association between gender and the type of careers children aspire to is significant pre- and post-workshop responses.
- There are positive changes (increases) across all the different disciplines in the percentages of children that know the career being promoted from the post-workshop responses compared to the pre-workshop responses.
- With regards to children’s inclination towards STEM career promoted, only the paleontology workshop amongst all the workshops show a minimal increase (from 24.6% to 25.4%) in children’s positive (yes) responses towards the proposed STEM career. The materials science and games design workshops both showed an increase in the percentage of participants that were not sure if they wanted to do the careers promoted, from 32.8% to 37.9% and 34.8% to 52.9% respectively.
- Many of the children (20.4%) in the materials science workshop, already had a career in mind and this career was the reason given for a ‘no’ or ‘not sure’ response to the question.
- Pre-workshop, 25% (n=17) of the participants indicated that they did not know what paleontologists do, this percentage dropped to 3.2% (n=2) post-workshop.
- Children in the environmental planning workshop were concerned about the decisions they had to make as environmental planners.
- A quarter of the children (25.5%, n =15) in the environmental modelling workshop already indicated other career aspirations they were interested in, as their reason for not choosing or being unsure of choosing environmental modelling as a career.

CHAPTER SEVEN – DISCUSSION

7.1 Introduction

This chapter discusses the findings from this research. Results from the pilot and main intervention phases are reviewed in terms of the impact on the young people and academics, the evaluation and pedagogical approaches, and the design and delivery of the intervention workshops. The evaluation approach is reviewed by reflecting on both the tools and the process. The pedagogical approach highlights the usefulness of combining learning theories. The impact of the study on the academics are discussed in terms of reflections from the academics, NUSTEM outreach team and the researcher to improve the workshops after implementation. Findings are also discussed on the aspirations of children particularly with regards to STEM aspirations, their knowledge of careers within STEM, inclination towards proposed STEM careers and subject knowledge. Children's perceptions of what people in STEM careers do, findings on stereotypes and preconceptions are also considered mainly around gendered results. Finally, findings from the practical implementation of the workshops are discussed.

7.2 Evaluation approach

The research provides a framework that academics can use to take aspects of their research to design and implement outreach activities in primary schools. This research provides an approach to evaluation of research-based STEM interventions. Reflections on the evaluation process and evaluation tools used are presented in this section. Fig. 25 shows the connectedness of the disciplines within the evaluation approach. The intervention activities from the five workshops, across the three disciplines shared the same Theory of Change process. All the five workshops from the three different disciplines had their design underpinned by the Theory of Change (ToC) model with similar short term outcomes – increasing /improving knowledge of STEM related concepts, knowledge of STEM-related applications, knowledge of STEM careers and science practical skills. Although the workshops shared the same Theory of Change process (ToC), they had distinct Logic Models (LM). Each workshop from the three STEM disciplines had their individual logic models that helped to align the objectives of the workshop to the Theory of Change model, such that all the workshops were linked to the model.

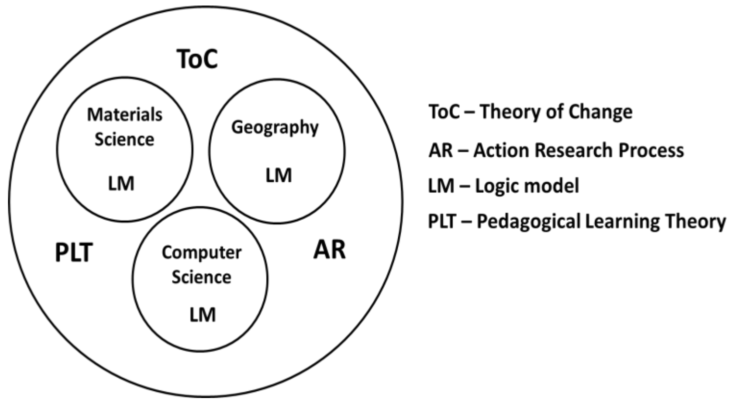

Figure 25: Summary of the research's evaluation and implementation approach

All the workshops from the three disciplines also made use of the iterative nature of the action research (AR) cycle. The design and implementation of each workshop went through the reflection, planning, acting and observation stages. Each workshop can also be viewed through elements of an integrated pedagogical framework (PLT) consisting of Direct Instruction and Cognitive Constructivism. This is discussed further in section 7.3.

7.2.1 Reflections on the evaluation process

This research provides a Theory of Change model (Maru et al., 2016; Douthwaite & Hoffecker, 2017; Davies, 2018) that is used to outline why and how an intervention aimed at widening aspirations and sustained STEM engagement will work with the intended goal of improving uptake in STEM disciplines. Using the action research cycle, the objectives of the individual discipline workshops are aligned with the four Theory of Change short term outcomes. These outcomes are increasing basic knowledge of STEM related concepts, increasing knowledge of STEM related applications, increasing knowledge of a wider range of STEM careers and improving science practical skills in young people. Extracts from each of these four pathways are incorporated and used for each set of the workshops design and incorporated into the implementation and delivery of the workshops.

During initial discussions with stakeholders, outlining and aligning discipline workshop objectives to the Theory of Change model was difficult at first but gradually got easier in subsequent workshops. There is a learning process aligning workshop objectives with the wider Theory of change and in collaboratively co-designing and co-creating activities that align with those objectives which gets easier with practice. It also shows the importance of piloting the interventions to allow for making needed improvements which the Theory of Change and action research processes accommodate. Tables 54 and 55 show how each of the workshop objectives were aligned to the Theory of Change outcomes.

Table 54: Table showing how the different workshop objectives link to the Theory of Change outcomes

Theory of Change Outcomes	**Games design**	**Materials science**	**Paleontology**	**Environmental modelling**	**Environmental Planning**
Outcome 1: Knowledge of some STEM related concepts	• Use of online games for learning • Learning new concepts ***Evidence:*** • Mapping out their game concepts	• Understanding what materials are and properties of materials ***Evidence:*** • Children able to identify materials and their properties in the materials identification activity	• Understanding of fossils ***Evidence:*** • Decline in description of fossils as bone 36% pre-workshop to 32% post-workshop • Increase in description of fossils as rocks 24% to 28.8%	• What models are and the concept of uncertainty ***Evidence:*** • Children use bean bags and bucket to understand concept of uncertainty. (not measured)	• What maps are • Maps change over time and space ***Evidence:*** • Responses from the knowledge map sheets; something that helps you get around and find things
Outcome 2: Knowledge of STEM related application	• Application of games ***Evidence:*** • Using concepts learnt to create game story and the game	• Understanding the use of prediction and testing ***Evidence:*** • Children able to predict and test the properties of materials	• Understanding of why paleontologists want to know about the past ***Evidence:*** • Children provide responses in knowledge map such as: ‘so we can see, predict what the future might be’ and ‘To see what the world was like in the past’	• Prediction and the uses of models ***Evidence:*** • Activity where children predict the weather and climate conditions of some countries	• Uses of maps ***Evidence:*** • Responses from the knowledge map sheets; ‘we can learn how our land area was years before now’

Table 55: Table showing how the different workshop objectives link to the Theory of Change outcomes (Continued)

Theory of Change Outcomes	Games design	Materials science	Paleontology	Environmental modelling	Environmental Planning
Outcome 3: Knowledge of a wide range of STEM careers	• Awareness of careers in games design • Understanding stereotypes ***Evidence:*** • In phase 2, Increase in children's knowledge career from 56% to 68% • Females created a diverse set of lead characters including females, males, animals and non-human, while the males created male characters.	• Awareness of materials science as a career ***Evidence:*** • In phase 1, only 2 people (3.8%) knew the career pre-workshop, increased to 35 (64.8%) post-workshop. • In phase 2, In phase 2, Increase in children's knowledge career from 13% to 31%	• Awareness of paleontology as a career ***Evidence:*** • In phase 2, Increase in children's knowledge career from 48% to 83%	• Awareness and knowledge of environmental modelling as a career ***Evidence:*** • In phase 2, Increase in children's knowledge career from 13% to 56%	• Awareness and understanding of environmental planning as a career ***Evidence:*** • In phase 2, Increase in children's knowledge career from 0% to 79%
Outcome 4: STEM practical skills	• Game design practical skills ***Evidence:*** • Game children created.	• Applying and using knowledge of materials and their properties ***Evidence:*** • Children's suggestion of uses for Nitinol	• Use of microfossils to understand climate in the past. ***Evidence:*** • Use of microscopes to find fossils from sand from the seabed	• Practical application of designing with models ***Evidence:*** • Children built models of houses with plasticine	• Use of maps for predicting the future ***Evidence:*** • Mapping of the coastline activity and decision making

7.2.2 Reflection on the evaluation tools

Work presented on the evaluation tool focuses on the pilot stage and highlights the iterative nature of the action research cycle in modifying and adapting the tools used across the discipline workshops. By working through different iterations across the different workshops, this research provides a model that seems to work. All the tools are accessing the information and knowledge they were intended to access from the young people. The tools are also useful for identifying gendered differences. The knowledge map is the common tool used in most of the disciplines apart from the games design workshops but can equally be adapted to that workshop.

While many research studies focus on one or two factors that influence uptake of STEM disciplines, this study presents a model that evaluates multiple factors and provides means of measuring content knowledge across different disciplines (use for contribution to knowledge chapter or discussion chapter. A summary of the measures assessed using the evaluation tools is shown in Table 56

Table 56: Summary of Indicators assessed using the research evaluation tools

<table>
<tr><th rowspan="2">Data Component</th><th colspan="5">STEM Multi-Discipline Inspired Workshops</th></tr>
<tr><th>Material Science</th><th>Paleontology</th><th>Environmental Modelling</th><th>Environmental Planning</th><th>Games Design</th></tr>
<tr><td>Gender distribution</td><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td>Aspirations</td><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td>STEM aspirations</td><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td>Knowledge of career Promoted</td><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td>Perception of what people in such career do</td><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td>Inclination towards career</td><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td></tr>
<tr><td>Reason for the career preference</td><td>√</td><td>√</td><td>√</td><td>√</td><td></td></tr>
<tr><td rowspan="3">Subject specific knowledge</td><td>What are materials</td><td>What are fossils</td><td>What is a model</td><td>What can maps tell us</td><td>How is a game produced</td></tr>
<tr><td rowspan="2">What can you use Nitinol for</td><td>How can we look back in time?</td><td>What is a prediction</td><td rowspan="2">What can we learn from maps</td><td rowspan="2">Design of individual game</td></tr>
<tr><td>Why do we want to look back in time</td><td>What is the difference between weather and Climate</td></tr>
<tr><td>Application</td><td>Exploring the smart material Nitinol and testing properties of materials</td><td>Exploring fossils using microscopes</td><td>Modelling of a house using plasticine</td><td>Tracing and identifying similarities and difference in maps</td><td>The game</td></tr>
<tr><td>Feedback (post workshop)</td><td>√</td><td>√</td><td>√</td><td>√</td><td>√</td></tr>
</table>

The evaluation tools used in this study are age appropriate for young people in primary schools and provide application of an evaluation system that is multi-disciplinary. Data from the evaluation provided useful insights into each child's reasoning behind their career preferences or choices.

7.3 Pedagogical approach

Combining elements of both pedagogical learning theories enable the program designs to benefit from the strengths of both theories and integrating them also compensates for the weaknesses of each. While Direct Instruction will accommodate learners with little or no prior knowledge about the subject content, Cognitive Constructivism will accommodate the individual differences of the participants thereby enabling participants to work independently and creatively.

This study provides evidence of effectively combining two pedagogical learning theories across different discipline intervention workshops, some elements from Direct Instruction and Cognitive constructivism are incorporated in the individual STEM discipline workshops. This supports research studies that argue for the combined use of the complementary aspects of both theories (James-Gordon, 2003; Charles, 2014).

Apart from the different elements of the integrated model employed across the different discipline workshops, a model of direct instruction was employed in the structure of the workshop where every workshop structure included

- whole class session
- Individual/group practice
- Final whole class session

Combining both theories builds on the strengths of each learning theory and together accommodate different types of learners across the novice-expert spectrum in the different STEM discipline areas. An integration of both theories facilitates learning and promotes proficiency and creativity. Tables 57 and 58 show how aspects of each learning theory was incorporated in each of the workshops. While some workshops made use of all 8 elements from both learning theories (for example the games design workshop), others made use of some elements, but still a mix from both learning theories. The research provides practical application using an integrated learning framework.

Table 57: Practical applications and use of elements from the Direct Instruction in the workshops

Learning theory	Elements from the learning theories	Computer science	Materials science	Paleontology	Environmental modelling	Environmental planning
Direct Instruction	Structured instruction	Using instruction guide & scaffolding to understand the game design process	Children provided with examples on how to record findings from testing	Children are shown a core sampler and told how to use it. They are also shown how to understand the past using microfossils	Children are told about prediction using an example of the weather	Children are shown how to manage coastlines
	Conceptual mapping	Children think of the game they want to create and map out the design	….	….	….	….
	Seatwork	Children work at individual paces to build their game	Children identify similarities & differences in materials	Children explore fossils using microscopes. Microfossil identification	Modelling of a house with plasticine	Children practice decision making on coastlines. Also differences and similarities in maps from different periods
	Interactive questioning	Children allowed to ask questions throughout the games design process	Children interactively engage and question facilitator during the workshop	Children interact with the facilitator and peers during exploration of microfossils	Children interact and discuss climate change with facilitator	Discussion with facilitator on coastline changes

Table 58: Practical applications and use of elements from Cognitive Constructivism in the workshops

Learning theory	Elements from the learning theories	Computer science	Materials science	Paleontology	Environmental modelling	Environmental planning
Cognitive Constructivism	Triggering Prior Knowledge	Children asked about their prior knowledge of the games industry	Children asked about their knowledge & perception of a materials scientist	Children asked about their knowledge & perception of a paleontologist	Children asked about their knowledge & perception of an environmental modeller	Children asked about their knowledge & perception of an environmental planner
	Eliciting moment of surprise	Showing children slides about the games industry & people that work there	Children shown slides explaining the career and introducing new concepts	Children told about fossils and that they are rocks not bones	Children told about what environmental modellers do	Children provided with slides on what environmental planning is about
	Application of new knowledge	Children put into practice new knowledge learnt about building games	Children test the different materials to determine their properties. Uses of Nitinol activity	Children explore seabed sand to search for microfossils	Children practice with bean bags to understand the concept of uncertainty	Practicing differences and similarities in maps for different time periods
	Feedback	Children evaluate each other's games and provide feedback	By testing the materials, feedback is provided about children's predictions	….	….	….

7.4 Impact on academics

The Theory of Change model created in this research is a nested model (Hansen et al., 2013; Mayne, 2015; Douthwaite & Hoffecker 2017; Bolton et al., 2018) of a wider NUSTEM's Theory of Change (Davenport et al., 2019). NUSTEM an outreach group that work with young children and their circle of influence (including teachers and families), is focused on getting more young people to choose a career in STEM post-18 years. The nested model was used to align the discipline workshop objectives with the over-arching NUSTEM objectives, and the perspectives of the NUSTEM team, academics and researcher. The action research process was also utilized to design and implement the subject specific workshops. The theory of change model helped frame the design of the workshops and provided the academics with a logic map that outlined how the different intended outcome were to be achieved.

Prior to the workshops, some of the academics involved in this research had limited experience working with young children, particularly for children under the age of 11 years (Primary school), therefore the experience for primary school-based outreach was new. Also given the current importance of extending academic research beyond academia to impact wider society (Darby, 2017; Phillips et al., 2018; Watermeyer and Chubb, 2018; Wilkinson, 2019), the imbalances in uptake of STEM disciplines (Universities UK, 2018) and the recency of evaluations of academic research for societal relevance (Given et al., 2015; REF 2014), the academics and researcher were keen to co-design and co-create workshops for the intervention. Since the co-design and co-creation process required different inputs of subject specific knowledge and expertise from the academics, outreach team and researcher, the Theory of Change process was appropriate. This is because Theory of Change is robust enough to accommodate the different perspectives from stakeholders (Davies, 2018; Guarneros-Meza et al., 2018) and it provides a shared understanding (Anderson, 2005) of what change is expected and how that change would be effected (Maru et al., 2016; Rogers et al., 2000; Douthwaite & Hoffecker, 2017). Also, because the co-creation and co-design of the workshop required reflections and improvements on the design and implementation of the workshops, the iterative nature of the action research process was useful (Kemmis & McTaggart, 1988; MacIsaac, 1995; Gabel 1995; Stringer, 2014).

Academics indicated enjoyment of classroom engagement which also afforded the opportunity of observing which aspects of the workshop activities did not fit or required a reorganisation or a change in activities. For example, during the pilot implementation of the environmental planning workshop, observations by the academic indicated that the young people did not understand properly two of the concepts embedded in the coastal exercise. Employing the iterative cyclical nature of the action research cycle (Bakersville 1999, Kemmis et al., 2013; Stringer et al., 2014; Coglan, 2019), the implementation of the prediction and management aspects of the activities were observed and reflected upon, modifications to the workshop design were made in the plan stage of the cycle and changes and adaptations were adopted in the act stage of the cycle. A similar process was employed to increase the time allocation for the question and answer session in environmental modelling workshop.

The combined use of the Theory of Change framework and the action research cycle provides an effective means by which academics can outline workshop objectives, design and implement intervention programmes and examine if the intended outcomes are achieved within the available time and resource constraints.

7.5 Impact of research on young people

Impact of the research is discussed in terms of children’s aspirations, their knowledge of STEM careers, their inclination towards STEM careers, stereotypes and preconceptions

7.5.1 Young people’s aspirations

Findings from research studies suggest that career aspirations occur or are formed in young people at an early age (Gottfredson 1981; Uka 2015; Reiss & Mujtaba, 2017; Kitchen et al., 2018). Results from this research are consistent with these studies showing that career aspirations are already formed from as early as 7 years of age in a child. For example, some of the careers 7-8 years olds aspired to, in the materials science workshop in phase 2 of the intervention include, vet, marine biologist, archeologist, games designer, teacher, nurse, hairdresser and scientist. These results reinforces the importance of starting career engagements and nurturing interests early in a child’s life, especially if STEM interests are intended to be fostered.

Results from this study are also in line with studies that inform that young people already have high aspirations (Kintrea et al., 2011; Chambers et al., 2018) as can be seen from the wide range of high career aspirations expressed by the children in the workshops. These include engineers, artists, marine biologists, book illustrator and dentist. These results support suggestions (Archer et al., 2014c) for the need to focus not only on ‘raising aspirations’, but ‘widening aspirations’ by informing and creating experiences around a wide range of careers. This helps generate interest, reduce imbalances and promotes participation in under-represented groups that could either be unaware of these careers, do not have access to the careers or have preconceptions that these careers are not for them without any prior experience of the career.

Findings show a large number of children across the school year groups and different workshops in the intervention aspired to be footballers. 10% (n=12) of the children from the pilot studies and 17% (n=48) across the different workshops in phase 2 of the main intervention. These results could be a function of the immediate environment where the schools are located. Newcastle upon Tyne is the home of a professional football club that participates in the Premier League with many games played in the stadium within the city. Football is a passion shared by many in the city (Newcastle United Foundation, 2019; NECC, 2019). This has fostered people’s interest, young and old in the area (chroniclelive.co.uk; 2018). Findings from this study supports Chambers et al.’s (2018) study that showed that 21% of over 13,000 children surveyed in the UK wanted to be a sports person which was the most popular career aspiration in that study. The finding in this thesis is also consistent with research studies that aspirations can be influenced by environment (Uka, 2015, Padwick et al., 2017).

78% of children in the digital games pilot studies indicate similar aspirations and expectations of attaining those aspirations. Studies in research have described aspirations as hopes of future occurrences (Gorard et al., 2012; Perry et al., 2009 Crawford et al. 2017) and expectation as perceptions of thought on future self (Gorard et al. 2012; Khattab, 2015) or expected-self (Markus & Nurius, 1986; Perry et al., 2009). While research studies have discussed the gap between a young person’s hope (aspiration) and belief about what might actually happen (expectation), often referred to as the aspiration-expectation gap (Hellenga et al., 2002; Perry et al., 2009; Boxer et al., 2011), findings from this study of a large number of children having similar aspirations and expectation, could be a function of children not understanding the difference between aspirations and expectations. It could also be because at that young age, participants have not experienced many of the constraints that come with dealing with reality rather than an ideal future world (Khattab, 2015).

Gendered differences were indicated in the pre-workshops aspirations of the children in the second phase of the intervention, in all of the workshops data except the games design workshop, which had a smaller sample size compared to the other workshops. Gender is a major factor influencing children's aspirational choices (Results indicate a significant association for environmental modelling (p= .036, Fisher's Exact Test), for environmental planning (p= .002, Fisher's Exact Test), for paleontology (p= .030, Fisher's Exact Test) and for materials science workshop (p= .003 Fisher's Exact Test). Gender is a major factor that influences children's occupational aspirations (Gottfredson & Lapan, 1997; Helwig, 2001; Tripney et al., 2010). Gottfredson (1981) describes gender as one of the major influences that children use in creating their zone of acceptable career alternatives. Other major factors that affect a child's addition or reduction of careers into their zone of acceptable alternatives are prestige, interests and accessibility. By widening their knowledge of careers, the children can start seeing the value or usefulness of these careers, how some of those careers can be appropriate for them and also breaking stereotypes or correcting incorrect conceptions. When further statistical tests were carried out using the post-workshop data, no association was identified between gender and the type of careers children aspire to, in all three geography workshops. Although an association was still evident in the materials science post-workshop data (p= .009, Fisher's Exact Test).

Results from the games design (pilot) suggests an association between gender and the type of STEM career aspired to, X^2 (1, N = 40) = 9.808, p =.002. The results also suggest an evidence of an association between aspiring to a STEM career in the health sciences (p=.000, Fisher's Exact test) and (p = .064, Fisher's Exact Test) from the materials science workshop in phase 1 of the main intervention. More males aspired to physical sciences careers compared to females while more females aspired to careers in health sciences compared to their male counterparts. This finding is important because it provides evidence that could inform where to focus intervention efforts directed at reducing the differences and inequalities in participation, particularly in the STEM disciplines. Although there are gender imbalances some STEM areas, health sciences has a better gender balance than other STEM areas. The result from this research study also supports a report showing over 70%

participation from females in medical and veterinary sciences degrees (UK Universities, 2018). Similar results were indicated in the pilot study of the games design workshop.

The games design workshop that was conducted over a series of sessions over the course of 5weeks, showed an increase in young people's aspirations in STEM careers from 30% to 45% and an increase in aspirations to computer science related careers from 5% to 25%. These findings highlight the importance of sustained engagement and real world applications to intervention activities (Reiss & Mujtaba, 2017; Kitchen et al., 2018). McClure et al (2017) argues that not only should STEM engagement start early, the engagement should be sustained. The National Research Council (2015) identified programmes that engage young people in sustained STEM practices as a means of producing positive learner outcomes. As children grow, their interests are influenced by their environments (Gorard, 2012; McClure, 2017) with different activities, things, engagements vying for their interest. If STEM engagements are not sustained, children or young people's interests might easily switch to things are activities they are interested in or can relate with. A research study suggests that young people are more likely to pursue careers they are interested in (Nugent et al., 2015). Capturing interests can be done through authentic learning opportunities (ACARA, 2016; Mildenhall et al., 2018) young people can relate with.

The findings also reinforces the influence of personal experiences on aspirations. Across the different workshops, only the games design workshop showed an increase in STEM aspirations post-workshop compared to pre-workshop aspirations. This might be a function of the games design workshop being the most hands-on experiential workshop amongst the different discipline workshops and also delivered over many sessions. It may also indicate that children's aspirations are difficult to change from one workshop, or difficult to change once they have been established. These highlights the relevance of early experiences (Riegle-Crumb et al., 2011) and also the repeated nature from sustained engagement over one-off interventions, as shown in the games design workshop.

7.5.2 Young people's knowledge of careers within STEM

Results suggest a general increase in children's knowledge of STEM careers post workshop compared to pre workshop across all the main intervention workshops. In phase 1 of the main intervention, there was an increase from 3.8% (n=2) to 64.8% (n=35) in the materials science workshop and 45% of the children in the games design workshop knew more jobs in the gaming industry post-workshop compared to their pre-workshop survey responses. In phase 2 of the intervention, there was an increase from 12.7% to 55.9% in the environmental modelling workshop, 47.7% to 82.5% in the paleontology workshop, from nil to 78.8% in the environmental planning workshop, 13.8% to 31% in the materials science workshop and 56.5% to 68.4% in the games design workshop.

There was a corresponding decline in the number of children that indicated that they did not know the career promoted post-workshop compared to their pre-workshop responses. In phase 2 of the main intervention, there was a decrease from 84.1% 37.3% in the environmental modelling workshop, 50.8% to 17.5% in the paleontology workshop, 98.4% to 15.4% in the environmental planning workshop, 81% to 67.2% in the materials science workshop and 43.5% to 31.6% in the games design workshop. These results are important because children's aspirations are constrained by what they know (Gale et al., 2010; Hildago, 2015; Chambers et al., 2018), therefore potentially limiting the kinds of careers they can aspire to. According to Gottfredson's theory (1981) on circumscription and compromise, children's zone of acceptable alternatives mirrors a set of occupations young people decide to retain or reject as a function of what they deem acceptable or suitable to their gender, ease or difficulty in achieving and its value in the society. The dimensions in which zone of acceptable alternatives are usually developed based on gender, social status or prestige, interest and accessibility (Gottfredson 1981; Satre & Mullet, 1992; Junk & Armstrong 2010) By providing intervention activities that incorporate career information, particularly careers the children are unaware of or are less known, their knowledge base of careers is increased. This provides opportunities to nurture interests in those newly known careers. These findings provide support for studies that advocate embedding careers information in STEM subject teaching (Reiss & Mujtaba, 2017; Archer et al., 2013) to improve knowledge of careers.

Whilst some of the children's pre-workshop responses indicate that that they did not know the career promoted, in the phase 1 material scientist workshop, they were able to give a fairly accurate description of what people in those careers do. For example, children describe what a material scientist does as *'experiment on/with materials'*, '*works with materials'*, *'find materials in most objects'*, and '*design materials'*. This is interesting because while they had some realistic guesses about what people in those career do, they were not confident enough to indicate their knowledge of the career. This uncertainty undermines self-efficacy and self-efficacy has been evidenced in literature as a factor influencing interest (Nugent et al., 2015) and a mediator of career aspirations (Gutman & Akerman, 2008). Intervention activities in this research increases children's knowledge and understanding of some STEM careers as evidenced in this finding and as shown in another research study (Castro et al., 2018), improves self-efficacy. Fisher's Exact test and a chi-square test of independence was carried out pre- and post-workshop respectively and no association was found between gender and if the children knew what a material scientist is, ($p = .723$, Fisher's Exact Test) and X^2 (1, N = 54) = .429, $p = .577$ respectively

7.5.3 *Young people's subject or discipline specific knowledge*

Evidence from literature suggests that in-depth understanding of STEM concepts (Cotabish et al., 2013; Wooten et al., 2013) and practical based or hands-on activities (Kitchen et al., 2018) help engagement with STEM. In this thesis research, children were able to engage with the games design through the creation of their own games. In order for them to create those games, they had to understand some of the concepts such as story points and tile map layers. The children then had to apply the new knowledge in creating their own games. By practicing the new knowledge learnt through repeated actions during the creation of the game, learning is reinforced (Hartle et al., 2012).

Children were able to increase their knowledge of what some STEM careers entail. Children's perception of what people in the promoted STEM careers do, presented a more descriptive response post workshop in many of the disciplines compared to their pre-workshop responses. The post-workshop responses include more subject specific vocabulary used by the participants. This suggests discipline-specific learning. Also, while some of the subject knowledge concepts were familiar to the children, for example, what materials are and what a prediction is, some concepts were new knowledge, for example, the difference between weather and climate.

By engaging with discipline specific content through hands-on activities, children were able to recognise the value of different areas of STEM to things or activities in their everyday life (Riegle-Crumb et al., 2011; Krishnamurthi et al., 2014). In the materials identification activity in the materials science workshop, children were able to identify properties of objects through the use of those objects in everyday life. For example they said, *'windows should be transparent so that people could see through them and light could pass through'* or that *'tables and chairs are hard so that they do not break easily'.* Another example is the practical application of maps in the environmental planning workshop to understand the usefulness of maps. Children used maps from two different time periods to identify similarities and differences in the landscape of the area. Also, since the maps was for the area where the children's school was located it made it relatable to the children. Children were able to understand the usefulness or value of maps in their knowledge map response. For instance, children said 'Some maps show you difference and they change over the years/ things change over time'

Combination of STEM content knowledge and practical skills are reinforced and enhanced when situated in authentic learning opportunities (ACARA, 2016; Mildenhall et al., 2018). Authentic learning opportunities can be achieved by providing children with experiences they can relate with (Lombardi, 2007; Harrington et al., 2014; English et al 2017).This study provides evidence of how subject content can be taught across different disciplines using practical hands activities by showing a systematic way in which specific STEM concepts are used to design and create age appropriate activities, children can relate with.

7.5.4 Young people's inclination towards STEM careers

To encourage young people to align with STEM careers, they need to self-identify with STEM careers and see people working in those careers as 'people like them' People like me (Archer et al., 2013; MacDonald, 2014; Saxton et al., 2014; Krishnamurthi et al., 2014). Analysis of the findings indicated that only the paleontology workshop showed a minimal percentage increase (from 24.6% to 25.4%) in children's positive inclination towards the proposed STEM career across the various disciplines. The material science and games design workshops showed an increase in the percentage of children that were not sure if they wanted to do the careers promoted, from 32.8% to 37.9% and 34.8% to 52.9% respectively. Although there was not much positive uptake in the proposed STEM career, there was an increase in percentage of young people that were undecided.

The aim of these intervention workshops are not to force young people to choose STEM careers but rather to create opportunities to nurture interests that might develop from exposure to STEM content and careers. Chambers et al. (2018) argue that children's perceptions about careers develop early in their lives and those perceptions are sometimes cemented at that early age. This could potentially lead to the children adding or retaining some of these STEM careers within their zone of possible alternatives (Gottfredson 19981; Gottfredson & Lapan, 1997). An increase in the percentage of children undecided could indicate they are now keeping their options open (a window of opportunity) and not excluding themselves from potential career opportunities. By providing access that is open to everyone with hands-on experiences, STEM intervention activities can be inclusive, career informed and explore possibilities without necessarily asking young people to make a career choice at that point in time.

Some of the children that 'did not want to do' the materials science or environmental modelling careers or 'were not sure' in the phase 2 of the main intervention, already had a career in mind to which they aspired to. 20% (n=12) of children from materials science and 25% (n=15) said they knew what they wanted to be or had a specific aspiration. This suggests that there might be some stability in children's aspirations and that these aspirations might not be as fleeting. The raises the question of how long can these aspirations remain stable given the many influences from a child's environment.

The positive inclination towards promoted careers immediately after the workshop showed a decline in positive inclinations when post-workshop data was collected a month later. For example, when children were asked if they would like to do the career promoted in the workshop in phase 2 of the main intervention, their positive response dropped from 26% to 10% in the material science workshop, from 8% to 6% in the environmental planning and from 17% to 16% in the games design workshop. Possible reasons for this result could be that the thrill of the workshops had worn out with time and other activities engaging more of the children's interest. The implication of this finding highlights the importance of sustaining engagement to increase impact on young people. This can involve drip feeding through many activities rather than a single intervention activity or workshop.

7.5.5 Young people's stereotypes and preconceptions

Van den Hurk (2019) describes stereotypes as an environmental factor influence. Findings from the study provide evidence of gender stereotypes preferences exhibited by children. For example, during the pilot phase sorting activity of the digital games, children's assignment of characters to job roles in the games industry showed the three characters selected the most for a job role were mostly males while the three characters selected the least for a job role were all female. These results imply that children have already starting forming stereotypes from that young age and have gendered preferences. The results also provide evidence of stereotypes in relations to careers. Bian et al. (2017) suggests that since the gaming industry mainly portrays dominance of males in roles and in the games, it reinforces stereotypes that the games industry might not be for 'people like me' (females).

Stereotypes are often based on insufficient information and sometimes that information can be inaccurate (Narayan, Park, & Peker (2007). Preconceptions can anchor and influence a person's feelings, actions and reactions. Some of the stereotypes identified in this study that improved with accurate information include a description of fossils as bones by 56% of the children, in the paleontology main pre-workshop. This dropped to 36% post-workshop. Fossils were also referred to as rocks by 24% of participants' pre workshop which increased to 28% post-workshop. Stereotypes can be challenged by changing perceptions through experiences that are inclusive and young people can identify with. Research studies suggest children exhibit gendered preferences or interests in things around them (O'Neil & Boulton, 1996; Harrison & O'Neill, 2003). Harrison & O'Nieill's study of 8 – 9 year olds show children classify musical instruments along gendered lines; musical instruments they would like to play with. Results from this thesis research also show children's alignment to particular objects by gender. Findings from the pilot studies of the materials science workshop shows males describe materials in terms of building materials and females describe material in terms of clothing. Also in the main intervention phase 1, associations were found between gender and specific objects children identified. These are books ($p=0.004$; Fisher's Exact Test), whiteboard ($p=0.014$; Fisher's Exact Test) and glasses ($p=0.022$; Fisher's Exact Test), with females more likely to identify these objects compared to males. Also, while males identified structural materials used for building, female identified materials that were more personal.

7.5.6 Enjoyment of workshops

Lack of experience of STEM content has been identified in literature as one of the barriers to participation (Avendano et al., 2018). Positive experiences and interests have also been linked to STEM career considerations (Dabney et al., 2012; van den Hurk et al., 2019).

Some of the activities participants indicated enjoying include the game creation, the nitinol activity, the fossils, microscope and sand activities, the exploration of the map and the modelling with plasticine, the practical hands on activities. Many of the positive feedback and aspects of the workshop remembered by participants across the workshops were mainly around these hands-on and interactive activities. This findings provide evidence highlighting the importance of using hands-on or practical activities to reinforce learning.

7.6 Reflections on practical implementation

Many aspects of the workshops worked as intended. For example, the structure of the material science workshop worked really well and children were able to relate the concepts in the workshop with daily objects they see around themselves. The robustness and flexibility of the digital games workshop permitted the workshop to be effective in different settings and timescales (a day, a week or over five weeks).

Reflections on the implementation of a workshop provides understanding of what works, why the process works (Crawford, Dytham & Naylor, 2017) and what needs to change. During design of workshops, there are usually moves to ensure that the workshop activities are designed to be implemented correctly or in the right manner. Evidence from implementation suggests that things might work well on paper but there needs to be actual implementation to uncover issues that might arise. For example during the pilot of the games design workshop, it was discovered that the game engine worked better using chrome rather than internet explorer. The testing of thermal conductivity using ice block cubes in the material science workshop uncovered logistics issues in terms of environments without access to freezers. These findings again, strengthens the significance of piloting and doing a second run of workshops deliveries to implement changes.

The implementation of the workshops also highlighted the importance of consideration on who delivers workshops or outreach activities to children. Research studies contain descriptions on the influences role models have on young people (Cheryan et al., 2011; Archer et al., 2013; Liu et al., 2014). Post-workshop results from the environmental modelling workshop (pilot study) show a large gender difference in the number of young people that would like to do a career in environmental modelling (81.8% males and 18.2% females). This raised the question if having males deliver the workshop, affected the gender of participants that would like to do the job. It underscores the importance of the consideration of controlling for different facilitators delivering workshops to young people.

7.6.1 Effects of unintended consequences

The study also highlights the importance of taking into consideration intended or unintended outcomes or consequences that might result from implementing an intervention program. This is in line with research studies that have discussed the possibilities of such unintended occurrences (Bolton et al., 2018). For example, even though participants indicated enjoyment of the environmental planning workshop with positive feedback from facilitators on the implementation of the workshop, young people did not indicate inclination towards the career. Further prompting revealed their perceptions of the career as ‘requiring to make difficult decisions’, ‘complicated’ and detrimental to ‘lives and houses’. While the understanding of subject specific content increased the impact on the children, it was not the intended impact. The reason for this finding could be that coastal erosion task provided a very clear illustration of the environmental planner’s work and by combining the area where participants live in and the decisions made for erosion, might have further driven home the importance of the decisions leading to the unintended consequences. Some children thought that people might die due to the decisions they would have to make if they chose to do that job. Actions taken to mitigate these effects included explaining to the participants what happens to people and their houses when coastal planning decisions are made and how long some of those decisions take to fully implement. The implication of this finding strengthens the importance of including regular feedback loops in the implementation and evaluation of interventions to ensure that the intended impacts are actualised. This also provides evidence on the usefulness and effectiveness of an action research approach.

7.7 Chapter summary

This chapter discusses the findings from the pilot and main intervention implementation with reflections on the evaluation process, implementation, evaluation tools and effects of unintended consequences. The research presents an age appropriate evaluation tool for young people to assess their STEM aspirations, knowledge of STEM careers and related concepts and inclination towards those STEM careers which are all situated within a Theory of Change framework to widen aspirations and sustain STEM engagements. The iterative nature of action research utilising these evaluation tools provides useful insights which can be used to effectively refine the interventions and evaluation tools for future deliveries.

The study provides evidence of insights into young people's preferences and reasoning. It also shows that evaluation approach and tools that can be used for younger children which have been carefully designed to be age appropriate with feedback loops to consistently measure intended outcomes.

CHAPTER EIGHT – ORIGINAL CONTRIBUTION TO KNOWLEDGE AND CONCLUSION

This chapter presents a summary of the research and discusses the originality of this research and its major contributions to the wider body of knowledge. The limitations of the research are also presented followed by avenues for future work. This is followed by a description of the interactions of the researcher with the wider research community.

The aims of this research was to develop an effective evaluation framework and provide a process that academics and practitioners can use to plan, develop, implement and assess the impact of STEM interventions. The research focused on interventions based on research work by academics. Using a Theory of Change process, four pathways for widening aspirations are outlined. These are: (1) increasing knowledge of a wider range of STEM careers, (2) providing/increasing basic knowledge of STEM related concepts, (3) improving or increasing science practical skills and (4) increasing knowledge of STEM related application. The study adopts an action research approach and multiple case studies methodology from three STEM disciplines: computer science, materials science and geography. Five workshops were designed and implemented; one each in computer science and materials science, and three in geography. These was carried out to explore the impact across disciplines and within a discipline.

The study leveraged expertise of academics and the NUSTEM outreach specialist to design and develop STEM career inspired interventions. Children's aspirations were examined since studies (Gorard et al., 2012; Uka, 2015) suggest they are formed early in a child's life and are influencers of children's interest (Tripney et al., 2010).

8.1 Summary of research findings

Some key findings from this study are:

- Evidence to support that career aspirations are formed at an early age in children and those aspirations are high aspirations.
- 'Footballer' was the most popular aspiration amongst the children.
- There was no gap between aspiration and expectation of achieving the career aspired to in 78% of children
- Results suggested a general increase in young people's knowledge of STEM careers post workshop compared to pre workshop across all the main intervention workshops

- While findings did not show increase in inclination towards promoted career except in the paleontology workshop, results indicated an increase in the number of children that were undecided if they wanted to do career promoted.
- Findings indicated gender stereotypes exhibited by the children. When the children were requested to assign roles to characters in the games design workshop, the three characters selected the most for a job role in the gaming industry were male while the three characters selected the least for a job role were all female.
- The evaluation tools used were age appropriate for young people in primary schools
- This research presents evidence of unintended consequences that can occur when implementing a STEM intervention

8.2 Original contributions to knowledge

Below, the key original contributions from this research to the wider body of knowledge are discussed.

1. **An effective evaluation framework**

This study set out to develop an effective evaluation framework that can be used to assess interventions based on academic research on young people's interest. An evaluation framework was developed using the Theory of Change to show the process of designing, implementing and evaluating interventions aligned to specific outcomes. The framework also helps identify how elements or aspects of academic research can be extracted and translated to age-appropriate activities and provides possible measures that can inform the evaluation of the intervention. This framework has then been tested across three disciplines to evaluate impact of academic research on young people through a series of workshops. Using the framework, this allows for evaluating effectively the motivations, aspirations and subject knowledge of young children.

2. **Application of a Theory of Change approach to STEM interventions.**

A key contribution of this research is the design and application of a Theory of Change framework in evaluating STEM intervention workshops. The research outlines a process where researchers or outreach practitioners with varying experience levels in public engagement or engagement with young children, can use and adapt to design and implement their own intervention.

While Theory of Change approach to evaluations have been used in medical disciplines (Mackenzie & Blamey, 2005; Maclean & Vannet, 2016), charity sector (Prinsen & Nijhof, 2015) and agricultural disciplines (Maru et al., 2016, Douthwaite & Hoffecker, 2017), they are used less in technology and engineering related disciplines. The PhD research provides application of the Theory of Change approach in computer science, materials science and geography disciplines. The framework provides pathways to widen children's aspirations.

Theory of change is useful for evaluators, academics, funders and STEM outreach facilitators because it not only provides clarity on the goals and objective of the intervention, it specifies how the intended outcomes are to be measured. The Theory of Change framework underpinned the design and development of the 5 workshops used in this research. Also, the combined use of a theory of change framework and logic models provides a systematic evidence base of what works and under what conditions the interventions works.

3. Extending impact of academic research beyond academia

The increasing importance given to the impact of academic research beyond academia in recent years (REF 2014; Given et al., 2015) has made it imperative to provide evidence of such societal impact. This PhD research provides an approach to working with stakeholders. It provides practical application on how academics, practitioners and researchers can all be involved in the co-design and co-creation of STEM intervention activities. Conversations in literature studies (Kieser & Leiner, 2009; Wolf & Rosenberg, 2012) have discussed the gaps in translating academic research work to practice often referred to in management research as the rigor-relevance gap (Kieser & Leiner, 2009; Wolf & Rosenberg, 2012; Phillips et al., 2018). By having practitioners, academics and the researcher working together, common ground to effectively translating research to practice, can be achieved, thereby bridging the rigor-relevance gap. This study also extends and contributes to research conversations with regards to the rigor-relevance gap beyond management disciplines into physical science disciplines. Also, case studies on STEM interventions showing impact from academic research have mainly been aimed at young people in secondary schools or Higher Education (REF, 2014). Few of the REF case studies were scoped for STEM intervention with younger children. This research targeted the under-represented group; young children under the age of 11 years.

4. Integration and application of pedagogical learning theories

This study contributes to research on pedagogical learning theories. It provides practical application of combining elements from 'direct instruction' and cognitive constructivism into an integrated pedagogical framework. This is consistent with studies (Roy & Novotny, 2001; Bell, 2011; Charles, 2014) that advocate combining learning theories because no single theory is able to accommodate all learning situations that occur in real life. Integrating the pedagogical learning theories in practice provides opportunities for learners to develop and improve their proficiency and creativity in the content being learnt. The study also highlights how elements from both learning theories are used for children to understand complex knowledge through scaffolding. An example of this is shown in the games design workshop where children had to learn new and complex tasks in order to design their games.

5. Evaluation tools for children

This research contributes to research on evaluation tools appropriate for young children. Many interventions in literature studies (Archer et al 2012; 2014; 2015; Scott 2016) focus on young people between the ages of 11-19, with much less focus on children below the age of 11 years. The knowledge maps used in this research provides evidence and an approach to evaluation of research based inspired, STEM interventions. The tool has been designed to be age appropriate for primary school children, can be adapted to discipline specific contexts and can be embedded in normal classroom teaching.Also, Saxton et al. (2014) identified the difficulty in measuring content knowledge due to reliance on specific context. This is particularly the case for children in the younger age group (Castro et al., 2018). The PhD research provides a means of measuring content knowledge across different disciplines. The use of effective evaluation tools allows available resources to be effectively allocated to nurture interests and tackle identified gaps and factors constraining equity and representation in STEM.

6. Aspirations of young people

Findings from this study contribute to research conversations about young people's aspirations. They provide supporting evidence of the high aspirations in young children from communities with low socio-economic status (SES) irrespective of the STEM interventions. This PhD study also provides evidence that suggests an association between gender and the type of STEM occupation young children aspired to. From the results, while males mostly aspired to STEM careers in the physical sciences, females aspired to careers in the health sciences.

7. Integration of careers into STEM interventions and practical applications

Early experiences and highlighting the usefulness of STEM have been suggested to influence children's career interests in STEM (Riegle-Crumb et al., 2011; Reiss & Mujtaba, 2017; Kitchen et al., 2018). This study contributes to career research by providing practical examples of how careers have been incorporated in age appropriate, hands-on activities that are easily embedded within regular in-school, classroom sessions. By using practical applications children can relate to, the children are able to understand the usefulness of STEM. The research also provides evidence of how subject content could be taught across different disciplines using these practical activities. This contributes to STEM learning research suggesting the use of STEM concepts understanding to develop and engage young people's interests (Cotabish et al., 2013; Wooten et al., 2013).

8. Process implementation of STEM intervention activities

This research also contributes to conversations about action research applications. The iterative reflect-plan-act-observe approach of action research underpinned the design and implementation of the different workshops in this study. The action research cycle was very useful in the co-design, co-creation and implementation of the workshop by providing opportunities to reflect on what worked, what did not work well and avenues to adapt and improve the workshops, based on feedback. The outlining of the structure of the workshops was useful in aligning the objectives of the workshop to the Theory of Change outcomes. This alignment guided the indicators chosen to evaluate the outcomes. The research also provides evidence of unintended consequences that can occur from intervention implementation. By incorporating evaluation and a feedback loop in the workshop design and implementation, using the action research cycle, any unintended consequences can be identified and mitigated.

9. Multi-disciplinary context

Another contribution of this study is the multi-disciplinary approach adopted. The use of multiple case studies help to showcase similarities in workshop structure, delivery and evaluation across the different STEM workshops and the context differences between disciplines. The study contributes to STEM learning research in computer science, materials science and geography. Although this study is limited to these three disciplines, theory of change framework, the workshop structures, evaluation approach and tools can be adapted by other disciplines. This would provide further evidence to demonstrate the adaptability and usability of the framework and processes.

8.3 Limitations and Future Works

This work is not without its limitations. This section describes some of these limitations. The sample size for the individual discipline workshops were small therefore generalization of findings should be interpreted with caution. However this limitation does not undermine the contributions of the approach to stakeholder engagement or the evaluation approach. Further studies can replicate the study adopting larger sample sizes.

This study was constrained to a specific geographical context in the North East of England. Findings from this study showed majority of children aspired to be a footballer which indicates cultural dependence; Newcastle is a city renowned for its football interests. Future research could replicate the study in other cities nationally or internationally to explore the differences in cultural context and if similar findings can be established with regards to aspirations.

Academic researchers from the different disciplines were actively involved in the design and piloting of the workshops. While the academics reflected on the implementation of the workshops and provided inputs on how the workshops could be improved, further investigation on the impact on academics were not pursued in this study. Future research could involve exploring how engaging in the design and implementation process has impacted on their way they practice in their different disciplines.

Also, while the different STEM workshops in the main intervention were facilitated by NUSTEM outreach specialist, further research can investigate the impact of the intervention if the workshops were delivered by the children's regular class teachers. Would the thrill of the workshops still persist and would similar or different findings be revealed?

Further research could also explore the aspiration-expectation gap with regards to young children. Expectations of achieving a specific career have been inferred to mediate a young person's aspiration. While aspirations might be disassociated from reality, expectations have been suggested to be more in tune with perceived reality (Khattab, 2015). Findings from this PhD study indicated that 78% of children had similar aspirations and expectations of attaining their aspired career. Future studies can explore at what point or age in a child's life does aspiration and expectation seem to diverge, and the gap widen?

8.4 Interactions with the research community and research impact

Undertaking this research study has provided opportunities for the researcher to interact with the research community. At the early stages of this research, initial findings from literature studies, the aim and objectives of the research, the methodology and intended structure of the study, were presented using a poster, at the UK Evaluation Society (UKES) conference in 2017. This conference focused on the use and usability of evaluation. Later in the same year, the poster describing the study was also presented at the Engineering & Environment Faculty PGR Conference at Northumbria University to academic faculty and postgraduate students.

The researcher contributed to the design and administration of evaluation survey of young people's aspiration, interest and understanding of the construction industry during the Newcastle Construction Week in 2017. The intent of the construction week was to provide young people with insights into careers and training opportunities within the construction industry. The researcher also undertook part-time work with NUSTEM, a STEM Outreach group (www.nustem.uk) as a senior research assistant. Her role involved evaluating the impact of NUSTEM's intervention activities on primary school children within some of their partner schools in the North East of England and data analysis.

In 2018, the researcher co-authored a paper that was accepted for publication and presented at the IEEE Global Engineering Conference (EDUCON) in Spain. The paper was concerned with exploring the use of a gaming environment to generate interest, knowledge and understanding of careers and stereotypes within the games industry. During the conference, the researcher was a panel member at one of the roundtable session that was addressing gender gap and exploring trust and unconscious bias. A presentation was also given at the British Education Research Association (BERA) conference later in the year, which focused on exploring career stereotypes and aspirations. The researcher was a recipient of the postgraduate scholar bursaries for the conference.

Other activities engaged in that year included being a guest speaker at the International Women in Engineering day program that was held in Newcastle. This event was aimed at supporting young school girls who were at decision points in selecting their GCSE's courses or thinking about degree options, in considering engineering related careers and their pathways. Work was also undertaken on the Building Routes Into Degrees with Greater Equality (BRIDGE) project (www.bridgeresearch.net/). The role of the researcher was to audit the educational, marketing and promotional materials in six modules of the Chartered Surveyor Degree Apprenticeship program at Northumbria University's Faculty of Engineering and Environment. The audit focused on the inclusivity of the materials with respect to gender and ethnicity by challenging stereotypes and unconscious bias. Some of the outputs of this research included the co-development of two good practice guides, one on promoting diversity and inclusion in marketing and promotional and the other for educational resources.

In 2019, the researcher presented work on designing effective evaluations for the application of academic research to interventions, with young children at the UKES 2019 conference in London. An outcome of this presentation was a request to co-write an article the Evaluator Magazine which has been accepted for publication. A paper based on the integrated pedagogical learning theories framework for improving interest in computer science and games was presented and accepted for publication at the Frontiers in Education (FIE) 2019 conference.

Publications related to this thesis are listed below:

1. **Dele-Ajayi, O., Emembolu, I., Peers, M., Shimwell, J. and Strachan, R., (2018)** Exploring Digital Careers, Stereotypes and Diversity with Young People through Game Design and Implementation. In: *Global Engineering Education Conference (EDUCON), 2018 IEEE.* (pp. 712-719). IEEE.
2. **Emembolu, I., Strachan, R., Davenport, C., (2019).** Designing Effective Evaluations for Applying Scientific Academic Research to Career Based Interventions with Younger Children. *The Evaluator* (accepted).

3. **Emembolu, I., Strachan, R., Davenport, C., Dele-Ajayi, O., Shimwell, J., (2019).** Improving Diversity and Uptake of Computer Science among Young People: Through a Games Design Intervention based on an Integrated Pedagogical Framework, *IEEE Frontiers in Education Conference, October 2019*, Cincinnati, USA (accepted).

Feedback from interactions and conversations with the research community have been inputs into the development and advancement of this PhD study.

8.5 Conclusion

This study provides a framework through which STEM interventions, based on the research work of academics, can be effectively designed and implemented for young children. The study makes use of age appropriate tools suitable across different disciplines. It contributes to conversations on STEM learning, evaluation tools, learning theories, STEM career integration and research with young people. The research provides an approach academics can adopt for STEM outreach. The study provides evidence of practical applications of STEM interventions.

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APPENDICES

A1: Summary of REF 2014 impact case studies involving young people and STEM research (excluding the health sciences)

Case Study	Institution	Unit of Assessment	Age group/ Sample	Summary of Impact
Innovations in STEM Education – the potential of visual, kinaesthetic and empathetic learning for children and the wider community	Nottingham Trent University	Education	**500 children (aged 4-6 years)**	increased engagement with, and attainment in, science and technology of pupils of varied ages and social background. It uses a broad portfolio of innovative approaches, (from novel labs to science-art theatre collaborations and community-based archaeo-astronomy projects. allowed 500 children (aged 4-6 years) to grasp complex concepts about space and planets, through its multi-sensory and multi-textual form
Assessment tools and the impact on learners' 'understanding and use' of mathematics in schools, colleges and higher education	University of Manchester	Education	16-17 years	The research improved the design and distribution of educational tests and software, textbooks, teaching materials, qualifications, and associated guides and research briefings in mathematics education. The MaLT project test papers have achieved sales of 350,000, with 382 interactive software versions. Some 27,000 certifications have been awarded using the Free Standing Mathematics qualifications. Research has influenced courses designed to aid transition into STEM in higher education, especially 13 programmes in seven universities engaged in a HE STEM funded mathematical modelling project.
The National Space Centre (NSC)	University of Leicester	Physics	**8-14 years**	The National Space Centre (NSC), sited in the Abbey Meadows area of the City of Leicester, combines elements of museum and visitor attraction with an educational mission to attract 8-14 year olds to the Science, Technology, Engineering and Mathematics (STEM) subjects using the inspiration of space science and exploration. Since its opening on June 30th 2001, the NSC has welcomed almost 2.5 million visitors to its galleries and full-dome planetarium

Bringing Computer Science, Programming and Computational Thinking into the Classroom	Heriot-Watt University	Computer Science and Informatics	years 2 and 3 of senior school (ages 12 and 13). 2,566 school pupils in 14 Scottish	Robertson's research in learning via game-authoring demonstrated sustainable success in bringing programming into schools.As of June 2013, a total of 2,566 school pupils in 14 Scottish schools have taken lessons using Adventure Author, spending 40,325 hours with the software. This is supported by associated lesson plans which allow fully flexible delivery. The majority of this activity represents permanent adoption by schools beyond Robertson's MGIS project'; That is, impact was achieved initially as part of MGIS, but schools have now adopted the materials and software in their normal routine
Using fundamental physics to improve physics teaching and up-take at A-levels and at university	University of Sussex	Physics	**16,000 pupils (2367 from Primary)**	Outcomes include enhanced science teaching in schools, an increased interest of school children in science and scientists' work, and a greater ability of school children to understand and reflect on science, leading to better-informed study choices
Delivering Astronomy Research into the Classroom	Queen Mary, University of London	Physics	300 secondary school pupils	The Cassini Scientist for a Day competitions and our Media Space summer schools have raised aspirations and increased awareness and knowledge of astronomy, and have improved the scientific thinking and writing skills of over 300 school pupils from UK-wide and local secondary schools.
The National Schools' Observatory	Liverpool John Moores University	Physics	**ages 8 to 18**	The NSO is a web-based resource set up by LJMU to exploit the educational and engagement potential of the Liverpool Telescope (LT) [Source 2]. The target audiences are pupils in UK and Irish schools of ages 8 to 18 and their teachers, and since its launch in 2004 has reached more than 4,000 registered UK and Irish teachers, with 60,000 sets of observations requested by schools (growing from 2,700 requests in 2004/5, to around 1,500 per month in 2013) and around 1.5 - 2 million webpages served each year

Voicebox: Research on the physics and evolution of speech facilitating science teaching in secondary schools	University College London	Geography, Environmental Studies and Archaeology	Secondary School Age	develop *Voicebox: The Physics and Evolution of Speech*, a pre-GCSE science teaching resource, with a booklet, DVD and physical apparatus. The booklet and DVD were distributed to about 6,500 UK science teachers. A follow-up evaluation in London schools confirmed that the *Voicebox* is seen as a valuable extension activity that has the potential to interest and engage pupils, including those with a low general level of interest in science subjects
Combating antisocial behaviour and pupils raising aspirations	University of Greenwich	Psychology, Psychiatry and Neuroscience	120 French and UK adolescents	The impact through partnerships with a local authority and a charity involve use of an assessment toolkit called the Emotion, Behaviour, Aspiration Toolkit (eBAT) to address factors that limit the aspirations and social mobility of young people to address factors that limit youth aspirations and social mobility
Using Medieval Village Research to Improve the Skills and Aspirations of Secondary School Students and Disadvantaged Adults	University of Cambridge	Geography, Environmental Studies and Archaeology	aged 13-15 40 Secondary school pupils	The Higher Education Field Academy (HEFA) is a research-led initiative in which thousands of secondary school students (mostly aged 13-15) from groups with low levels of progression to university education acquire new transferrable skills and measurably raised levels of personal confidence and educational aspirations. These impacts are achieved through a tailored scheme of work which involves them in investigating the origins and development of English villages using archaeological methods
Developing the role of extended schools	Newcastle University	Education		. Professional practice changes include greater willingness to collaborate across agencies and an amendment to policy on `raising aspirations' to become `reaching aspirations'. Additionally our innovative research methodology, a version of theory of change, has been taken up and used by schools, LAs and other organisations
Delivering Astronomy Research into the Classroom	Queen Mary, University of London	Physics	300 school pupils from UK-wide and local secondary schools	The Cassini Scientist for a Day competitions and our Media Space summer schools have raised aspirations and increased awareness and knowledge of astronomy, and have improved the scientific thinking and writing skills

UOA09-03: Stimulating engagement in particle physics through music	University of Oxford	Physics	17,000 people have attended performances across seven countries, including over 8,000 at events for schools	This public outreach programme from Oxford links physics, particle accelerators and music through Einstein who was an enthusiastic violinist.: Letters and emails received from teachers who attended an event [D] have described immediate interest from students: "[my pupils] came out buzzing and I had to try and answer some quite complex questions in the bus on the way home", "... the students were discussing it all the way back to the school"
UOA09-04: Exploring live events from the LHC on a smartphone	University of Oxford	Physics	**10% were aged 18 or under; 45% 19-35, 20% 36-50 and 11% 51 over**	smartphone application, *LHSee*, has enabled members of the public to understand better one of the experiments at the Large Hadron Collider. The software has enabled users to understand and be engaged with the process of discovery at the LHC and has raised aspirations for further engagement with science and the study of physics. It has been downloaded over 60,000 times and has achieved excellent user reviews and awards.
The Urban Scholars Programme - a research-based educational intervention	Brunel University	Education	aged 12 to 16 years from 33 London schools in areas of high social deprivation	The Urban Scholars Programme (USP) entails an innovative and sustained intervention study to address the `wastage of talent' among inner-city teenagers and to support schools with the implementation of the UK's Widening Participation Policy (2000), aimed at encouraging students from poorer backgrounds to study at university, raising the attitudes, aspirations and engagement in learning of the pupils who attended the programme,
Communicating Research to the Public through YouTube	University of Nottingham	Physics		In collaboration with film-maker Brady Haran we have developed the YouTube channel *Sixty Symbols* to present topics related to research in physics to the wider public.discourse on science and engineering, and through educational use in schools.
Curriculum and Assessment in Science Education	King's College London	Education	K-12	emphasis on `how science works' in the English and Welsh science curriculum; the US Framework for K-12 science education published in 2012 with its new emphasis on scientific practices; and the framework being used as a basis for the OECD Assessment of Science by the Programme for International Student Achievement

				(PISA) which will be administered in 70 countries in 2015
Africa's girls: promoting equality and empowerment	University College London	Education	5,100 Nigerian girls	The three studies described here have helped to improve the lives and prospects of girls in six African countries. Thanks to the IOE researchers and their project partners, hundreds of Nigerian families have allowed their daughters to return to school. In Kenya, a tougher approach has been adopted towards teachers who sexually abuse girl pupils. In Ghana, police are encouraging more girls to report assaults. Mozambique is promoting school clubs where issues such as HIV/AIDS can be discussed. Girls' clubs have been set up in Tanzania, and in South Africa education officials have been prompted to look for more effective ways of managing teenage pregnancy
Zombie Institute for Theoretical Studies: effectively engaging young people with bioscience	University of Glasgow	Biological Sciences	young people aged 11-18.	*Zombie Institute for Theoretical Studies (ZITS)'? Using an innovative platform to target the delivery of complex biomedical science to young people, the `Zombie Science' comedy show has effectively engaged more than 26,000 young people and adults at more than 300 events, touring festivals and secondary schools around the UK*
Young people in care: the support that puts university within reach	University College London	Education	19-year-olds	IOE research, led by Professor Sonia Jackson, has resulted in improved educational opportunities for a particularly disadvantaged and under-recognised group of young people — those from the public care system. The study, *By Degrees*, triggered new legislation and support systems to help these young people get to university and complete their studies

Physics at Work	University of Cambridge	Physics	key stage 4 school students	An annual interactive 3-day exhibition, titled "Physics at Work". In 2012 the event attracted 31 non-selective state schools and 17 selective/independent schools, 23 of which had visited the exhibition 3 or more times previously- a testament to its success. Building on the enthusiasm that the students showed during their participation in the event, teachers noted an increase in the number opting to study A-level physics and stated that those previously with no interest left with a very positive image of the subject.
Improving Young Peoples' Engagement with Education	University of the West of England, Bristol	Education		Young peoples' educational participation and achievement across Bristol has been improved through changes in school governance processes and structures within the city, as informed by UWE's research evidence. Many local schools now work in partnership with or are sponsored by local Further Education (FE) and Higher Education (HE) institutions

(Source: REF 2014 Case studies)

B1: Sample in loco parentis consent form used in this study

nustem

Northumbria University

In Loco Parentis Form for Head Teachers of Schools

Research: Impact of the Material Scientist workshop (NUSTEM) on young people's subject and career knowledge and their aspirations

The above study had been fully explained to me and I have had the opportunity to ask questions	☐
Parents/guardians of each child participating in this study had been fully informed about the nature of the workshop/research by letter sent home to parents/guardians on [..../...../2017]	☐
Parents/guardians had been given a reasonable period of time their child from participating in the study. (2 weeks) to withdraw	☐
I am willing to act in loco parentis in regard to consenting children whose parents have not contacted me, into the study.	☐
I have been given a copy of this Consent Form.	☐

Name of School...

Name of Head Teacher...

Signed... Date...

Name of Researcher...

Signed... Date...

Researcher Contact Details:

- ***Itoro Emembolu***, Northumbria University, itoro.emembolu@northumbria.ac.uk 07716616965

Project Supervisors Contact Details:

- ***Prof. Rebecca Strachan***, Associate Dean for Business and Engagement, Faculty of Engineering and Environment, Northumbria University, rebecca.strachan@northumbria.ac.uk
- ***Dr. Carol Davenport***, Director of Think Physics, Northumbria University, carol.davenport@northumbria.ac.uk
- ***Dr Rodrigo Ledesma-Aguilar***, Senior Lecturer, Mathematics Physics & Electrical Engineering rodrigo.ledesma@northumbria.ac.uk

B2: Sample information sheet sent home to parents for a workshop

NUSTEM Research at [Name] Primary School

Information for parents and carers about the Digital Games Project

Who are NUSTEM?

NUSTEM is a group based at Northumbria University which aims to inspire children and young people, teachers and families in science, technology, engineering and maths (often called STEM). We encourage people to play with science, investigate, make discoveries and share delights.

Now in its fourth year, there are 30 primary and secondary schools in the North East working with NUSTEM; Carville Primary School is one of our project partners.

What is the Digital Games Project?

NUSTEM are working with Carville Primary School to pilot a Digital Games Project. During the project children at Carville will be involved in 5 computer games design session led by experts from Northumbria University. We think that by showcasing careers in digital games we can raise the understanding and aspirations of children at Carville Primary School. This is an exciting project that, if successful, will be used to support children in schools across the North East.

What research are NUSTEM doing?

NUSTEM thinks it is important to do our project the right way. We want to make sure that our initiatives are having a positive impact on the children taking part in them. We also think that the lessons we can learn from pilot projects, such as this, can be passed on and benefit children in other schools in the North East and beyond.

We will be collecting data from children at Carville Primary School to find out what they the know about STEM careers and what jobs they would like to do in the future. We hope that through the course of the project children will develop a greater understanding of the STEM careers available to them when they are older.

What will happen to participants?

Data will be collected from children on two occasions to help us work out what impact the project is having. We will collect data before the project starts and towards the end of the workshops. There will also be activity sheets the children will use to design their own games. We will be collecting the following information through surveys:

- Your child's name and surname - this information will used to assign usernames and passwords to enable the children work on their designed game in school and at home. The information will be anonymised so that no one can tell it is from your child and destroyed once the data has been inputted. No child will be named in any reports from this project.

- Your child's gender - we are interested to know whether girls and boys see careers in games design differently and how they would design a game.
- Your child's year group - we are interested to see whether children's perceptions of careers change with age.
- Information about what your child would like to be when they are older and their current knowledge of STEM careers.

Does my child have to take part?

The Digital Games Project will take place in school as part of normal lessons. You can decide to opt out of our research activities, by asking us not to collect and keep data from your child. If you would like to opt-out, please complete the consent slip below.

No one will be annoyed if you don't want to take part. You can always agree now and change your mind later. It is up to you. If you'd like more information please contact joe.shimwell@northumbria.ac.uk.

NUSTEM Consent slip

If you **DO NOT** want your child/children to be involved in this research, please sign this form and return it to the school office.

Child's name: ______________________________

Child's class: ______________________________

Parent/guardian signature: ______________________________

Parent/guardian name: ______________________________

C1: Pre-questionnaire for the digital games workshop

1. Game Identifier/username……………………………………………………………………

2. Name of School……………………………………………………………………………

3. Are you a girl or a boy? (Please circle it below)

A) Girl B) Boy

4. What year are you in? (Please circle it below)

A) Year 4 B) Year 5 C) Year 6

5. What would you like to be when you grow up? ……………………………………………

6. Do you think you would actually do that when you grow up or would you do something else?

A) Yes B) No (Please circle your answer)

7. What do you think you would actually be when you grow up? ……………………………

8. Do you play online games regularly? (Please circle it below)

A) Yes B) No

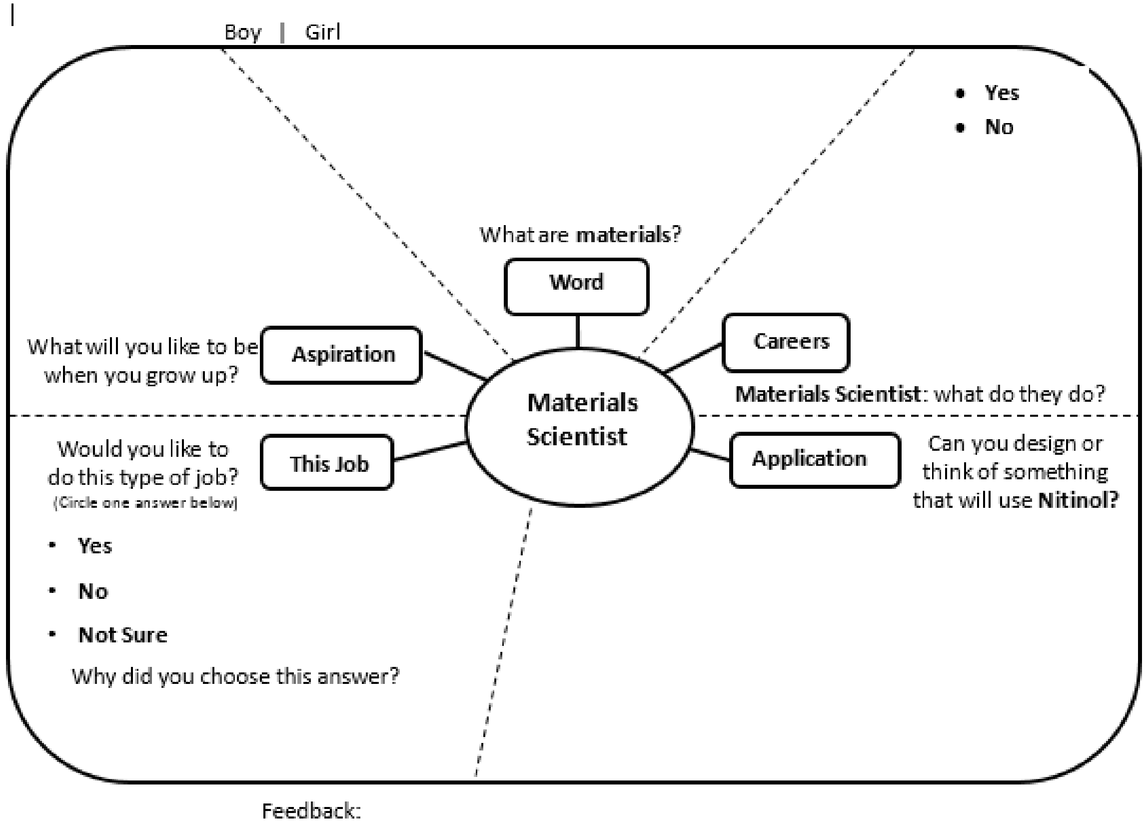
9. If yes, how often do you play computer games? ……………………………………………

10. If someone was to work in the games design industry, what kind of jobs might they have? Can you explain what they do in those jobs?

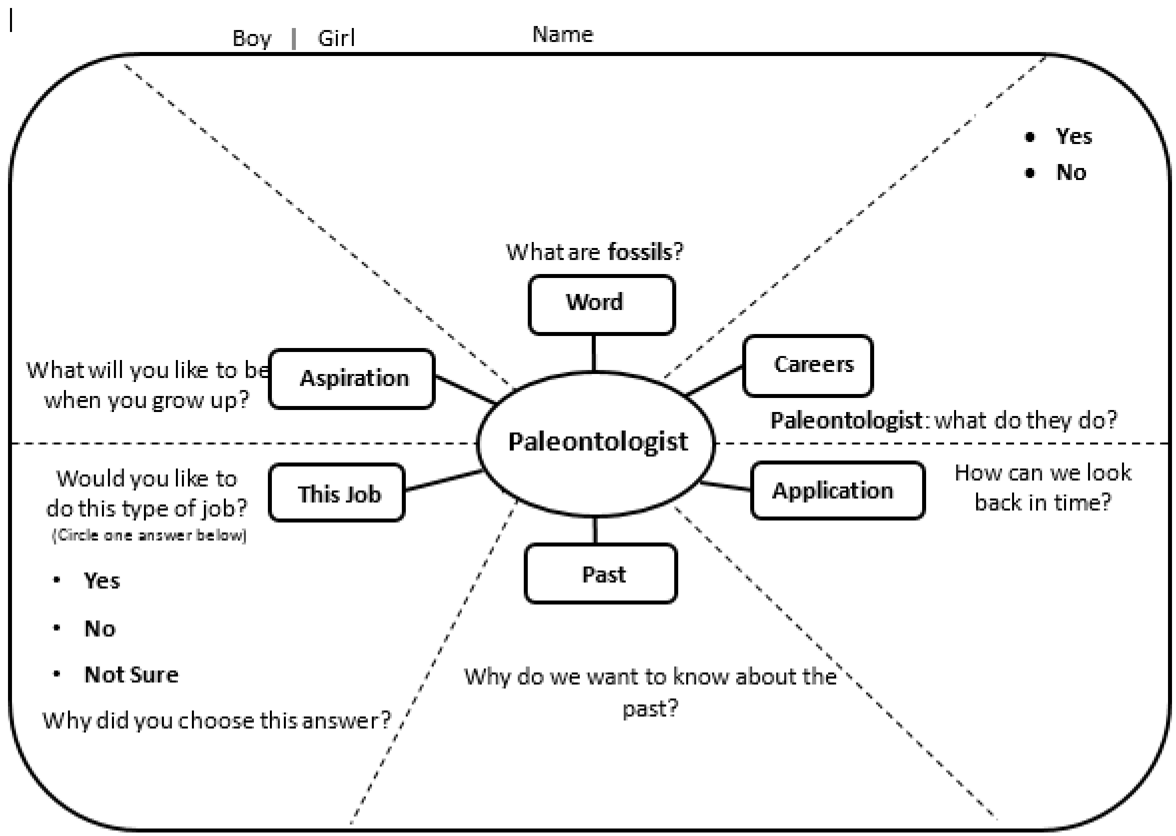
(List as many as you can think of)

Type of Job	**Description (What do they do in this type of Job?)**
1)	
2)	
3)	
4)	
5)	
6)	
7)	
8)	
9)	
10)	

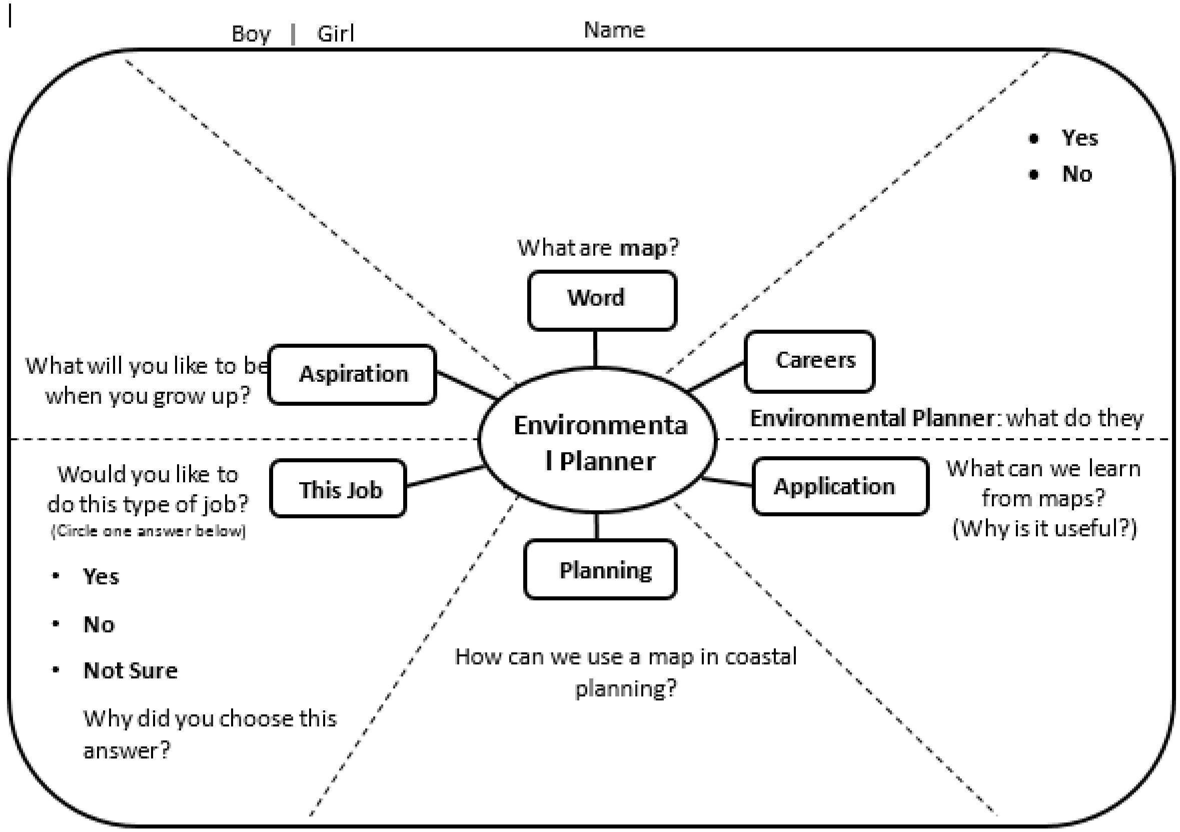
C2: Knowledge map sheet for materials science



C3: Knowledge map sheet for paleontology



C4: Knowledge map sheet for environmental planning



D1: Children's responses to what are fossils (pilot study)

What are Fossils?	Freq	Percent
No response	1	3.7
A type of bone	1	3.7
A whole big thing, what people can find	1	3.7
Fossils are a type of animal	1	3.7
Fossils are bodies of all sorts of creatures including plants. They could be remains of a body; bones	1	3.7
Fossils are bolls	1	3.7
Fossils are bones	1	3.7
Fossils are bones and ancient animals	1	3.7
Fossils are bones from the past	1	3.7
Fossils are fossils	1	3.7
Fossils are rocks	1	3.7
Fossils are shapes, rocks	1	3.7
Fossils are types of bones	1	3.7
Prehistoric bones from prehistoric animals	2	7.4
Prehistoric shapes of bones	1	3.7
Remains of animals from the past	1	3.7
Remains of animals, bones	1	3.7
Shapes, rocks	1	3.7
They are a type of bone that come from the past, not human but animals	1	3.7
They are bones	1	3.7
They are remains of things and patterns of animals	1	3.7
They are the bodies of animals and plants from prehistoric times	1	3.7
Things from the past	2	7.4
Things that have hardened up through time etc plants, animals	1	3.7
Things, people or animal bones	1	3.7
Total	27	100.0

D2: Children's responses to how can we look by in time (pilot study)

How can we look back in Time?	Freq.	%
No response	7	25.9
By digging and finding fossils	1	3.7
By microscope and fossils	1	3.7
By using types of fossils	1	3.7
Dinosaur bones and more	1	3.7
Fossils	1	3.7
Look under the microscope for grains of coral	1	3.7
Microscope	4	14.8
Research images	1	3.7
Study of dinosaur fossils and more	1	3.7
Study of dinosaur fossils and others	1	3.7
They look back in time because of the fossils they find	1	3.7
Through a microscope to identify things	1	3.7
Through fossils in the ground	1	3.7
Use a time machine to study fossils	1	3.7
Use images	1	3.7
Use stuff	1	3.7
With fossils	1	3.7
Total	27	100.0

D3: Children's responses to why do we want to know about the past (pilot study)

Why do we want to know about the past?	Freq.	%
No response	7	25.9
Because it is interesting to learn about	1	3.7
Because they are okay	1	3.7
For information	1	3.7
For the environment and foor information	1	3.7
I think it is a great thing to do	1	3.7
It is interesting to learn about	1	3.7
So we can find more fossils	1	3.7
So we can learn about it	1	3.7
So we know that things exist	1	3.7
They want to know about the past because they need to know about what happened	1	3.7
To find out how much oxygen there was and experiment	1	3.7
To find out how much oxygen there was, experiment on it and to also find out what will happen in the future	1	3.7
To learn about the past	1	3.7
To save the world by getting fruit and money off trees	2	7.4
To see what happened back at the time of 30 million and 50 million years	1	3.7
To see what the past was like	1	3.7
To see what the world used to be	1	3.7
To see what the world was like in the past	1	3.7
We could find out how much oxygen there was in the past	1	3.7
Total	27	100.0

D4: Children's responses to what is a map (pilot study)

What is a map?	Freq	Percent
a bit of paper that shows you where things are	1	4.5
a map	1	4.5
a map is a piece of paper that has locations in it to show you where to go	1	4.5
a map is a plaque that tells you where a location is	1	4.5
a map shows land on a sheet of paper and where things are in the world	1	4.5
a piece of paper with directions of where you want to go to	1	4.5
a thing people use if they are lost or if they need to go somewhere	1	4.5
a thing that helps you get to places that you don't know where they are	1	4.5
a thing to show you where you are and where places are	1	4.5
an object which shows you places	1	4.5
helps you find your way around	1	4.5
it is just a map	1	4.5
it shows you where stuff or places are	1	4.5
map of the world	1	4.5
shows where things are	1	4.5
something that can tell you where to go so if you are lost, you know the new way	1	4.5
something that helps you get around	1	4.5
something that helps you locate multiple objects	1	4.5
something that helps you find somewhere	1	4.5
tells you where places are	1	4.5
tells you where you need to go	1	4.5
tells you where you need to go and helps you find places	1	4.5
Total	**22**	**100.0**

D5: Children's responses to what can we learn from maps (pilot study)

What can we learn from maps?	Freq	Percent
No response	1	4.5
because they tell you where to go	1	4.5
house, school	1	4.5
some maps show you difference and they change over the years	1	4.5
that places are different over time	1	4.5
that things change over time	3	9.1
they are useful because they can show where things are and they can change throughout the year	1	4.5
they are useful when lost to help find way home	1	4.5
they can change throughout the years and new places can be added in	1	4.5
to see how places have changed over the years	1	4.5
we can learn how our land area was years before now	1	4.5
we can learn where places are. They are used to find places	1	4.5
we can learn whereabouts the place you need to be is	1	4.5
what used to be here and what is here now	1	4.5
where things are and how things have changed	1	4.5
you can find different places	1	4.5
you can find where you live if you get stuck	1	4.5
you can learn about the old buildings and how they have changed over the years	2	4.5
you can learn where the old places were back in the 1800s and can compare them to their new map	1	4.5
Total	22	100.0

D6: Children's responses to what can environmental planners learn from maps of coastlines (pilot study)

What can environmental planners learn from maps of coastlines	Freq	Percent
no response	5	22.7
don't know	1	4.5
so that the sea does not fill the sea beach	1	4.5
that they cannot build their stuff	1	4.5
they can learn how the coastliones are used now and can change it to benefit nature	1	4.5
they might rise or lower	1	4.5
to see how big the coast is	1	4.5
to see how large it is	1	4.5
to see how much land there is on the beach	1	4.5
to see what can go where on the beaches	1	4.5
to see where the sea is and which colour that is different to the coastline	1	4.5
to show how big the place is	1	4.5
to show where he/she is and to show how it changed	1	4.5
where the coastline is	1	4.5
where the land meets the sea and how tsunamis are created and when they might happen	1	4.5
whereabouts the land meets, changes position over the years	1	4.5
you can get higher or lower water levels	1	4.5
you could learn that they could change over time	1	4.5
Total	22	100.0

D7: Children's responses to what is a prediction (pilot study)

What is a Prediction?	Frequency	Percent
an opinion	2	7.4
a clever guess based on what you know	1	3.7
a guess on what is going to happen	1	3.7
a guess or estimate	1	3.7
a guess that could be possible	1	3.7
a guess you make and base it on something you already know	1	3.7
a guess you think will happen or what you will do	1	3.7
a thing you think will happen	1	3.7
an opinion or an estimate	1	3.7
an opinion, a thought or guess of what's going to happen	1	3.7
imagining what happens in the future	1	3.7
it is a guess	1	3.7
it is what you think is going to happen in the future or right now	1	3.7
something you imagine about what will happen next	1	3.7
what is going to happen at the end of a story	1	3.7
what you think and a guess	1	3.7
when you guess or think what will happen next	1	3.7
when you guess something	1	3.7
when you guess what happens next	1	3.7
when you guess what is going to happen and an estimate	1	3.7
when you have a good guess and think about what will happen	1	3.7
when you have an opinion on something	1	3.7
when you make a guess and try to guess what it is	1	3.7
when you predict what is going to happen	1	3.7
when you talk about something or someone	1	3.7
where you share your own ideas and predict what has happened	1	3.7
Total	27	100.0

E1: Findings from the engagement factors in the games design (phase 1)

Engagement Factors	Findings
Visual Appeal	• 14% (n=3) did not like the look of the games they evaluated • 45.4% (n=10) of children liked the look of the game they evaluated of which 30% (n=3) where female, 60% male (n=6) and 10% (1) couldn't identify the gender from data collected • 27% (n=6) were neutral regarding visual appeal when evaluating each other's games • There was no response from 14% (n=3) of the respondents • There was not enough evidence from this dataset to suggest an association between Gender and visual appeal of a game (p= .694, Fisher's Exact Test)
Theme	• 14% (n=3) did not like the story or type of the games they evaluated • 55% (n=12) of children liked the story or type of the games they evaluated of which 32% (n=4) where female, 58% male (n=7) and 8% (1) couldn't identify the gender from data collected • 18% (n=4) were neutral regarding the theme when evaluating each other's games • There was no response from 14% (n=3) of the respondents • There was not enough evidence from this dataset to suggest an association between Gender and the theme of the game (p= .655, Fisher's Exact Test)
Clarity of Goal	• 14% (n=3) were confused on what they needed to do in the games they evaluated • 46% (n=10) of children felt the goal(s) of the game they evaluated was clear of which 40% (n=4) where female, 50% male (n=5) and 10% (1) couldn't identify the gender from data collected • 23% (n=5) were neutral regarding how clear the goal of the game they were evaluating • There was no response from 18% (n=4) of the respondents • There was not enough evidence from this dataset to suggest an association between Gender and clarity of goal of the game (p= .768, Fisher's Exact Test)
Challenge	• 36% (n=8) did not find challenging the games they evaluated • 23% (n=5) of children found challenging the games they evaluated of which 20% (n=1) where female, 80% male (n=4) • 18 % (n=4) were neutral regarding how challenging they found the game they were evaluating • There was no response from 18% (n=4) of the respondents • There was not enough evidence from this dataset to suggest an association between Gender and how challenging the game (p=0.875, Fisher's Exact Test)

Reward	• 55% (n=12) did not feel they got rewards as they progressed in the game they evaluated; of which 42% (n=5) where female, 50% male (n=6) and 8% (n=1) couldn't identify the gender from data collected • 27% (n=6) of children felt they got much rewards from the games they evaluated of which 17% (n=1) where female, 66% male (n=4) and 17% (n=1) couldn't identify the gender from data collected • 5% (n=1) were neutral regarding how much rewards they got from the game they were evaluating • There was no response from 14% (n=3) of the respondents • There was not enough evidence from this dataset to suggest an association between Gender and rewards gotten from games (p= .820, Fisher's Exact Test)
Feedback	• 32% (n=7) did not feel they got feedback from the game they evaluated; of which 57% (n=4) where female, 29% male (n=2) and 14% (n=1) couldn't identify the gender from data collected • 32% (n=7) of children felt they got much feedback from the games they evaluated of which none (n=0) where female, 86% male (n=6) and 14% (n=1) couldn't identify the gender from data collected • 23% (n=5) were neutral regarding how much feedback they got from the game they were evaluating • There was no response from 14% (n=3) of the respondents • There was evidence from this dataset to suggest an association between Gender and feedback gotten from games (p= .027, Fisher's Exact Test)
Creativity	• 23% (n=5) did not feel they got rewards as they progressed in the game they evaluated; of which 40% (n=2) where female and 60% male (n=3) • 36% (n=8) of children felt the games they evaluated enabled their creativity of which 25% (n=2) where female, 63% male (n=5) and 12% (n=1) couldn't identify the gender from data collected • 14% (n=3) were neutral regarding how much the games enabled creativity from the game they were evaluating • There was no response from 27% (n=6) of the respondents • There was not enough evidence from this dataset to suggest an association between Gender and creativity in the games (p= .850, Fisher's Exact Test)

E2: Children's aspirations in the materials science pre- and post-workshop (phase 1)

STEM aspirations are highlighted in bold while the aspirations with an asterix shows the aspirations that are the same pre- and post-workshop

Aspiration (PRE-workshop)	Pre Workshop		Post Workshop		Aspiration (POST-workshop)
	Male (freq)	Female (freq)	Male (freq)	Female (freq)	
Footballer*	8	0	7	0	Footballer*
Teacher*	1	5	1	6	Teacher*
Vet*	0	4	1	5	**Vet***
Architect*	1	1	0	1	**Architect***
Dancer	0	2			
Game designer	2	0	3	1	**app designer**
Graphic designer*	2	0	2	0	**Graphic designer***
Author	0	1			
Car designer	1	0			
Carer	0	1	0	2	work with children
Chef	1	0	0	1	
Computing	1	0	0	1	**gamer**
Electrician	1	0			
Engineer	1	0	2	0	**Chemical/mechanical engineer**
Gymnast	0	1			
Head teacher	0	1			
Magician*	1	0	1	0	Magician*
Mechanic	1	0			
Midwife	0	1			
Military	1	0			
Navy officer*	1	0	1	0	Navy officer*
Runner*	1	0	1	0	Runner*
Olympic swimmer*	0	1	0	1	Olympic swimmer*
Olympic triathlete*	1	0	1	0	Olympic triathlete*
Paramedic	0	1			
Police officer*	1	0	1	0	Police officer*
Olympic sprinter	0	1			
Scientist	0	1			
Swimmer	1	0			
Teaching assistant*	1	0	1	0	Teaching assistant*
Work with animation*	0	1	0	1	**Animator on youtube***
Work with bones	0	1	0	1	**Archaeologist**
Zoologist*	0	1	0	1	**Zoologist***

Don’t know/ not sure	0	1	1	2	Don’t know/ not sure
Total	29	24			
			0	1	Attostry
			0	1	Beach artist
			0	1	**Coder**
			1	0	Comedian
			1	0	F1 driver
			1	0	**Pilot**
			1	0	Photographer
			1	0	Sports kit designer
			28	26	total

E3: Gender distribution in objects identified in materials science workshop (phase 1)

Objects Identified from surroundings	Total (freq)	Male (freq)	Female (freq)
window	33	19	14
door	26	16	10
table/desk	23	12	11
Water bottle	15	7	8
chair/stool	14	8	6
books	14	3	11
Pencil	10	3	7
White board	10	2	8
cupboard/ lockers	9	6	3
Coat/ Jumper	7	4	3
glasses	4	0	4
Lego	3	2	1
fan	3	3	0
headband	3	1	2
clock	3	3	0
Wall/Pillars	3	2	1
Pen	2	2	0
paper	2	2	0
sharpener	1	0	1
car	1	0	1
computer	1	1	0
ruler	1	1	0
buttons	1	1	0
gate	1	0	1
humans	1	1	0
toys	1	1	0

E4: Properties of materials identified by the children in materials science workshop (phase 1)

Object	The Material(s) the Object is made from	Properties of materials (Freq.)										
		secure	cheap	strength	comfort	transparency	flexibility	hardness	waterproof	light	fire resistant	rut resistant
Chair	Metal, plastic, wood	8	3	5	6		1			1		
Glasses	glass, plastic, sand		1			1						
Fan	metal, plastic		1	1								
Gate				1								
Humans	skin, bones, organs						1					
Window	glass, metal, plastic, sand	2		1		11						
Sharpener	metal							1				
Pen	plastic, ink				1							
Car	metal, rubber, leather	1			1							
Headband	plastic	1					1					
Laptop/computer / accessories	plastic, glass, metal											
Pillar/wall	brick			1								
Water bottle	plastic, metal, silicone	5		4		2		2	2	3		
Lego	plastic		1				2					
Door	metal, glass wood,	7		17		15		5		2	1	
Cupboard	metal, wood	3	1	7				2				
Button	plastic, string	1					1					
Book	paper, card, plastic, glue, ink, leather, cardboard, wood	4		1	5					6		
Clock	glass, plastic		1			2						
Table	metal, plastic, wood	13	3	11	3			1	1			1
Coat/jumper	cotton, wool, denim, fabric				3		3					
Whiteboard	metal, plastic, paper, wood,	8		2								
Pencil	graphite, wood, metal, rubber, leather	2		2								

E5: Children's suggested use of smart material Nitinol (phase 1)

Can you think up a use for Nitinol?	**Freq**	**%**
Car	13	24.7
Side windows of cars	1	1.9
Wine	1	1.9
A barbeque, if the grill was made of nitinol and it snapped, put it in hot water to recycle it, you can then have a paper clip	1	1.9
A coat hanger	5	9.5
A toy for a child	9	17.1
Barbed wire springs (wires that bend out of shape)	6	11.4
Beep boop the robot	1	1.9
Bike	1	1.9
Part of a circuit,	1	1.9
Can	3	5.7
Paper clips	9	17.1
Spoon	2	3.8
If jewelry snaps, put in hot water to make it come back (necklace, bracelets - if you bend it by accident, it will go back)	14	26.6
Hairclips (use to make hair clips so that it goes bendy)	3	5.7
Cups	2	3.8
Fan	1	1.9
Key (keys bend or breaks,)	7	13.3
Knives	2	3.8
Spanner, screwdriver	2	3.8
Machete, sword	1	1.9
Egg sorts	1	1.9
Bike	1	1.9
Medicine, you put it in an open wound and warm it up and it could stop the bleeding as long as they don't get poisoned by the materials it is made from	2	3.8
Metal part of a pencil	1	1.9
Photo frame	3	5.7
Self-tying waterproof watch, each should have unique sets of instructions so no one but you can set it back if stolen	1	1.9
Switch	1	1.9
To channel electricity into objects e.g. A lightbulb	1	1.9
Magic tricks	2	3.8
Turn rubbish into something useful	1	1.9

E6: Feedback on the materials science workshop (phase 1)

E7: Children's pre-workshop aspirations combined across the different workshops (phase 2)

E8: Children's post-workshop aspirations combined across the different workshops (phase 2)

E9: Children's pre- and post-workshop aspirations in the games design workshop (phase 2)

E10: Children's perception of the games designer career (phase 2)

What do you think a games designer does?							
Description	Pre- workshop			**Description**	Post- workshop		
	Gender				Gender		
	Male	Female	**Total**		Male	Female	**Total**
No response	0	1	1	No response	0	1	1
a games designer is where you create a game like the recent ones and other games	0	1	1	a games designer does a lot of stealing	1	0	1
a person who helps with development and engines of the game	1	0	1	creates games for all	0	1	1
attract kids	1	0	1	design games	3	5	8
creates and designs games	2	0	2	designs backgrounds, people and speech	1	0	1
design, code, build and work together	1	0	1	designs games, does textures and makes the look better	1	0	1
designs games	3	7	10	make and designs games	5	1	6
I think a games designer does a lot of stealing from a movie or a book	1	0	1	**Total**	**11**	**8**	**19**
makes a game, designs, then develops it	3	2	5				
Total	**12**	**11**	**23**				

E11: Feedback on the games design workshop (phase 2)

Feedback post workshop			
Description	Gender		Total
	Male	Female	
No response	4	2	6
I don't know	0	1	1
I liked everything but not the chairs	0	1	1
I liked free find	1	0	1
I liked making the robot play the instrument	0	1	1
I liked when we were creating the actual game	1	0	1
I loved making all of those things like origami, the houses, robots	1	0	1
I really liked when we designed it	0	1	1
it was great deleting, the stuff was annoying	0	1	1
loved everything	1	0	1
make the game already have a flat background	0	1	1
really good but I did not want to do it	1	0	1
the programming was complex	1	0	1
yes, everything	1	0	1
total	11	8	19

E12: Children's pre-workshop perception of the materials scientist career (phase 2)

Perception of the material scientist career	Freq.	%
no response	10	17.2
make materials	6	10.2
they make materials	3	5.2
look at materials	7	11.7
make stuff	2	3.4
a scientist that discovers materials	1	1.7
design materials	1	1.7
do portions	1	1.7
do things with materials	1	1.7
experiment materials	1	1.7
experiment on materials	1	1.7
find different materials	1	1.7
I think portions	1	1.7
look inside of materials	1	1.7
make and test materials	1	1.7
make materials and build	1	1.7
make materials into stuff	1	1.7
make metal	1	1.7
make new materials	1	1.7
make report	1	1.7
make stuff with materials	1	1.7
makes new materials	1	1.7
makes something	1	1.7
makes things out of different materials	1	1.7
material stuff	1	1.7
person who thinks of materials	1	1.7
test materials	1	1.7
they build materials	1	1.7
they discover materials	1	1.7
they do experiments	1	1.7
they do make things	1	1.7
they feel and investigate	1	1.7
they look at materials to see if they are safe to wear	1	1.7
they make it	1	1.7
they move stuff out of materials	1	1.7
Total	58	100.0

E13: Children's post-workshop perception of the materials scientist career (phase 2)

Perception of the material scientist career	Freq.	%
no response	9	15.5
discover different materials	1	1.7
discover materials	2	3.4
do they test materials?	1	1.7
estimated materials and building things	1	1.7
experiment material	3	5.2
experiments	1	1.7
explore materials	2	3.4
I don't know	3	5.2
I think a material scientist experiments on materials	1	1.7
I think a material scientist tests materials	1	1.7
look at materials	1	1.7
make materials	3	5.2
make new materials	1	1.7
make something	1	1.7
make stuff	1	1.7
measuring materials	1	1.7
mixes portions	1	1.7
see what materials about stuff	1	1.7
study materials	1	1.7
test things if they work	1	1.7
test materials	10	17.2
test materials and look into the materials	1	1.7
test materials to make things out of	1	1.7
testing and measuring different	1	1.7
testing materials	3	5.2
testing out materials	1	1.7
they check materials that are safe	1	1.7
they make materials	1	1.7
use materials and do experiments	1	1.7
work on materials	1	1.7
Total	58	100.0

E14: Children's pre-workshop perception of the paleontologist career (phase 2)

Perception of the paleontologist career	Freq.	%
I don't know	17	25.5
no response	9	13.8
fossils	2	3.1
look at rocks from the caves	2	3.1
study fossils	2	3.1
they study fossils	2	3.1
a dinosaur bone	1	1.5
a paleontologist is a scientist	1	1.5
a really good scientist	1	1.5
does all different jobs	1	1.5
find fossils	1	1.5
I think they do research with flowers	1	1.5
I think they look at fossils	1	1.5
I think they might search for fossils	1	1.5
I think they work on fossils and investigate which type	1	1.5
like fossils	1	1.5
living things	1	1.5
look about people	1	1.5
look at dinosaurs I think? Bones/fossils	1	1.5
look at fossils	1	1.5
look at old dinosaurs bones	1	1.5
metal	1	1.5
no	1	1.5
paint things	1	1.5
planet scientist	1	1.5
science	1	1.5
science stuff	1	1.5
scientist	1	1.5
search for fossils	2	3
searching about rocks	1	1.5
study bodies	1	1.5
study bones	1	1.5
they find fossils and discover them	2	3
they look at fossils	1	1.5
works on ores	1	1.5
Total	65	100.0

E15: Children's post-workshop perception of the paleontologist career (phase 2)

Perception of the paleontologist career	Freq.	%
no response/ I don't know	8	12.8
they study fossils	4	6.3
find fossils	3	4.8
they look at fossils	3	4.8
they search for fossils	6	12.8
look at fossils	2	3.2
paleontologists look at fossils	2	3.2
a person that digs fossils	1	1.6
a stiest	1	1.6
analyse fossils	1	1.6
discover DNA	1	1.6
do they dig up fossils from years ago	1	1.6
does it mean someone that studies fossils	1	1.6
explorers	1	1.6
find out about things that were in the past for the present	1	1.6
I think it is a fossil looked at	1	1.6
I think they find fossils	1	1.6
look at fossils and look in the past	1	1.6
look in time, look at fossils and sometimes bones	1	1.6
paleontologist examine fossils and dig up the remains of animals to explore	1	1.6
paleontologists have a look at fossils and find out what it was back at the timesof the dinosaurs	1	1.6
paleontologists search fossils	1	1.6
paleontologists work on stones	1	1.6
people who study and find information about fossils	1	1.6
science stuff and look at fossils and rocks, looks in the past	1	1.6
search about the past and what happened there	1	1.6
search for fossils and rocks	1	1.6
search for fossils/plants from a long time ago	1	1.6
they dig for fossils	1	1.6
they do that with fossils	1	1.6
they find and learn about fossils	1	1.6
they find fossils	1	1.6
they find fossils and bones	1	1.6
they find fossils from 65 million years	1	1.6
they investigate fossils	1	1.6

they look at fossils and look at how old they are	1	1.6
they look at fossils and look into the future, past	1	1.6
they look for fossils	1	1.6
they look in the past	1	1.6
they research bones and fossil	1	1.6
they search for fossils and look for them	1	1.6
you look at fossils	1	1.6
Total	63	100.0

E16: Children's pre-workshop perception of the environmental modeller career (phase 2)

Perception of the environmental modeller career	Freq.	%
No response	15	24.0
makes models for/in the environment/ designs a model	10	16.0
not sure/ no idea	3	4.8
cant remember		
a person that invented the environment and modelled the bins	1	1.6
a person that is really good in science or good in something else	1	1.6
a person who models and crafts	5	8.0
car engine	1	1.6
draw or makes things/something in the environment/ design for the environment/build stuff	5	8.0
help the environment/involve the environment	2	3.2
I think they look after wildlife	1	1.6
I think they teach children and carry out experiments	1	1.6
it makes plants grow in the garden/ stuff we plant	2	3.2
make better ways/ make environment better/ specialized in the environment	2	3.2
makes model of nature	1	1.6
new stuff/ try new things	1	1.6
person who works with computers	1	1.6
protects the environment/ protect nature/ protects animals	4	6.4
put in new things to help the environment and take out old things	1	1.6
they clear the environment/ they help keep the environment clean	2	3.2
they make clothes and they try them on	1	1.6
they predict the future	1	1.6
do prediction or a model about a climate/ weather		
they walk down the runway, they make things for the environment	1	1.6
makes machines for the world		
when you find something and fix it	1	1.6
Total	63	100.0

E17: Children's post-workshop perception of the environmental modeller career (phase 2)

Perception of the environmental modeller career	Freq.	%
no response	13	22.0
don't know	7	11.9
predicts the future	2	3.4
they predict the future	2	3.4
a person who designs a model	1	1.7
a person who has specialized in the environment	1	1.7
a person who makes a model of an environmental thing	1	1.7
a person who models the environment	1	1.7
Cannot really remember	2	3.4
do prediction or a model about a climate	1	1.7
do they show you what you have to do to protect the environment?	1	1.7
guess for the future	1	1.7
helps the environment	1	1.7
I think they do building stuff	1	1.7
I think they make models to help the environment become a better place	1	1.7
is it like when you make something to do with the environment	1	1.7
it is a model that tests stuff	1	1.7
it is a model where people test stuff on a model to see if it works or not	1	1.7
it is where they build different models	1	1.7
like he helps the environment	1	1.7
look after the environment and model the environment	1	1.7
make the environment better or make and model things	1	1.7
makes machines for the world	1	1.7
model the environment	2	3.4
predict the future by models	2	3.4
predicts	1	1.7
protects animals	1	1.7
someone who designs objects	1	1.7
test different stuff/thing	1	1.7
they do stuff for the environment and build stuff	1	1.7
they make stuff	1	1.7
they model the environment	1	1.7
they predict the climate	1	1.7
they predict weather in the future	1	1.7
they try new things	1	1.7
weather, models	1	1.7
Total	59	100.0

E18: Children's pre-workshop perception of the environmental planner career (phase 2)

Perception of the environmental planner career	Freq.	%
I don't know	10	16.4
plan the environment	2	3.3
a job that helps the environment stay clean	1	1.6
a nature job and litter	1	1.6
a plan for the environment	1	1.6
an environmental planner protects the environment	1	1.6
do they help keep the environment clean and heathy	1	1.6
eco war helping the earth	1	1.6
environmental planners plan out environments for building sites	1	1.6
global warming	1	1.6
growing up at graft	1	1.6
help the environment	1	1.6
helps plan some litter picks etc	1	1.6
helps the animals, uses a map	1	1.6
helps the environment	1	1.6
I don't know or maybe to stop pollution	1	1.6
I think environmental planner means like to plants environment	1	1.6
I think it can help people who are new to uni	1	1.6
I think it is like a job to care about the environment	1	1.6
I think they change the environment to make it better	1	1.6
I think they look after the environment	1	1.6
I think they plan buildings	1	1.6
I think they work with plants and animals	1	1.6
I think they would plan how to increase the environments safety	1	1.6
it is to help keep the environment clean and tidy	1	1.6
keeping the world a better place	1	1.6
like a eco warrior	1	1.6
litter picking, building buildings	1	1.6
not sure	1	1.6
plan studd out. Environment	1	1.6
plan stuff	1	1.6
plan to help the environment	1	1.6
plans how they will help the environment	1	1.6

plans that have something to do with the environment	1	1.6
plans the environment	1	1.6
plans what to do to help the environment	1	1.6
robot planner/book	1	1.6
save environment	1	1.6
someone who plans and helps the environment for the future	1	1.6
the world, helping it a better and safer place	1	1.6
they have a plan to change the environment to make it more tidy	1	1.6
they help keep the environment clean and healthy	1	1.6
they might find people in the environment and those people might try to save the environment and stop extinction	1	1.6
they might help the environment using it in a positive way	1	1.6
they plan what the environment will do	1	1.6
they stop people ruining the environment and create things wth increase money and minimise environmental loss	1	1.6
think of things that might make the environment better. Plan litter picks etc	1	1.6
to plan about the environmnet	1	1.6
to plan how to increase the safety of the environment	1	1.6
trying to help the environment	1	1.6
when you have an idea for changing the environment everyone helps	1	1.6
Total	61	100.0

E19: Children's post-workshop perception of the environmental planner career (phase 2)

Perception of the environmental planner career	Freq.	%
No response	3	5.8
I don't know	3	5.8
not sure	3	5.8
plan the environment	3	5.8
old maps, new maps	2	3.8
a map	1	1.9
an environmental planner decises where they think the coastline mark should be	1	1.9
an environmental planner plan what space is free to build and maps	1	1.9
decide if they are going to keep a piece of environment	1	1.9
don't know	1	1.9
get use t reading a new map or old maps	1	1.9
I think they work with nature and maps	1	1.9
it has like maps, routes on	1	1.9
it helps you plan where you are going to get rif of land	1	1.9
it is environmental	1	1.9
it plans to help the environment	1	1.9
it plans what the world will happen	1	1.9
it plans what to do	1	1.9
it's a map	1	1.9
not sure, maps	1	1.9
plan different things for the coast and beach	1	1.9
plan the future	1	1.9
plans about the environment	1	1.9
plans how the landscape can change the coastline over the years	1	1.9
plans what happens to the environment	1	1.9
plans what to do to help the environment	1	1.9
plans where to build things	1	1.9
plans where to build things without damaging the environment	1	1.9
predict the future and help the world	1	1.9
predict what is going to happen	1	1.9
shows you what has changed the environment over the years	1	1.9
they could plan out on maps what to do with the coastline	1	1.9
they could plan what to do with the environment	1	1.9

they decide where to put sealines and walls	1	1.9
they guess what year the coastline covers on all buildings	1	1.9
they look after the environment in your area	1	1.9
they look at maps and put barriers on	1	1.9
they make plans to the environment and choose to help it or leave it	1	1.9
they plan what happens with empty places with the environment	1	1.9
they protect villages and cities from being disturbed by the sea, by building a sea wall	1	1.9
they think of the best way to solve environmental problems	1	1.9
thing with the environment	1	1.9
things to do with the environment	1	1.9
Total	52	100.0

E20: Children's post workshop reason (immediately after workshop) for preferred choice in 'inclination towards environmental planning career (phase 2)

Reason for inclination towards environmental planner career	Freq.	%
because you could save lives but you could also destroy them	3	4.9
not my thing	2	3.3
not sure	2	3.3
because I could destroy peoples houses and they would not have a home	1	1.6
because I don't want to break houses	1	1.6
because I have a job in mind already and I am unsure if u would make the wrong decision	1	1.6
because I like doing hard work but this is too much for me	1	1.6
because I love animals	1	1.6
because I might make a mistake	1	1.6
because I want to help and not destroy the houses	1	1.6
because I will not want to pick any bit of land	1	1.6
because I would like to save homes and people but it would be hard	1	1.6
because it is hard to work	1	1.6
because it seems good too, but it seems too bad	1	1.6
because it would be a hard job	1	1.6
because it wouldn't be my thing	1	1.6
because it's confusing and there are some hard decisions	1	1.6
because it's too complicated	1	1.6
because it's too complicated and putting people's lives at risk	1	1.6
because people's lives could be harmed	1	1.6
because you could save everyone or let them die	1	1.6
because you could save lives but also you cant	1	1.6
because you have to make hard choices	1	1.6
boring	1	1.6
cause it would be too hard to decide	1	1.6
decisions are too hard	1	1.6
hard decisions and large costs	1	1.6
hard job	1	1.6
I am opinionated and would have a lot of disagreements	1	1.6
I do want to save the environment but they make really hard choices and most people won't like me if I buy in	1	1.6
I just don't think I would like it	1	1.6
I just don't want to do it	1	1.6
I think it will be hard but fun	1	1.6

I think its cruel and hard to only pick some places and not everywhere	1	1.6
I would feel guilty or I could feel proud	1	1.6
I would like to protect people	1	1.6
I wouldn’t want to have this job because I would be destroying houses	1	1.6
I’m not sure	1	1.6
I'm not a really big fan	1	1.6
I'm not interested in this job	1	1.6
I'm not really ??	1	1.6
if I did this job, I will get confused	1	1.6
it could be hard and dangerous	1	1.6
it is too complicated	1	1.6
it is tricky because you have to be patient to do it and I'm impatient	1	1.6
it would be a hard decision to if you want to save the land	1	1.6
no because then you have to make difficult decisions to ruin people's houses	1	1.6
not good at choices	1	1.6
not really my thing	1	1.6
not really my type of thing	1	1.6
sand in hands	1	1.6
scared to do something bad	1	1.6
to save wildlife	1	1.6
too boring for me, not interested	1	1.6
yes because I would like more people to die	1	1.6
you are e.g vacating other people…	1	1.6
you could save lives but you could also destroy them	1	1.6
Total	61	100.0

E21: Children's post workshop (a month after) reason for preferred choice in 'inclination towards environmental planning career (phase 2)

Reason for inclination towards environmental planner career	Freq.	%
No response	4	7.7
it would be hard	2	3.8
a lot of hard work and trust	1	1.9
because I am not into the environment	1	1.9
because I do not know what to do	1	1.9
because I don't like the sound of it	1	1.9
because I don't want to give up on the job that I have wanted since I was very little	1	1.9
because I liked to do but I like a lot	1	1.9
because I might do something else	1	1.9
because I think its boring	1	1.9
because I want to be a policeman	1	1.9
because I want to save places and the environment but its not my type	1	1.9
because I want to work at Chillis	1	1.9
because I will keep the environment safe and healthy	1	1.9
because I would like to be a police officerr but I would like to help the environment	1	1.9
because I would save lives but destroy lives	1	1.9
because it does not seem amazing	1	1.9
because it hurt you	1	1.9
because it would not be my thing	1	1.9
because it would save lives and destroy properties	1	1.9
because this would be too complicated for me	1	1.9
cause I would not know what to do	1	1.9
doesn't seem fun and its not for me	1	1.9
don't know how it had it been	1	1.9
I chose no because it would and I don't get it	1	1.9
I don't really like science	1	1.9
I don't think that's my kind of job	1	1.9
I havent decided what I want to do yet	1	1.9
I just think it would be too difficult	1	1.9
I think I can speak out well with confidence, however it would be a job which uses your mind	1	1.9
I want to be a lawyer and there is an environmental lawyer but no, because you'll make hard choices	1	1.9
I want to help animals and I love them	1	1.9
I would like to be a boxer or footballer	1	1.9

I would not like to have the pressure	1	1.9
I would save lives and make lives sad	1	1.9
I wouldn’t do it because it is too much pressure	1	1.9
I'm not sure between this job and my other choices	1	1.9
I'm not sure cause I think I would make mistakes	1	1.9
I'm too childish and the decisions are hard	1	1.9
it seems like a hard job and It doesn’t feel like the right job for me	1	1.9
its not for me	1	1.9
not sure because some decisions are very hard	1	1.9
not very interested in this type of stuff	1	1.9
so I can keep the place safe and healthy	1	1.9
sounds weird	1	1.9
to hard	1	1.9
too complicated	1	1.9
too much responsibility	1	1.9
Total	52	100.0

GLOSSARY OF ABBREVIATIONS

BEIS – Department for Business, Energy & Industrial Strategy

CIQ – Career Interest Questionnaire

CS – Computer Science

DBS – Disclosure Barring Service

DEAR – Disability Education Access Route in Ireland

DEL – Department for Employment and Learning in Northern Ireland

DfE – Department for Education

FSM – Free School Meals

GDPR – General Data Protection Regulation

HEAR – Higher Education Access Route in Ireland

HEFCE – Higher Education Funding Council for England

HEFCW – Higher Education Funding Council for Wales

MOOC – Massive Open Online Learning

NAO – National Audit Office

NCCPE – National Co-ordinating Centre for Public Engagement

NECC – North East England Chamber of Commerce

NPC – New Philanthropy Capital

NSC – National Space Centre

OFFA – Office of Fair Access

OfS – Office for Students

PSTT – Primary Science Teaching Trust

RCT – Randomised Control Trial

REF – Research Excellence Framework

SFC – Scottish Funding Council

SES – Socio-Economic Status

SITS – Student Interest in Technology and Sciences

SMART – Specific, Measurable, Attainable, Relevant and Time-bound

SMTSL – Students' Motivation towards Science Learning questionnaire

SOC – Standard Occupation Classification

S-STEM – Student STEM survey

STEM – Science, Technology, Engineering and Mathematics

STEM-CIS – STEM Career Interest Survey

TAPS – Teacher Assessment in Primary Science

TOSRA – Test of Science Related Attitude

UKCES – United Kingdom Commission for Employment and Skills

UKRI – UK Research and Innovation

UNESCO – United Nations Educational, Scientific and Cultural Organisation

WAPP – Widening Access and Participation Plan in Northern Ireland

WISERD – Wales Institute of Social and Economic Research, Data & Methods

WP – Widening Participation