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Title: Does teaching computer programming within Key Stage 1 of the primary curriculum enhance children's problem solving skills?

Lynn Blakemore

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Acknowledgements

“To maintain the state of doubt and to carry on systematic and protracted enquiry - these are the essentials of thinking” (Dewey, 2012, p.13).

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Abstract

In light of the changes to the ICT curriculum in England (DfE, 2013), this research examined the implications of developing a computer programming initiative into the Key Stage 1 curriculum in Jersey's primary schools. A number of studies have identified skills that can be developed through a programming environment (Lohead and Clements, 1979; Papert, 1993 and Clements and Gullo, 1994), but the narrative around the assessment of these skills remains very much in its infancy (De Araujo, Andrade and Sere Guerrero, 2016). This study hypothesised that teaching computer programming within the Key Stage 1 curriculum would enhance children's ability to problem solve, drawing on theoretical influences from Dewey (2012), Piaget (1965), Papert (1993) and more current notions of learning power and resilience held by Costa and Kallick (2000), Claxton (2007) and Claxton and Lucas (2015).

A mixed methods approach was adopted for this observational study and a multiple linear regression analysis conducted. A bespoke online assessment tool was created, based on Blockly (Google for Education, 2016), to gather data on children's problem solving skills. The assessment was two phase; phase 1 (2014 cohort) involved 335 children and phase 2 (2015 cohort) involved 387 children. Phase 1 gathered baseline data prior to the computer programming intervention that was delivered over one full term with phase 2. In addition, interviews were undertaken with all Year 2 practitioners and focus group sessions were held with some of the Year 2 children involved in the 'Primary Coding Project' (States of Jersey, 2014) to ascertain their perceptions of the newly introduced computing sessions. This data helped to shed light on some of the nuances involved in developing, implementing and integrating a new curriculum.

After considering the effects of gender and maths attainment, results revealed that participating in the coding intervention increased the total score attained in the problem solving activity, implying that computer programming is an important pedagogical approach to promoting problem solving skills and therefore, computational thinking. A relational shift between children and computers was also identified, which supported the notion of children being able to *adapt to* and *create with* new technologies of the future, contributing to the notion of supporting and developing resilience.

Table of Contents

Acknowledgements		p.2
Abstract		p.3
Table of Contents		p.4
List of Figures		p.7
List of Tables		p.8
Chapter 1	The policy landscape around the ICT and Computing curriculum and a small states response to curriculum change	p.9
1.1	Introduction	p.9
1.2	Background to the Computing for Primary Project	p.12
1.3	The Primary Coding Project	p.14
1.4	Sample of participants involved in the research	p.15
1.5	Approach to the research study	p.16
1.6	Motivations for pursuing this line of enquiry	p.18
1.7	The political context and identity of Computer Science and ICT within the curriculum arena.	p.19
1.8	Computer Science ‘versus’ Information Technology - demystifying some of the terms.	p.22
1.9	Programming, algorithms and making a jam sandwich.	p.23
1.10	Summary of Chapter	p.25
Chapter 2	A Review of the Literature	p.26
2.1	An overview of computing policy development	p.27
2.2	Children’s engagement with technologies and the introduction of computer science into the primary curriculum	p.28
2.3	Women in Computing	p.30
2.4	Gender bias and ‘stereotype threat’	p.31
2.5	The Coding Explosion	p.34
2.6	Computing and the development of metacognitive skills	p.33
2.7	Theory of Human Problem Solving	p.37
2.8	Problem solving in young children	p.42
2.9	Thinking about thinking – a pedagogical perspective	p.46
2.10	Technology and computational thinking	p.49
2.11	The Logo movement	p.49
2.12	Children and computational thinking	p.52
2.13	Curriculum considerations and developing a culture for computer programming in the primary curriculum	p.54
2.14	Computing and creativity	p.57

Chapter 3	Methodology	p.61
3.1	Introduction	p.61
3.2	The primary research question	p.62
3.3	Approaches to research methodologies and positionality	p.66
3.4	The nature of enquiry and the search for truth	p.68
3.5	Influence on methodology – pragmatism as a paradigm	p.70
3.6	A Mixed Methods approach	p.71
Chapter 4	The research design and data collection instruments	p.74
4.1	Research Design	p.74
4.2	An Embedded Mixed Methods design	p.77
4.3	Data collection tools	p.79
4.4	The Problem Solving Activity (Design and content)	p.80
4.5	Surveys with year 2 teachers	p.93
4.6	Focus groups with year 2 children – some context and justification of purpose of chosen methodology	p.96
4.7	Practical considerations in developing and leading the group	p.98
4.8	Expected roles of the participants and how this could shape the data	p.100
4.9	Ethical issues	p.100
Chapter 5	Approach to data analysis	p.105
5.1	Problem solving activity	p.105
5.2	Multiple linear regression approach	p.107
5.3	Analysis of the demographic profile of the data set (QUAN)	p.110
5.4	Preliminary analysis	p.111
5.5	Surveys and focus groups	p.112
5.6	Focus group with children – transcript of data (qual)	p.114
Chapter 6	Presentation and analysis of data	p.116
6.1	Results and analysis of problem solving activity (QUAN)	p.116
6.2	Results of survey from year 2 teachers (qual)	p.126
6.3	Data analysis of surveys	p.126
6.5	Data analysis of focus group	p.134
Chapter 7	Thematic Analysis	p.141
7.1	What the mixed methods data suggests	p.142
7.2	Theme 1: Knowledge and values	p.143
7.3	Theme 2: Curriculum	p.145
7.4	Theme 3: Policy	p.148
7.5	Theme 4: Resources	p.151

Chapter 8	Conclusion	p.155
8.1	Outcomes and implications for practice	p.155
8.2	Limitations of the study	p.164
8.3	Recommendations for future research	p.166
8.4	Personal and final reflections of a 'Digital Immigrant'	p.167
	References	p.168
	Appendices	p.194
Appendix 1	Jersey Computing Curriculum (2014) for Key Stage 1 and medium term planning to show examples of plugged and unplugged activities	p.194
Appendix 2	Data from online surveys with Year 2 Primary Teachers	p.???
Appendix 3	Data from focus groups with Year 2 children	p.199
Appendix 4	University of Sheffield ethical approval	p.205
Appendix 5	Information sheet for Gatekeeper (Head teacher and Teachers of Year 2)	p.206
Appendix 6	Information sheet for Parents of Year 2 children	p.210
Appendix 7	Optimal move allocation for Problem Solving Activity	p.213
Appendix 8	Re-coding of predictor variables	p.214
Appendix 9	Residuals statistics table and histogram	p.215
Appendix 10	Pearson correlation coefficients table	p.216

List of Figures

Figure 1	Convergent Parallel Mixed Methods	p.74
Figure 2	Explanatory Sequential Mixed Methods	p.74
Figure 3	Exploratory Sequential Mixed Methods	p.75
Figure 4	An Embedded Mixed Methods Design	p.77
Figure 5	Problem solving activity levels	p.82
Figure 6	Problem solving activity – level 1 start screen	p.83
Figure 7	Level 1 and 2 of problem solving activity	p.84
Figure 8	Level 3 - Feedback	p.85
Figure 9	Level 5 and level 6	p.86
Figure 10	Level 8 – Concrete operations and spatial awareness	p.86
Figure 11	Level 10 – Use of repeat blocks and while loops	p.87
Figure 12	Level 11 – Example of iteration	p.87
Figure 13	Level 15 – Combination of repeat blocks, while loops and IF statements	p.88
Figure 14	Final report for individual student	p.89
Figure 15	Scatter plot showing total score in problem solving activity against Year 2 Maths Achievement	p.119
Figure 16	Scatter plot showing total score in problem solving activity against Year 2 English Achievement	p.120

List of Tables

Table 1	Method chosen for this study	p.75
Table 2	Sample of questions for Year 2 teachers	p.94
Table 3	Sample of questions for focus groups (Year 2 children)	p.99
Table 4	Block penalty mechanism	p.106
Table 5	Statement of variables	p.110
Table 6	Descriptive statistics	p.111
Table 7	ANNOVA table	p.121
Table 8	Initial model coefficients and collinearity statistics	p.123
Table 9	Final model	p.125

Chapter 1:

The policy landscape around the ICT and Computing curriculum and a small states response to curriculum change

1.1 Introduction

The primary focus of this research is to examine the potential role of computer programming in enhancing children's problem solving skills. Broader implications of developing a computer programming initiative into the Key Stage 1 curriculum in Jersey's primary schools are also explored. This research is in response to the changes that were made to the National curriculum for England (DfE, 2013) and in direct correlation to the revised National curriculum for England; computing programmes of study (DfE, 2013). The new curriculum now advocates that "a high-quality computing education equips pupils to use computational thinking and creativity to understand and change the world" (DfE, 2013, p.1), with the overarching aims to ensure that all children can:

understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and data representation. Can analyse problems in computational terms, and have repeated practical experience of writing computer programs in order to solve such problems. Can evaluate and apply information technology, including new or unfamiliar technologies, analytically to solve problems and are responsible, competent, confident and creative users of information and communication technology (DfE, 2013, p.1).

Key concepts that emerge from the aims stated above include the notion of computational thinking (Wing, 2014), and more specifically problem solving. Gagne (1980) believed that "the central point of education is to teach people to think, to use their rational powers, to become better problem solvers" (p.85). Although this study is focussed around the development of children's problem solving skills, the notion itself can be seen as an imperative life skill (Jonassen, 2000) to be actively encouraged, regardless of age. Further explanation of the term 'problem solving' will be examined in the review of literature but to refer back to the above quote, it is the latter concept of developing children's problem solving skills that has become the motivation for this research.

Following the Education Reform Act (1988), information and communication technology (ICT) became statutory for all pupils from 5 to 16 in maintained schools with “the use of ICT considered as both a specialist subject and across the wider school curriculum” (Ofsted, 2011). The most recent, and major revision to the ICT curriculum (DfE, 2013) is a step-change from previous policies as for almost the last three decades computer programming has not been a core component of the curriculum. The focus of the ICT curriculum was primarily based upon the teaching of how to use hardware and software opposed to the idea of creating software and developing computational thinking. Schmidt (2011) suggested that ICT pedagogy and delivery was focussing on the wrong skill set and promoting “digital consumers opposed to digital creators” (Kenyon, 2013) which was then followed by the aptly but perhaps controversially named “Shut down or re-start” report (The Royal Society, 2012), initiated by the government to analyse the state of computing education in schools and identify ways to improve on the current curriculum offer. A suggested route was “to displace some of the routine ICT activity with more creative, rigorous and challenging Computer Science” (Furber, 2012, p.4), hence, the previous reference to the term ‘controversy’.

The main findings of the report highlighted that the current delivery of computing education was unsatisfactory across many schools in the United Kingdom (UK); it could be argued that this was down to the breadth of the existing curricula for Information and Communication Technology, which although allowed scope for teachers to develop and nurture interests in computing, was primarily focussed on developing basic digital literacy skills, for example, using a word-processor or creating a database. A recommendation of the report was that “Head teachers should start by recognizing the importance of Computer Science to the future lives and careers of the pupils in their care, and take this into account when appointing teachers by looking for those with relevant training and/or experience” (Furber, 2012, p.4), but equally recognise that in the majority of scenarios “Computer Science will be taught by existing staff, and they will need help” (The Royal Society, 2012, p.4). In addition, it was acknowledged within the report that continuing professional development for teachers of computing and the current infrastructure within some schools would need to be addressed in order to support and not inhibit any potential policy change.

In light of the curricula changes from ICT back to Computing (DfE 2013), Jersey has invested and led policy development in this domain and piloted a 'Primary Coding project' (States of Jersey, 2014) within two Island primary schools with the view of rolling out a computing programme of study across all primary schools from September 2014. As in past policy discourse, as an independent Island we have had the benefit of being able to watch and learn, and effectively 'piggy back' off the work done in the UK, tentatively, according to Sallis (2009) "making us policy importers, however, as an island, we are not entirely policy importers as we can ultimately generate our own policies or be in the position of taking the best bits and leaving the rest". The States of Jersey Education Department chose to capitalise on this opportunity to develop the discipline of Computer Science within the curriculum and recruited computing and IT teachers from a local secondary school to support the creation, development and implementation of a bespoke programme of study. It is hoped that by drawing upon the computing expertise of the secondary teaching team in combination with the primary teachers knowledge of young children's developmental needs, that a programme of study could be developed that would reflect that the initial themes were fit for purpose for the primary curriculum and context of Jersey, but would also be pedagogically sustainable. From a policy analysis perspective this also resonates with the concept of being "creators rather than consumers" (Sallis, 2009; Kenyon, 2013) which will be examined in more depth in Chapter 2.

On commencement of this study there appeared to be an abundance of research around technology and motivation (Fessakis et al, 2012; Henderson and Yeow, 2012) yet little around the impact of technology on cognitive development and the notion of computational thinking (Computing at School, 2012). Computational thinking encompasses the skill of problem solving and is defined and explored further in Chapter 2.7.

As a researcher I felt that there would be substantial value in exploring the 'Primary Coding Project' (States of Jersey, 2014) in depth over a two year period (2014-2016) in an attempt to capture some evidential data of both the process and potential impact that this intervention may have on the children and staff involved. The particular emphasis of this research study will be placed on pedagogy, policy and practice in Key Stage 1 of the primary curriculum in Jersey. Although primarily an impact evaluation study to ascertain if teaching computer

programming in Key Stage 1 enhances children’s problem solving skills, it also sets out to investigate the impact on policy and practice for both teachers and most importantly the children experiencing the policy transition.

1.2 Background to the Computing for Primary Project

The research is located in Jersey, Channel Islands; at this point I feel it would be pertinent to offer the reader a brief flavour of the Island’s relationship with the United Kingdom and consequently its uniqueness, specifically in relation to the context of policy making and curriculum reform and the implications this has on the study. Jersey is a parliamentary democracy and known as a dependency of the British Crown. It is recognised as a British island, but does not form part of the United Kingdom. Acts of the Westminster Parliament do not apply routinely to the Island, but occasionally mainland legislation does include the Island directly but with amendments as may be deemed necessary by the States of Jersey to reflect Island culture. The curriculum in Jersey, on the whole, emulates the National Curriculum (DfES, 2000) followed in England, however there are some changes which again take into account Jersey’s unique setting, culture and history. Jersey has its own Education (Jersey) Law (1999) and from a regulatory perspective Ofsted (DfE, 2015) has no jurisdiction in the Island, but has developed its own system of supporting both quality and accountability. The standards and achievement team “monitor standards and achievements in Jersey schools and colleges through the Professional Partner system and support self-evaluation and development through the Professional Partners, Teaching and Learning Advisers and specialist support” (States of Jersey, 2015).

Having this autonomy has enabled the States of Jersey to respond quickly to the proposed policy changes faced in England around the ICT curriculum and invest a substantial amount of money into its own ‘Primary Coding Project’ (States of Jersey, 2014) with its aim “to improve teachers’ computing skills and inspire students to use technology from the earliest possible age”. Other aims the project makes claim to are to “address the skill shortage in computing in primary schools, give staff extra skills to deliver computing to younger students, enthuse pupils to be the next generation of developers and develop wider skills, including numeracy and problem solving” (States of Jersey, 2014). Although all these aims are prevalent within

this research study, the latter of these objectives is at the core and will be the main theme examined throughout the narrative.

Taking the steer from the States of Jersey Education Department in regards to the expected aims of the new curriculum this research study will examine the following key research question, supported by three supplementary questions;

Research Question:

Does teaching computer programming within key stage 1 of the primary curriculum enhance children's problem solving skills?

Supplementary questions:

What are the views of Year 2, Key Stage 1 teachers around embedding programming and computational thinking skills into the key stage 1 curriculum?

What are year 2 children's perceptions of these programming sessions?

Can any differences be identified between the interest and engagement of male and female participants in the study?

For purposes of clarification and for this particular context, the following definition of terms within the stated research questions can be applied. Computer programming can be seen as the process of creating a set of instructions that can instruct a computer to achieve a particular task and this is what was tested in the online problem solving activity. Problem solving skills involves the mental processes that occur when trying to find a solution to a given problem (Wang, 2010) and although complex, is also seen as a basic life function (Zhong, Wang and Chiew, 2010), so in effect not exclusive to a programming environment. In relation to children, Garton (1993) provides a broader definition of problem solving that encompasses children's thinking and learning in general. So although computer programming requires problem solving skills to be employed and therefore implicit, within this study, they are also acknowledged as explicit processes. The term 'computational thinking' clearly aligns with the notion of problem solving skills as it can also be defined as the "thought processes involved in the logical reasoning that is needed to solve problems" (Sargent, 2016, p.22) but then goes

on to advocate that to be able to think computationally enables a better understanding of systems, which implies within a computing environment. Wing (2014) however, suggests that computation as a function can be applied to both human and machine thought processes.

This observational study examined children's problem solving skills primarily through an online assessment tool but prior to this assessment taking place children in phase 2 of the study were also exposed to a full term of a programming curriculum (the intervention), which involved activities outside of a computing environment. So although these terms may appear to amalgamate at times, in the given context they are different from each other.

Another point to make explicit is that although there is a clear relationship between this research study and the 'Primary Coding Project' (States of Jersey, 2014) it is equally important to recognise them as separate entities, each with their specific, albeit connected aims and purpose. To further support the reader with this delineation the following section explores the context of the 'Primary Coding Project' (States of Jersey, 2014).

1.3 The Primary Coding project

The Primary Coding project commenced in September 2013 and was designed to be implemented in three stages. The first stage involved the Secondary IT teaching team working alongside two partner primary schools, as pilot groups, where exposure to various key stages could support and inform the team to develop curriculum ideas and resources that could be tried and tested in the classroom. Feedback was provided from primary colleagues and equally as valuable, the children themselves. Stage 2 saw an extended invitation to a further eight schools to join the project and the remaining thirteen schools were invited to partake in the project from September 2014. The term 'invite' should be highlighted here, as engagement with the Primary Coding project was not compulsory but rather offered as a voluntary opportunity, funded by the States of Jersey to support the transition into the new computing component of the primary curriculum, introduced in September 2014. Nine schools were involved in stage 3 and these have been the focus of this research study. As these schools were not involved in the initial stages of the project I have been able to track their progress from the very start of their involvement.

To further support the curriculum transition, the website 'Computing for Primary' (<http://www.computingforprimary.co.uk>) was set up by the Secondary IT teaching team to capture the development of the Primary Coding project but also to act as a valuable pedagogic and curriculum resource for all primary schools involved. The progress of this research study has also been communicated through this medium in a quest to keep all those who have supported and contributed to the research updated. At the time of writing, this resource was aimed at teaching staff and not intended to be accessible to the children, though this idea is revisited in Chapter 6.5 when the focus group data is analysed.

1.4 Sample of participants involved in the research

Out of the thirteen schools invited to join the computing project in September 2014, which was planned to coincide with the start of the school year, two requested a January start opposed to a September start date. For this reason it was decided that these schools would not be included as participants in the research study. An additional primary school was a boy's school, part state funded and part privately funded but whose intake is from Key Stage 2 onward. Another school subsequently withdrew due to having new staff starting in that term, so potentially this left 9 state primary schools within the Island that could be involved in the study. 5 of these schools came from urban areas and the remaining 4 were rural. Following discussion with the IT teaching team from the local secondary school, it was decided that the focus would be on Year Two classes within Key Stage 1. The justification for this age range was twofold. Firstly, as one of the proposed methods was for the children to complete an online problem solving activity we needed to consider what age and stage of development that this would be appropriate for. From a cognitive and language perspective it was decided to focus on the latter phase of Key Stage 1 (Year Two, age 6-7 years) as this cohort of children, on the whole, would have had more time to acquire and establish skills in both of these domains. This is discussed further in Chapter 4.4.

The second factor that influenced the decision to focus on Year Two, came down to relevance and the pre-requisite of studying for an EdD in Early Childhood Education. What constitutes early childhood education could be debated but Taylor and Woods (1998) suggest that the

term “might be considered to embrace all of a child’s experiences from birth to eight” (p. 201) which would incorporate the Year Two children involved in this study.

Additional exclusions from the initial data collection were the two primary schools that were used as pilot groups for the project during 2013 but these schools were used to pilot the proposed research methods. Initially it was projected that the duration of the testing period would be for a full academic year however due to some resource challenges, particularly staffing and the ad-hoc start dates of some schools being able to join the project, it was agreed that the test period would be revised to one term of computer programming opposed to the full academic year.

1.5 Approach to the research study

The main core of the research study involved testing different groups of Year Two pupils, through a bespoke online problem solving tool, to examine a “treatment effect” (Cresswell, 2012, p. 178) between pupils’ who have experienced the ‘Primary Coding Project’ initiative for a full term and those who have not, characterising an observational study approach (Jepson et al, 2004). Due to the proposed changes to the ICT curriculum having not formally been implemented into the curriculum until September 2014, at the time of writing there were no baseline assessment tools to draw upon (De Aruajo, Andrade and Serey Guerrero, 2016), which meant that one would need to be created for the purposes of the research. This evokes questions around validity and reliability which are examined further in Chapter 4.4.

The first group of Year Two students involved in the study, had no experience of the ‘Primary Coding Project’ initiative, but completed the problem solving activity at the end of their academic year (3rd week of June 2014). This cohort would be classed as the control group, though they would not be assessed again following the initial activity. The second group of Year Two students also undertook the same problem solving activity at the end of their academic year (3rd week of June 2015), having received a term of computer programming sessions. This cohort was classed as the experimental group.

The characteristics and justification of this approach are discussed and clarified in the research methodology (Chapter 3), but it was critical to recognise the complexities of the sample in the early design stage of the study so any potential threats to validity could be avoided, or at least minimised. Cresswell (2012) states that:

Internal threats are experimental procedures, treatments, or experiences of the participants that threaten the researcher's ability to draw correct inferences from the data about the population in an experiment (p.174).

The statement above was taken into consideration in the design process of the research, which acknowledges and addresses the possibility of confounding variables. To ensure the two groups were comparable, each were assessed at the same point in their school year and were otherwise assumed to be similar considering they were not randomly assigned to the control and treatment groups. This was not achievable or appropriate due to ethical and realistic restrictions. Further detail on the profile of the two cohorts is provided later on in the study.

The 'Primary Coding Project' (States of Jersey, 2014) acknowledged from the onset that some primary teachers may well already have both the confidence and expertise to deliver and embed computing into the primary curriculum and if this was the case, it was intended that these skills and attributes would be both nurtured and utilised. However, for those primary teaching colleagues that did not have knowledge of computing, the project's aim was to support any skills gaps in preparation for the proposed curriculum changes. In order to capture some data around current skills and knowledge an online survey was designed and an invitation was sent out to all Year Two teachers who were going to be involved in the project from September 2014 (See Appendix 5). The aim of this data collection was also to ascertain thoughts and opinions around the proposed curriculum changes from a practitioner perspective. In addition to carrying out the problem solving activity and conducting online surveys, five focus group activities were also undertaken within one of the schools involved, to explore what some of the Year Two children's perceptions were about the new computing sessions (See Appendix 3).

As a lecturer in Childhood Studies where “increasingly research is being carried out that falls within the interpretivist paradigm” (Mukherji and Albon, 2010, p.24) I have always aligned myself with this methodology and as I write I am aware of my subconscious familiarity and more honestly, favouritism towards the qualitative and interpretative approach to research. This may have impacted on my own value-led response to this research which has employed a mixed methods approach, although conscious and reasoned justification for this will be explored in greater depth later on. As identified, this study collected both qualitative and quantitative data within the context of a mixed methods approach, with the aim that “their combined strengths accomplish more than is possible with a single method” (Morgan, 2014, p.274), though Morgan (2014) advocates that when using mixed methods more attention to research design is required, to ensure effective integration. The research design for this mixed method approach is outlined in Chapter 4.

1.6 Motivations for pursuing this line of enquiry

Winters (2012) states that “who you are will effect what you research” yet the topic and mechanics of this project are divergent to my own personal experiences and expertise so in effect challenges this idea. Bassey (2010) also concurs that “one of the prime reasons for doing any kind of research is that one has personal interests and concerns about the subject of the research” (p.90). From a personal perspective and as a resident of Jersey, it was the political driver of recent policy change that introduced me to the subject area but subsequent engagement with the surrounding literature and dialogue with those who informed the project in some way, ignited the curiosity and maintained the drive. So even though I have not experienced Computer Science as a curriculum subject and historically veered towards qualitative paradigms in previous research, the purpose and focus of this project dictated the process. To embark upon a mixed methods research project has been an academic challenge but one that I felt was necessary to take in order to effectively elucidate on the focus of enquiry. With the acknowledgement of some naivety around the concept of Computer Science as a subject I subsequently tried to submerge myself within it contextually; I endeavoured to do this by immersing myself in primary school staff development sessions to support the ‘Computing for Primary’ initiative and through integration with this specific sector

via the 'Computing At Schools' (CAS) community (2015) when opportunities to do this were presented.

Although the primary motivation of this study was driven by the desire to understand if participation in this programme led to improved problem solving skills, defined by Zhong, Wang and Chiew (2010) as "one of the basic life functions of the natural intelligence of the brain" (p.81), as I continued to engage with the reading, I also started to reflect upon my experiences with learners within a Further and Higher Education context. Although anecdotal, I have been involved in frequent dialogue with FE and HE colleagues around what is perceived to be an increase in some students' resilience levels (Claxton, 2007). Some students appear to lack confidence when being challenged and accept failure as part of the learning process, which is perhaps "easier to espouse than to effect" (Canon and Edmondson, 2005, p.310), or in other words, easier to support than apply in practice.

I would suggest that this belief has been intensified by political agendas that appear to demand a 'results and accountability' culture, but nonetheless are seen as challenges that we are now faced with in the educational arena. When considering how this challenge could be addressed, or at least balanced out, Costa and Kallick (2000) present the idea of "The Habits of Mind", influenced by Dewey (2012), which they describe as a "set of 16 problem solving, life related skills, necessary to effectively operate in society and promote strategic reasoning, insightfulness, perseverance, creativity and craftsmanship". The two key characteristics that I feel are pertinent to this debate and the notion of problem solving, are the statements around 'persisting' and being able to take 'responsible risks' which includes facing the "fear of making mistakes or of coming up short" (Costa and Kallick, 2000, p.34). Although there has been an abundance of research and focus on resilience in relation to children and young people's well-being (Bonnie, 1995; Townshend et al, 2016; Bradshaw, 2016) I would assert that perhaps resilience and perseverance in problem solving could in some way play an integral part here.

1.7 The political context and identity of Computer Science and ICT within the curriculum arena.

Whenever curriculum changes are proposed or imposed on educators, it can be understandably unsettling, evoke questions around the justification for making these changes and potentially create anxieties in response to the proposed change. This links to the statement made by Furber (2012) in the “Shut down or re-start” report (The Royal Society, 2012) that “we have met ‘sparkling’ teachers who are clearly already capable of delivering Computer Science lessons in schools, but many others will find these proposals daunting” (p. 4).

After a consultation period the UK Government, supported by experts in the field and a range of industry stakeholders, believed that “ICT as a subject name carried strong negative connotations of a dated and unchallenging curriculum that did not properly serve the needs and ambitions of pupils” (DfE, 2013, p.2) so subsequently changed the subject name of ICT to computing in the quest to elevate the status of the subject but at the same time ensure that the title more accurately reflected the breadth of content within the programme of study. This policy change impacts on the role of current ICT teachers and students synonymously.

For some ICT teachers this change was quite a daunting prospect, not only requiring the development of new knowledge acquisition and skill set (Britland, 2013), but also a mind shift in pedagogy and philosophy. At the time of writing it was hoped that this could be resolved within the Computer Science and IT community with the acknowledgement that the subjects are different, but complementary. However, more recent policy changes (DfE, 2015) saw the announcement from the government not to redevelop the ICT curriculum on the grounds that it shared a “similar qualification space” (DfE, 2015, p.11) to that of Computer Science. Subsequently, the decision to introduce the computing curriculum to all five to fourteen year olds has created the domino effect in creating the need for more computer science teachers across both the primary and secondary sector. Although this could be perceived as a positive recruitment drive, creating jobs within this particular domain, it is not without its challenges; this is partly due to the “growing need for graduates in the technology and digital industries” (Vaughan, 2015), where higher wages can be demanded but I would tentatively suggest that

it could also be concomitant to the notion of human characteristics, albeit at times a stereotypical perception, that seems to draw individuals into particular vocations (Konrad et al, 2000; AAUW, 2015). What I suggest here is the idea that teaching evidently has a social dimension to its role (Van Maele and Van Houtte, 2012) and therefore it could be questioned whether this would be an attractive career proposition for computer science graduates (Diekman et al, 2012). That is not to say that computing jobs do not have a social purpose, but in some of these roles perhaps the communal goals and relationships are not as obvious or perhaps well communicated.

From a student's standpoint there is potential impact on those students interested in studying for a qualification in ICT rather than in what might be perceived as the more academically focussed field of Computer Science. According to Vaughan (2015) "official figures show that more than 111,000 students sat the GCSE in ICT in the summer, up from more than 96,000 the year before. Just 35,000 pupils sat the computing GCSE". So although the Primary Coding project (States of Jersey, 2014) is advocating the introduction of Computer Science into the primary curriculum there is a counter argument that highlights the idea that "many young people will need the skills to produce online content for the world of work using certain tools, but they will not necessarily need to know how to create those tools" (Berry, 2015). With the more academic focus of Computer Science and its "deep links with mathematics, science and design and technology" (DfE, 2013) there is the danger that it could become elitist, only being accessible to more able students, which I would suggest makes the Primary Coding Project (States of Jersey, 2014) even more relevant in relation to engaging young children in this discipline from an early age so that it can support students' GCSE and A level study options and more importantly choices, later on. This aligns with the thoughts of both Cooper and Weaver (2003) and Zarrett et al (2000) who advocate that if students have had no exposure to computer science by the time they arrive in high school then many "have already made decisions against pursuing it, either considering it a speciality topic outside of their abilities or associated with a stereotype they find unattractive" (cited in Werner, Kawamoto and Denner, no date).

Integral to the discipline of Computer Science is the concept of computational thinking which, in short, is defined by Wing (2014) as "the thought processes involved in formulating a

problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out”. Computer Science has produced, at an astounding pace, remarkable technology that has transformed our lives with profound societal impact (National Academies Press, 2010). This effect was foreseen by Gotlieb and Borodin (1973) in their book *Social Issues in Computing* but furthermore, in the last few years, we have gained more awareness and come to appreciate that “computer science offers not just useful software and hardware artefacts, but also an intellectual framework for thinking” (Wing, 2014).

In relation to the recent policy reformation, computational thinking is positioned at the heart of the National Curriculum (2013) programme of study for Computing with the recently updated framework stating that “a high quality computing education equips pupils to use computational thinking and creativity to understand and change the world” (DfE, 2013b, p.188). It could be said that this is an extremely ambitious statement to be included within a programme of study, potentially a challenging concept to measure and without doubt a huge responsibility on practitioners to be able to deliver on. CAS (2012) go on to suggest that “pupils who can think computationally are better able to conceptualise and understand computer-based technology, and so are better equipped to function in modern society” (p.3) and in effect will become better prepared for the world that doesn’t yet exist, with both technology and challenges that we have yet to be exposed to. So effectively, everyone can benefit from thinking computationally and from a policy perspective it goes some way to support the grand vision held by Wing (2014) and the ethos behind the Primary Coding Project (States of Jersey, 2013) that is “computational thinking will be a fundamental skill—just like reading, writing, and arithmetic—used by everyone by the middle of the 21st Century”. However, if this vision is to come to fruition then I would advocate that an understanding of the concepts and terminologies that fall within this domain need to be made more accessible to those who are perhaps less familiar, which resonates personally.

Through having to submerge myself in what has felt like learning a new language at times, both from a content and methodological perspective, I feel it would be pertinent to offer a definition of terms from the domain of Computer Science in order to explicate on some of the specific terminology that may be referred to within the study.

1.8 Computer Science ‘versus’ Information Technology - demystifying some of the terms

The term Computing signifies the whole curriculum in relation to the use of computers, with Computer Science (CS) being a constituent part, alongside Information Technology (IT) and Digital Literacy (DL) (Computing at School, 2012). However, the intention of this study is not to focus on the strands of IT and DL but to debate the position of CS within the curriculum and if CS is to be supported as a curriculum subject in schools then an understanding of what it entails needs to be ascertained. To offer one definition that emphasises its significance I refer back to the work of Computing at School (2012) who state that:

Computer Science is the study of principles and practices that underpin an understanding and modelling of computation, and of their application in the development of computer systems. At its heart lies the notion of computational thinking: a mode of thought that goes well beyond software and hardware, and that provides a framework within which to reason about systems and problems (Computing at School, 2012, p.3).

From the quote above it is important to acknowledge that one of the main principles of Computer Science is to teach children disciplines with long term value opposed to skills with short term significance, though these skills still have their place. Computer Science remains independent from specific technologies and sometimes removed from computers themselves; the terms “plugged and un-plugged” (Bell, Witten and Fellows, 2006) have been used to identify that computer science teaching does not have to involve the use of computers. Computer Science’s attention lies with the mechanics of how computers and systems work, how they are designed and subsequently programmed. To highlight the distinction between Computer Science and the previous Information Technology curriculum, CAS (2012) present the interesting idea that “CS teaches a pupil how to be an effective author of computational tools (i.e. software), while IT teaches how to be a thoughtful user of those tools” (p.4). The emphasis on author and user aligns with my own thoughts around the notion of consumer or creator presented initially in the introduction (Chapter 1) and examined further in the review of literature (see Chapter 2).

1.9 Programming, algorithms and making a jam sandwich.

The terms programming and code have been treated as interchangeable terms in computing literature (Bell, Witten and Fellows, 2006; CAS, 2012) and given that they are used interchangeably I will use both of these terms from here on to describe the development of the language associated with computing, though the term coding will be referred to in Chapter 2 in relation to initiatives that have gained recent momentum (American Association for the Advancement of Science, AAAS, 2016).

Programming is a creative process executed by programmers to instruct a computer on how to carry out a particular task. There is an extensive array of programming languages that can be used which are influenced by the problem to be solved. Unlike human languages, programming languages leave no room for ambiguity so are characteristically very precise. An algorithm is a precise method of solving a given problem, which can range from the very simple (e.g. various stages of making a cup of tea) to the more complex (school timetabling) and algorithms can be presented in many different programming languages. To offer contextual insight to this I recall an observation of a lesson where the teacher was introducing this concept to a group of year 2 children. In reference to the Key Stage 1 Computer Science curriculum one of the learning objectives states “a pupil should know how to write executable programs in a least one language’ and identifies that ‘a computer program is like the narrative part of a story, and the computer’s job is to do what the narrator says” (CAS, 2012). As CAS points out “computers have not intelligence, and so follow the narrator’s instructions blindly” (2012). I observed the teacher telling the children that he had missed his breakfast, was now very hungry and needed to make a jam sandwich. He produced all the ingredients and tools needed but told the children that, like the computer, he had no intelligence as to how to actually do it. The children very quickly became the narrators of this story and started to vocalise instructions to the teacher (computer) and create an algorithm that made a jam sandwich. Frequently, algorithms are “required to repeat certain steps until told to stop or until a particular condition has been met” (BBC, 2016), so on this example the children also had to apply the concept of iteration which “is the process of repeating a sequence of steps until the required answer is achieved” (The British Computer Society, 2005, p.256). In this

instance, the iteration would mean instructing the teacher to keep on eating the sandwich until it had gone.

What became apparent very quickly was that what the children assumed to be quite precise instructions were actually quite ambiguous, resulting in confusion for the teacher (computer) in regards to successfully making the jam sandwich and subsequently eating it. Although a relatively simple idea, what I witnessed was Year Two children engaged in creating an algorithm, iteration and adaptive thinking (Robinson, 1993); the children also experienced first-hand how precision of instructions was key in the whole process, a crucial component of computational thinking (DfE, 2013; Wing, 2014) and problem solving (Gagne, 1980; Jonassen, 2000).

1.10 Summary of Chapter:

In this chapter I have sought to provide a contextual understanding of policy making in the microstate of Jersey and in addition, highlighted the political drivers that have informed the recent policy reformation around the National curriculum for England, computing programmes of study (DfE, 2013). The States of Jersey's response to this change saw the investment in the two year 'Primary Coding Project' to develop a bespoke programme of study and support primary teachers with the transition.

The potential benefits and challenges of this policy change have been highlighted and I have illustrated that Computer Science as a discipline is more than programming alone, but programming is also a key central process for Computer Science. According to Clements and Gullo (1984, p.1051), the "computer programming environment holds the promise of becoming an effective device for cognitive process instruction – teaching how, rather than what" in an educational context. CAS (2012) proposes that "programming encourages creativity, logical thought, precision and problem-solving, and helps foster the personal, learning and thinking skills required in the modern school curriculum" (p.10). It is this key central process that provides the very pertinent link back to the question that this study aims to answer;

'Does teaching computer programming within Key Stage 1 of the primary curriculum enhance children's problem solving skills?'

The following chapter will offer further context to the research through an examination of the key literature around computer programming and problem solving.

Chapter 2: A Review of the Literature

This chapter provides the reader with a review of the relevant literature, which includes a historical overview of computing policy development and an examination of children's engagement with computing and technology over the last two decades. It explores children's engagement with technology from a motivational perspective but also highlights the absence of research around the use of technology and its impact on children's cognitive development. The notion of children being consumers of technology opposed to creators of technology is also re-presented within this chapter and remains an important thread throughout the study.

The literature then transitions into the gender domain and concepts such as gender bias and stereotype threat are highlighted as it was felt that these could be pertinent to the study and potentially key (or supportive/underpin) to the data analysis. Although in the context of ICT, this is supported by Brooker and Siraj-Blatchford (2002) who advocate that in order to support equality of access "it is important to look carefully for any gender bias in access to ICT equipment in the classroom" (cited in Yun Sung, Siraj Blatchford and Kucirkova, 2016, p.7).

Retaining a focus on policy and practice this chapter then considers the literature around the more recent re-introduction of computing or coding into the educational arena and examines the impact of these types of activities on meta-cognitive skills. The theory of human problem solving is examined in depth and as a result plays a significant part in this chapter as its relevance to the main research question is of paramount importance. The research draws from both psychological and computer science sources; this highlights the difference across both disciplines but also emphasises the synergy between the mental and computerised processes. This leads into a more contextual discussion of young children and problem solving, drawing upon multiple theories (Gopnik, Meltzoff and Kuhl, 1999; Hobson, 2002; Garton, 2004) of how this complex process is evidenced within early year's development. Some application to Piaget's theory of cognitive development is also identified, in particular reference to the nature of the problem solving activity undertaken for this study.

The final section examines the potential influences on the curriculum in light of the re-introduction of computer science. Pedagogical philosophy and practice is explored from a

heuristic perspective (Papert, 1993) and draws on the concept of Dewey's (2012) origins of thinking and the notion of perseverance in problem solving activities. A key message that evolves in this chapter is our societies' cultural emphasis on teaching opposed to that of learning, though this debate is supported with more recent evidence that indicates a change in both this mind-set and practice (Claxton, 2007; ReflectEd, 2017).

Building on this trajectory, the notion of culture is further examined. This is in relation to responding to and sustaining a policy change with consideration of how the pedagogical change, with its emphasis on developing computational thinking and raised awareness of metacognition, could contribute to the educational debate around skills children need to be equipped for the 21st Century. This is complemented and concluded with the idea that computer programming and creativity can and should be aligned together and go some way to support the notion of a 21st Century curriculum.

2.1 An overview of computing policy development

Historically there have been major developments in computing within the English education system stemming from 1969 when some mathematic departments initiated computer education as qualifications within secondary education (The Royal Society, 2012, p.163). Computer Studies and Computer Science were used as interchangeable titles until 1987 which witnessed the birth of a new subject called "Information Technology" (IT) that was approved by the Schools Examinations Council (SEC) to sit under its criteria for "general subjects" opposed to the criteria for "Computing" (The Royal Society, 2012, p.163). As a result of the Stevenson report (1996) "Information and Communications Technology in UK Schools", the term ICT was introduced into curriculum dialogue for the first time and went on to be increasingly acknowledged as a key skill in conjunction with its numeracy and literacy counterparts. IT has been partnered with other curriculum areas such as business and more formally in the first National Curriculum, embedded within "Design and Technology" (DfEE, 1990); recent policy development though has seen a paradigm shift, with computing being put back into the forefront of the curriculum arena (The Royal Society, 2012).

2.2 Children’s engagement with technologies and the introduction of computer science into the primary curriculum

There is an abundance of research around technology and its potential impact on the younger generation (Tapscott, 1999, 2009; Howe and Strauss, 1991, 2000; Prensky, 2001; Oblinger and Oblinger, 2005 and Palfrey and Gasser, 2008). Many authors propose that as a result of children and young people being immersed in a digital world, their behaviour has changed with “claims that they think differently, they learn differently, they exhibit different social characteristics and have different expectations about life and learning” (Jones and Shao, 2011, p.3). To support this perceived generational change Prensky (2001) presented the narrative around “digital natives and digital immigrants” (p.1), with the former being used to describe children and adolescents that are familiar with and have a sense of fluency in the use of technology on the grounds that they had been born into the digital generation. The latter term of digital immigrant was assigned to older generations who may well be effective users of technology but have had to adapt to a new technological environment and adopt new skill sets. In response to the idea of this generation “thinking differently”, Prensky (2001) further claimed that “as a result of this ubiquitous environment and the sheer volume of their interaction with it, today’s students think and process information fundamentally differently from their predecessors” (p.1). This bold, scientific claim that engaging with technology can lead to structural changes to occur in the brain has since been challenged (Hattie, 2008) and is discussed further on in the study. Perhaps what should be reflected upon here is the notion that technological advances “are bringing about the emergence of new learning styles adopted by students” (Dede, 2005, cited in Margaryan et al, 2008, p.1) and as a result of this, pedagogy and practice needs to be responsive to these changes.

From an early years perspective, Morgan and Siraj-Blatchford (2013) state that “the number and the range of ICTs that have been introduced into the home has massively increased in recent years and a significant proportion of this new technology has been purchased specifically for use by young children” (p.4); it is not uncommon for “young children to own, access and use new technologies, for example, hand held devices on a daily basis” (Yun Sung, Siraj Blatchford and Kucirkova, 2016, p.3). This emphasises the need for the early year’s curriculum to also be responsive, supporting the aims of the ‘Primary Coding Project’ more

specifically to “inspire students to use technology from the earliest possible age...and give staff extra skills to deliver computing to younger students (States of Jersey, 2014).

In relation to technology, in particular hand held devices, society has witnessed an exponential growth in the use of iPads (Apple inc, 2013; Berson et al, 2012), with Henderson and Yeow (2012) stating that “Apple’s iPad has attracted a lot of attention since its release in 2010 and one area in which it has been adopted is the education sector” (p.78). Undoubtedly there are benefits and opportunities to be accredited to integrating iPads within a primary schools setting. The findings of Henderson and Yeow’s (2012) study suggest that “students were generally very eager to use the device, and able to pick it up and use it intuitively with little instruction” (p.87), but this leads back to the idea purported by Schmidt (2011) that current pedagogy and delivery may be inappropriate, which could result in schools and educators being sucked into a marketing vacuity and consumerism model of practice. Research does indicate that young children are more likely to engage in technology and be motivated by it (Fessakis et al, 2012; Henderson and Yeow, 2012) though there appears to be little statistical evidence showing any direct correlation between the impact on children’s cognitive development and ultimately attainment (Hattie, 2008; Heinrich, 2011). In light of the current changes to the ICT curriculum (DfE, 2015) it is reasonable to suggest that the Government and some stakeholders had felt that the existing ICT curriculum was not developing the full range of skills required by the Digital sector (Livingstone and Hope, 2011; Schmidt, 2007), hence the shift back to Computer Science as a discipline.

In response to the idea of moving school children from being “digital consumers to digital creators” (Kenyon, 2013) it would be pertinent to elicit the incentives and benefits to embedding computer programming into the primary curriculum. A review undertaken by Livingstone and Hope (2011), initially commissioned to examine the skill needs of the UK’s video games and visual effects industries, suggested that the current educational system was not meeting the needs of these industries in relation to developing a system or model that supports the “fusion of art and technology skills”, going on to state that “if the UK is to retain its global strengths in the high-tech creative and digital industries more generally it must urgently address the need for more rigorous teaching of computing in schools” (Livingstone and Hope, 2011, p.3). This presents both policy makers and educators with a dilemma in

regards to ensuring that the curriculum primarily meets the holistic needs of children and young people, yet at the same time supports the needs of the industry in terms of employability and sustaining economic growth.

This leads into another debate within computer science and children's engagement with technology, around gender and the under representation of women in this domain, which is relevant for this study that is examining the correlation between computer programming and problem solving. If girls were to feel that computer programming was not for them then they could be resistant towards the curriculum change and more directly the teaching and consequently not develop these problem solving skills. Although this could be argued to be a significant area of research in its own right, it is clearly a pertinent topic to cover within the literature for this study and will provide some foundations for the analysis further on.

2.3 Women in Computing

Prottzman (2011) states that "even though the first computer programmers were women, they currently make up only a quarter of the computing industry" (p.iv). This concern is supported by Margolis and Fisher (2003) who identified that "at the turn of the century women were surfing the web in equal proportion to men, and women made up a majority of Internet consumers. Yet few women are learning how to create, invent and design computer technology" (p.2). Current statistics suggest that the balance is still inequitable with data gathered by the American Association of University Women (AAUW) (2015) indicating that "the percentage of women in computing careers has dropped from a high of near 40 percent in the mid-1980s to just 26 percent in 2013", though it should be noted that this data is not representative in some Asian countries. Girls are studying and excelling in maths and science yet this increase in educational choices and achievement is not mirrored in engineering and computing subjects (Corbett and Hill, 2015), though various authors have taken on the baton to address this underrepresentation (Abbate, 2012; Smith, 2013; National Science Foundation, 2014c).

Potential reasons cited for this underrepresentation are numerous (AAUW, 2015). They include both structural and cultural barriers, which have resulted in researchers examining

both college and workplace environments in an attempt to ascertain factors that may be putting women off careers in this domain. Issues such as the narrow focus of engineering, isolation and work life balances are highlighted as being potential contributing factors, however, in relation to this project, the notion of stereotypes and biases is worthy of further examination.

2.4 Gender bias and 'stereotype threat'

Stereotypes and biases are significant cultural factors that may impact on women's manifestation in the computing world. According to Dovidio et al (2010) a "stereotype is an association of specific characteristics with a group (p.37) which can be both descriptive, in regards to telling us what men and women are like, or more dangerously, prescriptive, informing us of what men and women should be like. Stereotypes can be drawn upon when gathering and processing new information about individuals or groups of people and making predictions, though this act draws on less cognitive resources than if we were to base our information gathering on our own individual observations, whenever we were introduced to new people. In support of this statement Fiske and Taylor (1991) wrote that "human beings have been described as cognitive misers who are reluctant to engage in effortful thought unless absolutely necessary" (p.132). Although this could be seen as a bold assertion to make, it supports the idea held by Heilman (2012) and Dovidio et al (2010) who state that "for this reason, stereotypes are very powerful and difficult to override, and they can lead to biased behaviour or discrimination when we view members of a group based on their group status rather than as individuals" (cited in AAUW, 2015, p.37).

Gender stereotypes can be seen to apportion greater social value on males and view a man's competence more favourably than a woman's (Ridgeway, 2001). An area where men are stereotypically viewed as being more competent than women is in mathematics. Ironically, this idea can perpetuate through parents' and teachers' expectations of children which can then go on to affect the attitudes children develop towards maths (Gunderson et al, 2012; Varma, 2010). This would also align to Rosenthal's self-fulfilling prophesy or Pygmalion theory (1994) around expectancy effects. The AAUW (2015) also highlight that "parents' and

teachers' own feelings about math can rub off on children" (p.37) identifying a study that found:

the more anxious female teachers were about math, the more likely girls (but not boys) in their class were to endorse the commonly held stereotype that "boys are good at math, and girls are good at reading" and the lower these girls' math achievement was (Beilock et al, 2010, p.)

Although the context here is maths I feel this could just as easily be replaced with the term computing, with "the more academic focus of computer science and its deep links with mathematics" (Wing, 2008; DfE, 2013; De Araujo, Andrade and Sere Guerrero, 2016; Boylan, 2017) and personally two key points emerge from this statement. The first is connected to the notion of 'stereotype threat', a phenomenon described by Steele (1997) as "an anxiety that people experience when they fear being judged in terms of a group-based stereotype" and to be prone to this "individuals must only be aware of the stereotype, identify with the group that is stereotyped, and care about succeeding in the domain in which the stereotype applies" (p. 802). In relation to performance and achievement, stereotype threat is said to induce physiological stress responses which can include an increased heart rate and raised cortisol levels which have been suggested to "hijack cognitive resources, specifically working memory capacity, needed for successful performance" (Schmader and Croft, 2011, p792). Koch et al (2014) concur that there is evidence to show that stereotype threat has decreased math performance amongst some women. This could be a contributing factor as to why women remain underrepresented in the computing workforce (AAUW, 2015) and leads into the next point which is around the role of parents and educational practitioners in the development of gender-related attitudes. In relation to this project the focus, however, is on the role of the teacher rather than the parent.

It has already been ascertained that a teacher's expectations of children can go on to affect the attitudes that children can then develop towards a subject (Gunderson et al, 2012; Varma, 2010), so the gender of the teachers involved in this project, the majority of which were female, could become an influential factor in how the new computing curriculum is both perceived and embraced. This will be examined in the data collated from the surveys of the Year Two teachers.

Gender could also be a factor to consider when analysing the data of the focus groups which involved both boys and girls. There is clear evidence to suggest that stereotypes can inform preferences (AAUW, 2015) so teachers should remain mindful of this. Gender identity and expectations are established at an early age (Cvencek, Greenwald and Meltzoff, 2011). The Primary Coding Project (States of Jersey, 2014) aims to work with children from Nursery through to Key Stage 2 which means that it could positively influence children's perception of the subject before stereotypes become established; this also supports the statement by Prottzman (2011) indicating that "women are most likely to succeed in CS when they are introduced to computing concepts as children and are exposed over a long period of time" (p. iv).

So why is this an issue? The underrepresentation of any gender within a particular field of study or workforce is worthy of further of scrutiny in a pursuit to address any potential barriers and biases that may be in place. In a response to address the shortage of women in science, technology, engineering and mathematics (STEM subjects), with computing given a particular emphasis, President Obama (2014) made reference to a sporting metaphor exclaiming "half our team, we're not even putting on the field. We've got to change those numbers". AAUW (2015) have been a leader in the field in attempting to address this imbalance, through igniting nationwide interest which has led to "new initiatives in schools, colleges and the government" and although some progress has been made in some fields of science "in engineering and computing women remain a distinct minority" (p.ix). Diversity within these fields is essential if society aspires to develop creativity and support innovation; I would advocate that both girls and boys need to be introduced to the concept of computing and computational thinking in the early years curriculum and subsequently empowered to achieve in any field they endeavour to pursue. Interestingly, an area of computing that has gained recent exposure with both younger and older generations alike is that of coding, which will be explored in the next section.

2.5 The coding explosion

Having previously identified that the terms 'programming' and 'code' have been used interchangeably within the literature it is interesting to note that in regard to recent initiatives

it is the term 'code' that has appeared to be used more favourably. To illustrate, from a policy and practice perspective, Estonia introduced coding in primary schools in 2012 (Wilson, 2014) and the United Kingdom followed suit last year (Cellan-Jones, 2014). United States initiatives such as the "Hour of Code" (code.org, 2015), supported by large organisations like Microsoft and Google, advocate that every student should have the chance to learn computer coding, though the idea is not new.

Wolfram (1995) asserted that fundamentally "learning to code should be seen in the same way as learning the skill of handwriting so children can then use it as a tool for solving problems in a wider context" with deeper level thinking occurring when young children "learn to conceptualise the problem they're creating the code to solve" (p.46). Studies such as Liao and Bright (1991) also identify positive effects of computer programming learning to the cognitive development of young children although it is also stressed that it is imperative that any learning activities for programming must be "carefully designed so that they are meaningful and challenging (and thus engaging) but also achievable in order to avoid the discouragement of children" (Perlman, 1976, p.14). According to Hauglands (1992), conception of the term "carefully designed" computer programming software and environments should "support autonomous or guided open-ended explorations in the process of which the children participate actively, think and control the computer" (p.88). This was considered in the designing of the problem solving tool in Chapter 4.4. On reflection upon the statements drawn from these studies, emphasising the need for meaningful and engaging learning opportunities to avoid potential discouragement could resonate with the discourse that is sometimes associated with the maths curriculum (Jennings and Dunne, 1996: Hersh, 1997;), with Hersh (1997) declaring over a decade ago that:

People don't like mathematics because of the way it is *mis-represented* in school. The maths that millions of school children experience is an impoverished version of the subject that bears little resemblance to the mathematics of life or work, or even the mathematics in which mathematicians engage (p.18).

Dunne (1996) subsequently went on to develop the "Maths Makes Sense" learning system (Dunne, 2013) in an effort to transform primary children's understanding and enjoyment of maths, an initiative that a number of primary schools in Jersey have adopted (Dunne, 2005).

In relation to computer science, it is imperative as a recently introduced policy change that it is perceived as purposeful to its audience, teachers and students alike, to avoid disengagement.

2.6 Computing and the development of metacognitive skills

Two decades ago Papert (1993) talked about the notion of “computer aided instruction” (CAI, Suppes, 1990) which looked at how computers could be used to teach children, or as he articulated, how “the *computer is being used to program the child*” (p.5) with the focus being on the tool opposed to the user. This is relatable when looking at the debate around the ICT curriculum discussed back in Chapter 2.2 and resonates clearly with the ideas asserted by Schmidt (2011), Livingstone and Hope (2011) and The Royal Society (2012). Research has suggested that through the process of trying to teach the computer how to solve a particular problem however, children are opened up to the opportunity to express their thoughts, observe the outcomes, elucidate their thought processes and receive instant feedback through causality (Penner, 2000). What is more, Clements and Nastasi (1999) suggest that the process of programming not only promotes the cognitive development of a child but more importantly encourages metacognitive skills (Clements and Nastasi, 1999) by encouraging children to reflect upon their own thinking as they work through the problem. Together this raises questions about the extent to which children’s ‘problem solving skills’ can be supported by their engagement with computer programming.

With this in mind, I was recently made aware of Rosendale Primary School in England (name of which was reported in the study), who were working on a project funded by the Education Endowment Foundation (Rowland, 2015), conducting a “randomised control trial that focuses the impact of teaching metacognition in 30 primary schools across the country” (p.5). This project was in response to the “Pupil Premium” (Dunford, 2013-15, cited in Rowland, 2015, p.7) initiative which ascended from a political commitment to supporting social mobility during the reign of the coalition government (2010-15). In relation to policy development the Pupil Premium is being heralded as “one of the best policies to come out of the Department for Education (DfE) or its predecessor departments” (Rowland, 2015). The reasons for this encompass the emphasis on schools being able to support their disadvantaged pupils,

regardless of catchment area, with the notion that these children can be present within poorer and more affluent neighbourhoods. Schools are awarded funding under the “Pupil Premium” (Rowland, 2015) policy but equally held accountable for the impact that the funding has; what individual schools do have though is the autonomy to invest the funds allocated into pedagogy and practice that will support an individual child’s needs, in a responsive manner.

Rosendale Primary chose to focus on the concept of metacognition in order to try and close the attainment gap within their school. They arrived at this decision by drawing from evidenced based research provided by the Sutton Trust-Education Endowment Foundation (EEF) Teaching and learning Toolkit which “is increasingly being used by schools as an accessible summary of educational research which provides guidance for teachers and schools on how to use their resources to improve the attainment of disadvantaged pupils” (Rowland, 2015, p.42).

Relating the Rosendale case study (Rowland, 2015) back to my own research project, Flavell (1976) defined metacognition as “knowledge about cognition and control of cognition, for example, I am engaging in metacognition if I notice that I am having more trouble learning A than B; [or] if it strikes me that I should double check C before accepting it as fact” (p. 232); so effectively I would suggest that metacognition is integral to problem solving. It is also relatable on the grounds that the States of Jersey chose to invest substantial resources into the ‘Primary Coding Project’ (2014) with one of its policy and pedagogical aims to “deliver computing to younger students, enthuse pupils to be the next generation of developers and develop wider skills, including numeracy and problem solving” (States of Jersey, 2014). Featherstone and Bayley (2006) identify problem solving as one of the six key skills required for successful learning and state that:

The ability to meet the challenge of a problem, to approach it in an ordered and systematic way, to use previous experience and knowledge to develop strategies for solving it, to evaluate the success of a chosen approach, to persevere, where necessary rejecting the unsuccessful and starting again are all very sophisticated attributes. They are not, however, beyond the young child and are essential for independence of mind and thought (Featherstone and Bayley, 2006, p.55).

In response to this idea I would assert that computer programming establishes a significant competence for learning and from a pedagogical viewpoint is “considered beneficial in the improvement of higher order thinking over the development of algorithmic problem-solving skills” (Fessakis et al, 2012, p.87). Perseverance is also a key attribute in developing resilience which links into Claxton’s (2007) idea around the need to support children in “being ready, willing and able to lock on to learning” (p.17). He refers to perseverance as “stickability” and “being able to tolerate the feelings of learning” (Claxton, p.17) which will be examined in Chapter 2.9. So, this suggests that incorporating programming into the curriculum may not only support the development of children’s problem solving skills and awareness of metacognition, but also, inadvertently, support the ethos of the Pupil Premium initiative (Dunford, 2013-15, cited in Rowland, 2015, p.7), which is due to be implemented in Jersey from 2016 (States of Jersey).

The next section will explore related studies on problem solving, examining its cognitive foundation within the domain of psychology and computational intelligence. Various approaches to problem solving will be presented alongside factors that can influence the cognitive process. A discussion around the cognitive characteristics of problem solvers and the impact of their knowledge will also take place followed by an examination of how this fits into the educational arena and more specifically the purpose of this study.

2.7 Theory of Human Problem Solving

When the magician pulls the rabbit from the hat, the spectator can respond either with mystification or with curiosity. He can enjoy the surprise and the wonder of the unexplained (and perhaps the inexplicable), or he can search for an explanation (Simon and Newell, 1970, p.145).

With origins found in Aristotle's era (384-322BC) it is evident that researchers across multi-disciplines have long been intrigued and sought to understand the cognitive process of human problem solving and though complex to theorise, it is equally identified by Zhong, Wang and Chiew (2010) as “one of the basic life functions of the natural intelligence of the brain” (p.81). When searching the literature for a statement that would encapsulate an explanation of human problem solving I was overloaded with information (Chang, D’Zurilla and Sanna, 2004;

Smyth, Morris, Levy and Ellis, 1987; Sternberg, 1994 and Ward, Smith and Vaid, 1997; Zhong, Wang and Chiew, 2010). Newell, Shaw and Simon's (1958) also note that from their own experience of searching for a definition, in an attempt to inform their own research, they were initially left unsatisfied. Reasons for this resonate in the quote above which highlights the notion that problem solving, at that time, was perceived by some to be a mystical and magical activity perhaps worthy of preserving as unexplainable, making the alignment to that of the magician's code. The notion of 'curiosity' as a characteristic in problem solving will be explored further on in the study (Chapter 2.9).

To conduct a comprehensive review of psychological literature around problem solving is beyond the scope of this study but has been addressed in various other sources (Chang, D'Zurilla and Sanna, 2004; Smyth, Morris, Levy and Ellis, 1987; Sternberg, 1994 and Ward, Smith and Vaid, 1997). Though some psychological perspectives have been drawn upon for the purposes of this study it was felt pertinent to examine research that has focused on education and more specifically computing (Clements and Gullo, 1984; Fessakis, Gouli and Mavroudi, 2012). Through researching, what I felt I needed to distinguish between, or at least examine further, was the potential relationship or synergy between problem solving and logical reasoning.

As previously acknowledged, problem solving is a term that is used across disciplines, at times from different perspectives and therefore frequently assigned different terminologies; an example of this lies within the field of psychology where it is referred to as a mental process but within computer science it becomes a computerised process. In relation to algorithms, which are defined as a "well defined procedure, or a sequence of unambiguous instructions" (Zandbergen, 2015, p.76), leaving no room for subjectivity, this definition can be applied across both fields. For example, a mental process could involve the steps necessary to make a cup of tea, where a step by step process is applied in order to achieve the end result; in this instance the process could vary according to the individual and the particular goal required. Similarly, to make a computer carry out a task, you need to write a program or in effect - instruct the computer as to what you want it to do and how to do it. The computer then executes the program, following each step as instructed, to accomplish the end goal. In both of these scenarios the instructor or programmer gets to dictate the process, but the algorithm

remains the basic technique used to get the job done. A distinctive feature across both of these domains is that in the creation of an algorithm it should be re-creatable, so effectively every time you carry out the same algorithm it should perform in the same way and create the same result. Iteration is also a term referred to in computing, referred to back in Chapter 1.9 and involves the repetition of a process until a condition is met or in relation to problem solving, a solution is found. Every repetition is effectively an iteration and the results of one iteration then becomes the start point for the next.

According to Schraw, Dunkle and Bendixen (1995) problems, in general, can be classified into two categories, ill-defined and well-defined, from either of which solutions are then sought. Ill-defined problems can be seen as those problems that are amiss of clear goals, solution pathways, or expected solution opposed to well-defined problems which have specific goals, clearly defined solution pathways and clear expected solutions.

In examining approaches and factors in problem solving further, Ormrod (1999) and Polya (1954) proposed that a problem was essentially made up of three components; the givens, the goals and the operations with Wang (2010) further clarifying the terms as “the givens are information available as part of the problem, the goals are defined as the desired termination state of a solution to problem and the operations are potential actions, or iterations, that can be executed to achieve the goals of a solution” (p.82). These three components were considered characteristics during the planning and design phase of the problem solving activity and will be discussed in the design section (Chapter 4.4).

For any problem presented there is a concomitant problem space which Wang and Chiew (2010) identify as “all the possible goals and paths related to the problem known by a problem solver” (p.82), though it should be acknowledged that a solution may not always be available within the solver’s space for various reasons such as the problem being ill defined, ambiguity of goals or lack of method or pathway in the solvers cognitive domain, or present state of knowledge, to draw upon. This state of knowledge is purely what the problem solver already understands about the given problem in that specific time that can be retrieved almost

instantly. Again these are all relevant factors that were considered in the design process of the problem solving activity that was created.

Clearly, problem spaces can vary immensely in size from negotiating a move in chess to trying to solve life problems, for example with relationships, where solutions can be less linear. Consequently, the problem solver's search for a potential solution, or algorithms, can result in an "odyssey through the problem space, from one knowledge state to another, until his current knowledge state includes the problem solution – that is, until he knows the answer" (Simon and Newall, 1971, p.151). So effectively this challenges the solver to draw upon metacognitive skills that are not already within the problem space and in regards to the design of the problem solving activity implemented in this study it was crucial to capture some of this algorithmic process, through examining the pathways and quantity of moves it took some children to solve the tasks in comparison to others (see Chapter 4.4).

A plethora of approaches to problem solving have been studied within psychology (Matlin, 1998; Ormrod, 1999; Rubenstein and Firstenberg, 1995; Wang et al., 2006; Wang and Ruhe, 2007). These include methods such as analogy, which according to Wang and Chiew (2010) refers to "reducing a new problem to an existing or similar one for which solutions have already been known", analysis and synthesis, or in other words "reducing a given problem to a known category and then finding particular solutions" or applying an heuristic approach that relates to "adopting rule of thumb or the most possible solutions" (p.83). Attempting to derive an explanation of the processes of human thinking or information processing from inside the head, can obviously be met with some scepticism (Simon and Newall, 1971, p. 147). This is a challenge that could also be aligned with Freud's work around the unconscious (Robinson, 1993).

Although some basic characteristics of the human information processing system have been identified it is argued that some of the finer detail is elusive due the processing system being influenced by the task environment, and therefore require adaptive thought (Garton, 2004). This would link back to the *jam sandwich* algorithm discussed back in Chapter 1.9 where the children were seen to be adapting their thought processes in order to offer more precise instructions to solve the given problem and achieve the appropriate outcome.

Wang and Chiew (2010) present typical psychological traits associated with successful problem solving which include the correct identification of goal, persistence, adoption of efficient search strategies and the ability to trace back to, or re-visit a previous point in search for a solution process. Significant traits between the expert and novice problem solver are highlighted by Smith (1991) as:

scope of knowledge on accumulated information, problem solving schemas, skills, expertise, memory capacity, problem representation ability, abstraction and categorization abilities, analysis and synthesis skills, long term concentration ability, motivation, efficiency and accuracy (p.225).

It is important to emphasise that the cognitive process of problem solving is a complex and dynamic procedure, involving interactive meta-cognitive behaviour and unlike a machine, a human's capacity to problem solve can be influenced by age and external influences (Payne and Wenger, 1998). For example, an older person presents a juxtaposition where they may be able to draw from a wider pool of knowledge to solve a problem yet equally age could inhibit the efficiency of problem solving due to physiological or psychological factors. Similarly, DeLoache, Miller and Pierroutsakos (1998) refer to age from the perspective of children as problem solvers and state that whilst this is "marked by flexibilities and opportunism from an early age, their performances are limited by the strategies they have access to, the resources available for problem solving, their ability to manage the process and the social contexts in which problems are presented" (p. 826).

Additionally, it should be acknowledged that motivation and attitude could influence an individual's capacity to engage successfully in the problem solving process and could be linked to the ability to concentrate (Csikszentmihalyi and Nakamura, 1989), as well as external social pressure. This is an evitable limitation of the quantitative base of data but at the same time a necessary compromise as a result of the methodological choices made. When analysing the data gathered from the problem solving activity for this study (see Chapter 6) it will be imperative to reflect further upon this.

2.8 Problem solving in young children

Within the context of early childhood development, it is now well documented that babies are born with a biological capacity and drive to respond to complex problems to help them make sense of the world around them (Gopnik, Meltzoff and Kuhl, 1999; Hobson, 2002; Bornstein, Arterberry and Nash, 2011). The role of the environment, alongside the “communicative and social nature of human interaction” (Garton, 2004, p.13), often referred to as the epistemic triangle (Chapman, 1991), are also viewed as crucial components in actively supporting the developing child. This theory integrates the Piagetian view of the child interacting with its environment, but also combines Vygotskian (1986) recognition of social interaction. The emphasis of this particular research is placed on the former view due to the context and design of the problem solving activity, which examines children’s mental activities in one environment. This could be viewed as a limitation to the study due to the shift in thinking and general understanding of how of knowledge is gained and used in particular scenarios and situations (Penner, 2000). However, I would advocate that the notion of developing knowledge through social interaction and the physical environment is recognised through the children engaging in peer support and collaborative problem solving activities (Garton, 2004) within the programming sessions delivered in the classroom. This would resonate with Newman, Griffin, and Cole (1989) who argued:

that considering the social environment within which an activity occurs is a necessity for understanding and fostering cognitive change. That is, conceptual change is not just an intrapsychological phenomenon; rather, it is the result of shared activity in which interpsychological processes occur (cited in Penner, 2000, p. 7).

Although definitions of human problem solving have already been offered, to support the focus of this study, exploring children’s problem solving in Key Stage 1, it was felt pertinent to offer some definitions relating specifically to children. Garton (1993) defines problem solving as “children’s thinking and learning in general or as the particular tasks that children are required to solve” (p.3). DeLoache, Miller and Pierroutsakos (1998) however, present a more detailed and comprehensive definition which acknowledges problem solving as:

consisting of a goal, one or more obstacles that make achieving the goals not immediately possible, one or typically more strategies that can be used to solve the problem, other resources (knowledge and other people, etc.) that can affect which strategies are used, and evaluation of the outcome of the problem-solving process (cited in Garton, 2004, p.4).

Garton's (1993) definition has breadth opposed to specificity and DeLoache, Miller and Pierroutsakos (1998) connect the notions of problem solving and logical reasoning together. Revisiting the task that was set earlier to examine the potential relationship or synergy between problem solving and logical reasoning, Garton (2004) would argue that problem solving could be distinguished from logical reasoning on the grounds that "problem solving can refer to both the activity *and* the task" compared to logical reasoning "which normally refers solely to the cognitive activity, or the particular task a child is asked to solve" (p.4). For the purposes of this study I have chosen to use the term problem solving, as it covers both the cognitive process and the task, but I actually see the terminology as interchangeable.

The ability to solve problems can often involve dealing with pragmatics, which aligns with logic and effectively problem solving, but also with semantics (Corte and Verschaffel, 1987; Lamon, 1993), which is having the capacity of being able to interpret the problem. Given that the focus of this study is examining children's abilities to find solutions to given problems, when designing the problem solving activity, semantics was something that needed to be considered. This was key in regards to being able to develop an appropriately designed activity that would as far as possible, not exclude a child's ability to respond on the grounds that they could not read or comprehend the written instructions. As previously identified, this also informed the research study's justification to focus on the latter phase of Key Stage 1, as from a cognitive and language perspective this cohort of children, on the whole, would have had more time to acquire and establish skills in both of these domains.

Linking back to Papert (1993) and his Piagetian inferences, this stage of cognitive development was relevant to the second epoch of "concrete operations" (Piaget, 1965, cited in Papert, 1993, p.153), a period of concrete logic in which "thought goes far beyond the immediate situation but still does not work through the operation of universal principles" (Papert, 1993, p.153). At this stage of development, he perceived the child to be mature

enough to use logical thought or operations, or rules, but still only able to apply logic to objects in the physical sense, hence the term concrete. In other words, children in this developmental stage should be able to solve problems in a logical fashion, but are typically not able to think in an abstract or hypothetical domain. In an attempt to clarify my own thinking around the concepts of pragmatics and logic I would assert that they are interconnected and are approaches that can be employed in the process of problem solving. Sometimes the problem may require some abstract thinking and the need to come up with a creative solution, so although similarities exist in the characteristics in these concepts I would propose that they are complementary, but manifestly different.

Bringing this back to the focus of the study, which was to examine the impact of a curriculum change on enhancing children's problem solving skills, it would be pertinent to further examine the theoretical ideas around how children think, and in effect engage in the process of learning, more directly to their influence on the early years curriculum.

As previously touched upon, Piaget (1965) famously presented his ideas of how children's minds work and although since contested (Gardner, 1999; Satterley, 1987), he still remains hugely influential in the field of educational theory and it could be said gained a resurgence of interest among developmental psychologists over the last decade (Feldman, 2004; Homer and Hayward, 2008; Kuhn, 2008; Shayer, 2008). His insight into the role of maturation and its influence in children's developing capacity to make sense of the world around them, proposing that they cannot undertake certain tasks until they are psychologically mature enough to do so, has undoubtedly influenced both curriculum and practice.

Piaget (1965) inferred that children's thinking does not develop in a smooth trajectory and that there were particular points at which their thinking "takes off", transitioning into completely new areas and capabilities, as identified earlier, in particular relation to problem solving. This has been taken to mean that prior to these outlined ages and stages, children are not capable, regardless of a child's individual cognitive capabilities, of understanding things in certain ways and this framework has been influential in structuring the school curriculum. Accumulating evidence (Birney and Sternberg, 2011) challenged the rigidity of the proposed stages of development, with its particular focus on children's age, in addition to the

argument that many children accomplish concrete operations earlier than Piaget's proposals and conversely, the acknowledgement of some people never attaining formal operations. This was articulated and evidenced by some of the teachers involved in the delivery of the Primary Coding Project (States of Jersey, 2014), who noted that during the computer programming sessions some of the younger cohorts that were exposed to the new curriculum exceeded the proposed learning outcomes and expected attainment levels. So although Piaget's contribution to educational and developmental theory has been significant (Garton, 2004) and it contributed to some of the thinking around the quantitative methodological design, its heavy focus on the individual at the detriment of social or cultural influences on learning should also be acknowledged.

Having examined some of the theories that underpin the idea of young children as problem solvers (Gopnik, Meltzoff and Kuhl, 1999; Hobson, 2002; Bornstein, Arterberry and Nash, 2011) and acknowledged the wider influences of social, environmental and cultural learning (Garton, 2004) it interesting to then align this back to curriculum policy and societal expectations. According to Fadel, Bialik and Trilling (2015):

Educating our children, in theory, is meant to prepare them to fit in with the world of the future, empowering them to actively work to improve it further. Yet there is growing evidence from scientific studies, from employer surveys, from widespread public opinion, and from educators themselves, that our education systems, globally, are not delivering fully on this promise—students are often not adequately prepared to succeed in today's, let alone tomorrow's, world.

In stark contrast to some of the theories already identified that acknowledge the incredible cognitive potential of young children, the educational ethos of schools has historically leant towards infantilising children, exposing them to a curriculum which is based around extrinsic demands, prescribed by a curriculum design to meet political and societal expectations (Carr, 1998). Building on the notion presented by Fadel, Bialik and Trilling (2015) around preparing and empowering children to be able to function effectively in the future world, the next section explores the concept of teaching and learning in more depth, acknowledging the position of computer programming and its potential in developing children's metacognitive skills.

2.9 Thinking about thinking – a pedagogical perspective

“To maintain the state of doubt and to carry on systematic and protracted enquiry - these are the essentials of thinking” (Dewey, 2012, p.13).

Although essentially still examining the cognitive aspects of problem solving, in particularly the notion of cognitive conflict, in an attempt to unravel some of the origins of thinking, I have drawn upon Dewey (2012) who suggests that it involves elements of perplexity, confusion or doubt and that it is not an instance of spontaneous combustion but “something specific which occasions and evokes it” (p.12). Thinking can cause a state of disequilibrium (Piaget, 1929) and in relation to problem solving require the thinker to draw on past experience and prior knowledge in order to make sense of the situation. This notion is supported by Garton (2004) who states that “learners must therefore search for new constructs, which can synthesize the different viewpoints and restore equilibrium. This process occurs internally and is later manifested externally by talk and actions; it has therefore been called an ‘inside-out’ theory” (p.36). So, although both theories acknowledge the cognitive process that individuals go through to make sense of a situation or problem, the latter emphasises the act of externalising the action, using communication and the environment to restore cognitive balance. In relation to computer programming it has been documented by Werner, Hanks and McDowell (2004) that “pair programming”, or programming with a partner, can be beneficial to both students (cited in Werner, Denner and Campe, 2012, p.215). Again this would affirm the pedagogical approach taken by the Primary Coding Project (State of Jersey, 2014) team to employ peer support methods to consolidate cognitive development and also go some way to support differentiation within the cohort.

Although complex to define, what the quote by Dewey (2012) highlights is that perseverance is a contributing factor in the process. When talking about teaching and learning the term pedagogy is a familiar term applied to the art of teaching but interestingly, Papert (1993) poses a very pertinent question around the omission of an equivalent term in the art of learning. A further question is then posed in relation to this omission of term being aligned to societal value. If we consider teacher training courses we talk about methods that can be employed to make us better teachers, yet there appears to be less emphasis on methods to

make us better learners, though Claxton (2007) and Hattie (2008) go some way to address this in their work around “Building Learning Power” and “Visible learning: A synthesis of over 800 meta-analyses relating to achievement”.

Historically, heuristics is a term that has been applied to the art of intellectual discovery, which links back to Descartes and if stretched, to the Greeks (Papert, 1993). More contemporary thinking has been linked to Polya (1954), a mathematician whose theme throughout the book ‘How to Solve it’ resonates with Papert’s (1993) criticisms that “school gives more importance to knowledge about numbers and grammar than to knowledge about learning, except in place of the word learning, Polya says principles of solving problems” (p. 85). I would suggest that this links back to the more traditional educational thought that sees intelligence as inherent and subsequently an attribute not associated with being learned. Wing (2006) also referred to the notion of “heuristics to reason about possible solutions” (cited in De Araujo, Andrade and Sere Guerrero, 2016, p.1).

Revisiting the justification of the focus of this study in the introduction, Gagne believed that “the central point of education is to teach people to think, to use their rational powers, to become better problem solvers” (1980, p.85) and like Gagne educators regard problem solving as an imperative life skill (Jonassen, 2000). This aligns clearly with Dewey (2012, p.13) who states that “the most important factor in the training of good mental habits consists in acquiring the attitude of suspended conclusion, and in mastering the various methods of searching for new materials to corroborate or to refute the first suggestions that occur”. However, what we appear to have seen in the current educational system is a misplaced emphasis on memorizing information and completing examinations, which could be argued has become the primary arbiter of success in society (Claxton and Lucas, 2015).

Although a shift of emphasis is evident in some individual schools (Rowland, 2015) it raises a very complex question about children’s learning in schools today. From a 21st Century perspective, the question to be asked is - what should children learn for a world where a lot of routine and impersonal chores can be taken care of by computer systems? It could be argued that memorising copious amounts of content in an age where we can almost instantly

find the answer to any question via the Internet, is no longer a requirement. Fadel, Bialik and Trilling (2015) suggest that:

there are many reasonable answers to these questions but they rarely focus just on teaching more knowledge, rather on learning more relevant knowledge, how to apply that knowledge in new and different ways, and on developing the other three dimensions of learning: skills, character qualities, and meta-learning strategies (p.26)

In relation to the focus of this study the question becomes – should children be developing problem solving skills that allow them to succeed in 21st century life or do they need skills to pass exams that will allow them access to universities and recognition from potential employers? These philosophical questions are on one hand beyond the scope of this study yet at the same time the synergetic relationship between them makes them all relevant. In response to these questions, Fadel, Bialik and Trilling (2015) present the concept of ‘four dimensional education’ (p.67) with the first dimension relating to the acquisition and application of relevant knowledge. Building on this idea and aligning the concept to my own research I propose that the other three dimensions can be synthesised to competencies that are integral to the aims of this project, but in this case they encompass;

- Skills = computational thinking
- Character = curiosity, perseverance and resilience
- Meta-learning = metacognition

Fadel, Bialik and Trilling (2015) question the term metacognition as being “overly technical” (p. 168) in comparison to meta-learning but for the purposes of this study I felt meta-cognition emphasised the act of thinking, which in turn sets the foundations for learning. A definition of terms was established back in Chapter 1.5 and the notion of computational thinking was identified as a “fundamental analytical skill that everyone, not just computer scientists, can use to help solve problems, design systems, and understand human behaviour” (NAP, 2010, p.vii). It is not reliant upon technology though computation has been embedded in the curriculum through various approaches such as computer literacy, which involves using tools to create things such as newsletters and webpages, or other approaches that could involve the teaching of various programming languages or programming applications, such as games

and robots. Having already examined the relationship between computing and metacognition in Chapter 2.6, the first two approaches will now be explored in more depth, followed by an examination of their contribution to children's learning.

2.10 Technology and computational thinking

There is a division in thinking around the role of technology in computational thinking with NAP (2010) of the opinion that "at its core, computational thinking was independent of technology – that being a competent computational thinker did not necessarily imply anything about one's ability to use modern technology" (p. 61). Bell, Witten and Fellows (2006) refer to this as "Computer Science – unplugged", as previously introduced back in Chapter 1.5, focussing on the principles that underpin computer science, but providing guidance for teaching these without the necessity of a computer. Conversely, there is the view that the relationship between computational thinking and emerging technology is so connected that they could be regarded as one and the same thing. It is with this interpretation that I move into the next stage of discussion and explore the notion of computer programming as a vehicle of providing tangible tools for computational thinking.

2.11 The Logo movement

In the 1960s Papert presented the idea of a computer based microworld (Logo programming) that could provide;

an environment in which children could learn to manipulate, to extend, to apply to projects, thereby gaining a greater and more articulate mastery of the world, a sense of the power of applied knowledge and a self-confidently realistic image of himself as an intellectual agent (p.220).

His influential work on the use of computers supporting cognitive development originated twofold from the influences of Piaget's constructivism and artificial intelligence (Clements, 1986). Clements (1986) goes on to explain that a particular strength of the artificial intelligence (AI) approach to studying human processing skills is the "provision of a concrete

embodiment for abstract cognitive processes” (p.95) which Papert (1975) believed would support children in being able to think concretely about their thinking.

Through Logo, Papert (1975) also suggested that children could develop understanding, prediction and reasoning through programming either a turtle graphic on screen or a turtle robot. He referred to this as “body syntonic reasoning” (p. 245) encouraging children to imagine what motions they would do if they were the turtle, which could support the notion of “perspective taking” (Flavell, Green and Flavell, 1990, cited in Boyd and Bee, 2014), that suggests “the child develops a whole series of complex rules for figuring out precisely what the other person sees or experiences” (p.182). The Primary Coding Project (States of Jersey, 2014) has witnessed children from Nursery through to Year 1 accomplishing this operational competence. This would support some of the evidence that challenges the rigidity of Piaget’s (1977) original theories around the notion of egocentrism as it should be acknowledged that “adopting another persons’ perspective can be challenging even for adults” (Kesselring and Muller, 2010, p. 328). For example, a pre-school child’s egocentrism may impact on their ability to communicate with another person as a result of them being situated in and influenced by their own physical perspective. Conversely, an adult may be unable to comprehend the instructions of a newly purchased technology product as a result of those writing the manuals being able to adjust to the cognitive challenge of writing these instructions from the perspective of the new owner, opposed to someone with existing knowledge and expertise of the product. This suggests that egocentrism should be viewed as a lifelong theme rather than a stage of development.

Referring back to the idea of meta-cognition, Lochhead and Clement (1979) support the idea that the computer programming environment presents an operative device for cognitive process instruction with the teaching of *how*, opposed to *what* to think supporting the development of metacognitive abilities.

The child, even at preschool ages, is in control: The child programs the computer. And in teaching the computer how to think, children embark on an exploration about how they themselves think. The experience can be heady: Thinking about thinking turns the child into an epistemologist, an experience not even shared by most adults (Papert, 1980, p.19).

Programming encourages children to “invent, construct, and modify their own projects” (Clements and Gullo, 1984, p.1052) so in addition to feeling a sense of accomplishment in what they have created this could also enable divergent thinking to take place. More recently, the resurgence of the “Maker Movement” (Halverson and Sheridan, 2014) and initiatives such as “makerspaces” (Hatch, 2014, cited in Halverson and Sheridan, 2014, p.496), also emphasise the connection between making and learning and problem solving within an educational and digital context.

In a programming environment children are encouraged to reflect on how they think and recognise when they do and when they do not comprehend instructions. It presents children with an environment where they are required to “debug” situations (Clements, 1986, p.101) which may facilitate their ability to become more conscious of their errors and potentially engage in dialogue around solution monitoring. So in effect, the computer programming environment allows children to address structured and unstructured problems and I would advocate that debugging is a good example of a closed problem, as opposed to a more open approach to creating code to achieve a particular aim. This cognitive activity can be supported by the adult if necessary, by explicitly pointing it out when children are debugging or by suggesting it as a tool in the process of finding a solution. Clements (1986) goes on to suggest that teachers “might also promote a learning from debugging atmosphere, expanding this notion beyond a limited ‘fix a computer program’ perspective to the use of debugging as an allegory for cognitive monitoring in myriad situations” (p.101). This idea is particularly relevant to the aims of this study which not only seeks to explore the effects of computer programming on children’s problem solving skills, but also through the qualitative methods employed, examines the notion of how this may then translate to other areas of learning.

Although numerous intellectual ideas that were introduced by the Logo movement underpin the concept of computational thinking there are differences in the environmental context that these activities were and are embedded that are worthy of noting. At the time that Logo was presented “computational infrastructure was expensive, and access to networking and personal computing was non-existent for all practical purposes” (National Academies Press, 2010, p.46). This is no longer the case with access to devices and networks now being more accessible, and what might then have seemed quite an eccentric concept is now being

acknowledged as acceptable, even the norm. As a consequence, the pervasive presence of computational devices in our everyday lives emphasises the importance for “systems of formal education to provide individuals with appropriate tools for managing and using such devices effectively” (National Academies Press, 2010, p.46).

As previously highlighted, the introduction of the computing programme of study into the English National Curriculum (DfE, 2014), with its central aim to teach young children about computational thinking, means that children within Key Stage 1 “are now being taught about the thought processes involved in the logical reasoning that is needed to solve problems, devise procedures and better understand systems” (Sargent, 2016, p.22). This means that it is pedagogically more accessible to all children and although the formal introduction of computer programming is within Key Stage 1 (DfE, 2014) the concepts can be introduced to children at a very young age. As a consequence, this means that there are implications and opportunities for Foundations Stage practice (Morgan and Siraj-Blatchford, 2013; Sung, Kucirkova and Siraj-Blatchford, 2015) which will now be explored.

2.12 Children and computational thinking

“Babies are a kind of special computer...made of neurons, instead of silicon chips, and programmed by evolution” (Gopnik, Meltzoff and Kuhl, 1999, p. 6).

I have already attempted to define certain terms that are relevant in this thesis in Chapter 1, however, given the salience of the term ‘computational thinking’ I felt that it was important to discuss this term further in relation to the early years context.

Within this study it has been identified that in regards to logical reasoning (DfE, 2013), computer programmers need to be able to “identify and fix problems in theirs and other’s code” (Sargent, 2016, p.22). This may sound like a complex operation but in terms of early years development, could present in everyday activities such as pattern recognition (Bornstein, Arterberry and Nash, 2011; Yun Sung, Siraj-Blatchford and Kucirkova, 2016) making links to generalisations and predicting solutions to given problems. An example of this could be exploring the concept of speed by providing the children with a selection of ramps

of varying gradients and then asking the children to predict which vehicle would be the fastest. They could then adapt some of the vehicles or change an environmental factor, for example, the surface on which the ramps are situated, to then predict different outcomes.

The term algorithmic thinking was also introduced earlier (Robinson, 1993; DfE, 2013) and is a cognitive skill that can certainly be applied across the early years curriculum through skills of sequencing and the act of devising rules to solve a given problem (Wang and Chiew, 2010). An example of this was offered in the jam sandwich scenario (chapter 1.9) but could equally be reproduced by asking children to produce a set of instructions to create a model during block play or by creating a set of clues to find hidden treasure.

Sargent (2016) also refers to the term “abstraction” (p.23) defined as a “means to simplify a problem so that it is easier to think about and tackle”. Theoretically, this could link to the analogy method proposed by Wang and Chiew (2010) of reducing a new problem to that of similar one for which a solution has already been found but from a local context is also embedded in the pedagogy of the well renowned Critical Skills Programme (CSP) (Wragg, Wragg and Chamberlin, 2004), and an initiative that involved two hundred teachers in Jersey being trained over a period of two years. To “assess whether the programme was achieving its aims in providing learners with the skills, values and attitudes to become independent and interdependent lifelong learners in the 21st Century” (States of Jersey, 2003) a report was commissioned and led by Professor Ted Wragg, by which the impact of the programme was evaluated over two and a half terms. In CSP, the process of abstraction (Sargent, 2016) would be referred to as ‘chunking the challenge’ and the application within the early years classroom could be through the process of sorting and classifying objects. For example, the practitioner could present the idea of a teddy bears’ picnic but identify one of the guests as a vegetarian. The children could then sort and classify food objects into meat and non-meat products in order to ensure that all the bears’ needs were accommodated for.

The final term to be situated within the early year’s context is that of evaluation, or to put it simply, the consideration of whether a process or action worked or not. To apply this particular skill to the early year’s classroom I have drawn upon an activity that I observed in the field. The theme was Jack and the Beanstalk and the children were provided with a floor

map which depicted various stages of the story and a Bee-bot. The children were then challenged to program the Bee-bot to take certain routes in order to arrive at a particular destination. The evaluative skills were then promoted through identifying if the Bee-bot had arrived at the specified destination, if not why not, what had gone wrong with the initial instructions given and what would they need to change to ensure that the Bee-bot reached the correct destination next time they programmed it. This would fall under the more complex act of “conceptual learning that requires the development of understanding” (Yun Sung, Siraj Blatchford and Kucirkova, 2016) which could be argued is a key component of problem solving.

Having applied the concept of computational thinking, an integral component of the new curriculum (DfE, 2013) into the early year’s classroom, it becomes clearer that the pedagogical change involves fundamental principles that support the development of problem solving skills. These principles include concepts such as abstraction, logic and algorithms and the ability to evaluate and apply information to new situations or problem spaces (Wang and Chiew, 2010), which are crucial skills that contribute to the vision held by the States of Jersey (2003) of developing “independent and interdependent lifelong learners in the 21st Century”. Staying with this theme, this review will now re-consider the curriculum in relation to its surrounding culture, which I would advocate can contribute to both the success and demise of a new curricula initiative.

2.13 Curriculum considerations and developing a culture for computer programming in the primary curriculum

In the design and development stages of a new curriculum the first and most obvious consideration is the need for developmentally appropriate and engaging learning opportunities to be created (Liao and Bright, 1991; Perlman, 1976). As previously referred to, Hauglands (1992) talked about the need for “carefully designed” computer programming software and environments that should “support autonomous or guided open-ended explorations in the process of which the children participate actively, think and control the computer” (p.88). This would align to a constructivist perspective (Hmelo-Silver, Chernobilsky and Jordan, 2008), which sees the learners as constructors of their own

meaning, however, it “can be challenging to draw a clear distinction between constructivism and cognitivism, because constructivism is a natural progression from cognitivism and both are interested in cognitive processes” (p.55). Maintaining the idea of children as builders and co-constructors of their own knowledge, also requires us to acknowledge that to be able to build, materials are required, which is where the second and subtler consideration comes into play in regards to how the surrounding culture can play a part.

Due to both secondary IT teachers and primary teachers potentially working collaboratively in developing a computing curriculum across the primary sector, factors such as ownership can become prevalent. This could present challenges but I would argue could equally be a helpful influence in relation to creating a positive culture in response to the curriculum change.

Some cultures may provide a wealth of materials, endorsing the concept of Piagetian (1929) learning in supporting children with their construction of knowledge and understanding of particular concepts with the material that surrounds them. However, Papert (1993) challenges this idea by stating that “where Piaget would explain the slower development of a particular concept by its greater complexity or formality, I see the critical factor as the relative poverty of the culture in those materials that would make the concept simple and concrete” (p.7). This is both an interesting and assertive challenge, which implies that it is simply the wrong tools for the task at hand, which again emphasises the point made earlier around the need to provide appropriate software and environments that are conducive to learning. Building upon the idea of a culture being able to provide a polarity of materials, I further support the ideology that in some cases cultures may provide the material yet block their use. This notion is captured by Papert (1993) when he states that:

In the case of formal mathematics, there is both a shortage of formal materials and a cultural block as well. The mathophobia endemic in contemporary culture blocks many people from learning anything they recognize as “math,” although they may have no trouble with mathematical knowledge they do not perceive as such’ (p.42).

On personal reflection, I can relate to this idea, as my own perception towards learning mathematical knowledge has probably contributed to this apparent mathophobia endemic.

Crucially, what it draws our attention to is the awareness of a more complex cultural paradigm that can run parallel to the more concrete concept of curriculum design and development. For example, the culture between the two primary schools chosen to be part of the pilot for this project needs consideration as it is not unusual for schools to develop a particular ethos towards the arts or sports.

Staying within the theme of culture Gere (2002) raises the notion that “digital culture has become such an everyday background feature of life in post-industrial societies that its shape, form and function have been naturalised” (cited in Carrington and Marsh, 2006, p. 284). In the case of this pilot project it could be argued that due to the proposed age of the children, technology in the broader sense of the term may feel quite natural, linking into the statement made by Carrington and Marsh (2006) that “the naturalization and invisibility of digital culture must be more so for early adolescents and children who do not have a cultural or personal memory of a time preceding digital culture” (p.284). Buckingham (2006, p.2) however argues that the term “digital generation” is just easy rhetoric and impossible to sit in age defined categories therefore creating many kinds of 'digital natives' (Prensky, 2001). I concur with the idea held by Carrington and Marsh (2006) that it could highlight the potential challenge of engaging some teachers into such a programme (Heinrich, 2012) who may initially lack the knowledge and confidence to engage comfortably.

To re-visit the original dichotomy of being passive consumers or developing creators of technology I propose that integrating computer programming into the primary curriculum and introducing young children to these learning opportunities may not initially feel like a natural extension of the world around them (Gere, 2002). A paradigm shift between consumer activity and creating activities may be needed. Higgins et al (2012) however disputes the idea of today's children being “digital natives and the net generation” (p. 20) in regards to the idea that they learn differently from older people stating that “there has been no evidence that the human brain has evolved in the last 50 years, so our learning capacity remains the same as it was before digital technologies became so prevalent” (p.20). This challenges the idea that because young children have grown up with technology it cannot be assumed that they are experts in this domain and that “most young people are fluent in their use of some technologies, but none are expert at all of them” (Higgins et al, 2012).

Encouraging children to become creators of technology therefore needs to be supported by curriculum infrastructure, or framework. The notion of the curriculum being used as a political tool has already been identified (Carr, 1998) and critics of the current curriculum (Claxton and Lucas, 2015; Fadel, Bialik and Trilling, 2015) have already suggested that some key components are absent, creativity being one of them. Rather than hope for a complete paradigm shift between traditionalist and more progressive views of what the school system should look like (Claxton and Lucas, 2015), maybe some of the desired attributes, such as cultivating creativity in children, could be achieved through smaller changes to pedagogy and practice. This leads the discussion to the notion that teaching of computer programming could be a vehicle to contribute to this challenge.

2.14 Computing and creativity

Re-visiting Fadel, Bialik and Trilling's (2015) suggestion of "four dimensional education" (p.67), two of the four key skills that are advocated along with communication and collaboration are creativity and critical thinking (Center for Curriculum Redesign, CCR, 2015).

Imagination is more important than knowledge. For knowledge is limited to all we now know and understand, while imagination embraces the entire world, and all there ever will be to know and understand (Albert Einstein).

A prophetic statement that emphasises the skills that are crucial for the present and future society and what digital technologies may do is contribute to re-igniting more creativity and critical thinking into the classroom (Starkey, 2012). Drawing again from the CSP (Wragg, 2004) initiative and local perspective, Jersey embraced this programme, with Charlesworth (2005) advocating that even though CSP had been previously only been implemented across all key stages, it could successfully be employed within the Foundation Stage. At the time the DfEE (2000) stated that 'the most successful learners ask questions, show a sense of curiosity, and enquire'. Charlesworth (2005) supported this by adding "children have a love of discovery – and it is our responsibility, as educators, to foster this quality; to nourish it, embrace it and enhance it in our children" (p.115). Not only does this support the concept of computational thinking but it also emphasises the importance of nurturing skills such as curiosity and discovery.

Research studies (Becta, 2007; Livingstone and Hope, 2011) seem to support this debate and as a result more prevalence on the terms computer science and creativity seem to become synthesised, which is an ideology and partnership that candidly I have not previously recognised. I would however advocate that creativity fits within this study's conceptualisation of problem solving and can be seen within the design of the problem solving activity in regards to the different ways that children can employ and present solutions to the given problems. A concrete example of this could be the children's use of the repeat command button.

Traditionally the notion of creativity has been associated with the arts, which according to Runco and Richards (1997) was misleading and has led to what he perceived as an "art bias" (cited in Fadel, Bialik and Trilling, 2015, p.110). Historically the UK has been linked to various media related inventions such as photography, television and computers, in both concept and practice (Gordon, 2000), yet as highlighted by Schmidt (2011) currently, none of the world's driving exponents in these spheres of influence are from the UK. Schmidt asserts:

To change that you need to start at the beginning with education. We need to reignite children's passion for science, engineering and maths. In the 1980's the BBC not only broadcast programming for kids about coding, but (in partnership with Acorn) shipped over a million BBC Micro computers into schools and homes. That was a fabulous initiative, but it's long gone. I was flabbergasted to learn that today computer science isn't even taught as standard in UK schools. Your IT curriculum focuses on teaching how to use software, but gives no insight into how it's made. That is just throwing away your great computing heritage (2011).

It could be argued that it is has been fashionable to jump onto the computing "bandwagon" over the last 18 months (Harrison, 2012) and it is not uncommon for some politicians to see this as an opportunity for policy reformation, at the cost of belittling everything that came before. Carr (1998) offers "an analysis of the political and social role of the curriculum in a modern democratic society" (p.323). He refers to the role of the democratic curriculum as a recorder and messenger of both the past and future social and political events, but highlights how these intertwined relationships that come into play during curriculum development can often be implicit and wrapped up in the "notion of the hidden curriculum" (p,325). The recent reforms to the ICT curriculum however have not been implicit but a cultural, economic and political response to a perceived demand for societal change to meet the demands of 21st

Century skills (Fadel, Bialik and Trilling, 2015). Due to the nature of different social groups holding various political views in relation to what should inform and shape society's direction this then can create conflicting ideologies as to how and what curriculum should look like. Inglis (1985) referred to this practise of curriculum contestation as a battle of ideals:

The curriculum is the battleground for an intellectual civil war and the battle for cultural authority...is a fervent one. Its different guerrillas include parents, pupils, teachers, bureaucrats, left, right, centre, nationalities and the compelling mercenaries of market forces (p.23).

I would suggest that the market forces in this particular curriculum reform have centred on the digital industries (Livingstone and Hope, 2011) with a vested economical drive to support a potential skills gap but this should not be at the detriment of a child's educational experience. So if the time is right for a technology reformation in schools then this needs to be done in a carefully considered and informed manner, by the key stakeholders, to avoid it becoming a vogue. The Primary Coding Project (States of Jersey, 2014) appears to be an example of this in action. In relation to education, in particularly, pedagogy, policy and practice the key arguments that can be drawn from the review of literature are that the ICT curriculum was too focused on teaching children how to use software, but offered little insight into how it was made (Schmidt, 2011), reinforcing the notion of encouraging consumers opposed to creators of technology. Interestingly, there is a narrative around children establishing "newfound roles as online cultural producers" (Williams and Smith, 2007, p.36) which could be seen to contradict the notion of presenting children as consumers, although I would suggest that this is more in relation to producing online content for digital texts (Dowdall, 2009, cited in Carrington and Robinson, 2009), which would fall under the 'Digital Literacy' strand of the new Computing curriculum (DfE, 2013). However, from a contextual perspective it could suggest that away from some of the curriculum constraints of the school environment the role of children as creators, or producers, is evident.

There is an abundance of research indicating young children are more likely to engage in technology and be motivated by it (Fessakis et al, 2012; Henderson and Yeow, 2012) yet there is a lack of any recent statistical evidence to show any direct correlation between the impact on children's learning and ultimately attainment (Hattie, 2008; Heinrich, 2011). Past studies

have shown some evidence that programming can increase problem solving ability (Billings, 1983; Milner, 1973; Soloway, Lohead and Clements, 1982; Statz, 1974) though another report by Pea and Sheingold (1987) suggested that children's programming ability was limited to specific contexts, so perhaps not transferable. Starkey (2012) acknowledges that "a curriculum for learning in the digital age will continue to include concepts that will help each generation understand the world in which they live and to participate in society" (p.27); so as technology progresses, education must also adapt to ensure that future members of society develop the skills to be able to function effectively. It is from these notions that the subsequent research questions were born and which will now be explored within the methodology chapter.

Chapter 3: Methodology

3.1 Introduction

This chapter will examine the methodological paradigms and perspectives that have guided the research activity and introduce the reader to the approaches that have been adopted to support this mixed methods study.

The start of the chapter reiterates the motivation of the study and the subsequent research questions that were designed to examine and support the study. This is followed by a critical debate around some of the challenges a researcher can face as a result of various dynamics. For this particular study, it includes elements such as where the research is situated (in this case within the landscape of educational policy), managing responsibilities and meeting the expectations and needs of different stakeholders, such as policy makers, teachers and children. The notion of positionality and awareness of my own presence in the research is also discussed.

In response to meeting the expectations and needs of different stakeholders this research required some collaboration with other professionals and the roles and involvement of these professionals should be made explicit. I have also identified the direct relationship between 'The Primary Coding Project' (States of Jersey, 2014) and this research study, but at the same time tried to emphasise their distinct purposes throughout the study. One example of this relationship could be applied to the problem solving assessment tool. This was initially created by the teaching staff involved in delivering the Primary Coding Project (States of Jersey, 2014) as a mechanism to gather evidence based data, which could then go on to support any future decisions made around the curriculum change. As a researcher, my role was then to examine the tool in relation to theory, both from a content and methodological perspective and share these with the team to make refinements where appropriate. Further details on the design of the tool is justified later on.

The quantitative data from the problem solving activity was collected by the Primary Coding Project team, who administered each school test, to ensure consistency, and I joined them on

some of these visits when the scheduling allowed. The raw data from the problem solving activity was then given to the statistician within the Education Department so that some initial analysis could be done alongside some additional educational data that was held confidentially in their database. These findings were presented to me and the Primary Coding team, after which further analysis was then guided by me, as the researcher, to make subsequent decisions as to how the data could be interrogated further in order to arrive at a final model.

What then follows in this chapter is an examination of the methodological influences that have been employed and ultimately shaped the study. Pragmatism as a paradigm is introduced, drawing on the work of Dewey (1986) and Morgan (2014); the philosophy underpinning pragmatism becomes a key driver that leads into the selection and justification of employing a mixed methods approach in the quest to address the research questions. The complexities associated with using a mixed methods approach are also examined in depth.

Chapter four goes on to explore key theories that underpin mixed method research design and provides a clear rationale for the “embedded mixed methods” (Cresswell, 2014) design employed for this particular study. A detailed consideration and justification around the design of each individual method is also presented in this section alongside the more practical procedural details for the collection of data from the problem solving activity (year 2 children), the surveys (year 2 teachers) and the focus groups (year 2 children) that were undertaken.

All aspects of ethical practice applicable to this study are also given due consideration in this chapter before moving on to Chapter 5 which examines the approach taken to the analysis of all data collected. However, to bring the focus back to initial methodological thoughts the main research question and the supplementary questions that were subsequently developed to support the study are re-presented below.

3.2 The primary research question

Does teaching computer programming within Key Stage 1 of the primary curriculum enhance children’s problem solving skills?

Supplementary research questions were also created and are presented below:

What are the views of Year Two, Key Stage 1 teachers around embedding programming and computational thinking skills into the key stage 1 curriculum?

What are Year Two children's perceptions of programming sessions; what do they think they are learning?

Can any differences be identified between the interest and engagement of male and female participants in the study?

As articulated in Chapter 1 the primary research question set out to examine if the teaching of programming in Key Stage 1 had a positive effect on children's problem solving skills. It was also constructed in response to what was perceived by myself and others to be a limited pool of research around technology and the impact on children's cognitive development (Computing at School, 2012; Werner, Denner and Campe, 2012). The latter three questions were designed to examine the policy and pedagogical impact of the curriculum change, in addition to supporting the broader aims of the Primary Coding Project (States of Jersey, 2014). These were "to improve teachers' computing skills and inspire students to use technology from the earliest possible age" and to "address the skill shortage in computing in primary schools, give staff extra skills to deliver computing to younger students, enthuse pupils to be the next generation of developers and develop wider skills, including numeracy and problem solving" (States of Jersey, 2014).

In response to the curriculum changes that were being proposed for schools in England an opportunity was presented to Jersey to develop and invest in its own computing curriculum (See Appendix 1). At the onset of the Primary Coding Project (States of Jersey, 2014) there was no baseline assessment tool to gather any measurable data on children's computing skills at Key Stage 1, though changes to The National Curriculum (DfE, 2013) in England were to be employed from September 2014. For the purpose of this study a baseline assessment tool was created by the Primary Coding Project team (States of Jersey, 2014), to gather quantitative data, placing the island in a unique position to examine the potential impact such a policy and pedagogical change may have on children's cognitive skills. Interestingly, Hattie (2008) advocates that the "notion that exposure to certain types of experience will alter the nature of human information processing is almost impossible to investigate" (Hattie, 2008, p.

197). From a research perspective, this could be perceived as a daunting proclamation as it suggests that to ascertain if the programming intervention planned within this study (which is a type of experience), has a direct impact on children's problem solving skills (a form of human information processing skills), is almost impossible to investigate. That said, it is worth emphasising here that this research study sought to ascertain if the intervention could enhance, as opposed to alter procession skills, the latter of which was also a claim by Prensky (2001).

In a quest to find an answer to the posed research question I was drawn to the work of Pring (2000) and the notion he presents as the "false dualism of educational research" (p.247) debate:

Educational research is being subject to damaging criticism from both outside and within the research community. The external critics are impatient of research which does not give evidence-based answers to the questions they ask. The internal critics condemn the very research which seeks to provide those answers. These differences are reflected in the rigid distinction between quantitative and qualitative research (Pring, 2000, p.247).

This appears to present the dichotomy of "policy makers looking for a 'science of teaching' or a 'science of school management'" (Reynolds, 1998, p.129) on one hand, to demonstrate exactly what needs to be done to raise standards. This links to the avowal by Hite (2001) that the "lingua franca of policy and of the policy formation process at virtually all levels (local, state/province/district, regional, national, international) is predominately quantitative" and "to speak with professional adequacy and effectiveness in this context requires the adoption and use of the prevailing expectations and language of quantitative reasoning" (p. 17). I would say that this has been a challenge, and to some degree remains one in the policy arena of early childhood education where the qualitative paradigm is seen to prevail over the quantitative paradigm. Research that could challenge this claim could be The Effective Provision of Pre-school Education (EPPE) project (Sylva et al, 2004), which was a longitudinal study funded by the DfES from 1997-2004. The project has become renowned for contributing towards evidence based policy in the early year's domain, with policy makers having confidence in its robust mixed methods research design.

Others, however, argue that such an aspiration is constructed on false beliefs about what research can deliver and Pring (2000) goes on to state, “the nature of educational transactions or encounters mean that they are not open to the kind of explanation which provides the basis for systematic intervention” (p.247). Qualitative and quantitative methods of research have historically been seen as oppositional concepts with the view that researchers should align their loyalties to one or the other, presenting a dual between positivist and interpretivist paradigms. Essentially Pring (2000) argues that the dualism debated here is a “false dichotomy” and that:

Such dichotomies are mistaken...researchers have fallen into a philosophical trap, which is very old indeed. It is the ancient dualism between mind and body, between publicly accessible and the privately privileged. Educational research is both and neither (p.33).

From a personal stance, influenced by reading and my own philosophy around research, I would support Pring’s (2000) assertion that there is no such thing as a correct approach to educational research. The approach has to depend on and be driven by the research question in hand, which in this case required the collection of quantitative data. In addition, educational research has been heavily criticised for reasons such as “the research does not provide the answers to the questions that government and policy-makers ask and it does not help professional practice” (Hillage et al, 1998; Tooley, 1998; Hargreaves, 1996, cited in Pring, 2000, p.247). In application to this study it could be argued that that the methodology does seek to provide an answer to policy makers, which in this case is the States of Jersey Education Department. This is based partly upon gaining empirical evidence to support the drive to promote more evidence based policy making, but equally under the interpretivist paradigm, with the aim of informing pedagogy and practice through data gathered from some of the stakeholders directly impacted by the policy change, such as the teachers and the children. Returning to the division between the two research paradigms and how these are sometimes viewed from a stakeholder perspective it becomes evident that by giving emphasis to one particular distinction, it in turn “obscures or eliminates other, more subtle ones” (Pring, 2000, p.248). Dewey (1916) also fervently challenged the idea of these “false dualisms” or being in opposition to each other by referring to “body and mind, theoretical knowledge and practice, physical mechanisms and ideal purpose. Upon the philosophical side, these various dualisms

culminate in a sharp demarcation of individual minds from the world, and hence from one another” (p.291). These philosophical positions influenced my own thinking around the methodology chosen for this study and potentially how any outcomes from the research might then go on to be received.

At this point I feel it would be pertinent to share my own positionality and predispositions in regards to research methodologies and methods, elucidating on the terms epistemology and ontology. Troyna (1995) reinforces the researcher’s connection with their study by stating that “all research, from its conception through to the production of data, its interpretations and dissemination, reflects a partisanship which derives from the social identity and values of the researcher” (p.403). From a personal perspective and in relation to this research study, I would certainly say that my values around education were the initial driving force that propelled me to take on a project that sat outside of any previous experiences of this area. However, relationships with colleagues, affected by the curriculum change, also ignited my curiosity. This ‘partisanship’ is further discussed little later on.

3.3 Approaches to research methodologies and positionality

Following the work of Kuhn (1962) approaches to methodologies within research have been seen to reside in paradigms which can be defined by Cohen et al (2011) as “a way of looking at or researching phenomena, a world view, a view of what counts as accepted or correct scientific knowledge, or way of working” (p.5) or by Kuhn (1962) “as an accepted model or pattern” (p.23). As further knowledge is gained, old paradigms which have existed in the past, such as the original idea that placed the earth at the centre of the universe, can be both challenged and replaced. This is what appears to have happened in relation to the understanding of scientific and positivistic research approaches with Popper (1980) suggesting that “the idea of a value-free, neutral, objective, positivist science has been replaced by a post-positivist, critical realist view of science with its hallmarks in conjecture” (p.57). Although balanced, or mixed methods are an acceptable part of post-positivism, acknowledging the value of combining quantitative and qualitative approaches has been a measured process, and these different traditions have “engaged in sporadic warfare” (Robson, 1993, p.18). This is none more so than in the psychology domain, where a protracted

debate as to the value of qualitative approaches has been evident (Morgan 1996, 1998; Stevenson & Cooper, 1997; Sherrard, 1997; 1998 Stevenson and Cooper, 1998).

It could be argued that the traditional quantitative versus qualitative has seen a paradigm shift, however, my intention is not to enter this debate and question the merits of each position, but rather seek to align with the basic beliefs of the post-positivist paradigm, that the marriage of the two traditions (Bryman, 1988) is possible and was the right approach to take for this study. We could then ask the question of whether a mixed method approach represents the birth of a new paradigm and although this is explored further in Chapter 3, Cohen (2011) challenges this concept. He states metaphorically that “it is a young paradigm, and it is dangerous to predict what an adult will be like on the basis of his or her characteristics when a baby” (p.26).

Accountability is a significant principle in post-positivism and as suggested by Sikes (2004) is seen to be best achieved by using methods such as reflexivity, whereby the researcher is “coming clean” (Guba, 1990, p.21) about their predispositions. In regards to my own position as a researcher the notion of accountability can be attached to my need to produce an academically credible report for my own EdD studies but equally accountability refers to my position of responsibility with the States of Jersey Education system.

Reflexivity is seen as a means of achieving transparency, by reflecting critically on the self as the human instrument, or scientific observer, who is part of the setting, context and culture that he or she is attempting to understand and represent (Guba & Lincoln, 1981; Altheide & Johns, 1994). Stevenson and Cooper (1997) believe that by understanding the researcher’s behaviour in a reflexive manner can ensure that the methodological approach that has been adopted, the individuals preconceived assumptions about the world, and their involvement in the process, is detached from the findings. This complements the view of Greene (2000), who considers that the inquirers’ bias should be acknowledged as an important part of the research process for purposes of authenticity. This resonates with Griffiths (1998) when she writes that:

Without some acknowledgement of initial opinions, including beliefs and values, the research will certainly be biased. Not only does such acknowledgment help to unmask any bias that is implicit in those views but it also helps to provide a way of responding critically and sensitively to the research (p.130).

To go some way towards addressing any potential assumptions and internal influences I refer to Sikes (2004) who purports that “a good rule is never to think that anything is straightforward and ‘obvious’, never to take anything for granted and never to leave an assumption unquestioned” (p.15) which has been the mantra through this research journey. With this in mind, personal potential bias will be explored further in the next section.

3.4 The nature of enquiry and the search for truth

Hitchcock and Hughes (1995, p.21) suggest “that ontological assumptions (assumptions about the nature of reality and the nature of things) give rise to epistemological assumptions (ways or researching and enquiring into the nature of reality and nature of things)”. The interrelationship between these two subsequently informs the considerations given to the methodological process that the researcher may then explore. Cohen et al (2011) adjoins the concept of axiology, which refers to an individual’s values and belief system, to this blend and states that:

This view moves us beyond regarding research methods as simply a technical exercise and as concerned with understanding the world; this is informed by how we view our world(s), what we take understanding to be and what we see as the purposes of understanding, and what is deemed valuable (p.3).

I am in no doubt that the discussion around research and value freedom will continue to perpetuate and that different views will continue to resonate around this area. My position lies with Troyna (1995), Griffiths (1998) and Bassey (2010) in that researchers should be explicit and honest in their social identity and value base but that it should “be clear who is making the statement and that it is an expression of value and not of fact, thereby locating the polemic firmly within an ethic of respect for truth and respect for persons” (Griffiths, 1998, p. 90). Tedlock (2005) concurs with this idea when he writes that:

We have moved far from the Enlightenment goals of “value-free” social science based on a rationalist presumption of canonical ethics; we have entered into the arena of postcolonial social science, with its focus on morally engaged research’ (p.474).

In relation to this study it would be pertinent to acknowledge that certain values could be held within the Primary Coding Project (States of Jersey, 2014) team which could be influential in the study. For example, the Education Department, who have supported and invested in the project from a financial perspective would be keen to receive feedback that the money invested in the department had been a worthwhile venture; in addition, the teaching staff involved in developing and delivering the initiative would equally be eager to receive favourable results from the research. In a quest to adhere to the notion of “morally engaged research” (Tedlock, 2005, p.474) it is crucial for the researcher to remain aware of unconscious bias. This is reflected in the rigour applied to both the analysis and interpretation process of this study to ensure the findings were trustworthy.

Although, I also have a vested interest in the Primary Coding Project (States of Jersey, 2014) from both a personal (the project team are colleagues) and professional capacity (as the researcher), the fact that computer programming was not part of my background has enabled me to maintain some distance from any potential outcome that the initiative would present.

To conclude this discussion, I feel confident in supporting the assertion that research methodologies and methods cannot be value free and adjoin that any research that purports to be value free could be accused of being disingenuous to its audience. Savin-Baden and Howell Major (2010) capture the essence of this idea when they write that:

Researchers should not strive to be wholly detached from their research. This does not mean thy abandon carefulness, or what Bentz and Shapiro (1998) have called ‘mindfulness’ in the research process. It simply means that our view of the world is always from within it, and what we see, or what we erase from view, will be framed by our cultural resources, particularly our language (p.10).

From a personal standpoint I believe that the acknowledgement of values and self-reflexivity is imperative to the research process, as is also taking ownership of what we write as

researchers. By presenting my own position I have tried to illustrate how ontological influences may have impacted on the research process.

3.5 Influence on methodology – pragmatism as a paradigm

Having examined various theoretical perspectives around human problem solving in Chapter 2.2 it is clear that the ability to understand what the goal of the problem is and what rules could be applied represent the key to solving the problem. I considered and reflected on this statement and subsequently, this reflection went on to influence the methodological approach taken for this study. I chose to apply a pragmatist approach to this research, drawing on Dewey's (1986) concept of inquiry (Morgan, 2014) which links beliefs and actions, or theory to methods, through a process of decision making, which Patton (1988) refers to as a "paradigm of choices" (p.117) and Johnson and Onwuegbuzie (2004) suggests is a "contingency theory" approach when considering research design:

which accepts that quantitative, qualitative, and mixed methods are all superior under different circumstances and it is the researcher's task to examine the specific contingencies and make the decision about which research approach, or which combination of approaches, should be used in a specific study (p.22-23).

This theory implies that pragmatism does not require a specific method or combination of methods but neither does it dismiss others, promoting equal status between paradigms. Feilzer (2010) further adds "that it does not expect to find unvarying causal links or truths but aims to interrogate a particular question, theory, or phenomenon with the appropriate research method" (p.13). The above notions aligned with my own deductions around the most appropriate approach to employ, therefore fitting into the philosophy of pragmatism with the view and emphasis being placed on the researcher believing in the methods chosen.

In order to further my own understanding of using pragmatism as a paradigm, this lead me naturally into an attempt to define the term paradigm which in itself, is not without debate. Initially, Guba and Lincoln's (1990) work around paradigms involved just the two philosophies, referred to as positivism and constructivism, though later on this list expanded to five named paradigms which included post-positivism, critical theory and participatory research (Guba

and Lincoln, 2005). In attempting to define the term Lincoln & Guba (2005) do provide some clarity, by suggesting that a paradigm should be seen as having four elements; ethics; or the moral action in human activity, epistemology; or the construction of knowledge, ontology; which raises basic questions about the nature of reality, and methodology; which helps us focus on the best means of obtaining knowledge from the world.

According to Morgan (2014), “within pragmatism, all experience begins with a problem to be addressed or a question to be answered” (p.41) and once established these notions can then be connected to a set of procedures that can examine the original issue. Inquiry within the pragmatic paradigm creates a process of planning stemming from the research question posed, through into the design and justification of chosen methods, but it also generates a cycle of informing future research questions and dialogue around the strength of particular methods available, hence bonding purpose and process together. Both Dewey’s model of inquiry (1986) and the philosophy underpinning pragmatism seemed to provide the tools to ascertain the most appropriate approach to take with this research. The synergy between the approach, with its emphasis on problem solving, and the actual research question, which was to explore an intervention that may impact on children’s own problem solving abilities, made for further relevance. Having reflected on a pragmatic system of inquiry (Morgan, 2014) the decision was made to employ a mixed methods approach to my own research, though pragmatism is by no means limited to this genre. A blend of numerical and qualitative methods can endeavour to “explain, describe, illustrate and enlighten” (Yin, 2009, p.19-20) a proposed study and in a quest to address the research questions, both will be employed within this study.

3.6 A Mixed Methods approach

In the selection of a research method, it is pertinent to acknowledge that forces of structure and agency shape the outcome. Pearce (2012) suggests that although as researchers we may like to think that we select the most perfect research design and method(s) to interrogate a given question, we know that agency has its limits, and subsequently research decisions can become influenced by our personal methodological training and the penchants of the audience (Denscombe, 2008). To expand on this a little, my past research experiences have

all been of a qualitative nature and therefore this is where I feel most comfortable and this has been influential in regards to the creation of previous research choices and questions.

Pearce (2012) claims that “these structural forces shape and are shaped by reigning methodological paradigms, or sets of widely accepted beliefs and values about how research should be conducted, that shift through time” (p. 829). Re-visiting the notion of paradigms, three commonly assumed, if not directly referenced, paradigms of the research arena have been the so-called “*qualitative or constructivist* paradigm, the *quantitative or positivist* paradigm. The newly developing *pragmatic* paradigm” (Pearce, 2012, p.830), that has been previously discussed, presents the idea that research needs to find real answers to real questions and that past paradigm wars (Gage, 1989) “where one stood by one’s allegiances to quantitative or qualitative methodologies” (Cohen et al 2011, p. 21) are no longer a researcher requirement. However, I feel that this idea could be challenged as even if a researcher classifies their work as either strictly quantitative or qualitative they would still be claiming to be answering ‘real questions.’

Terminology associated with mixed methods research can be variable (Creswell, 2014). Terms such as “integrating, synthesis, quantitative and qualitative methods, multi-method and mixed methodology” (Creswell, 2014, p.217) are used but debated. Creswell and Clark (2007) makes the distinction that mixed methods combine both qualitative and quantitative approaches whilst multi-method studies employ the multiple collection of qualitative or quantitative data, but Morgan (2014) purports that the multi-method approach is seldom applied to the use of multiple quantitative methods. For the purpose of this study, which draws data from both quantitative and qualitative methods it seems appropriate to refer to it under the mixed methods term.

Creswell (2014) posits mixed methods potentially as the “third paradigm” but Clark (2014) suggests that this positioning is problematic as the philosophical debates around the combining of the two philosophical ideas, often underpinned with the theory of pragmatism (Tashoakkori and Teddlie, 2003, 2010; Biesta, 2010; Maxcy, 2003), remains debatable (as identified in Chapter 3.4). Using different methods for their variable strengths is not justifiable if clear links are not established between the chosen methods and research question to justify

the benefits of combining both methods and therefore minimizing the potential limitations of using these approaches in isolation. The research question for this study attempts to ascertain a link between the teaching of computer programming in the Key stage 1 curriculum in enhancing children's problem solving skills, which suggested that quantitative data would need to be gathered, but subsequent questions around policy changes, training and sustainability necessitated the combination of a qualitative approach, which will subsequently be discussed. In an attempt to move on from the paradigm debates, the question to reflect upon is that as researchers, do we really need to position ourselves within a definitive category or under a specific research banner? Or, perhaps be bolder in our beliefs and choices aligning with Seale's (1999) suggestion that "research should be seen as a craft skill, relatively autonomous from the need to resolve philosophical or epistemology debates, but it can nevertheless draw on these as resources in developing methodological awareness" (p.67).

That said, there are documented challenges in the employment of a convergent mixed methods design (Gorard, 2013; Creswell, 2014) which lies around how to converge or merge the data effectively and Creswell (2014) highlights the challenges that this form of research presents for the inquirer which include:

the need for extensive data collection, the time intensive nature of analyzing both qualitative and quantitative data, and the requirement for the researcher to be familiar with both qualitative and quantitative forms of research. The complexity of the design also calls for clear, visual models to understand the details and the flow of research activities in this design (p.219).

Additionally, from a pragmatic perspective, purpose and procedures need to have "integration of data and results" (Morgan, 2014) as a key driver throughout the process of inquiry which will be explored in the next chapter.

Chapter 4: The research design and data collection instruments

4.1 Research design

Although there have been numerous typologies for classifying and identifying different types of mixed methods strategies drawn from multiple fields, such as public health and educational policy having identified a substantial amount of overlap in the narratives Creswell and Plano Clark (2011) categorise three basic mixed methods designs which include convergent parallel, explanatory sequential and exploratory sequential. To offer further context to these methods they are presented visually in figure 1, 2 and 3:

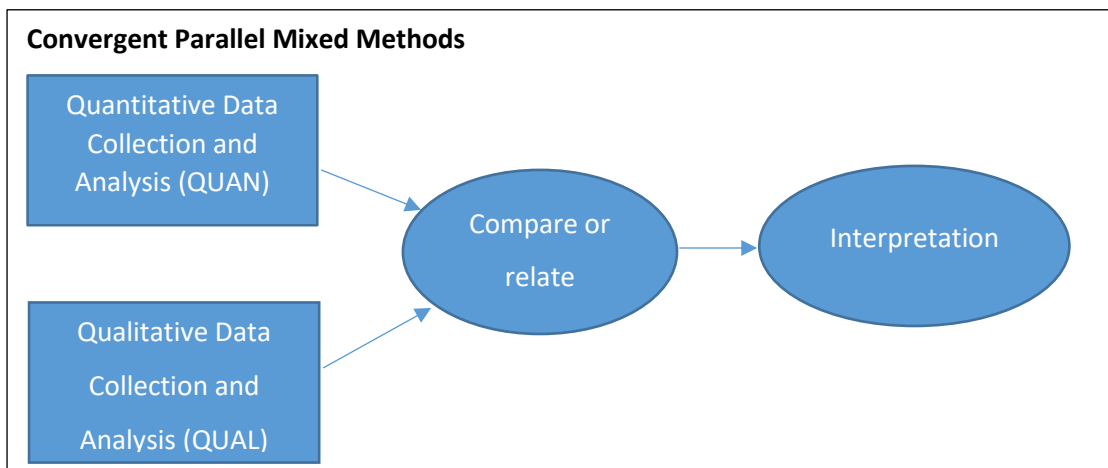


Figure 1: Creswell (2014, p.220).

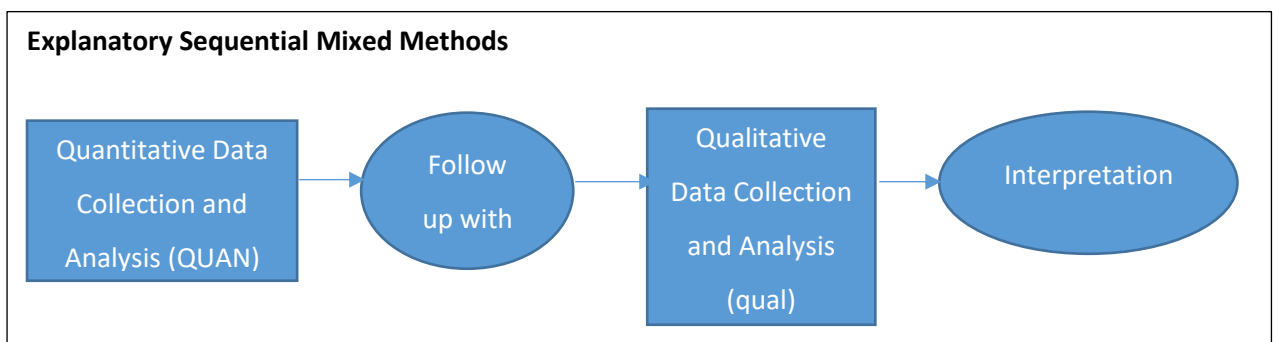


Figure 2: Creswell (2014, p.220).

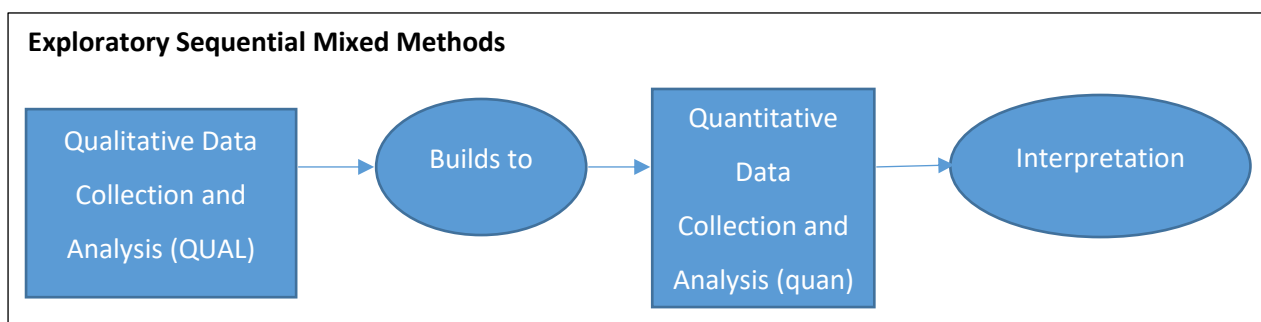


Figure 3: Creswell (2014, p.220).

In order to make informed choices around my own project methodology, an exploration and examination of these three basic mixed methods designs was deemed to be a necessary starting point (Cresswell, 2014; Gorard, 2013). Neither of these models fully supported the needs of the research which then lead me to examine more advanced mixed methods designs that incorporate the fundamentals of the convergent, explanatory sequential, and exploratory sequential approaches (Creswell and Plano Clark, 2011). For this particular study, I chose to employ an ‘Embedded Mixed Methods’ design (Creswell, 2014), which is a prevalent design when investigating an intervention or program in an applied setting, which in this research is situated in schools (see table 1):

Reasons for choosing mixed methods	Expected Outcomes	Recommended Mixed Methods Design
Understanding experimental results by incorporating perspectives of individuals	An understanding of participant views within the context of an experimental intervention	Embedded mixed methods design

Table 1: Creswell (2014, p.231) – method chosen for this study.

The 'Embedded Mixed Methods' design (Creswell, 2014) seemed to fit the purpose of the research as it enabled the researcher to garner the perspectives of individuals, which in this case was the Year 2 teachers and children. By using this model, the qualitative input would be embedded which I felt was necessary for understanding the experimental results and vice versa.

It could be argued that by attaching a label to a research design, restrictions may then come into play, such as attempting to fit into a typology of a particular model, rather than focussing on the unique characteristics of the study. With this in mind I adapted and created a model that I felt captured the intentions of the project. The design nests one or more forms of data i.e. qualitative or quantitative or both, within a larger design, which in this study was an observational study (Jepson et al, 2004). The design was also sequential in nature, where the quantitative and qualitative components were conducted consecutively (Leech, 2014); however, the qualitative data collection was not dependent upon, or used to inform phase 1 and 2 of the experiment but would be interpreted and inform the final analysis. Morgan (2014) refers to this approach as additional coverage where the researcher "assigns different methods to different purposes, allowing the overall project to pursue a wider range of research goals than would be possible with any single method" (p.73). A common analogy aligns this approach to assembling "many pieces of a complex puzzle into a coherent whole" (Jick, 1979, p.608) or conversely Lawrenz and Huffamn (2002) present the idea of "making connections between Islands of data that are grouped into archipelagos" (p.336). Both of these analogies relate back to the aims of this study and have therefore being influential in its design. Additional coverage "promotes the goal of integrating the findings from different methods into a more holistic understanding" (Morgan, 2014, p.74) and from a practical perspective employs a strict division of labour, with each method playing a comparatively self-contained function within a larger project. A visual representation of the design for this study is presented below (figure 4):

4.2 An Embedded Mixed Methods design:

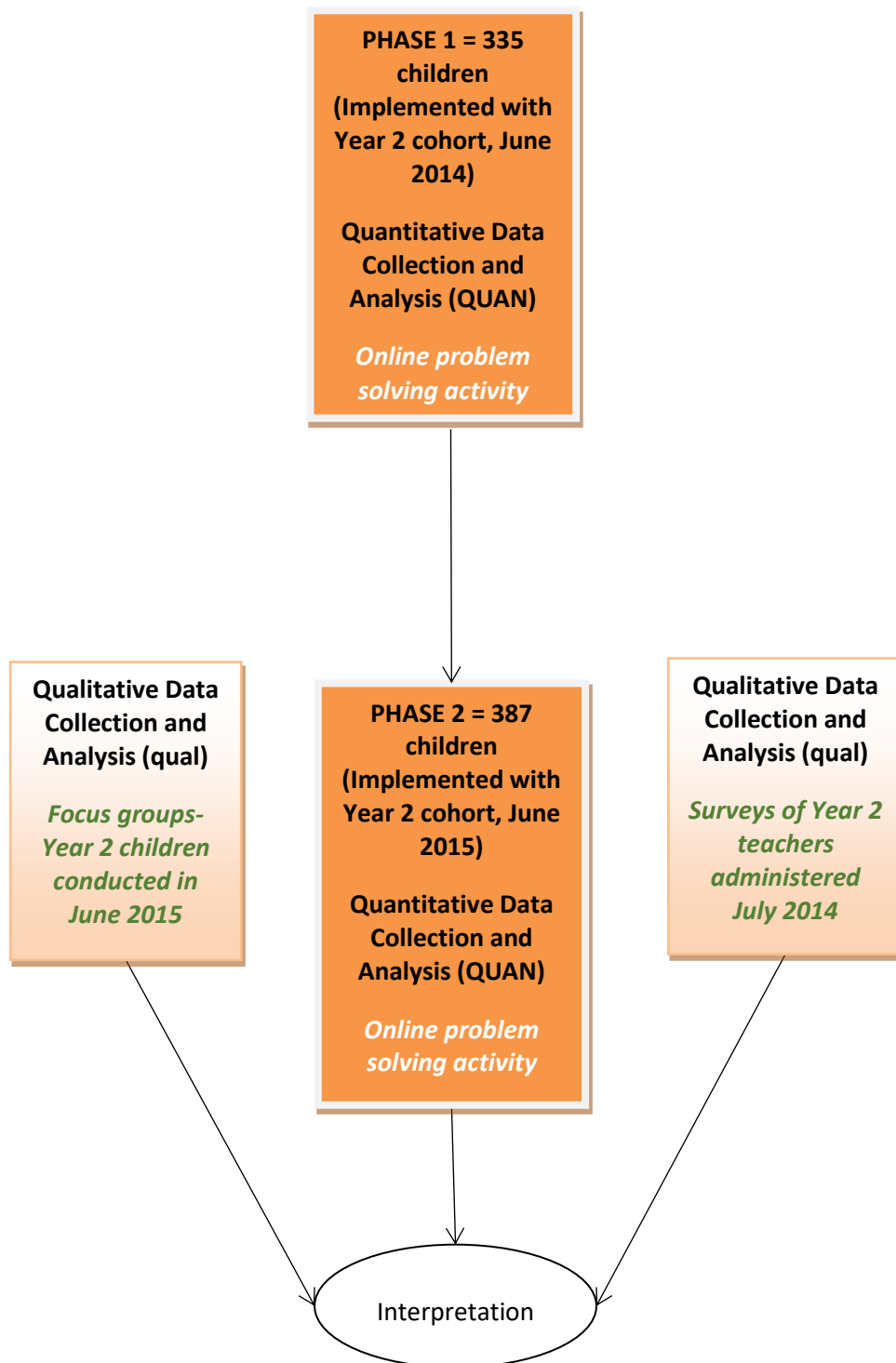


Figure 4: An Embedded Mixed Methods design.

From a notational perspective (Morgan, 2014) the quantitative element (QUAN) is capitalised and is therefore emphasised visually in the design (as seen in figure 4). This constituted the initial baseline data that needed to be collected in order to measure the effect in phase 2. A dominant status design QUAN+qual has been applied with the quantitative component showing more emphasis and preceding the qualitative component. This data will also be presented in the first section of the presentation and analysis of data for purposes of prevalence in addition to clarity. That said irrespective of the type of dominant component design, the non-dominant component must remain well respected (Leech and Onwuegbuzie, 2009). It is imperative for integration to be provided in all mixed methods studies (Hesse-Biber, 2010; Johnson and Onwuegbuzie, 2011) with one approach integrating the different components throughout the study and an alternative approach, which could include a section towards the end, that provides “meta-inferences and focuses specifically on integration” (Leech, 2014, p.877). The latter was considered to be the most effective method for this particular study though it is worthy to note that with either approach it remains imperative that integration is key. As this research design was sequential in its approach a discussion of the chosen methods will be presented in the order that it was conducted and for purposes of clarity and integration (Johnson and Onwuegbuzie, 2011).

The study begins with phase 1 which involved the administration of an online problem solving activity to year 2 children who had not experienced the computer programming within their curriculum. This was led and implemented by the Primary Coding Project team. The research design then proceeds to an exploratory stage which involved the collection of qualitative data through the conduction of online surveys with all key stage 1 teachers involved in the computer programming initiative. The findings from phase 1 testing did not influence the qualitative activities though as this data was gathered and incorporated to gain some insight into the existing knowledge of staff and garner views on their potential buy in to the new policy and programme development. As the dominant gender response was female, this was a factor that would be subject to further examination in the analysis section in relation to any gender bias or issues of stereotype threat (Steele, 1997; AAUW, 2015).

The survey also hoped to ascertain notions around sustainability should the quantitative data reveal that the computing programming intervention had a positive effect on children's problem solving skills. Additional qualitative data was also gathered through the implementation of focus groups with some of the year 2 children involved in the initiative. This element of the research was designed to understand the children's perceptions of the activities.

Phase 2 involved administration of the same online problem solving activity to a different cohort of year 2 children, having experienced computer programming sessions over an eight-week period, for an hour a week to examine any causal impact. No enhancements or changes were made to the administration of the tests in phase 2 to ensure that the process was as replicable to phase 1 as it could possibly be. The final stage of the research involved the integration and analysis of all the data gathered in an attempt to address the initial research question 'Does teaching computer programming within key stage 1 of the primary curriculum enhance children's problem solving skills?' and examine the supplementary questions of 'What are the views of year 2, key stage 1 teachers around embedding programming and computational thinking skills into the key stage 1 curriculum?'. 'What are year 2 children's perceptions of programming sessions; what do they think they are learning?' and 'Can any differences be identified between the performance of male and female participants in the study?'

4.3 Data collection tools

As discussed back in Chapter 1.5 the main core of the study involved testing different groups of year 2 children to examine the effect that the Primary Coding project (States of Jersey, 2014) may have on children's problem solving skills. Alongside the collection of quantitative data, plans to capture some of the richer nuances of the study through subsequent qualitative research methods were also devised, through surveying year 2 teachers and holding focus groups with year 2 children. At this stage it was proposed that all year 2 teachers involved in the initiative would be asked to complete an online survey to ascertain what their perceptions/attitudes towards teaching computing in key stage 1 were. This was carried out

using SurveyMonkey (1999-2017), a web based survey software and was sent out to all the teachers via their work email contact which was the mode of contact recommended by the Head teachers involved in the project. The purpose of the focus groups was to elucidate on what children thought they were doing during the sessions. Further details of these chosen tools will now be discussed.

4.4 The Problem Solving Activity (Design and content)

No existing baseline assessment tools were available when this element of the research was conducted (De Aruajo, Andrade and Serey Guerrero, 2016), as the changes to the ICT curriculum were not implemented until September 2014. As a consequence, a bespoke online tool was created by the Primary Coding Project team to gather this quantitative data. As these measures would be central to the study it was important to consider the validity and reliability of such a tool and why the results gained from it would be trustworthy. The creation of the tool was primarily informed by the first phase of the Primary Coding Project (States of Jersey, 2014) which as previously identified involved the Secondary ICT teaching team working alongside two partner primary schools as pilot groups. This enabled the team to gain practical experiences and perspectives from nursery through to year 6, which would then become pivotal in developing curriculum ideas and resources that would be age and stage appropriate. A real benefit of employing a pilot phase meant that it provided a mechanism for these ideas and resources to be tried and tested with the children who would be affected by the policy change and adapted where necessary. So effectively the children involved in the pilot were active participants, or “social actors” as referenced by James, Jenks and Prout (1998, p.396) in informing both the design of the problem solving activity and ultimately the new curriculum.

Further considerations around the design process involved ensuring that the problem solving activity was carefully designed to ensure it was meaningful, provided academic challenge but equally supported achievement, so as not to dissuade the children participating (Liao and Bright, 1991; Perlman, 1976). Also, revisiting the assertion by Haughlands (1992) that computer programming software and environments should be thoughtfully designed to “support autonomous or guided open-ended explorations in the process of which the children

participate actively, think and control the computer” (p.88) informed the design process and became a significant feature. The design of the problem solving activity also set out to acquire data around children’s ability to solve problems independently (Simon and Newall, 1971; Wang and Chiew, 2010), without social intervention, for example scaffolding (Boyd and Bee, 2014) or prompts from others; therefore, the design needed to support autonomous interaction as much as feasible. A review by Lye and Koh (2014) partly support this approach when they “propose that a constructionism-based problem solving learning environment could be designed...” (p.54) though no mention of how this could be assessed is offered. Due to the main aim of this study examining the impact of an intervention on children’s problem solving skills, it was felt relevant to create an environment that supported independent thinking to be able to glean clearer data for analysis.

To further support the notion of autonomy and, as previously alluded to, variables such as children’s familiarity with hardware and potential language barriers were also considered in the design stage of the research to ensure a more accurate measurement of results of the children’s problem solving skills, opposed to that of their technological aptitude or language acquisition. For example, the clarity of tasks was considered and supported with minimal use of written language so as not to disadvantage less able readers or students with English as a second language. This links back to the consideration of semantics (Corte and Verschaffel, 1987; Lamon, 1993) in chapter 2, both of whom have engaged in studies exploring children’s capacities to problem solve, but more specifically to the notion of being able to interpret problems, which can require an understanding of language construction and relationships. With this in mind Blockly was the tool chosen to be used to create the problem solving activity. Google for Education (2016) states that:

Blockly is library that adds a visual code editor to web and Android apps. The Blockly editor uses interlocking, graphical blocks to represent code concepts like variables, logical expressions, loops, and more. It allows users to apply programming principles without having to worry about syntax or the intimidation of a blinking cursor on the command line.

As previously highlighted the initial research approach (phase 1) involved the creation of a computer based ‘problem solving’ activity (15 minute duration) to implement with year 2

children who had not been exposed to computer programming within the curriculum (test base – over 360 children) in early July 2014 to allow us to gather initial baseline assessment data. The same computer based problem solving activity (phase 2) was implemented again with Year 2 children within the same schools in early July 2015, with these children having experienced computing programming sessions, for one hour per week over a period of eight weeks. On both occasions the programme sought to capture how many stages the children could complete, identify how long it took children to complete each stage, in addition to capturing how many moves children made to solve a problem, though this latter statement will be analysed further on.

Before commencing the activity all the children were shown an instructional video which advised them on what they could expect to see and what they needed to do. This was done for both phase 1 and phase 2 and the delivery by staff was standardised to ensure equity.

Once the children had signed in with their name, they would be presented with the following screen:

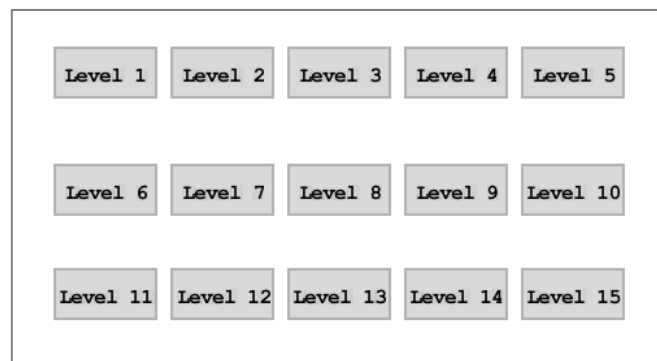


Figure 5: Problem solving activity levels

The problem solving activity consisted of 15 different levels with each level increasing in complexity, although it should be acknowledged that due to reasons of individuality that some children may find some levels easier than others. The theme of the activity was visual and constant in that at each level the children were required to programme a mouse to reach the cheese; this meant that the problem presented could be categorised as being “well-defined and had a specific goal” (Schraw, Dunkle and Bendixen, 1995). The requisite was for

all the children to attempt the levels in a sequential manner, although due to this being a timed activity the option of skipping a level was created and could be used if necessary. The additional reason for this option was also to ensure that all children had the opportunity to try out the more complex levels and demonstrate their skills at the various stages.

Each level had optimal moves assigned to it (Appendix 6) which had been identified by the Primary Coding Project (States of Jersey, 2014) team prior to the children undertaking the activity. These were set primarily on the grounds of efficiency, a significant trait in problem solvers (Smith, 1991), so for example, at level 13 the optimal move was 5 but it could equally be completed in as many as 21. The formation of the scoring system that was devised by the team to support the analysis of the results took into consideration the levels that were achieved, optimal moves made, timeframe each level was completed in and also if specific solutions, such as 'repeat blocks', had been utilised. The use of repeaters blocks will be demonstrated further on and additional considerations and justifications for the scoring system is addressed in the preliminary analysis section (Chapter 5).

On choosing a level, the child would be shown the following screen:

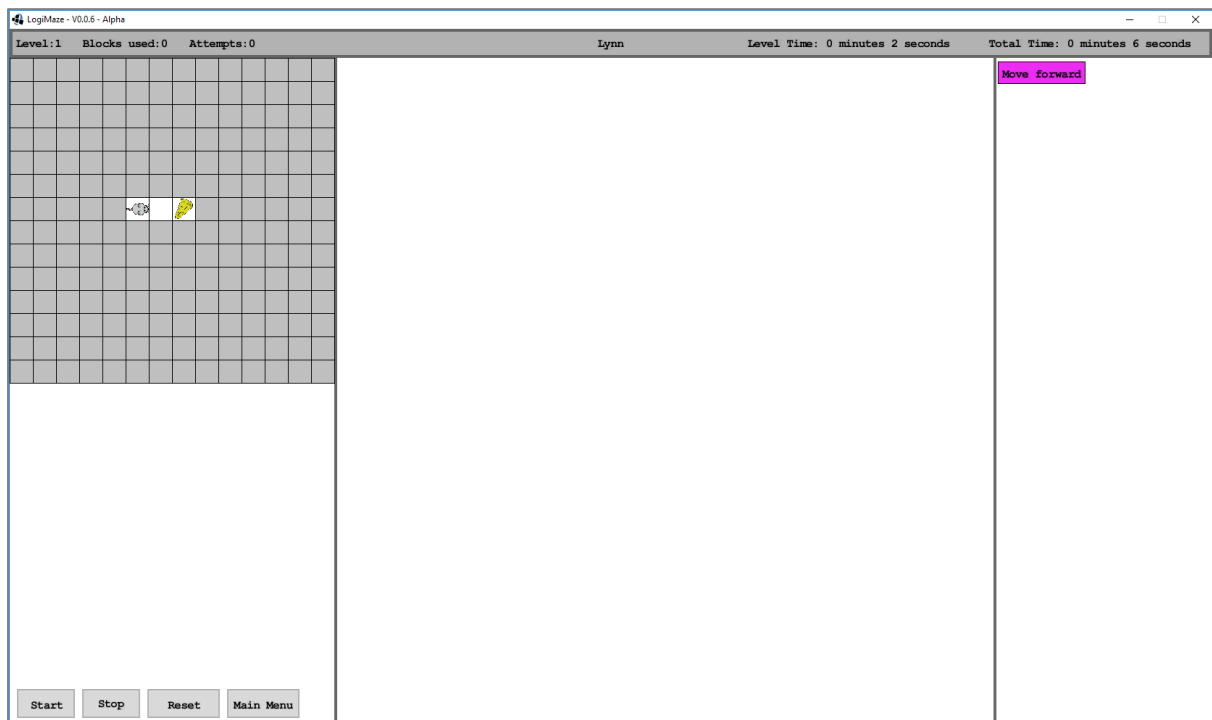


Figure 6: Problem solving activity – Level 1 start screen

The algorithm would be run when 'Start' is selected and the success or failure of the attempt can be seen on the left hand side. The centre space area is a drag and drop workspace where the algorithm is created. The right hand side column shows the block options available for that level.

Level 1 and level 2 of the activity were very straightforward, requiring the use of two blocks and then four blocks to achieve the given goal. This was done to put the children at ease and build confidence (Liao and Bright, 1991; Perlman, 1976). Below are screenshots of different levels of the problem solving activity undertaken by the children to offer a visual representation of the design and implementation of the research tool.

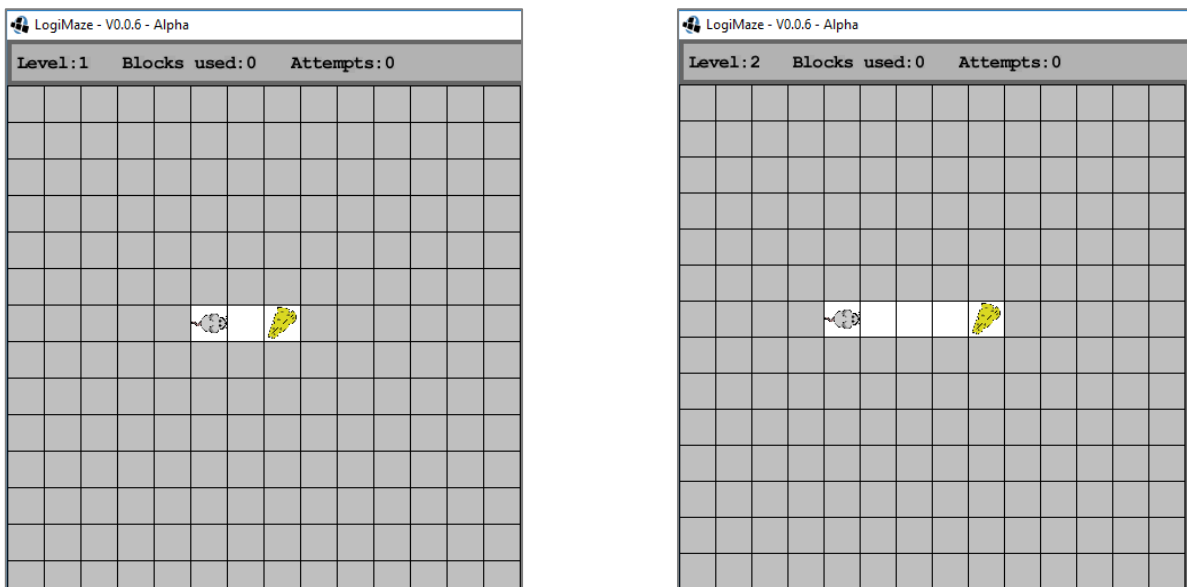


Figure 7: Level 1 and 2 of problem solving activity

As the children created their programme the instructional blocks snapped together to create a connected sequence of code which the mouse would follow.

The design of the problem solving tool enabled the children involved to receive instant feedback as to whether or not they had achieved the set goal, so in relation to supporting cognitive development this would align with the thoughts of Clements and Nastasi (1999) that receiving instant feedback through causality could promote the notion of metacognition, encouraging children to think about their own thinking whilst working through the given problem.

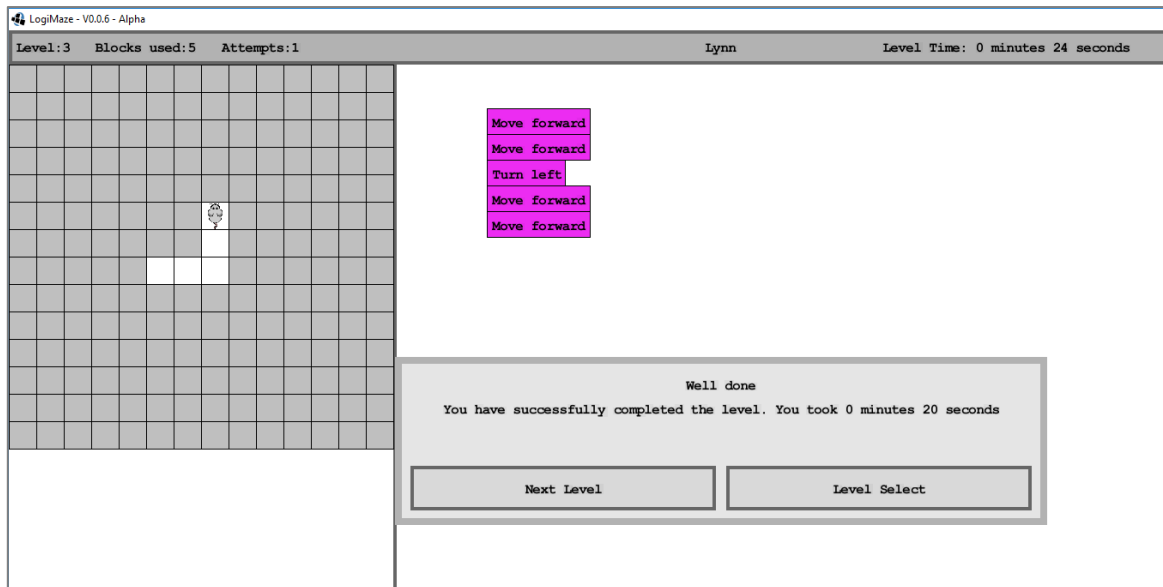


Figure 8: Level 3 - Feedback

Again, level 3 and level 4 of the activity was expected to be reasonably straight forward, requiring the children to understand the difference between turning left and right, however, in level 4, it becomes more complex as the mouse is facing downward so the children had to be able to understand that moving forward was determined by the way they were facing, so using the command “move forward” would be the appropriate one to employ. Papert (1993, p.37) referred to this as “body syntonic reasoning”, which in the Logo environment encouraged children to imagine what motions they would do if they were the turtle. In this case the children are having to imagine themselves as the mouse, which could support the notion of “perspective taking” (Flavell, Green and Flavell, 1990, cited in Boyd and Bee, 2014) and as previously highlighted suggests “the child develops a whole series of complex rules for figuring out precisely what the other person sees or experiences” (p.182).

Level 5 required two turns to be made to reach the destination and although level 6 was similar to level 5 the mouse was facing in the wrong direction so this needed to be adjusted from at the start.

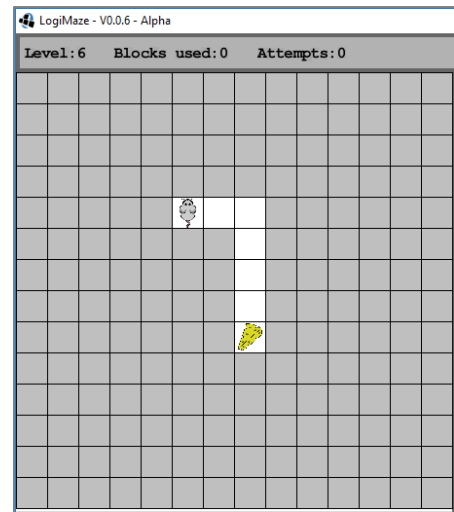
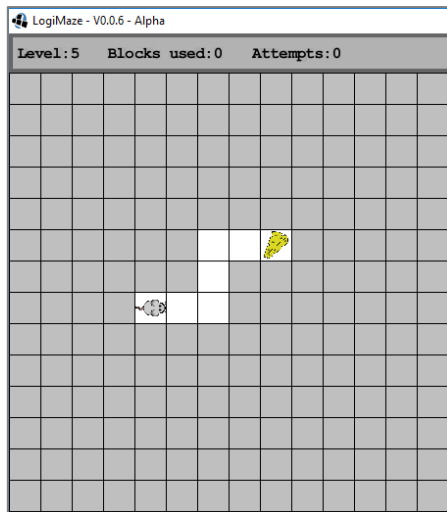


Figure 9: Level 5 and level 6

Similarly to level 6, at level 8 the mouse was also facing the wrong way but this time it was pointing down which added more complexity to the task as from a spatial awareness perspective it is more difficult to work out which way the mouse needs to turn from this dimension or orientation.

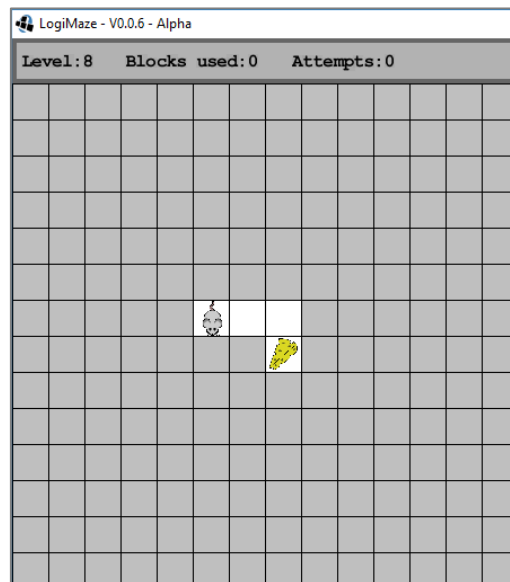


Figure 10: Level 8 – Concrete operations and spatial awareness

From level 10 onwards opportunities were presented for the children to programme using additional tools such as repeat blocks, while loops and IF statements. If chosen, the repeat blocks enabled the children to program the mouse more efficiently (Smith, 1991) than

manually entering each move needed on an individual basis, although either options could effectively work.

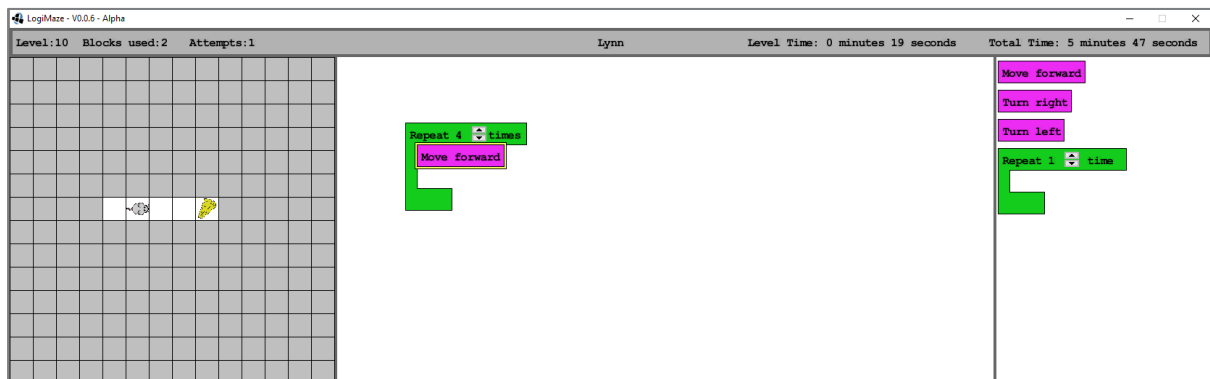


Figure 11: Level 10 - Use of repeat blocks, while loops.

While loops are also used within programming when instructions need to be repeated and this is referred to as iteration. According to The British Computer Society (2015) “iteration is the process of repeating a sequence of steps. In other words, iteration will involve a loop that is repeated (iterated) until the required answer is achieved. The first time the instructions in the loop is executed is the first iteration” (p.256). An example of this in the problem solving activity can be seen below:

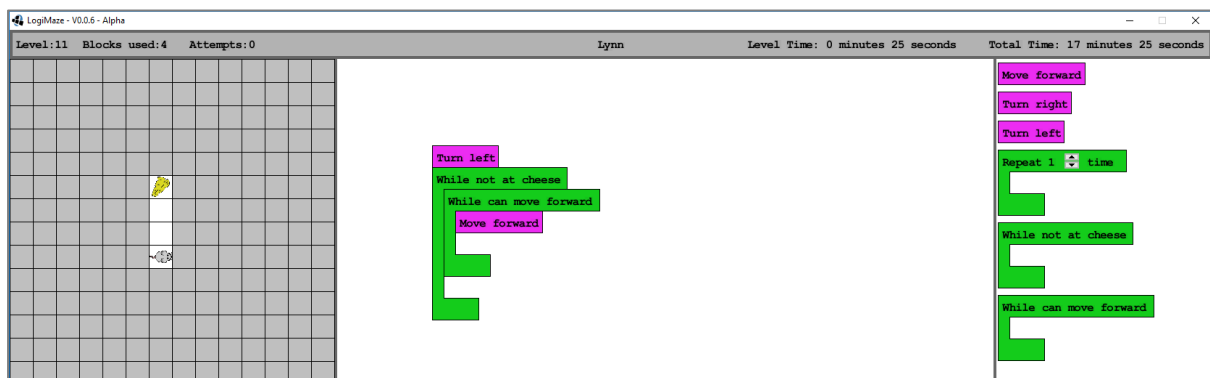


Figure 12: Level 11 – Example of iteration

This enabled the programmer or in this case, the student, to complete certain levels more efficiently, for example, level 13 could be achieved within 5 moves opposed to 21 without iteration.

When involved in designing programmes, points will arise when a decision of some sort must be made and this is referred to as selection and executed by using 'IF statements' and these were introduced at level 14. For example, children could program 'While not at cheese – Move forward – If path to left – Turn left. By placing the IF statement into the algorithm this would tell the program to look left after each move forward, but if no option was available to take a path to the left then the program will continue to move towards the target. By incorporating these options into the problem solving activity it offered the children opportunities to employ and present different solutions to the given problems and potentially create more intelligent algorithms. This would result in children gaining a higher problem solving score according to the scoring system devised and discussed further in Chapter 5.

See below for examples of an IF statement and then how these can be combined together to create a more complex instruction:

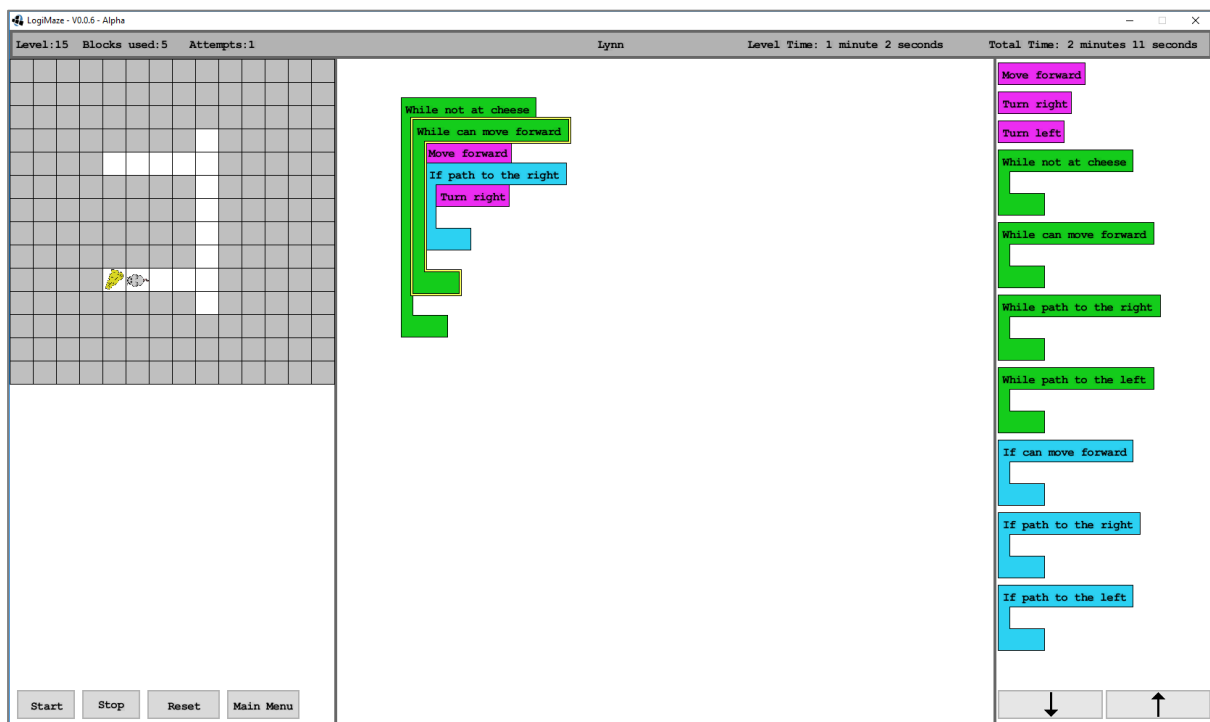


Figure 13: Level 15 – Combination of repeat blocks, while loops and IF statements

Increasing the complexity of levels within the problem solving tool was a deliberate design choice so that the children could demonstrate different levels of logical thought and

potentially draw upon metacognitive skills that are perhaps not already in the children’s problem space. As referred to previously, Simon and Newall (1971, p. 151), suggest that in the search for a solution or algorithm the problem solver can “odyssey from one knowledge state to another, until his current knowledge state includes the problem solution” or the answer is found. It was hoped that through capturing the algorithmic data that the children were creating to solve the given problems, some of the cognitive processes that the children were applying could then be examined and ultimately used to inform overall scores, although as previously mentioned this was not a straight forward process. For example, students that have been taught the action of using repeaters may complete the problem in fewer moves than those children having had no experience of the computer programming sessions. However, these children might still solve the problem by drawing on other techniques, within their own ‘problem space’ (Simon and Newall, 1971; Wang and Chiew, 2010), or through applying problem solving methods (Wang and Chiew, 2010) such as analogy, which needed to be considered in the overall weighting. An example of the data captured per individual student that was then used to calculate the problem solving score can be seen below:

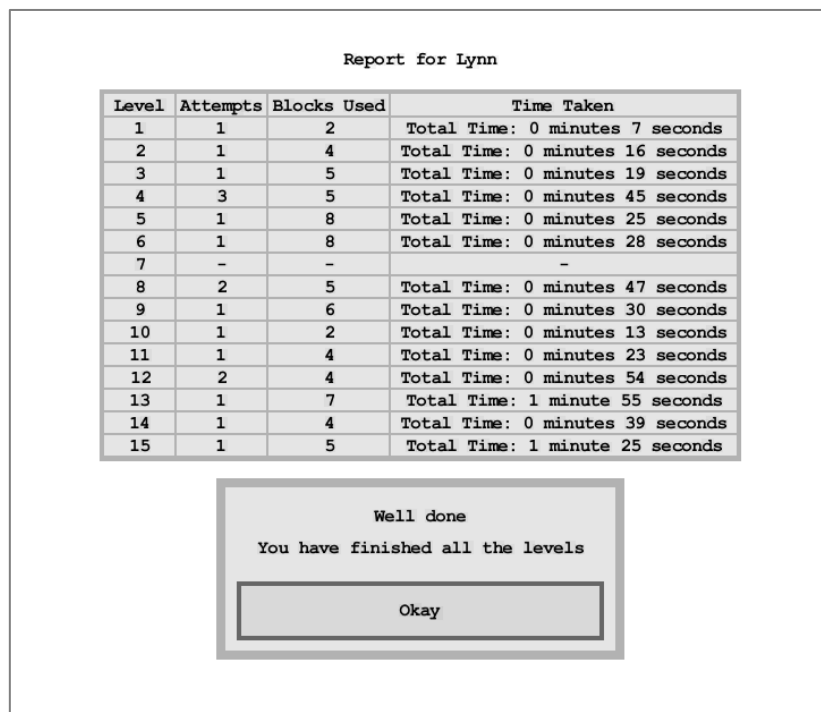


Figure 14: Final report for individual student

Although, creating such a tool was a resource challenge in relation to both expertise and time, from a research perspective I needed to ensure that it would stand up to scrutiny, therefore, using the review of literature to underpin the design of the problem solving activity was imperative. What this void in existing resources did ensure however, was that the tool being used was initialled solely for the research and therefore supported one important issue around validity in as much as it provided a guarantee that none of the children could have been exposed to this particular activity prior to the implementation of the project.

As previously stated, the sample size in phase 1 (2014) was 335 children and phase 2 (2015) involved 387 children, representative of the wider population of year 2 students in Jersey. In theory a sample size which consists of the entire population is ideal however this is not practical for numerous reasons, such as cost, time, staffing and general feasibility. A general rule of thumb is that the larger the sample size the better (Cohen et al, 2011) as long as the sample is representative of the population as a whole. This is because as sample size increases the margin of error decreases. A large sample size, within social science research, means that a 5% significance level is reasonable.

The practicalities of administering the activity

One of the main practicalities of administering the activity was around the window of opportunity available to gather data prior to the when the curriculum changes were to be implemented. This was crucial to enable analysis of both data sets, pre-intervention, with phase 1 children and post-intervention, with those children involved in phase 2. As mentioned early on in the study there appeared to be an abundance of research around technology and motivation (Fessakis et al, 2012; Henderson and Yeow, 2012) yet little evidence based research around the impact on children's cognitive development. There is however, a "widespread belief that computer programming based learning activities facilitate the development of algorithmic reasoning and problem solving capability in general" (Fessakis et al, 2012, p.96) which has been explored by Fessakis (2012) through a qualitative case study method with a class of Kindergarten children and by Clements (1994) who presented a study, involving eighteen 6 year old children, that examined the effects of computer programming on cognition. Although this study indicated that programming could "increase some aspects

of problem solving ability” and provided some evidence that “programming may affect cognitive style” (Clements and Gullo, 1984), there was no evidence to show that it had any significant impact on cognitive development. Both studies highlighted the fact that small sample sizes limited their results and Clements and Gullo (1984) also emphasised the point that at the time of his study the knowledge base around appropriate techniques for teaching programming to this particular age range was also limited and influenced their choice of sample size.

Interestingly, Fessakis (2012) recommended that interviews with children could be a valuable resource for future research, which have been included in this study. In relation to this research study I would assert that it appears to be quite unique; with 335 children in phase 1 (2014) and 387 children in phase 2 (2015) the sample size was relatively large, which can be a challenge to manage as a researcher and heavy to resource. I was extremely fortunate to be offered both the skills and the time of the Primary Coding project (States of Jersey, 2014) team to create and administer the problem solving activity.

Referring back to Cresswell’s (2012) statement around internal threats (Chapter 1.5), subsequent protocols were devised to manage potential threats that could be associated with the implementation of the testing process which was designed as an online problem solving activity tool. For example, if the children involved communicated with each other during the activity this could influence the outcomes of the problem solving activity and render the accuracy and validity of results gleaned. Use of equipment was deliberated and it was decided that for consistency and further validity measures that all children involved in the activity completed the task on a small portable computer; it was also considered that some children may not be familiar with this hardware so consequently all the portable computers were issued with mouse control, as it was agreed that most children would have used this hardware through their schools’ curriculum requirements. The problem solving activity tool was designed with minimal text, barring some simple instructions, as its purpose was to gather data on the children’s ability to problem solve, opposed to testing their language skills, which could be variable due to developmental stages and some children having English as an additional language.

Although technically not an internal threat, maturation was another factor that needed further consideration, as although all participants would be in year 2 when they took part in the activity it is well documented that birth dates may impact on educational outcomes (Borg and Falzon, 1995; Crawford, Dearden and Meghir, 2010). This factor, along with others are examined further in Chapter 5.

I obtained additional educational data for example, attainment levels, additional learning needs and dates of birth from the State statistician and this data was used to develop the quantitative phase of the analysis. The full list of variables is presented in Chapter 6.

An observational study – a methodological justification

Initially I struggled to ascertain if the problem solving activity part of this study fell into a ‘true’ or ‘quasi’ experimental design, or if it should be undertaken as an observational study (Cochran, 1965; Jepson et al 2004), due to the boundaries in some literature being quite vague. Cochran (1965) defined an observational study as having “the objective to elucidate cause and effect relationships in which it is not feasible to use controlled experimentation, concerning treatment, interventions, or policies and the effects they cause, and in this respect it resembles an experiment” (Cochran, 1965, cited in Rosenbaum, 2002, p.67).

The fact that this study involved a control group indicated a characteristic of being experimental, however for it to be a true experimental design it would need to have comparable measures from both groups, for example, pre-test and post-test scores for the control and treatment groups and it would also need to involve randomly assigned participants (Keppel and Wickens, 2003). Pre-test and post-test scores were not gathered from the control group and experimental group in this study but as previously stated, to ensure the two groups were comparable, each were assessed at the same time point in their school year and were otherwise assumed to be similar, considering they were not randomly assigned to the control and treatment groups. This is a common approach in educational research due to ethical considerations (Gorard, 2013) which could potentially deem it unethical to randomly assign pupils to a programme which you think could be beneficial, yet deliberately exclude others. However, in this particular study the control group could be seen

as the year 2 children who had not done the programming course, compared against the children who had received the programming intervention. The additional confounding variables that were gathered and further analysed as part of this study would help to account for the progress which the children would make anyway, regardless of the programming course, often referred to as “maturation effects” (Cresswell, 2012, p.174).

Although true experiments (Keppel and Wickens, 2003) are not commonly a conventional method within the educational arena, what is now being demanded is the need for more evidence based research to inform educational policy and practice (Rowland, 2015). The way to do this is through capturing rigorous data, be it quantitative or qualitative data, which helps to validate the choices and changes that are subsequently made to educational policy and practice that can then lead towards the promotion of a more evidenced based profession. After reflecting further on the purpose and characteristics of the research study an observational approach was deemed to be the most appropriate approach to employ.

4.5 Surveys with year 2 teachers

Initially, as the researcher, I considered interviewing as a method to survey the views of Year Two teachers opposed to questionnaires. However, the advantage of using questionnaires was the opportunity to sample a larger audience and gain “a broad picture of their experiences or views” (Clough and Nutbrown, 2008, p. 144) without being physically present. This enabled me to target all the Year 2 teachers involved in supporting the computing sessions from September 2014, opposed to selecting a smaller number of participants to conduct interviews with. What is worth noting here is Nutbrown’s reference to the opportunity of gaining a “broad picture” (2008, p.144) as effectively it could be argued that the participants involved in this study, being majority female, contradicts this idea. The notion of gender is further considered when analysing the data in Chapter 6 and 7.

The questions developed for the survey were initially informed by the research questions, but also drew from the aims of the ‘Primary Coding Project’ (States of Jersey, 2014) outlined in Chapter One. The survey questions asked can be found in table 2.

Survey questions for Year 2 teachers					
Question 1:	Are you male or female?				
Question 2:	What is your age?				
Question 3:	What do you understand by the term computer programming?				
Question 4:	Have you experienced computer programming before this initiative?				
Question 5:	If you answered No to question 4 then please move on to question 6. If you answered YES to question 4, which programmes/languages have you used?				
Question 6:	What do you think are the possible benefits of introducing computer programming into the Key Sage 1 curriculum?				
Question 7:	What do you think could be potential negatives to introducing computer programming into the Key Stage 1 curriculum?				
Question 8:	As a Key Stage 1 practitioner, please rate how confident you currently feel about delivering programming into the curriculum, with 1 being not at all confident through to 10 being extremely confident.				
Question 9:	As a Key Stage 1 practitioner, please rate how confident you currently feel about embedding programming into the curriculum, with 1 being not at all confident through to 10 being extremely confident.				
Question 10:	As a Key Stage 1 practitioner, do you have any concerns in regards to implementing and embedding programming into the curriculum from September 2014? If you answered NO, please move onto question 12.				
Question 11:	If YES, please identify your concerns using the rating scale below.				
		Very concerned	Slightly concerned	Not concerned at all	Total
	Personal Knowledge	3	4	0	7
	Training	4	3	0	7
	Assessing/tracking children's progress	4	2	1	7
Question 12:	Please take the time to share any other concerns that you may have in the box below.				
Question 13:	Finally, what do you understand by the term computational thinking?				

Table 2: Survey questions for Year 2 teachers

Part of the 'Primary Coding Project's' (States of Jersey, 2014) ambition was to support the development of teachers computing skills and address any skill shortage in the sector who were now being required to deliver a new primary computing curriculum. Although this was beyond the scope of this study, from a research perspective, it was still essential to find out from the year 2 teachers what existing knowledge and experience around computing was already out there; if there were any skill shortages, what were these skills and what training

needs could be identified to support the curriculum change. Copies of the devised questions and data collected can be found in Appendix 2.

Survey design

I decided upon an Internet based survey, primarily following on from advice from a Primary Head meeting, where the majority of Head teachers felt that this would be the most effective method of contacting their staff. A mix of closed and open questions were included in the design and consideration was given to the order of questions “to entice participants and not to put them off participating” (Cohen, Manion and Morrison, 2011, p.277). Open questions with free text responses allowed for participants to have some flexibility in their responses, but I was also conscious of not making the survey too long, which could have resulted in a low response rate or data less useful than a more structured approach may yield, so a combination of both seemed most appropriate. Thirteen questions were devised of which two had “branching instructions” (e.g. skip to item 13) (Cohen, Manion and Morrison, 2011, p.278) which Redline et al (2002) suggests can be problematic. The survey was piloted with one of the primary schools that was exempt from this study, due to being part of the pilot group for the computing in primary project, and the branching instructions showed not to be an issue.

Three of the thirteen questions were designed to ascertain attitudinal perspectives and Likert items (Likert, 1932) requiring participants to either rate a response to given statements on a scale that had values ranging from ‘not at all confident’ to ‘highly confident’ (Q.8 and Q.9), so employing a sliding scale (Cohen, Manion and Morrison, 2011, p.386) but also respond to one question (Q. 11) that asked participants to assign themselves to a category of either ‘very concerned, slightly concerned and not concerned at all’ . Scores obtained on all questions posed were designed to enable me to gather a measurement of the degree to which concepts are valued, therefore, indicating the strength of the respondent’s attitude.

Opportunities to allow respondents to respond using a neutral option were avoided. The use of mid-point, or neutral options is a well debated issue (Weems and Onwuegbuzie, 2001;

Harzing, Köster and Zhao, 2012). Further arguments to support this decision were informed by Garland (1991) who suggested that “social desirability bias, which is the tendency of research subjects to give socially desirable responses instead of choosing responses that are reflective of their true feelings” (p.68) can be minimized by excluding the mid-point option from the scale. Studies undertaken by Weems and Onwuegbuzie (2001) also indicated “that there was high rate of midpoint choices among the respondents, implying that such response category seems to weaken the reliability rather than enhance it” (p.170). Interestingly the choice to use or not use neutral options in Likert ratings can be aligned with cultural behaviour with both Chen and Stevenson (1995) and Harzing, Koster and Zhao (2012) implying that Asians were found to have a higher inclination to choose the neutral or middle option. With this in mind it is important to consider the context of your own research to justify the decisions made. The fact that the participants of the survey were all qualified teachers, holding a status of professionalism (Osgood, 2006; Dalli, 2008), pushed me towards removing the neutral option and guiding the respondents to make clear judgment calls on their own feelings towards these three questions posed.

Advantages of using this type of scaling instruments is that it allows the researcher to “build in a degree of sensitivity and differentiation of response whilst still generating numbers” (Cohen, Manion and Morrison, 2011, p.386) though cautionary factors such as words and numbers having different meanings for different respondents did need consideration. Research (Friedman and Amoo, 1999; Hartley and Betts, 2010) also suggest that respondents can be biased towards the left-hand side of a bi-polar scale and therefore in the survey design stage I felt it could be pertinent to mix the item scales so that positive scores can be found on both the left and right hand side of the scale. The Internet based survey was sent out to 19 participants, which represented all the Year 2 teachers involved in the next phase of the ‘Primary Coding Project’ (States of Jersey, 2014) who would be receiving a full term of computer programming sessions.

4.6 Focus groups with Year 2 children – context and justification of this chosen method

Five focus groups were held in June 2015, which involved a total of twenty seven children, fourteen girls and thirteen boys. The class teacher assigned the children to groups which

were all mixed gender apart from group 2. Heary and Hennessey (2002) have advocated for homogeneity when assigning groups, though Hill et al (1996) acknowledge that both mixed gender and single gendered groups have been efficacious. Re-visiting the pragmatic approach and “model of inquiry” (Dewey, 1986) that underpins this study, is the notion that the study itself should be the primary influence as to what composition is decided upon (Dewey, 1986; Gibson, 2007). Further considerations around the casual formation of groups was also influenced by a conscious act of not wishing to fall into a trap of holding any pre-conceived ideas around computer programming and gender, which was examined in chapter 2.3.

So as not to encroach on any other part of the curriculum, I had planned to complete the focus group activity during one of the children’s scheduled computer programming sessions. Having liaised with the member of staff from the Primary Coding Project (States of Jersey, 2014) who was delivering the session, we managed to work together to ensure that minimum disruption would be experienced and all of the children would still receive the same experience and coverage within their taught session. It was hoped that by carrying out the focus groups within this session would also help the children to contextualise the questions more (Morgan, 1998). I assigned each group 10 minutes out of the 60 minute programming session that was being delivered in parallel, which I felt was an appropriate duration for the age of the children and also allowed for transition between groups. I also felt that as the structure of the focus group was informed around suggested questions, devised prior to implementation, opposed to any practical or creative activities (Gibson, 2007), that this time allocation would be sufficient.

Barbour and Kitzinger (1999) suggest that a focus group can provide the opportunity for exchanges that enable exploration of specific issues, which otherwise would not be addressed. This method is distinguished from the broader category of interviews because group interaction is used to explore the phenomena, rather than the dynamics being directed by the interviewer. The non-hierarchical nature of such groups can also mean that power shifts away from the researcher towards the participant, although internal hierarchies may exist within the group of participants. Feminist researchers consider this transfer of power is necessary, as traditional approaches can create a situation whereby the reality of human

experience in context is lost, whereas, the focus group can re-address the power balance (Bohan, 1992).

The participant in a focus group is not seen as an individual acting in isolation (Morse and Field, 1996), but is the member of a social group, and therefore, subject to the dynamics of this situation. Moreover, the explicit use of group interaction is seen to produce data and insights that would be less achievable without this experience (Morgan, 1988). So effectively, “the aim of a focus group is not to develop consensus but to produce qualitative data that provides insight into the attitudes, perceptions, motivations, concerns and opinions of participants” (Gibson, 2007, p.474). However, Mitchell (1999) warns against the use of focus groups as the sole means of interview in an inquiry, on the basis that such an event is more likely to facilitate the exploration of mutual experiences than pursue research issues, which will be reflected upon further in Chapter 6.3. Moreover, the reduced control of the researcher is viewed by Kvale (1996) as disadvantageous, as it can result not only in detours in the discussion, but the raising of unrelated issues and chaotic data collection.

4.7 Practical considerations in developing and leading the group

I chose focus groups as the tool to discover children’s perspectives on their experiences with the computer programming initiative, yet turning to the literature on focus groups, there is “little guidance about conducting focus groups of children” (Christensen and James, 2008, p.100). Gibson (2007) acknowledges that there has been an expansion in research incorporating focus groups with children and young people, though these studies are primarily focussed around health education and psychology.

Highlighted concerns such as older children dominating the dialogue and issues of dynamics when bringing children together who are unfamiliar with each other were minimised in this study due to the focus groups being made up of children who were in the same school and key stage, working and socialising together on a day to day basis (Kennedy et al, 2001). The decision for conducting the focus groups within one primary school was justified on the grounds that this would minimise other variables coming into play. For example, if a question was posed around the children’s enjoyment of computer programming as a subject their

responses could be influenced by teaching styles, so to restrict the sample to one school ensured that all the children were coming from the same experience. Some examples of the questions asked to the children can be found in table 3.

Sample of questions for focus group (Year 2 children)	
Question 1:	Tell me what you know about Computer Science
Question 2:	What sort of things do you do in these sessions? What do you enjoy and what's challenging?
Question 3:	Do you think that what you are learning in the computer programming sessions helps you in other subjects in school?

Table 3: Sample of questions for focus groups (Year 2 children)

A break out room adjacent to where the children were being taught was prepared for the focus groups to take place in. A circular seating plan, around a table, was set up before the children arrived "in order to maximise interactions among the participants and maximise observer involvement" (Dilorio et al, 1994, p.277) in a non-authoritative manner. I felt that the use of a table may potentially help to minimise any feelings of self-consciousness (Hennessy and Heary, 2005) and also would replicate their everyday experience of sitting in their classroom environment, hence adding a sense of normality to the activity. As the children all knew each other it was not necessary to do any ice breaking exercises with the groups but I ensured that I introduced myself before each activity, explained why I was there and what I hoped to achieve from the session and also told the children how long the activity would take. This introduction was based upon a standard statement that had been prepared to ensure that each group received the same information. Some general ground rules were established around taking turns to speak, listening to others, alongside reassurance that this was an informal activity and therefore the children should be confident that there were no right or wrong answers to any of the questions being posed.

With regard to transparency, the children were shown the Dictaphone that was used to record each session and "verbal permission to use taping equipment sought" (Gibson, 2007, p.479), as some children may have felt uncomfortable with this, which is discussed further in chapter 4.7. Conversely, what was not considered and factored into the timing of the activity was the

novelty of being recorded and for some of the children the opportunity for them to hear their own voices played back, although this was done briefly for one group that specifically asked.

4.8 Expected roles of the participants and how this could shape the data

As previously identified the thinking behind involving the children through focus groups was to attempt to examine what the children were actually experiencing (Gibson, 2007) during the computing sessions and in turn try to explore some of their perceptions of the curriculum change. It was hoped that this data could then be aligned with the data gathered from the surveys implemented with the teachers to examine any emerging themes. However, at the time of implementing the focus groups what became apparent and needs acknowledging was the limited experience of computer programming sessions that the children had actually been involved allowing them to reflect and draw from. This was due to the changes that were made to the duration of study in the planning stage. In order to gather a deeper insight into children's perceptions of the curriculum change, focus groups with children involved in the initial piloting of the initiative could have been sought.

4.9 Ethical issues

All research involves a consideration of ethics but Murkerji and Albon (2010) highlight that in the field of early childhood research we should be "particularly mindful of ethics owing to the age and vulnerability of children birth to eight years" (p.33), that said it must be stressed that alongside being mindful of children's vulnerability their capacity for competence and ability to be valuable and unique participants' in research also needs to be acknowledged, thus allowing the researcher to gain perspectives through a different lens (Clough and Nutbrown, 2007).

On completion of the University's ethical application procedure (See Appendix 3), informal conversations with the States of Jersey Education Department suggested that they were very keen for the research to go ahead. I attended a Primary Head teacher meeting in March 2014 to introduce and inform all Head teachers, as the Gatekeepers (Christensen and James, 2008) of the potential research proposal. Information sheets were forwarded to all Head teachers and Year 2 teachers after this meeting (see Appendix 4). Following on from this, information

sheets outlining the focus and scope of the research were sent out to all parents whose children attended the schools that were going to be involved in the research (See Appendix 5). Information about the project was also uploaded onto the States of Jersey website and Facebook feed.

Due to the scale of the project and to ensure that parents/guardians did not feel pressured into agreeing to take part, parents/guardians were asked to contact their school should they have chosen to opt out of the project. A potential challenge with this method was that although Head teachers and Year 2 teachers had confirmed when they were giving out the information sheets, as a researcher I had no formal confirmation from parents or guardians that they had been received, though reassuringly I did receive some email requests from parents and guardians asking for further details on the nature of the data that was going to be collected. Justification for choosing this method of gaining consent came down to the fact that the Head teachers, as gatekeepers (Christensen and James, 2008) had sanctioned the research, which was inherent to the curriculum changes proposed for primary schools from September 2014.

The initial research activity, which involved the computer based problem solving activity, was embedded into the primary school's programming curriculum so that no extra time commitment was being asked of the children involved in the project. Should any of the children participating in the computer based problem solving activity planned appear to become distressed then they were given the option to stop at any time in the process, without any recourse. The computer based problem solving activity was designed to be a length of time thought to be appropriate for this age group, therefore alleviating any unnecessary stress or pressure on the children involved. Although the activity was implemented by secondary teachers involved in the pilot programme, the Year 2 teachers remained present in the classroom so that a familiar face was present at all times to help to address the concept of any power imbalance between adults and children that could have been a factor (Clough and Nutbrown, 2007). All participants were reminded of their right to withdraw at any point during the research process.

The data gathered from the problem solving activity was stored securely and although individual children are identifiable on the initial spreadsheet created to store the data no students would be identifiable within the study. Student data was also extracted from the Education Department in order to examine any corresponding variables against the aggregated results; this data was controlled by the Education Department statistician who anonymised the corresponding data prior to disclosing it. In regards to protecting the anonymity of the schools involved in the project, for the purposes of the research each school was assigned an identifier, or personal code. It should be reiterated here that the purpose of the research was not to compare establishments against each other, but to gather data that could be examined in relation to the effects of the new computer science curriculum on both students and practitioners.

Participation in the focus groups (children) and in the survey (teachers) was entirely voluntary. Children were able to withdraw from the focus groups at any time though it was explained to both parents and the children that it might not be possible to omit the data collected from the focus groups, as it was a group discussion and may be difficult to identify the individual child. Omitting data collected could also have a bearing on subsequent discussion in the focus group. The research was undertaken on school premises within school hours so issues of personal safety were negligible. It was also an environment familiar to all participants, in particular the children. Some researchers agree that using schools can create an atmosphere and environment where the children are 'insiders' which can negate any potential power imbalances that can occur between the researcher and participants, particularly if participants are taken out of their familiar surroundings (Morgan et al, 2002; Broome and Richards, 2003; Hill, 2005). Conversely, this familiarity can also be viewed as a challenge (Green and Hart, 1999) where children may resume back to behaviours that are associated with the environment that they are in such as putting their hand up before speaking. The environment as a potential distraction is identified and discussed further within the analysis (Chapter 5).

No names or personal identifiers were used in the reporting of the data and it was explained that it was the responsibility of the researcher to ensure that any data reported was non-disclosive so that participants could not be identified through any involvement in the research

methods proposed. All participants were assigned a unique code at the point of data collection. Information regarding the unique code and the name of the research participant was held on a password protected file that only the researcher had access to. The focus groups were audio recorded, with permission gained from the children involved and, as previously stated, recordings were accorded unique identifiers and held securely on a computer at Highlands College.

The same principles were applied to the data extracted from the online survey. All the teachers who had participated were allocated a unique code so that their comments could be presented and analysed but confidentiality maintained. As stated in Chapter 6, eleven out of nineteen teachers responded to the online survey. I was able to identify and contact individual teachers using their email address, but through the survey software. Uncompleted surveys were sent two reminders over a 4 week period after which I accepted non-compliance. This did pose an ethical challenge as residing in a small Island community I knew some of the potential participants quite well so I needed to be mindful of this and not abuse this position and over coerce to achieve a higher completion rate.

It was communicated to all participants involved in the study that the data would only be used for analysis purposes and all data would be kept electronically and securely for the duration of the project, in line with the University of Sheffield requirements, after which all data would be destroyed.

Summary of chapter

This chapter has explored and justified the thinking behind the design of the research methodology, an embedded mixed methods approach, in addition to examining the intention of the quantitative and qualitative research tools utilised. The practicalities of administration have been examined, particularly in relation to the problem solving activity. Examples of the content of the problem solving activity were presented in the main body of text to enhance the context of dialogue and data gathered from the qualitative methods has clearly been signposted into the Appendices. The final discussion was based around the consideration and justification of ethical decisions and practice that was adhered to during the research process.

Moving forward, the next chapter will explore the approach taken to analysing the quantitative and qualitative data gathered, which will be followed by a presentation and analysis of the data.

Chapter 5: Approach to data analysis

As this study employed a mixed methods approach it meant that the analysis section would be bringing together three different data sets. The first element of the study to be examined is the problem solving activity (quantitative data), which is followed by the approach considered for the qualitative survey data collated from the year 2 teaching staff. The final discussion is around the approach employed to analyse the qualitative data derived from the focus groups with the children.

5.1 Problem solving activity

Having gathered the data from both the 2014 and 2015 cohorts of year 2 children, involving nine schools with over 330 children in each cohort, a spreadsheet was created to store the multiple data gathered from the problem solving activity in preparation for analysing some baseline calculations around any confounding variables.

Prior to performing any analysis, a meeting between myself and members of the ICT secondary teaching team was organised and a discussion held around how to weight any penalties that would need to be applied to individual scores. A similar approach was taken in a study by Werner, Denner and Campe (2012) when attempting to measure children's computational thinking in a Middle School environment, although instead of penalties they refer to "partial credit" (p.218). As identified in chapter 4.4 penalties were given according to how many levels were achieved, the number of attempts taken to achieve a level and how many blocks were used in the process i.e. the less blocks used the better, on the grounds of efficiency (Smith, 1991). The number of attempts to solve a particular problem was debated at length as each level had an 'optimal move allocation' (see Appendix 6) but given the scenario of a child taking more moves to complete the challenge and ultimately 'getting there in the end' showed perseverance and resilience, which as previously identified are key attributes aligned to problem solving (Claxton, 2007; Fadel, Bialik and Trilling, 2015).

Multiple clicks could also denote disengagement with the task, or the "boredom effect" (Field, 2013, p.871), opposed to children making deliberated moves and this was considered when

contemplating the duration of the activity. As a result, the following mechanisms were applied:

Block penalty	0.1
Attempts penalty	0.5
Blocks not used penalty	0.2

Table 4: Block penalty mechanism

The 'Block penalty' was applied if a student used more blocks than the most efficient solution. The number of 'extra' blocks used was multiplied by 0.1. The 'Blocks not used' penalty had the purpose to penalise students who didn't use a block which would have increased the efficiency of their algorithm. An example of this would have been not using a repeat block when the best solution would have been to use one. This was key when trying to differentiate the students who were able to problem solve and effectively apply computational thinking (Wing, 2014) abilities. The rationale behind this was to measure whether students were writing efficient algorithms. The process of achieving this would involve them thinking computationally and using skills such as pattern recognition. Many of the levels within the activity were designed to produce patterns and it was hoped that students would identify some of these patterns and use iteration (loop) to repeat the patterns, opposed to repeating multiple linear instructions. Although the attempts penalty within the constructed metric may seem severe when compared with the other two penalties, emphasis was placed on not only the efficiency of the algorithm created but also the ability to find a solution in the fewest number of attempts.

The totality of the penalties would then be applied to individual students' scores for the spreadsheet to re-calculate the overall problem solving score data that would be used in the regression analysis.

It should be acknowledged here that some children participated in the problem solving activity but were taken into a different environment to complete it due to having specific learning needs and this will be further considered within the analysis section.

5.2 Multiple linear regression approach

To develop a model for the relationship between a set of independent variables, for example, the pupils' prior educational attainment in core subjects, demographic groups and their problem solving skills, multiple linear regression was used. Although Field (2013) advocates that predictors should be selected carefully and "based upon sound theoretical rationale or past research that has demonstrated their importance" (p.321), due to the lack of quantitative research around this area on assessment (Werner, Denner and Campe, 2012; Wilson et al, 2010), the selection of variables was based on the review of literature and the aspects of pupils' education and background that I believed would influence their problem solving ability. An acknowledgment of confounding variables has been highlighted and discussed in both Chapter 1 and Chapter 4 but I propose that further consideration is recognised here. The purpose of multiple linear regression is to isolate the relationship between an independent variable and the outcome variable from the effects of one or more other variables (or covariates). In this study I wanted to examine the relationship between being taught computer programming (independent variable) and the score on the problem solving activity (dependent variable) but needed to control for covariates such as maths ability (Wing, 2008; Gunderson et al, 2012; Varma, 2010; De Araujo, Andrade and Sere Guerrero, 2016, Boylan, 2017) or gender (Cooper and Weaver, 2003; Zarrett et al, 2000) which could confound the results. These covariates were not of central interest to the main research question. Effectively, multiple linear regression can be used to adjust for confounding variables and isolate the relationship of interest.

The academic potential of one cohort of Year 2 children against another was the obvious factor to cogitate; for example, one cohort may be particularly strong in a domain such as maths or equally, not as able as the other cohort, which ultimately could have an impact on the results achieved. By comparing the results of the problem solving activity to that of the additional educational baseline data, shared by the Education Department, it was hoped that this should be able to highlight if these variables were influential factors in the data gathered. The educational baseline data used would have gone through a moderation process and could be regarded as more reliable than assessment data gathered by teachers in a more informal environment, for example, when baseline data is gathered at reception age.

This supporting data would also be expedient in relation to factors such as children's literacy ability, special educational needs (SEN) and English as a second language (EAL), as although the activity was designed with minimum written instructions this may have been significant to the overall analysis. Attendance was another predictor variable that was considered for inclusion, however, on reflection and for reasons of accuracy it was felt that if this factor was to be included then more specific data would be required as to whether the children had attended the actual programming sessions rather than the more general attendance data that would be held by the schools and the Education Department. For example, a child may have been in attendance for part of that day but perhaps sent home due to illness and therefore not have attended the programming session. Such a pupil would be recorded as present but we would have no assessment records, which would skew the attendance data.

Other supplementary variables that were considered were summer born babies (Jaekel et al, 2015) and "Looked after children" (NSPCC, 2016). In relation to summer born babies there has been considerable interest in this domain (Crawford, Dearden and Greaves, 2011; Verachtert et al, 2010; Robertson, 2011) with various research suggesting that delayed school entry (DSE) may be beneficial to these babies (Martin, 2009; Gledhill, Ford and Goodman, 2002; Graue and DiPerna, 2000). However, Jaekel et al (2015) assert that reports around this area are inconclusive; their own longitudinal study, involving a total of 999 children, investigating the effects of DSE against age-appropriate school entry (ASE) on academic achievement, showed no significant difference "after minimizing selection bias and accounting for confounding effects of pre-school knowledge" (p. 656).

Although the results suggest that delaying school entry for summer birth babies may not be advantageous it should not dismiss any perceived concerns held by parents and practitioners. Factors such as developmental immaturity can be present across the age ranges and could possibly be beneficial to some children; equally, delaying school entry could have detrimental effects on children with developmental impairments or special education needs where early intervention could be viewed as a supportive mechanism. Although the study conducted by Jaekel et al (2015) was a large sample, longitudinal study, with its findings based upon "assessments according to age (standardized tests) and according to grade level (teacher ratings)" (p.655), as with all research it should be viewed and interpreted with caution. From

my own experience both as a researcher and practitioner I would question the accuracy and rigorousness of teacher assessment, due to its subjective nature and ever changing position in the policy arena, where there is often a challenge between child-centred, pedagogical values (Robert-Holmes, 2015).

Looked after children are children in the care system and can be defined as being “looked after by a local authority and provided with accommodation for a continuous period for more than 24 hours, is subject to a care order, or is subject to a placement order” (The Children Act, 1989). The reason for this factor to be included as a confounding variable is in response to research that has shown that educational outcomes for these children can be affected, though it should be acknowledged that the “attainment of looked after children in key stage 1 continues to improve, with reading attainment increasing from 64 per cent achieving the expected level, to 71 per cent in 2014” (DfE, 2014, p.1). The data highlighted that “the reading attainment gap closed by 1 per cent between 2013 and 2014, while the mathematics gap was unchanged from 2013” (Dfe, 2014, p.). As this study was examining the base line data for the children’s literacy and numeracy levels it seemed pertinent to also acknowledge these broader influences.

Additional external and unavoidable influences evolved around children who had accessed coding clubs outside of their school day or used similar computer programming software at home as this could be advantageous to some children being more familiar with programming principles. It was anticipated however, that some of these issues would be addressed by the sample being sufficiently large to account for ‘between pupil’ and ‘between-cohort’ variability (Cohen, Manion and Morrison, 2007; Gorard, 2013).

What would have been interesting to also include was the data from the “Jersey Premium” scheme (States of Jersey, 2017), mirroring the Department for Education (DfE) “Pupil Premium” initiative currently running in England (Rowland, 2015). Unfortunately, this data would not have been available for the phase 1 cohort back in 2014 and therefore no subsequent comparisons could have been made, due to it being so current.

The table below (table 5) summarises the variables considered in the preliminary stages of analysis:

<p>Dependent Variable: Total score on logical reasoning task (TOTAL)</p> <p>Independent Variables: SCHOOL, CODING (yes/no), SUMMER BIRTH (yes/no), GENDER (male/female), FIRST LANGUAGE (English, Portuguese, Polish, Other), ENGLISH AS AN ADDITIONAL LANGUAGE (yes/no), LOOKED AFTER CHILDREN (yes/no), SPECIAL EDUCATIONAL NEEDS (none, school action, school action plus, Statement of SEN), YEAR 1 AUTUMN READING LEVELS, YEAR 1 AUTUMN WRITING LEVELS, YEAR 1 AUTUMN ENGLISH LEVEL, YEAR 1 AUTUMN MATHEMATICS LEVEL, YEAR 1 AUTUMN SCIENCE LEVEL, YEAR 2 SUMMER READING LEVEL, YEAR 2 SUMMER WRITING LEVEL, YEAR 2 SUMMER ENGLISH LEVEL, YEAR 2 SUMMER MATHEMATICS LEVEL, YEAR 2 SUMMER SCIENCE LEVEL, KEY STAGE 1 PROGRESS CHECK IN ENGLISH, KEY STAGE 1 PROGRESS CHECK IN MATHEMATICS, KEY STAGE 1 PROGRESS CHECK IN SCIENCE (attainment and progress variables are measured in points)</p>

Table 5: Statement of variables

Originally SEN was recorded as an ordinal variable, however using dummy variables means that the order information was lost. This process was a necessary compromise to include SEN within the regression analysis. For the purposes of this research it can be assumed that ‘none’ is defined as no support provided, ‘school action’ is the lowest category of support, followed by ‘school action plus’, with the highest level of support being a ‘Statement of SEN’.

To justify that the overall profile of the pupils in phase 1 of the study was comparable to that of phase 2, an analysis of the demographics of the data set was carried out.

5.3 Analysis of the demographic profile of the data set (QUAN)

There were no significant demographic differences in gender, summer born, EAL, SEN or school profile between phase 1 and 2. School profile was included as a demographic variable in order to show the percentage of students in each school. Table 6 shows the descriptive statistics for each phase.

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
No Coding	331	548.3181	297.02742	16.32610	516.2017	580.4344
Coding	363	805.2598	268.50611	14.09292	777.5456	832.9741
Total	694	682.7127	310.10608	11.77147	659.6007	705.8247

Table 6: Descriptive Statistics

5.4 Preliminary analysis

As presented previously, Table 5 identifies the dependent variable as equating to the total (TOTAL) score the children gained on the problem solving activity. All predictor variables (or independent variables) that were felt could be significant or influencing the initial data gathered can be found re-coded in Appendix 8. The categorical predictors of FIRST LANGUAGE, SEN and SCHOOL were re-coded to create dichotomous variables that could then be used in the regression model. OTHER was included as a variable with the FIRST LANGUAGE category, in addition to POL (polish) and POR (Portuguese) to account for one Russian child taking part.

After talking through all the options with the statistician I decided that a backward elimination process (Cohen, Manion and Morrison, 2011) should be the next step to employ, which is where all independent variables are inputted into the equation and then subsequently removed one by one if they are found not to contribute to the regression process. This method is used to minimise suppressor effects (Ludlow and Klein, 2014), or to coin its original term of “clearing variates” (Mendershausen, 1939) defined as “a useful determining variate without causal connection with the dependent variate; its role in the set consists of clearing another determining (observational) variate of the effect of a disturbing basis variate” (p. 99). In other words, where a predictor variable has a significant effect but only when correlated with another predictor. The Education Department statistician fitted the model using an automated method and then supported this with a Stepwise (Field, 2013) approach. Although

for some statisticians Stepwise is frowned upon as it “assesses the fit of a variable based on the other variables in the model” so effectively, “variables might be considered bad predictors only because of what has been put in the model” (Field, 2013, p.323). We both agreed that for the purposes of exploration and model construction that this would be a good starting point. However, although this process was deemed to be an appropriate one for the initial data analysis there was no guarantee that the most suitable model would be constructed through this procedure.

Following a meeting between myself and the statistician to discuss the initial model that was produced, I highlighted any highly correlated variables that needed to be removed before running any subsequent models. This input was based upon the theoretical background to the study and contextual knowledge which influenced my thinking around which variables would be sensible to include or omit. These adjustments are documented in the presentation and analysis of the quantitative data found in Chapter 6.

5.5 Surveys and focus groups

Cohen, Manion and Morrison (2007) acknowledge that “there is not one single or correct way to analyse and present qualitative data; how one does it should abide by the issues of fitness for purpose” (p. 461). As a researcher I needed to be clear about what I wanted the data analysis to achieve in order to guide the type of analysis to be undertaken. In addition to the general challenges that needed to be considered, the added complexity with using a mixed methods approach lies in the ability to integrate and marry up the data collected across paradigms (Morgan, 2014). In regards to the data collected from the focus groups and surveys, I looked to apply a thematic/conceptual framework of analysis so that meaning can be generated more easily (Miles and Huberman, 1994). The mean was used for the analysis as opposed to the median as it is not as heavily impacted by extreme values or skewed data, for example, if there was any missing data (Uebersax, 2006).

In preparing to analyse the qualitative data collected it was important to revisit the supplementary questions that were devised to support the research. This re-established my focus on what I hoped to achieve with the methods employed. Both the survey and the focus

groups were designed to explore and raise issues that may be associated with developing and embedding computer programming into the Key Stage 1 curriculum. Further considerations made to the analysis of the data collected related to ensuring that my written interpretation reflected the true voice of all participants, regardless of the diversity in age. I recall Nutbrown (2010) suggesting that when analysing qualitative data it was important to avoid reference to 'validity' and instead focus on 'integrity' although the notion held by Hughes (2001) is that "knowledge is valid if it is the authentic and true voice of the participants" (p36). Maxwell (1992) suggests that a more appropriate term than validity in qualitative research should be that of 'understanding' and Blumenfeld-Jones (1995) cites 'fidelity' as a key requirement when researchers report back findings of their research. I feel that both terms are of paramount importance for a researcher when attempting to analyse with integrity the voices of participants, both adults and children, but it is a challenge acknowledged by Cohen et al (2007) that "qualitative data is often heavy on interpretation, and one has to note that there are frequently multiple interpretations to be made of qualitative data – that is their glory and their headache!" (p.461).

As the researcher analyses the data, Cohen et al (2007) go on to write that "he or she will have ideas, insights, comments, reflections to make on data. These can be noted down in memos and, indeed, these can become data themselves in the process of reflexivity (although they should be kept separate from the primary data themselves)" (p.469). This practice was adopted during this study in an attempt to be honest and open about how values may have influenced the research.

The next challenge I faced was deciding on the most effective way of presenting the qualitative data I had collected. Ideas to consider involved questions such as should I write down individual responses verbatim, or look for key issues that may emerge from individual contributions and then amalgamate and summarise findings into key areas. I felt that it was important to use verbatim data in the quest to avoid the "lost in translation" factor (Tierney and Lincoln, 1997, p.23). Ball (1990) and Bowe et al (1992) use a lot of verbatim for this reason yet conversely, Walford (2001) openly "admits that he rarely fully transcribed more than a few interviews for any of his research studies" (p.65) due to the time restraints invoked in such a process. As the qualitative data included contributions from children I felt that it was

important to present the data in its original form “to keep the flavour of the original data, so they report direct phrases and sentences, not only because they are often more illuminative and direct than the researchers’ own words, but also because they feel that it is important to be faithful to the exact words used” (Cohen et al, 2007, p.462).

5.6 Focus group with children – transcript of data (qual)

As stated in Chapter four, five focus groups involving a total of twenty-seven children, fourteen girls and thirteen boys, were conducted in June 2015. The information retrieved from the focus groups yielded some rich and valuable data on which to base the analysis but then the complex task of transcribing the voice recorder began. I had previously tested the equipment but it still remained, on occasion, difficult to decipher due to voice recognition. The voice recorder captured the atmosphere through intonations and expressions which then complimented the written transcription, which can be found in Appendix 3. I felt a huge sense of responsibility having transcribed and brought to print the voices of all the children of the group and was very aware that as stated by Mukherji and Albon (2010) “in writing up, you are representing people’s views or actions and that doing this carries an ethical responsibility” (p.245). I did consider continuing to involve the children in the research process by taking the completed transcripts back to the focus groups to ensure that what I had written was in essence a true representation of the group discussion. However, after further reflection it felt like this would be too much of a time commitment on the children’s part, combined with the time in between the focus group activity taking place and the transcription being complete, making its relevance questionable.

I proposed to follow the same principle of discussing the qualitative data from the focus groups using the guidelines I had devised to support the focus group session as a framework. Chenail (1995) suggests that “there are many different ways of deciding how to tell your story” (p. 14) so having completed the transcribing of the data, which I felt was important to do verbatim, I then found I was able to extract the more specific dialogue that was generated from each discussion point and remove some of the general chatter, which did, on occasion digress. Krueger (1998) identifies this as one of the disadvantages of focus groups; the reduced hierarchical nature of focus groups compared to that of an interview method “results

in some inefficiencies such as detours in the discussion and the raising of some irrelevant issues” (p.48), which be seen in the raw data collected (Appendix 3). This can result in data becoming quite chaotic (Kvale, 1996) and somewhat challenging to order, requiring quite a lengthy procedure of arranging or “compiling” of data (Yin, 2016, p.186) into some manageable order. Interviewing the children was challenging, due to events such as some of the children being interrupted by friends, becoming distracted by the other children in the group or more dominant children around them, as some unexpected events could happen during the process, but I still feel that this was the most appropriate and effective tool to use.

From the data gathered I decided to present the phrases and key words within the group that they were generated from and in the order that the discussion took place. I also decided to categorise the phrases and key words by gender. This would enable the children’s voices to be presented in a coherent manner to which would then form the basis of further analysis and the creation of a thematic narrative across both qualitative data sets. The narrative has been gendered and numerically coded (G1= Girl, first to speak and B1=Boy, first to speak) for clarity. Any words or phrases that were stated more than once, but by the same child, were omitted to avoid repetition. The children’s voices are evidenced in Appendix 3.

Following the preliminary analysis of the qualitative data to extract the main issues and findings, the next step in the analysis process would be to look at any themes that had emerged, across both sets of qualitative data, which could be examined in further depth. These themes are presented in Chapter 7. Having explored the approaches to be taken when it comes to analysing the data sets within this mixed methods study the next chapter presents the findings from each of the methods employed.

Chapter 6: Presentation and analysis of data

This next chapter presents and analyses the three different data sets that were gathered for the study. For purposes of clarity the results and analysis of the problem solving activity data are presented and analysed first followed by the analysis of the qualitative data gleaned from the survey and focus group activities. This is subsequently brought together under key themes that were identified. I chose to present the quantitative/statistical data within the main body of text, for both visual clarity and impact but the presentation of the qualitative data has been signposted to the appendix (1 and 2). This was a pragmatic decision and by no means a reflection on value or relevance of the data.

6.1 Results and analysis of problem solving activity (QUAN)

According to Sullivan (2012) “the effect size is the main finding of a quantitative study” (p.279) as it helps to determine the magnitude of the expected effect of the computing programme on children’s problem solving skills. Statistical significance examines if the findings from a study are more likely associated with chance as opposed to the intervention, which in this case was the programming course. Glass (cited in Sullivan, 2012) states that “you should describe the results in terms of measures of magnitude – not just, does a treatment affect people, but how much does it affect them” (p.279). So effectively the P value can identify or inform the researcher if an effect might be claimed to exist in some larger population that the research wishes to generalise the results to, but it will not reveal the scale or degree of the effect in real world terms. Ultimately, both concepts are essential for researchers’ being able to acknowledge and comprehend the full impact of a study.

As previously stated, it is worth noting that the children involved in phase 1 and phase 2 were consecutive Year 2 cohorts. The average total score for all children before the coding intervention was 548.32 compared to 810.03 post intervention. Taking the average total score for each school meant that the focus remained on the schools opposed to looking at children’s individual data. That said, the raw data initially gathered showed that fewer levels of the problem solving activity were completed by the children in 2014 with an average of 6.78, compared to 2015, where the completion average increased to 9.50. The average point score for the set of tasks completed by each child, which had a maximum of 100, also increased

from 48.94 in 2014 to 59.50 in 2015. This could indicate that children were completing the levels more efficiently, in a quicker time and using more optimal moves and will have contributed to the higher average total scores.

All schools showed an increase in performance between 2014 and 2015, with the highest increase in total score being 355.12 and the least at 56.45. The proportion of attempts achieving a maximum score also rose by approximately 10% from 25.67% in 2014 to 35.48% in 2015.

The score difference could be attributable to various factors, including student ability, gender, teaching technique, amongst others. However, the purpose of this study was not to compare results between individual schools but to look at whether the programme positively affected the wider population of students across schools. The demographic variables of each cohort were considered in Chapter 5, where it was established that there were no significant differences between phase 1 and phase 2, therefore it can be assumed that these variables did not influence the score difference as a result of both groups having a broadly similar demographic profile.

Linking back to the literature review, the positive results could be concomitant with the children developing their problem space (Wang and Chiew, 2010) as a result of the intervention and a general increase in their state of knowledge, for example, with the use of repeaters. Equally, the results could also acknowledge the less linear context of problem solving, exploring and finding potential solutions by the students that also achieved the end result, but in a less efficient manner, such as trial and error. In Werner, Kawamoto and Denner's (no date) study which looked at assessing students' computational thinking in Middle School, they acknowledge this as being key to analysis by asking questions such as "do students place the correct instruction at the correct program location in one attempt or do they make multiple attempts?" (Lee, 2010, cited in Werner, Kawamoto and Denner, no date). De Araujo, Andrade and Sere Guerrero (2016) also advocate that "content analysis allows us to make inferences about the reasoning that students appear to have been using, and gain further insight into students thought processes" (p. 214). Simon and Newall (1971) referred to this cognitive process as "an odyssey through the problem space" (p.151) challenging the

problem solver to draw upon metacognitive skills outside of the current problem space in order to seek a solution.

In relation to gender, all but one school showed boys scoring higher than girls. Males averaged 841.63 and female pupils scored an average of 630.24. In one school girls slightly outperformed the boys (30.27). This result was not surprising as research commonly shows a correlation between high achievements in maths amongst male students (Gundersen et al, 2012; Varma, 2010). I would suggest that this is pertinent to this particular study which focusses on the development of problem solving and logical reasoning skills (DfE, 2013), which are skills that would be found within the mathematical domain (Wing, 2008; De Araujo, Andrade and Sere Guerrero, 2016, Boylan, 2017). Although expected, these results were slightly concerning as they could be seen to affirm the stereotype around maths and computing being viewed as predominantly male orientated subjects (AAUW, 2015).

English as an additional language (EAL) and summer births were also independent variables that were considered but there was only a marginal difference in average total score. In relation to the Summer Birth data, this would align with the extensive research conducted by Jaekel et al (2015), Crawford, Dearden and Greaves (2011) and Robertson (2011) but also Gledhill, Ford and Goodman (2002) and Graue and DiPerna (2000) that the results around summer births and potentially delaying school entry (DSE) are inconclusive and showed no significant difference 'after minimizing selection bias and accounting for confounding effects of pre-school knowledge' (Jaekal, 2015, p. 656).

The factor SEN was also explored as part of the initial analysis and did have an effect on the average total score. School action, where pupils require more minimalistic intervention, had the lowest average score (489.31) when compared to No SEN (726.59), School Action + (547.33) and Statement of SEN (562.58), which is interesting to note. The prediction here would have been that children with a statement of SEN would have scored lower than that of the other children. These results could question the support that children that fall into the category of School Action are not getting enough support to enable them to reach their potential. As previously identified, some children with SEN completed the activity in a

separate room, with one to one support, which could, depending upon the amount of support these children received, have skewed this data.

The next steps in the preliminary data analysis involved exploring the relationship between Year 2 subject achievement (Maths and English) and the outcome score of the problem solving activity.

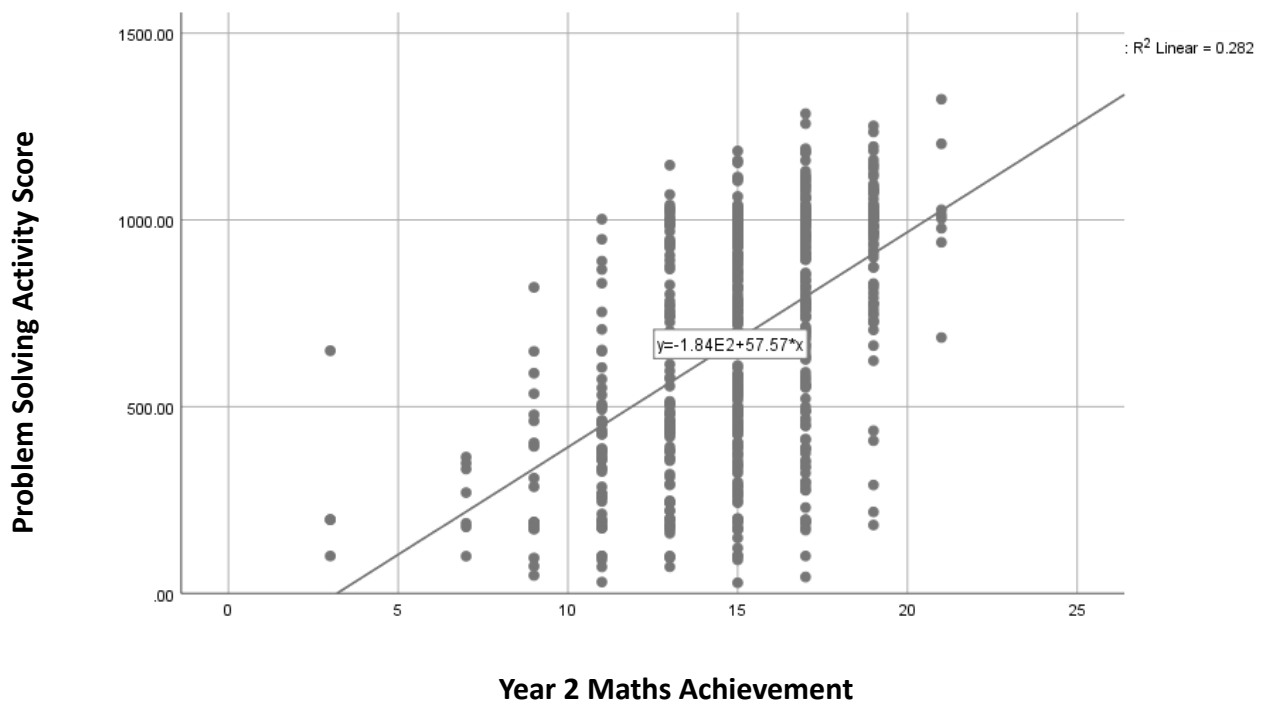


Figure 15: Scatter plot showing total score in problem solving activity against Year 2 Maths achievement

The scatter plot in figure 15 showed positive correlation between Year 2 Maths achievement and score achieved in the problem solving activity (Wing, 2008; Gunderson et al, 2012; Varma, 2010).

The points on the scatter plot are directional from the bottom left to the top right area of the plot. The overall pattern of the scatter plot suggests a positive linear association with the score achieved. Higher values of the explanatory variable, Year 2 Maths achievement, are associated with higher values of the response variable, score achieved, hence the positive

linear association between the two. Figure 15 did not highlight any outliers which would require further consideration. Year 2 Maths achievement, with a Pearson correlation coefficient of 0.531, had the strongest positive correlation with score achieved in the problem solving activity out of the variables considered.

R squared (R^2) indicates how well the data fits the regression line, and represents the proportion of explained (vs unexplained) variance. In general, the higher the R squared (always a value between 0 and 1) the better the model fits the data. However, in fields where predictions are more difficult, i.e. predicting human behaviour, a lower R^2 is expected. As there are statistically significant factors, conclusions can still be drawn. A relatively low R^2 value of 0.282 suggests that the regression line does not fit the data well, with only 28.2% of the variance accounted for. This means that more than 70% of variables are unexplained and were not accounted for and could include sleep, diet and health of the children.

The next scatter plot shown in figure 16 considered the possible relationship between Year 2 English achievement and score achieved on the problem solving activity.

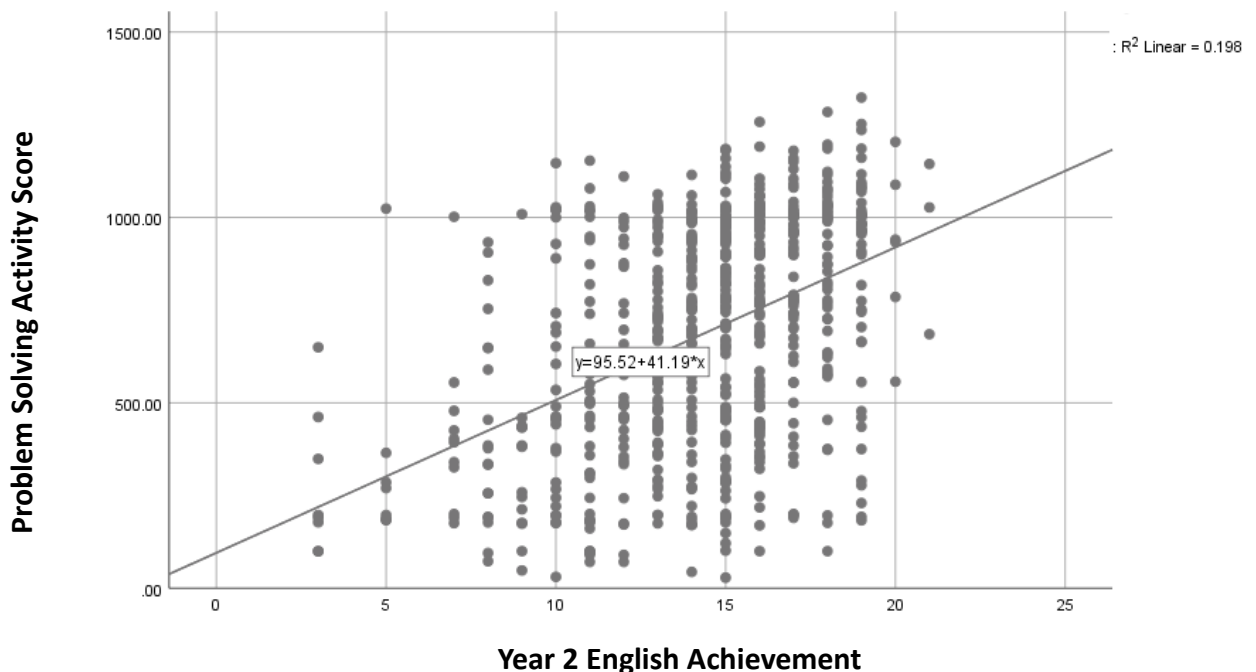


Figure 16: Scatter plot showing total score in problem solving activity against Year 2 English achievement

The scatter plot in figure 16 showed moderate positive correlation, with a Pearson correlation coefficient of .445, between Year 2 English achievement and score achieved in the problem solving activity. The points on the scatter plot were fairly evenly spread across a range of scores so no linear association could be assumed. The low R^2 value of 0.198 indicates that the regression model accounts for 19.8% of the variability of the data around the mean.

The overall pattern of the scatter plot suggested that a strong performance in Year 2 English achievement was not correlated with a higher score in the problem solving activity. Again, in relation to outliers, the points on the scatter plot were spread out so there were no individual points that fell outside the overall pattern, which would require further investigation.

From looking at the scatter plots they did suggest that the data met the assumptions of normality, that is, homoscedasticity and independence of residuals. Although not shown here this was checked by examining the residual statistics (Appendix 9).

The Pearson correlation coefficients for the explanatory variables are highlighted in and can be found in Appendix 10. This measures the strength of linear relationship between variables. When considering the multicollinearity of variables, there was clearly a strong correlation between Year 2 Writing achievement and Year 2 English achievement, and similarly between Year 2 Reading achievement with Year 2 English achievement. This was an expected outcome and therefore suggests that additional conclusions drawn from the data set would be reliable.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11429956.182	1	11429956.182	143.255	<0.001
Within Groups	55212928.390	692	79787.469		
Total	66642884.572	693			

Table7: ANOVA table

As previously discussed, a backwards step-wise variable selection method was used for the regression model. The ANOVA table in Table 7 is a test to ensure that at least one of the predictor variables has a linear relationship with the response variable. In this case there was

statistically significant difference between group means as determined by one-way ANOVA ($F(693,1) = 143.255$, $p < 0.001$). The variability between groups is quantified by the sum of squares (11429956.182) and the variability within the groups, or unexplained random error is quantified by the sum of squares with a value of 55212928.390. There were 694 total data points collected hence the total degrees of freedom is $n-1=693$. As there are two groups being compared there are $m-1=1$ degrees of freedom associated with the factor.

The F -statistic is the ratio of the mean square for between groups to the mean square within groups so can be calculated as follows $11429956.182/79787.469 = 143.255$. The F -statistic follows an F -distribution with (1, 692) degrees of freedom.

Model	Unstandardized Coefficients		Collinearity Statistics
	B	p	VIF
(Constant)	-271.966	.001	
SummerBirth	10.433	.629	1.099
Gender	106.161	<.001	1.187
Y1English	.980	.889	4.200
Y1Maths	5.818	.463	3.641
Y1Science	2.955	.676	3.316
Y2English	11.813	.128	6.910
Y2Maths	45.958	<.001	5.518
Y2Science	-4.355	.601	5.015
Sch2	-366.880	.005	1.080
Sch3	-115.625	.002	2.045
Sch4	-112.629	.008	1.640
Sch5	-135.932	<.001	2.203
Sch6	-89.418	.012	2.095
Sch7	-165.240	<.001	1.813
Sch8	-203.193	<.001	1.568
Sch9	-69.874	.674	1.152
Polish	27.438	.450	1.075
Portuguese	11.048	.672	1.297
Other	-86.452	.052	1.131
SA	-60.427	.139	1.193
SAPlus	-24.978	.488	1.224
Statement	-6.867	.940	1.200
Coding	290.370	<.001	1.279

Table 8: Initial model coefficients and collinearity statistics

β - Unstandardized coefficients are used in prediction and interpretation

p - If the effect of a variable is significant at the 0.05 level it should be kept. If it is not significant it is not a good predictor and should be discarded

There were some highly correlated independent variables, or multicollinearity, which is a common problem but also one that needs to be addressed as it can affect the validity of the model (Morrow-Howell, 1994; Marsh et al, 2004). When multicollinearity occurs between predictors it can become challenging to “assess the individual performance of a predictor” (Field, 2013, p.325) so effectively, if predictors are highly correlated it becomes hard to justify which of the variables is significant. By deciding which variables were theoretically the most important it then became possible to omit any others that were highly correlated.

If the coefficients were significant at the ($p < 0.05$) level it can be concluded that the coefficients are statistically significant and should be considered for the model; any significant variables are highlighted above in yellow. These include Coding, Year 2 Maths Achievement, Gender and multiple schools. As mentioned previously, SCHOOLS, alongside SEN and FIRSTLANGUAGE are dummy variables, used when categorical variables have more than two categories. According to Field (2013) “these groups cannot be distinguished using a single variable coded with zeros and ones” (p.419), so in this instance several variables were created (Appendix 8).

On considering the variance inflation factors (VIFs) Year 1 Maths Achievement, Year 1 English Achievement and Year 1 Science Achievement were identified as high which showed that these variables were highly correlated to other variables in the model. Year 2 Maths Achievement, Year 2 English Achievement and Year 2 Science Achievement also had high VIFs but it was decided to keep the Year 2 variables in the model, whilst removing the Year 1 variables, as I felt that the Year 2 variables were a more current predictor of the children’s’ abilities and therefore held more relevance. In other words, the Year 2 variables provided data that was closer to the point at which the children undertook the problem solving activity. The model was then re-run and the VIFs were reduced, showing that multicollinearity had been addressed. From the initial model R^2 dropped from 54.7% to 44.6%, which is a large

change in explained variance but this is inevitable when removing predictors as illustrated previously. A detailed summary of the final model for score attained is presented in Table 9.

Model	Unstandardized Coefficients β	Standard Error	Standardized Coefficients β	t	p	Collinearity Statistics VIF
(Constant)	-312.140	48.715		-6.408	<.001	
Coding	240.306	17.706	.388	13.572	<.001	1.003
Gender	77.975	17.684	.126	4.409	<.001	1.000
Y2Maths	55.265	3.098	.509	17.840	<.001	1.003

Table 9: Final model

The final model shown in Table 9 can be interpreted as follows. After considering the effect of gender and maths attainment, which were both significant predictors of problem solving score, the model predicts that participating in the coding curriculum increases the total score attained in the problem solving activity by 240.3 points. After participating in coding the strongest predictors of total score were gender and maths ability (Year 2 Maths Achievement) with β values of 77.975 and 55.265 respectfully. All of the coefficients were significantly different from 0 using the t statistics at p 0.05 level. The standardised coefficients, or z scores, allow you to compare the magnitudes of the coefficients (Kim and Feree, 1981) through standardising the scales of the variables and the coefficients are .388, .126 and .509 for Coding, Gender and Y" Maths respectively. These results illustrate that the coding intervention had a statistically significant effect on children's problem solving skills. However, when looking at the coefficient for coding it has a substantial effect of contextual significance, as the value of 240.3 is many times larger than the predicted effects of gender and maths. This means that phase 2 students were far more efficient at problem solving, at least in this constructed context, than their peers (phase 1).

6.2 Results of survey from year 2 teachers (qual)

11 out of 19 participants completed the online survey. As previously stated three of the thirteen questions that were asked (Q8; Q9 and Q11) had been designed to ascertain attitudinal perspectives with a Likert rating applied (Likert, 1932). The closed questions (Q1; Q2; Q4 and Q10) were to establish more determining factors. The remaining questions (Q3; Q5; Q6; Q7; Q12 and Q13) were designed to ascertain either existing knowledge or any other comments that could be deemed beneficial for the purposes of the study. Codes/identifiers were given to individual participants so that their comments could be seen in context with their gender and age range, for example a female between the age of 18-24 would become F18-24 with a unique number applied to the end. The data for all questions can be found in Appendix 1.

6.3 Data analysis of surveys

For purposes of clarity I decided to discuss the qualitative data collected from the surveys following the same order that the questions were asked. The first two questions posed were contextual and designed to establish the gender and age of the participants, which could be influential when analysing the results. The number of female respondents participating in the research did outweigh the males; over two thirds being female (one participant skipped this question, but was identifiably female from the email address offered, which would have increased the actual figure presented). The notion of gender in the context of computer science may be worthy of further consideration during the analysis, particularly around the under-representation of females in the field (Prottzman, 2011; AAUW, 2015). Whether this is due to bias, preference, or a combination of both would be the focus of different study but could be underlying influences in regards to some of the responses presented within the survey data. Establishing the participants' age was also considered to be relevant data to determine if the age of participants showed any correlation to how they responded and either aligned with or challenged Prensky's (2001) concept of the 'digital generation' (Buckingham, 2006, p.2).

Question 3 was posed to ascertain the participants' existing understanding of the term computer programming to which all respondents were able to articulate some understanding accurately, either as a result of drawing upon previous knowledge (45.45%) or as a result of experiencing the Primary Coding Project (54.55%). Out of the five participants who answered 'yes' to experiencing computer programming prior to the Primary Coding Project, three of these were the male teachers. Although this is a small group of participants it does show that 60% of participants who had previous knowledge of computer programming were male, aligning to the suggestion by the AAUW (2015) that there is still an inequitable gender balance in this domain. Question 5 was a branching question posed to those participants who had answered yes to having previous experience of computer programming; three out of five of the participants with experience were able to name a programme/language that they had used (two respondents skipped a response) but one participant who answered 'no' to having previous computer programming experience went on to recall a 'lego' programme that she had been introduced to through the project.

Participants were then asked what they thought the potential benefits could be from introducing computer programming into the Key Stage 1 curriculum (Question 6). One participant was unsure of what possible benefits might arise as a result of the curriculum change but the other ten participants offered contributions around the following domains. Seven comments were made around the development of children's computational thinking, with being able to think logically identified as an integral component of this. This aligns with the definition presented by Wing (2014) back in Chapter 1.5 that computational thinking is "the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out" and that it is a "mode of thought that goes well beyond software and hardware, and that provides a framework within which to reason about systems and problems" (CAS, 2012, p.3). Interestingly, this philosophy, and that of developing "creators opposed to consumers" of technology (Schmidt, 2011; Kenyon, 2013) came across in all but one of the comments made, with only one participant stating that 'computer programming could enhance ICT skills.'

Four comments were made in relation to computer programming potentially having cross curricular benefits, with maths being specifically noted along with problem solving in the

more general sense. This aligns with evidence gleaned from previous studies around the enhancement of problem solving skills (Billings, 1983; Milner, 1973; Soloway, Lohead and Clements, 1982; Statz, 1974) but interestingly, although some teachers' perceptions' were of computer programming having cross curriculum benefits, this is challenged by Pea, Hawkins and Sheingold (1993) when they suggested that computer programming skills were limited to specific contexts opposed to developing transferable skills that could be utilised across curriculum areas. However, their idea can equally be challenged when analysing the data gathered from the children's focus group activity, which is further examined in chapter 6.5 in relation to broader skills that might be developed, such as resilience and perseverance, that in themselves become transferable (Wang and Chiew, 2010; Claxton, 2007; Fadel, Bialik and Trilling, 2015).

Three participants mentioned that the introduction of computer programming into Key Stage 1 could be a positive contribution in preparing children for the future, a concept which is supported by CAS (2012) when they present that idea that pupils who are able to think computationally will effectively become better prepared for the world that doesn't yet exist, with both technology and challenges that they have yet to be exposed to. One comment that I also felt was important to highlight stated that 'the younger you start with new initiatives the easier it is for children to acquire the skills and knowledge required.' There is research to support this idea in relation to concepts such as language acquisition (MacWhinney, 2011; Boyd and Bee, 2014) so therefore it would not be unrealistic to think that learning programming languages could also fall into this bracket but I would suggest that developmentally appropriate practice (DAP) (Kim, 2011) is also crucial when developing an early childhood curriculum. This links back to having an awareness of the influences of pertinent early year's theories of development (Piaget, 1977) yet equally not categorising and potentially restricting children's cognitive abilities (Papert, 1975; Kesselring and Muller, 2010), as debated back in chapter 2.2.

The relationship between logic and problem solving was also explored in Chapter 2.2 and as identified by Featherstone and Bayley (2006):

The ability to meet the challenge of a problem, to approach it in an ordered and systematic way, to use previous experience and knowledge to develop strategies for solving it, to evaluate the success of a chosen approach, to persevere, where necessary rejecting the unsuccessful and starting again are all very sophisticated attributes. They are not, however, beyond the young child and are essential for independence of mind and thought (p.55).

This quote supports the notion that for most school aged children, who are developing “figurative schemes at an impressive rate” through exposure to a breadth of curricula content, start to develop “a set of immensely powerful, abstract, general rules or strategies for examining or interacting with the world” (Boyd and Bee, 2014, 187). This reiterates the ideas presented by Piaget back in Chapter 2.8 that the concrete operation stage are “critical building blocks of logical thinking” (Piaget, 1977, p.64) that allows the child to understand and apply internal rules to make sense of objects from a relational perspective. I would suggest that this also complements the ideals of Fadel, Bialik and Trilling’s (2015) 21st Century learning tenet and their concept of ‘four dimensional education’ (p.26), the first dimension relating to the acquisition and application of relevant knowledge, the second and fourth being linked to skills and meta-learning, but the third being associated with character, and more specifically perseverance and resilience.

Two comments suggested that having computer programming in the Key Stage 1 curriculum could engage children; these statements were compared to that of the children’s focus group data where the notion was affirmed and will be discussed further in Chapter 6.5. Another comment was made about transition, for example for preparing children for Key Stage 2 and finally one comment identified the opportunity for staff training as a positive aspect of the curriculum change. What was reassuring at this stage of the analysis was that the data collected reflected the aims of the Primary Coding Project (States of Jersey, 2014) which was “to improve teachers computing skills and inspire students to use technology from the earliest possible age”, in addition to addressing “the skill shortage in computing in primary schools, give staff extra skills to deliver computing to younger students, enthuse pupils to be the next generation of developers and develop wider skills, including numeracy and problem solving”.

Question 7 asked the participants to reflect upon any potential limitations to introducing computer programming into the Key Stage 1 curriculum and again responses were offered from ten of the eleven respondents. Three comments stated that they could not think of any negative consequences of teaching computer programming to children in this key stage. Two comments indicated that they felt that some basic ICT skills that the children would normally develop through exposure to the previous curriculum could be lost as a result of the changes. This concern was also raised back in Chapter 1.5 by Berry (2015) who highlighted the notion that “many young people will need the skills to produce online content for the world of work using certain tools, but they will not necessarily need to know how to create those tools”. So although this project advocates the curriculum change from ICT to Computer Science, it would be unfortunate if this was at the detriment of children losing some application skills. CAS (2013) attempt to reassure by stating:

Things that have long been part of ICT in schools, such as finding things out, exchanging and sharing information, and reviewing, modifying and evaluating work, remain as important now, for a broad and balanced technological education, as they ever were. The new programme of study provides ample scope for pupils to develop understanding, knowledge and skills in these areas, as you’ll see from some of the examples in this guide (p.4).

Two more comments also highlighted the challenges of curriculum coverage. One comment indicated that it could put added pressure on to staff who already found the breadth of the Primary Curriculum (DfE, 2013) difficult to cover, with the current restraints on their time; the other associated comment was around ensuring coverage of the Computing programme of study (DfE, 2013) itself. The issue of resources and infrastructure was also emphasised by two respondents, with one comment specifically referring to ‘computers not working, therefore raising the stress levels with small children having to wait a long time.’ It was a little unclear if this related to the child or teacher’s stress levels but from experience I felt confident in making the assumption that it could apply to both. This was a pertinent comment to make as having the infrastructure in place is crucial in ensuring a programme’s success. Having visited various primary schools for the purpose of this research it was evident that infrastructure and resources was variable across establishments as prior to the commencement of the project, schools had invested in different technology dependent upon their needs and values;

sometimes these decisions were made with good intentions but a lack of direction. This could link back to the notion of some schools and educators being influenced and focussing on the wrong skill set and potentially buying into a consumerism model of practice (Schmidt, 2011).

In Chapter 2.5 the idea of creating a culture to support a positive learning environment was examined. Although the notion of culture involves more than the physical resources and tools to support a curriculum, I would advocate that if staff and children come up against poor infrastructure and equipment, that places barriers between interaction and engagement, then both staff and children, particularly very young children, will quickly become discouraged. As previously discussed, this is also crucial when devising a new programme of learning and links to another comment made around accessibility. One respondent felt that computer programming sessions would 'suit pupils whose language skills are more developed. If you can't read or write you may be disadvantaged and get a wrong impression of the subject before being able to access it.' This connects to Perlman's philosophy (1976) that it is imperative that any learning activities for programming must be "carefully designed so that they are meaningful and challenging (and thus engaging) but also achievable in order to avoid the discouragement of children" (p.14).

What dominated the response to Question 7 was the issue around teachers' existing knowledge of computer programming. Two responses admitted that their own knowledge would be 'sketchy' and they would need to go through a stage of 'getting their head around the changes' and another two emphasised the need for staff training, but it was not stated whether this applied to themselves or their colleagues; either way, through this research, it has identified a need for training. It was acknowledged from the onset that some primary teachers may already have both the confidence and expertise to deliver and embed computing into the primary curriculum and if this was the case, it was intended that these skills and attributes would be both nurtured and utilised (States of Jersey, 2014). However, for those colleagues that did not have knowledge of computing, the project's aim was to support any skills gaps and empower primary schools to embrace the prospective curriculum changes.

Questions 8 and 9 are Likert items (Likert, 1932), used to ascertain the participants' current levels of confidence in being able to deliver and embed computer programming into the curriculum. The mean of the response scores for each of the questions similarly rated (Q.8 = 4.55 and Q.9 = 4.64), where a rating of 1 was 'not at all confident' and 10 was 'extremely confident'. I was expecting higher overall confidence levels for question 8 than for question 9, however the practitioners felt more confident embedding programming into the curriculum than delivering programming into the curriculum. The spread of confidence levels was fairly evenly distributed across question 9 but it would be interesting to see if this was indicative over a larger sample size. The fact that nobody rated themselves as 'extremely confident' was not a surprise and aligns with the notion by Britland (2013) that a change in curriculum often requires a change in mind set.

Question 10 asked participants if they had any concerns in regards to implementing and embedding computer programming into the curriculum from September 2014 of which 63.64% responded that they had concerns. Two out of the three males were included in the data which indicated that although the three male teachers had previously identified with having past experience of computer programming in question 3, concerns remained around the delivery and embedding of computer programming in the curriculum. Question 11 asked for those participants acknowledging concerns to be more specific in regards to placing those concerns, again using a scale of 'very concerned, slightly concerns to not concerned at all', to ascertain a measurement. Of the seven participants that acknowledged having concerns, 100% of these were around 'personal knowledge' and 'training.' One respondent subsequently identified with having no concerns around the assessment or tracking of children's progress within this domain, which was surprising, but in the context of the sample size, should be viewed with caution.

Participants were then asked to share any other concerns (Question 12) that they may have had as a result of the proposed curriculum change which received four responses. Three responses were in relation to current skill sets, potential training and CPD opportunities in order for teaching colleagues to feel comfortable in delivering and embedding computer programming into the curriculum, which again links back to the acknowledgement of the

‘Primary Coding Project’ (States of Jersey, 2014) commitment to ‘support any skills gaps and empower primary schools to embrace the prospective curriculum changes’.

One comment did highlight concerns around the language used when referring to the introduction of computer programming into the primary curriculum. The respondent highlighted concerns around the language used and went on to articulate that ‘when put into English for those who are not technology geeks it doesn’t seem that bad.’ I felt that this comment was quite powerful from a dual perspective. Firstly, it related back to the idea of developing a culturally conducive environment to support the re-introduction of computer programming into back into today’s curriculum, but this comment also resonated on a personal level. Chapter 1 is where I presented my own positionality in regards to both the research area and chosen methodology which at times I associated with the idea of learning a whole new language; this then lead me into trying to de-mystify some of the terminology within the computer science domain (Chapter 1.5) to ensure that this particular study was accessible. It could be argued that computer science as an area has been presented and captured through media representation as a subject for more academic students ‘or geeks’ (Graham and Latulipe, 2003; Hoegh and Moskal, 2009) so this notion needs to be broken down with more accessible language, introduced within the early years curriculum, but most imperatively in a developmentally appropriate way.

Interestingly question 13 was devised to establish the participants existing understanding of the term ‘computational thinking’ which at the time of writing I felt was and still is, the philosophy underpinning the curriculum and pedagogical change (CAS, 2012; Wing, 2014). Nine participants offered pertinent responses that included processes such as ‘problem solving, logical thought, ordered thinking and chunking tasks’ but one participant skipped the question and the other stated ‘that they would have to look it up. More jargon!’ This inferred that by posing this particular question, I had ascertained some of the participants’ existing understanding of the term but perhaps I had also inadvertently contributed to the perception or stereotype that I previously purported needed to be broken down.

Having interpreted the data gathered from the surveys two main issues around validity should be highlighted. As stated by Yin (2016) “a valid study is one that has properly interpreted its

data, so that the conclusions accurately reflect and represent the real world that was studied” (p.88) and although I am confident that these are the views of the teachers that were involved in the Primary Coding Project (States of Jersey, 2014) the sample size was smaller than I had hoped for (11 out of 19 potential responses were achieved) which left eight voices unrepresented. That said, the survey was not intended to produce generalizable data, but to add a depth and alternative element to the other data that was collected in order to answer the research question.

An additional point to consider would be in relation to the questions posed to ascertain a knowledge baseline. As the survey was implemented online an element of trust and professionalism needs to be assumed. Participants’ responses could have been influenced by other parties, texts or search engines, which in this case it could be argued that the process itself becomes self-serving, for example, they may not have known the answer to question 13 on commencement of the survey but having researched it further, they know now. This would have been the same had hard copies of the survey been sent out to the participants so the only alternative way to manage this would have been to administer the surveys face to face, but from a resourcing and time perspective this would have proved challenging for all involved. The fact that some of the responses received openly admitted to not understanding a particular term and others linked their responses to experience or classroom practice, suggests that they were answered authentically.

6.4 Data analysis of focus groups (qual)

As the facilitator of the focus group I started the activity by posing the question ‘tell me what you know about computer science’ to focus the children’s thinking on the purpose of the activity but at the same time ascertain what they understood by the terminology. Four out of the five groups involved gave examples of programmes that they had been introduced to in these sessions, for example, Scratch and Beebot, and all groups shared comments that linked to the process of either following or giving instructions in order to complete a task or find out something. In relation to the research question this demonstrated that the children’s perception of computer science was associated with the process of algorithmic thinking. Fessakis et al (2012) supports the idea that computer programming constitutes a significant

competence for learning and development of algorithmic problem-solving skills but also aligns with the emphasis made by CAS (2012) around the need for precision and being methodical when following or giving instructions.

One boy in group 4 (B1) referred to the term 'debugging' and further explained this as 'like you fix the computer basically.' Clements (1986) advocated that teachers should promote learning from a debugging atmosphere, building on the notion of fixing a computer program to the viewpoint of "debugging as an allegory for cognitive monitoring in myriad situations" (p.101) which leads into a comment made by B2 (group 4) who referred to programming shapes and using repeaters and angles. This could support the idea of promoting learning in myriad situations as it indicated his awareness of cross curricular learning (Billings, 1983; Milner, 1973; Soloway, Lohead and Clements, 1982; Statz, 1974). This statement is backed up further on by the same child when asked if computer programming sessions helps them in other subjects.

Although the children had not been asked about their feelings towards the computer programming sessions at this point, as some of the children were keen to share their thoughts I did not want to restrict the dialogue so felt the session should remain quite fluid. G1 (group 1) referred to it as 'really cool', G1 and G2 (group 2) both used the term 'interesting' as did B2 in group 4; additionally, G3 (group 3) said she also found it 'exciting and interesting.' Although a very small sample, it was interesting to review the responses from a gender perspective and would indicate that in this instance gender preference towards the subject is not prevalent, or at least minimised when children are introduced and exposed to computing to the concept of computing within the early years and over a sustained period of time (Prottzman, 2011). Studies which have examined gender and the use of IT (Siraj-Blatchford and Whitebread, 2013; OFCOM, 2013, Davies, 2015), have suggested boys have preferences over girls for computer games and found girls to engage in IT more for purposes of communication, leading designers of technology into producing what was referred to as "pink software" games (Dickey, 2006) in an attempt to address potential imbalances. Although gender stereotyping is a complex debate in itself the changes to the curriculum, with its emphasis on computational thinking opposed to games (Freedman, 2012; Yun Sung, Siraj Blatchford and Kucirkova, 2016), may make it more appealing to both.

This leads appropriately into the next question posed which was to find out more about what the children did in these sessions and what aspects they particularly liked or found challenging. Again programmes such as Beebot and Scratch were referred to by group 1 and group 2 with G1 (group 1) stating that 'you get to play games and it's really fun the way you get to program...it's like you're making your own little thing'. This would seemingly support Hauglands (1992) thoughts around the notion of carefully designed computer programming software and environments with the emphasis that it should provide autonomous opportunities for children to explore, actively participate and 'control the computer' (p.88) by creating a language and subsequently, an action. This provides some evidence around how computer programming can support the problem solving process in relation to making independent choices.

Some of the children commented that they enjoyed playing maths games (B2, group 1, B1, group 5) and having the freedom to choose anything you want on the computer (G1, group 5), go on Google (B3, group 1), put music on and go on the computers for golden time (B1, group 5). As these responses were not specifically linked to computer programming it could be suggested that perhaps some of the motivation and excitement shown towards these sessions were due to having access to the computers (Fessakis et al, 2012; Henderson and Yeow, 2012) rather than the content of the computer programming sessions and activities themselves. In hindsight, some visual representations of computer programming activities that they had been exposed to, both plugged and unplugged, may have helped the children to recall and respond more specifically/directly to the question posed. In group 4 one boy (B3) felt that having a new teacher in to help them with computers was a good thing; another boy (B2, group 4) commented that he found 'it interesting about all the shapes and stuff cos we learnt a new one called the decagon, but it's quite sad because we only have one more week left'; in the same group B1 responded by saying 'but when we're in year 3 we'll still get it won't we?' All of these comments suggest that the computer programming sessions have been well received by these children and indicate that they would like to continue it when they move up into the next year group. I would suggest that this response is directly linked to the confidence and passion within the Primary Coding project team, all of whom believed in the initiative and were keen to achieve the aims and objectives (States of Jersey, 2014).

Conversely, one girl (G1, group 2) stated that she found it 'difficult following instructions' and then made a pertinent point around always being 'late on the computer and I don't get on it...then the sessions may be finished so I get a problem with the computer when it's on Beebot.' She then followed this with the comment 'I don't even understand what he means half the time.' Although these challenges came from only one child, I think two key points are raised and have been previously discussed within the review of literature.

The first challenge is around resources and ensuring that children can access computers and programmes efficiently; technology as a motivator has already been highlighted (Fessakis et al, 2012; Henderson and Yeow, 2012) but equally, when technical issues arise it can very quickly de-motivate and become a frustration for children. The second challenge is around ensuring that the curriculum is accessible to all children, which aligns to the studies by Liao and Bright (1991), Perlman (1976) and Hauglands (1992) who all advocate the imperativeness of the curriculum design process to ensure that learning activities are meaningful, challenging but equally achievable.

The next topic of discussion that I wanted to explore was around transferable skills so the children were asked if they thought that by learning computer programming helped them in other subjects in school. There was a clear consensus linking computer programming with maths with G1 (group 1), B1 and B2 (group 4) and B1 (group 5) all offering examples of learning new shapes and applying the concept of degrees, such as 90, 180 and 360, when entering directional instructions into programmes/ programmable resources. Two children (B1 and B3, group 4) also made reference to the science curriculum, stating that 'debugging is a lot like science and stuff like that' (B3, group 4) with B1 (group 4) adding to this statement with 'and you can fix it' which would support the notion of encouraging children to work out solutions to solve given problems (Wang and Chiew, 2010). Although not directly linked to the idea of computer programming supporting other areas of the curriculum I did feel that two comments made by B1 and B3 (group 4) were worthy of noting. Additionally, I did find one comment made by G1 (Group 4) particularly interesting, as although it wasn't directly linked to the question posed it did evoke thoughts around a potential shift in the relationship between children and computers, which is addressed in Chapter 7.2.

B1 (group 4) then declared that the teacher who had been delivering the computer programming sessions 'teaches year 9 and 10 and I think it's really special cos they're 8 years older than us, so we're learning our 90 times tables and we're in year 2 and they're in year 10, but now we're learning what year 10's learn'. B2 (group 4) followed this statement up with the avowal that 'when we're in year 10 we're going to be amazing at this.' It could be argued that these children were just repeating what they had heard the teacher say to them but what came through from their comments was the children's confidence and self-belief in their potential. I feel compelled here to refer back to studies such as Liao and Bright (1991), Perlman (1976) and Hauglands (1992) which although are quite dated studies, they all reiterate the importance of ensuring that learning activities for computing are carefully designed to promote optimum cognitive development; they should be designed to support autonomy and exploration, be purposeful and challenging, but more crucially be achievable. On the basis of these findings, it is imperative that the computing programmes of study for primary (DfE, 2013) supports these demands and as children transition into secondary school, that the programmes of study continue to 'stretch and challenge' appropriately.

The final question was created to try to ascertain if the impact of the computer programming sessions was being shared with any of their friends or family outside of the school curriculum, however limited data was yielded from this question. Reasons for this could have been connected to the question itself being a little ambiguous and also as a result of it being the last question to be asked. One girl (G2, group 1) stated that she shared what she had learnt with friends in the playground and with her parents and family, but the response felt like it was perhaps offered to please opposed to an authentic reply. Five girls from group 2 shared some of their home experiences, with one stating that she didn't go on Scratch at home (G3), although whether this was because she didn't have it at home was not established. G2 said that she didn't have Scratch at home, with G1 proclaiming that she couldn't go on Scratch as she didn't have a computer. A similar response was offered by G6 who acknowledged that she did have a computer 'but it's very old and it can't go that well, it's like 12 years old...so I can't do it.' G4 said that she had a new computer and when prompted to see if she did anything at home like she did in the computer programming sessions she acknowledged that she used Scratch at home. This data implies that although programming has been seen to enhance children's problem solving skills in the school environment, through the curriculum,

there could well be some inequities in relation to children accessing such resources within the home environment.

No data was gathered for this question from groups 3, 4 and 5 due to the children indicating, through their body language (Gibson, 2007) that they were ready to go back into their class. This could link in to the idea presented earlier by Green and Hart (1999) who suggested that conducting focus groups within a familiar environment can create challenges of their own. In this instance I think that the challenge might have stemmed from the children's awareness that a computer programming session was taking place in the adjacent room which could have made them feel like they were missing out, even though the session was designed to mitigate this. Reflecting further, Huang et al (2016) concur that "Children, especially young children, were more likely to become bored by verbal communication, and they sometimes might find it difficult to express their views and feelings in words" (p.352). Adhering to ethical protocols this choice was offered and respected (Clough and Nutbrown, 2007; Murkerji and Albon, 2010).

Overall, I feel that the focus group sessions offered a valuable insight into the curriculum change from the children's perspective, although this method was not without its challenges. In hindsight I feel that I could possibly have explored a variety of nonverbal methods of data collection "to motivate children and generate richer data, such as drawing, photography, observation, role play, using cards, reading books, playing games, writing and mapping" (Huang et al, 2016, p. 352). Gibson (2007) and Morgan et al (2002) both advocate that the inclusion of activities can support children's concentration time as well as offering younger children an alternative method of expressing their thoughts and clarifying meanings. For this specific study I could have supported the focus group sessions further by bringing in resources that the children had already been exposed to in some of the computing sessions, or alternatively provided the children with some visual stimuli, for example photographs of programmes that the children had used, which may have supported the children's contextual understanding and recollection of what the computing sessions involved.

Examining the concept of 'clarifying meaning' further, providing additional resources may have helped to contextualise an intriguing comment that was offered by one child around the

notion of 'the computer programming the child' which as Huang et al (2016) identify "it was often difficult for the adult researchers to interpret data collected from children. Sometimes, the spoken words children used did not mean exactly what they wanted to express" (p.352), for example, in the focus groups (Group 1, B1) stated that 'I was just going to say...erm...I think it's really special cos sometimes it makes me think that we're working for the program.' As the facilitator I probed this statement further but the child in question then changed focus. This is a challenge that is also identified by others (Mack, Giarelli and Bernhardt, 2016; Kortessluoma et al, 2003 and Morgan et al, 2002). That said it was crucial to value and remain non-judgemental regarding any comments that were shared by the children (Christensen, 2004).

Maintaining the notion of positive interactions, I felt it was important to try and extend this to being able to communicate the outcomes of the project back to the children in some manner. One avenue of attempting to do this could be by giving the children access to the Computing for Primary website. This would align with feedback from Gibson et al (2005) who have identified that some children involved in research studies have commented on the lack of feedback that they have received post study and enable those children who were interested to be informed of outcomes. The way this would be presented to children would need further consideration to ensure that it was age appropriate.

Having analysed each individual data set in detail but up to now as separate components, the next and most critical stage of a mixed method approach was to ensure that each data set could be seen as a justifiable and crucial piece of the larger puzzle. In other words, that each method chosen was purposeful and necessary to inform the research outcome, opposed to just supporting the notion of triangulation. The next chapter endeavours to bring these elements together to support the philosophy underpinning this paradigm.

Chapter 7: Thematic analysis

Prior to bringing all of the data together it felt relevant to re-state the original research question that had ultimately informed this study, followed by the additional questions that were devised to examine the implications for practice.

Research Question:

Does teaching computer programming within key stage 1 of the primary curriculum enhance children's problem solving skills?

Supplementary questions:

What are the views of Year 2, Key Stage 1 teachers around embedding programming and computational thinking skills into the key stage 1 curriculum?

What are year 2 children's perceptions of these programming sessions?

Can any differences be identified between the interest and engagement of male and female participants in the study?

As discussed in Chapter 3.8 a crucial element when employing a mixed methods approach is the importance of integrating the data that has been gathered, which as previously highlighted, has documented challenges (Gorard, 2013; Creswell, 2014). Some of these challenges are around the extensiveness of the data collected and the intensity of analysing across research paradigms. This is due to the complexities that mixed methods design can evoke and means that it is imperative to maintain the focus and some degree of flow for the activities and narrative that emerge as a result. Additionally and linking back to the pragmatic philosophy underpinning the design of this research, a clear understanding of purpose and procedures needs to remain a key driver, not only in the process of inquiry but also in relation to that of integration (Morgan, 2014).

7.1 What the mixed methods data suggests

Having analysed all data sets, the next stage of investigation would focus on integrating the story so far. Having compared the quantitative data sets gathered in phase 1 and phase 2, as outlined in the embedded mixed methods design, it was found that after considering the effect of gender and maths attainment, participating in the coding curriculum increases the total score attained in the problem solving activity by 240.3 points.

It can therefore be asserted that teaching computer programming within Key Stage 1 of the primary curriculum does appear to enhance children's problem solving skills and therefore this indicates that including programming into the curriculum is of value. However, this value statement cannot just be accepted without being fully problematized. Drawing from the literature review and data collected from this research, questions around what it actually means to 'embed' problem solving skills and ensuring widespread inclusion within the curriculum need further exploration. Other potential issues surrounding the implementation of the new curriculum are resources and training needs, which will now be examined in line with the literature and data gathered from the study.

I decided to do this by exploring commonalities between the two sets of qualitative data discussed in 6.3, 6.4 and 6.5. This links back to the 'Embedded Mixed Methods' design (Creswell, 2014) chosen for this study, where the reason for choosing this method includes "understanding experimental results by incorporating perspectives of individuals" (in this case the teachers and the children) and furthermore, gaining "an understanding of participant views within the context of an experimental intervention" (the problem solving activity) (Creswell, 2014, p.231). The thematic coding of both sets of qualitative data was done manually and involved reading each transcript separately and recording and identifying passages of text that initially appeared to be linked by a common theme or idea. This enabled me to then index the text from both transcripts into categories and establish a "framework of thematic ideas" (Gibbs, 2007, p.288). Following on from this, the themes were further examined to see if there were any "cluster themes" (Smith and Osborn, 2008, p.75). After reviewing and grouping the data gathered (Yin, 2016) the core themes that emerged from the qualitative data fell broadly into the categories of knowledge, values, curriculum, policy and

resources, although there was some overlap. In light of synergetic characteristics, it felt pertinent to combine both knowledge and values together; ironically, knowledge and values do then emerge as being at the core and integral to the other themes, particularly in regards to the development and sustainability of change. In fact, it is worth acknowledging here that the synergy between all themes becomes evident through the discourse.

Participants' voices within the transcribed data have been presented in italics and coded accordingly. The first theme to be discussed is knowledge and values.

7.2 Theme 1: Knowledge and values

Part of the qualitative methodology was designed to ascertain both staff and children's existing knowledge around computer programming, in regards to terminology and content but more importantly to also explore attitudes towards the inclusion of computer programming into the curriculum.

Both data sets showed evidence of varying degrees of knowledge around what was involved in computer programming, though the staff were able to articulate this in far more depth than the children, which was to be expected. The children demonstrated some understanding of what computer programming sessions were about but frequently referred to other activities that involved technology such as searching the Internet and playing games, which indicated a lack of clarity between what defines computer programming against more general activities involving technology. This could align with the suggestion made by both Schmidt (2011) and Kenyon (2013) in chapter 1 that previous pedagogy was focussing on skills and values that were promoting digital consumers opposed to creators. Another explanation for this lack of distinction between the concepts is most likely as a result of this particular generation not having exposure to computing within the curriculum offer before, whereas, the teachers, being adults, may well have experienced computer programming during their school experience. That said, the lack of differentiation between usage and activities could be seen as a positive finding in regards to children (in Year 2) not separating computer programming from other uses of technology, such as gaming and searching the Internet and effectively it being part of what they just do.

The staff who participated in this study demonstrated varying levels of understanding of what computer programming involved, alongside the notion of computational thinking, but on the whole all had some, if not quite detailed knowledge of both concepts. However, on a broader perspective I would predict that this may not be the case in all schools and that further work could be done to establish a clearer delineation between the previous pedagogy of ICT to that of Computer Science, to avoid them being perceived as one and the same. This may naturally be established as schools immerse themselves in the reformed curriculum and become more familiar with the principles underpinning computing, but it is also something that could be developed with wider stakeholders, such as parents, to support their understanding of how computer programming can impact on children's problem solving skills.

From a personal perspective I felt that it was imperative to demystify some of the terminology around computing in Chapter 1.8 on embarking on this study, which could be something for schools to consider employing. Interestingly this was also a concern indicated twice by one of the respondents in the survey, initially by stating that '*when put into English for those of us who are not technology geeks it doesn't seem that bad*' and then subsequently responding to another question with '*more jargon*' (F35-44-1).

For this research study I felt that it was crucial to gather some insight as to how both the staff and the children were feeling about the inclusion of computer programming into the curriculum. From a staff point of view, this was pertinent as underpinning values could be projected into delivery and subsequently this could then impact on the experience presented to the children both positively and negatively. If staff felt comfortable and confident with the content of the new curriculum the delivery is more likely to engage and enthuse children which is evidenced in some of the children's comments about the sessions they had experienced from the 'Primary Coding project' (States of Jersey (2014) team. Adjectives such as '*really cool*' (G1, group 1), '*interesting*' (G1, group 2; G3, group 3; B2, group 4), '*it's fun*' (B1, group 3) and '*really special*' (B1, group 4) implied that some of the children were certainly motivated by the sessions. Conversely, if any primary staff taking over the delivery of the new curriculum felt uncomfortable or anxious about the new course content then this may present in a less positive way, however, I think it should be emphasised here that this challenge is not exclusive to primary teachers; it was highlighted back in Chapter 1.7 that for some ICT

secondary teachers the need to develop knowledge around computing and adapt a new pedagogical approach, was a daunting process (Britland, 2013).

Back in Chapter 2.12 the notion of the surrounding culture (Piaget, 1929; Papert, 1993) in relation to promoting an effective learning environment was examined and will be revisited in the section below under resources. However, this also feels significant to the debate around values, but on a broader scale than the individual. Papert (1993) offered the case of formal mathematics, citing a “mathophobia endemic” (p.42) where society seems to have created a culture where it is acceptable not to be able to do maths and as a result the culture blocks many people from learning anything that recognisably falls into this category. Ironically, it is worth highlighting that the same cultural acceptance does not align to literacy, or consequently illiteracy. As referred to back in 2.12, for the new computing curriculum to be embedded successfully the more complex cultural paradigm that can run parallel to the more concrete concept of curriculum design and development needs to be nurtured so that computer programming does not become a phobic subject. This will be examined further in relation to curriculum content and resources which are also integral elements.

A final point to make in this section also links directly to knowledge and values. All but one staff surveyed felt that there were positive benefits to be had from introducing computer programming into the Key Stage 1 curriculum and eight out of eleven participants were aware that computational thinking, which underpins the revised curriculum, involved logic and problem solving skills. To have a curriculum that endeavours to develop children’s computational thinking skills should in itself be relatively easy to market and advocate for, particularly if the link between developing problem solving skills can become the trajectory to fostering resilience in children (Bonnie, 1995). There are, however, other facets that need to simultaneously come together to ensure that this can happen, one of which is the curriculum itself.

7.3 Theme 2: Curriculum

Across both data sets it was evident that there was a desire, or at least an acceptance for the new computing curriculum, but simultaneously there was also evidence of some trepidation.

On the whole, staff acknowledged the pedagogical benefits of computer programming in relation to developing children's computational thinking which as stated by Wing (2014) involves "the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out" (p.33). Data extracted from the surveys with Year 2 teachers aligned with this theory with comments made around '*children being able sequence a series of instructions and develop a deeper understanding of how computers work*' and the notion that '*logical thinking was much more explicit in the new curriculum.*' This also resonated with a couple of the children's comments such as '*debugging means, like you fix the computer basically*' (B1, Group 4) and G2 (Group 3) who made reference to Scratch and purported that '*it's just a really good thing to help you learn with the computers.*' What I do find interesting here is the subtle use of the word '*with*' the computers, as this implies that perhaps a different relationship has started to be established or more accurately, reignited, between the child and the computer. This is in contrast to a more passive phrase that was captured around '*going on the computers for golden time*' (B1, Group 4). I use the term reignited as this was a notion that was advocated by Papert (1980) where he advocated that "the child, even at pre-school ages, is in control: the child programs the computer. The quantitative data provided evidence that programming enhances problem solving skills but when situated alongside the qualitative data, convergent findings can add depth that justify and capitalise on the mixed methods approach that was taken for this study. With this in mind, the comment made above around working '*with*' computers could also suggest is that one of the reasons why programming encourages problem solving is due to children feeling like they are in partnership with the computers, which is viewed as very different from other school based activities.

So, in teaching the computer how to think, children embark on an exploration about how they themselves think" (p.19). This is a powerful concept that supports the debate around encouraging creators rather than consumers of technology (Schmidt, 2011; Kenyon, 2013; Halverson and Sheridan, 2014) but also supports the idea of developing metacognitive awareness within the curriculum (Rowland, 2015), which is currently perceived as an important skill in educational settings and enables children to be more aware of the process of problem solving.

Pertinent comments were presented by three members of staff around computer programming being introduced in Key Stage 1 contributing to preparing children for the future. Although these could be perceived as quite bold statements they resonate with research around the 21st Century learning tenet of Fadel, Bialik and Trilling (2015). Data from the children also supported the idea of preparation for the future, although their perception of the future was more on a personal aspirational level, than that of an economically driven vision. Comments from year 2 children such as *'we're learning what year 10's learn'* (B1, Group 4) and *'when we're in year 10 we're going to be amazing at this'* (B2, Group 4) suggest that the new curriculum has raised expectations in regards to what primary aged children are potentially capable of understanding and achieving within the computer programming domain. Although this should be viewed positively it could add to the apprehension felt by existing secondary ICT teachers, who in the past may have been delivering the same computing concepts to students when entering their secondary education phase.

Having focussed on some of the benefits of the new curriculum and positive comments that could be drawn from the data gathered, there were equally some children that found computer programming challenging, although some of these challenges implicated resourcing issues which will be discussed further on. In relation to the curriculum itself, comments such as *'I don't understand what he means half the time'* (G1, Group 2) and *'that's quite boring'* (B1, Group 1) suggest that there needs to be further consideration around differentiation in order to support the individual needs of each child. Although the Primary Coding Project (States of Jersey, 2014) has promoted a peer support approach to differentiation which was identified as a benefit by F35-44-6 with *'older children peer tutoring younger children'*, there could be an opportunity to support this further by combining this with more task orientated opportunities. This would align with the point raised by one of the teachers surveyed who stated that *'if you can't read or write you may be disadvantaged and get the wrong impression of the subject before being able to access it'* (M35-44-8) and additionally the suggestion by the DfE (2013) around ensuring that the curriculum is engaging and enthusing children from an early age to support accessibility and avoids academic elitism. This is where the Primary Coding Project's (States of Jersey, 2014) role has been crucial in not only supporting the development of a well-informed, age and stage appropriate curriculum,

but additionally in its role of supporting staff, with their varied experiences of computer programming, being able to implement and embed computer programming into Key Stage 1.

Both sets of data highlighted cross curricula opportunities and some of the children's comments implied that transferable learning had occurred, for example, across maths and science, which goes against Pea, Hawkins and Sheingold (1993) suggestion that computer programming skills were limited to specific contexts opposed to developing transferable skills that could be utilised across curriculum areas. Although the data gathered from the problem solving activity itself did not directly examine transferable skills, the results garnered from the quantitative data suggests that programming improves children's problem solving skills and therefore these skills could then be viewed as transferable. A more recent project is currently been undertaken by Boylan (2017), supported by the Education Endowment Foundation, evaluating the impact of teaching programming (Scratch) on the development of pupils' mathematical skills in Key Stage Two. Although situated within a different Key Stage, in relation to transferable skills, this study promotes the notion of "Theory of Change" (Boylan, 2017) of which an important feature emphasises "the importance of teacher mediation" (p.3). This refers to the importance of teachers making connections, in the case of Boylan's (2017) study between "computational thinking and Scratch programming and mathematics" (p.3), but in this research is applicable to computer programming and problem solving skills. In order for the skills to potentially be transferred within other curriculum areas, teachers need to be confident in embedding computing into the curriculum.

The increasing demand to engage in evidence based practice to inform educational policy and practice (Rowland, 2015) was introduced back in Chapter 4 and emphasised the importance of capturing rigorous data to validate any choices and changes that are made to policy and practice. With that said, the next theme to be discussed relates to policy.

7.4 Theme 3: Policy

The data gathered around both the staff and children's responses to the policy and curriculum reform was overall very positive. 10 out of 11 staff responded with positive comments as to what benefits could arise from introducing computer programming into the curriculum.

Personally, I feel that The Primary Coding Project's (States of Jersey, 2014) tenet to actively involve the primary school staff in the development of the new curriculum helped to ensure a sense of involvement and ownership, which is key when embarking on any transformation. It could be argued that historically, policy and curriculum reform has always been based around extrinsic demands to meet political and societal expectations (Carr, 1998). The driving forces of this particular policy change were not exempt from this and therefore any potential political agendas should always be scrutinised. It could be argued that big names in technology and the gaming industry have played an integral role in driving this policy into play (Livingstone and Hope, 2011; Schmidt, 2011). However, re-visiting the philosophy presented by Fadel, Bialik and Trilling (2015) it is difficult to dispute that as a result of technological advances, children of today need to be equipped with the skills to enable them to adapt to tomorrow. Again, this resonated with the survey data in relation to the question around the benefits of introducing computer programming into the curriculum; *'sets children up for the future, especially in this day and age where technology is an essential part of life'* (M25-34-3), *'pupils can create own games or apps or effects and not just watch or play one already made'* (M35-44-8) and it can help *'children to understand the role of the process rather than just being handed a product'* (F25-34-10). All of these benefits include engaging in some sort of problem solving activity and are therefore corroborated in the results of the quantitative data. Not only did the quantitative data indicate that children improved their problem solving skills, but the qualitative data from the teachers indicated that they believed that this would help children be better prepared for the future, supporting the argument that implementing programming across Key Stage 1 is viable.

The comments above suggested that for some staff there was already confidence in the new curriculum as they could see its purpose and could relate to its values of teaching children a discipline with long term value opposed to skills with more short term significance.

Conversely, when educators are faced with multiple education policy reforms (The Royal Society, 2012) over a period of time, it is understandable that the perception can become cynical and the changes viewed as in vogue, or merely that of a response to a political statement.

This is an example of where there becomes synergy between the themes that have been identified, as I would suggest that for a policy change to be accepted it needs to be purposeful and relatable, which can clearly link back to an individual's values (Cohen et al, 2011). In Chapter 7.1 the importance of de-mystifying the terminology was discussed in relation to knowledge, for example, *'when put into English for those of us who are not technology geeks it doesn't seem that bad'* and then subsequently responding to another question with *'more jargon'* (F35-44-1). I would argue that this is just as imperative in regards to policy discourse, which is sometimes left to the layperson to try and interpret and deliver.

Another relational notion is that around elitism and this was evidenced in some of the children's comments such as *'I don't understand what he means half the time'* (G1, Group 2), which also featured earlier in regards to creating an accessible curriculum. An additional comment was also captured that said *'I can't go on Scratch if I don't have a computer'* (G1, Group 2) which suggests an inequitable situation. It can be comfortably ascertained that everyone can benefit from thinking computationally (CAS, 2012, Wing, 2014) but it needs to be accessible to all children in order to avoid academic elitism. The introduction of the policy into the Key Stage 1 of the primary curriculum could go some way to negate this potential challenge with one staff participant contributing at *'the younger you start with new initiatives the easier it is for the children to acquire the skills and knowledge required'* (F35-44-11). This also supports the suggestion by the DfE (2013) around the importance of enthusing children with the concepts of computer programming from an early age to support engagement. Comments extracted from both sets of qualitative data and highlighted in the previous themes support this policy directive.

From a final policy perspective, it could be argued that for computer programming to be sustained and be established as a valued component of the National Curriculum (DfE, 2013) then it needs to make a difference and that difference needs mechanisms in place to capture the benefits through evidenced based practice (Rolland, 2015). The quantitative findings from this research have been an initial mechanism to evidence that teaching computer programming within Key Stage 1 of the primary curriculum appears to enhance children's problem solving skills. However, from a sustainability perspective it will be around how effectively teachers become at continuing to embed programming into the curriculum

(Boylan, 2017) and subsequently, how the impact of this can then be assessed on a longer term basis.

Whenever policy reformation takes place consideration of the infrastructure also needs to occur, which was a concern identified by one of the staff participants (F35-44-11) and will be further discussed under the next theme of resources.

7.5 Theme 4: Resources

Papert (1993) talked about the need for appropriate resources and this is equally supported from data gathered by both staff and children. From a software perspective, the data gathered from the focus groups with the children indicate that overall the software that was being introduced to them through the programming project was engaging and appropriately challenging; where one comment was made around not understanding and another around an activity being boring, I feel this has been addressed within theme 2 under curriculum and differentiation. It does, however, resonate back to the importance of ensuring resources are considerately designed in a way to ensure meaningful engagement and provide equitable challenges, that can stretch a child's cognitive processes but also supports achievement to avoid discouraging any children from participating (Liao and Bright, 1991; Perlman, 1976). Resources should also "support autonomous or guided open-ended explorations in the process of which the children participate actively, think and control the computer" (Haughlands, 1992, p.88). These were all considerations that were employed in the initial design of the problem solving activity and the subsequent implementation of the intervention, to gather the data that showed the relationship between programming and problem solving.

Examining and integrating the feedback from a hardware perspective, it is clear to see the synergy between the themes. In theme 1, hardware was linked to the notion of knowledge and values as it was identified that there were some concerns as to what hardware to invest in when faced with various options, which could be influenced by the values or preferences of those investing or advising. Choice and purchase of hardware could also be influenced by

policy (theme 3), for example, a response to a technology agenda being driven through by the States of Jersey Education Department, or equally any other local government initiative.

In Chapter 1.8 it was stated that Computer Science remains independent from specific technologies and can sometimes operate away from computers themselves. The terms 'plugged and un-plugged' were referred to by Bell, Witten and Fellows (2006) to describe the fact that computer science teaching does not have to involve the use of computers, but when 'plugged' is required it is imperative that the equipment is functional. Comments from both children and staff allude to the importance of this with G1 (Group 2) stating that *'sometimes I go on Scratch but it never works really'* and *'I always be late on the computer and I don't get on it...then the sessions maybe finished so I get a problem with the computer when it's on Beebot'* (G1, Group 2). Both of these comments highlight the potential frustration that children can feel when the resources provided do not work effectively, however, it is worth noting that these comments were received from the same child who also asserted *'I don't even understand what he means half the time'* which could also indicate that the issue may be to do with this individual child's interaction with the programming, thus highlighting once more the need for differentiation within the programming curriculum.

In addition, one member of staff (F35-44-6) also stated that a potential limitation to introducing computer programming into the Key Stage 1 curriculum could be around *'Computers not working therefore raising stress levels with small children having to wait a long time'*, which could impact on a child's enthusiasm and participation. This highlights the fact that having the right technological infrastructure is a crucial component when introducing such a change to avoid children and staff from becoming disengaged.

Theme 2 (Curriculum) presented the argument that investment was certainly needed in technology but equally in the concept of pedagogy. A major change to the new curriculum is its focus on the relationship between technology and computational thinking in supporting the development of skills that are needed for children in the 21st Century (Fadel, Bialik and Trilling, 2015; DfE, 2013 and CAS, 2012). It could be argued that an investment in pedagogical change could be viewed as a solid, long term investment, which is what the States of Jersey chose to do in the form of the Primary Coding Project (States of Jersey, 2014) but as resources

also includes staff, for purposes of longevity, a longer term strategy for training and continued professional development could be pertinent. The demand and desire for more training, to develop both skills and raise confidence levels, was evident within the collated data with F35-44-6 identifying *'staff getting training'* as one of the benefits of the introduction of the new curriculum. Some concerns that were highlighted around training needs stated that depending on existing knowledge there could be *'needs for lots of training if never experienced any programming before'* (F25-34-9), *'Staff need training in addition to a curriculum that's already under a lot of time pressure'* (F335-44-6) and *'will there be any other training or will our IT co-ordinators filter knowledge down and train in house?'* (F45-54-7).

The data captured from the children's experience of the programming sessions was very favourable but was in response to the teaching received from the Primary Coding Project (States of Jersey, 2014) teaching team. The notion of succession planning is an important point to consider further in order to support both the transition and ownership of delivery back to the primary teaching staff, indicated in the latter comment made by F45-54-7. One participant commented that as a result of the introduction of computer programming into the Key Stage 1 curriculum *'as the Key Stage 1 Manager, I need to ensure the rest of the team understand the curriculum and how to embed it. I need to create CPD opportunities for them as well as learn the material myself'* (F25-34-10). This comment quite pertinently acknowledges the need to provide staff with training opportunities but also highlights the more complex ability of being able to embed programming into the curriculum, where from the data collected it showed that 63.64% of staff had concerns. In Question 11 of the survey that was undertaken, which asked participants to be more specific around any concerns that they had, 7 out of the 11 staff that acknowledged having concerns, 100% of these were around personal knowledge and training.

A final point to discuss around resources links to both personal knowledge and training, exemplified in the statement *'I feel that staff in Key Stage 2 will need to be skilled to a high level for it to be effective as we raise expectations further down the school'* (M35-44-8). The raised expectations demanded of children in Key Stage 1, as a result of the computer programming sessions and development of the new curriculum, was articulated positively through some of the children's data who were clearly very proud of themselves for being able

to tackle computing concepts that had previously being expected within the secondary school curriculum (Theme 1). Conversely, the knock on effect of these new expectations in Key Stage 1 and 2 then present a training need for secondary teachers which can't be ignored.

Although four individual themes were established from the qualitative data, a synergy between all the themes was evident throughout the discourse, highlighting the dynamic relationship between them. The next and concluding chapter examines what the mixed methods data revealed in direct relation to the ambitions of the research study. Explicit links to the theory underpinning the curriculum reform and changes to pedagogy and practice will be reaffirmed along with a discussion around implications for practice. This is followed by the identification of any future research and a final, personal reflection on the research process itself.

Chapter 8: Conclusion

8.1 Outcomes and implications for practice

This observational study was conducted with 335 year 2 children in phase 1 and then a subsequent cohort of 387 year 2 children in phase 2 and presented positive results. As previously stated, it was found that after considering the effect of gender and maths attainment, participation in the coding curriculum, the intervention implemented by the Primary Coding Project (States of Jersey, 2014), increased the total score attained in the problem solving activity by 240.3 points. As a result of these findings it suggests that the recent change to the ICT programme of study is one to be positively received in relation to student outcomes. However, more immediate benefits could also be evidenced in regards to children seeing themselves as 'getting ahead of the game', with the raised expectations of the curriculum. This was evidenced from the comments drawn from the focus groups with the children that referred to their learning of concepts that had previously been taught to secondary school students alongside comments inferring 'how amazing' they, as year 2 students, would be when they got to that stage of their education.

Problem solving (Simon and Newall, 1971; Garton, 2004; Wang and Chiew, 2010;) was the cognitive strand primarily examined within this research but this specific, yet complex skill, sits within the broader term of computational thinking (DfE, 2013; Wing, 2014). As previously identified, Wing (2014) describes the ability to think computationally as "the thought processes involved in formulating a problem and expressing its solution(s) in such a way that a computer—human or machine—can effectively carry out" and Sargent (2016) refers to this way of thinking as the "thought processes involved in the logical reasoning that is needed to solve problems, devise procedures and better understand systems" (p.22). Both definitions underpin the philosophy of the new computing curriculum. This concept is subsequently presented through the narrative of this study as a fundamental characteristic, alongside problem solving, which could support children in being able to *adapt to* and *create with* new technologies of the future.

The research never explicitly set out to examine gender, although an awareness of gender interest and participation, both of staff and children involved in the study, did need to be noted to enable effective analysis of the data sets.

Although the problem solving data showed that boys scored higher than girls in all but one school, this was in line with previous findings where research has shown a correlation between high achievements in maths amongst male students (Gunderson et al, 2012; Varma, 2010); this includes concepts such as problem solving and logical reasoning skills. The fact that no patterns emerged from any of the other data collected to imply any gender preference towards interest and participation in computer programming was very positive. Although research identifies that there remains a gender imbalance within the computing workforce (AAUW, 2015; Corbett and Hill, 2015) no evidence of this presented itself within the boundaries of this study. As a result of this, the change in curriculum can be viewed as a positive step in the right direction in enthusing *both* genders to potentially enter into computing roles in the future, although it should be acknowledged that a curriculum alone is not a vehicle to enthuse.

In relation to teachers and gender, the imbalance of the survey participants, eight female teachers and three male, was highlighted back in Chapter 2.4. It was also identified that out of the five participants who answered yes to experiencing computer programming prior to the Primary Coding project, three of these were the male teachers (60%) again supporting the suggestion by the AAUW (2015) that the gender balance within the domain of computer programming remains inequitable. However, reflecting further on this point further it could be argued that with the introduction of computing into the primary curriculum, having predominantly female primary teachers could effectively work in favour of helping to shift implicit biases for both women and men in the field of computing, therefore negating potential stereotype threat (Steele, 1997).

One thing is certain, as the curriculum continues to develop attention must be given to the content to ensure that it is engaging and accessible to both genders in a quest to address the underrepresentation of women in computing (AAUW, 2015 and Yun Sung, Siraj Blatchford and Kucirkova, 2016). At the same time, from a teaching perspective, staff development and

training opportunities need to be in place to harness the will and enthusiasm captured in the data from male and female staff, *'Engaging, lots of opportunities for cross-curricular learning'* (F18-24-5), to equip and support these practitioners in delivering a curriculum that motivates and enthuses both girls and boys.

Additional skills and attributes that could be argued to emerge through both the quantitative and qualitative narrative were the concepts of metacognition, resilience and creativity and these were subsequently examined further. In relation to metacognition, an association could be made that because of the principles of computer programming, children's metacognitive skills were naturally being encouraged and nurtured through the pedagogy and process of programming, for example, creating algorithms and then reflecting upon and adjusting these in order to find potential solutions for given situations (Clements and Nastasi, 1999; Yun Sung, Siraj Blatchford and Kucirkova, 2016).

The notion of resilience has been acknowledged throughout this study and endeavouring to develop resilience in today's children remains a topical debate (Claxton, 2007; Fadel, Bialik and Trilling, 2015). Bonnie (1995) states that "we are all born with an innate capacity for resilience, by which we are able to develop social competence, problem solving skills, a critical consciousness, autonomy, and a sense of purpose" (p.2). This study does not provide evidence of any relationship between problem solving and resilience, nor did it seek to do so, however, as a result of nurturing children's problem solving skills it could result in being a potential fringe benefit.

Building on the idea of connectivity, resilience is commonly associated with the more general concept of well-being (Bonnie, 1995; Townshend et al, 2016; Bradshaw, 2016). What is interesting here is the notion that teaching computer programming, with its emphasis on developing computational thinking and problem solving skills, could potentially be viewed as a component in nurturing resilience. Computer programming could be a pragmatic and logical approach to supporting children's resilience and therefore, overall well-being. Initially, this could be received with a sense of irony, as technology and well-being can be regarded as a contested issue.

To support this study's results, it is worth revisiting Bell, Witten and Fellow's (2006) explanation of computer science that refers to the principles that underpin the computer science curriculum and how these can be taught without the necessity of a computer. This is reiterated by CAS (2011) when they state that "computational thinking is a mode of thought that goes well beyond software and hardware, and that provides a framework within which to reason about systems and problems" (cited in Yun Sung, Siraj Blatchford and Kucirkova, 2016, p.9). This particular study did use technology as the vehicle within the intervention to gather the quantitative data, but it is important to re-emphasise that computational thinking as a skill, can be removed from technology. As previously referred to this is evidenced in the Jersey Computing Curriculum (2014) and medium term planning documents (Appendix 1).

Both metacognition and resilience resonate within the statement by Dewey (2012) that "to maintain the state of doubt and to carry on systematic and protracted enquiry - these are the essentials of thinking" (Dewey, 2012, p.13) who has influenced this observational study from both a theoretical understanding of how we think, but also from a methodological stance, with the pragmatic approach that was employed through the process.

From a creativity perspective, the review of literature presented the notion of developing "creators rather than consumers" from both a policy perspective (Sallis, 2009) and that of children's use of and relationship with technology (Schmidt, 2011; Kenyon, 2013; Yun Sung, Siraj Blatchford and Kucirkova, 2016). Children's use of and relationship with technology was evidenced during the focus group with the comment from one child about working *with* computers, implying a shift in behaviour. From the standpoint of how children interact with technology the new curriculum advocates that:

We want our children to understand and play an active role in the digital world that surrounds them, not to be passive consumers of an opaque and mysterious technology. A sound understanding of computing concepts will help them see how to get the best from the systems they use, and how to solve problems when things go wrong (CAS, 2012, p.5).

It could be said that the changes made to the curriculum (DfE, 2013), in relation to content and pedagogy, acknowledges and provides opportunities to develop creators opposed to

passive consumers of technology, which as highlighted by Yun Sung, Siraj Blatchford and Kucirkova, (2016) “provides a welcome return to emphasising ‘making’ rather than simply using technology” (p.9). Again, the subtle, yet powerful reference from this study indicating a possible shift in this relationship reverts back to the focus group and the reference to the act of working *with* opposed to *on* the computer. This supports the early notion presented by Papert (1980) emphasising the importance of children being able to control their environment, in this case the computer, and as a result of programming or teaching the computer, engage in a deeper awareness of their own cognitive processes. On a more practical note it also aligns with “makerspaces” (Halverson and Sheridan, 2014) as a growing philosophy and the shift through this movement in encouraging children to be makers rather than consumers and providing environments that promote the concept of making, with emphasis on the process opposed to the tools.

In relation to the idea of being creators opposed to consumers of policy development (Sallis, 2009) the States of Jersey Education Department chose to capitalise on this policy opportunity to develop the discipline of Computer Science within the curriculum. It recruited computing and IT teachers from a local secondary school to support the creation, development and implementation of a bespoke programme of study. The aim was to draw upon the computing expertise of the secondary teaching team, in combination with primary teachers’ knowledge of young children’s developmental needs, to create a programme of study that would be fit for purpose for the primary curriculum and context of Jersey, but pedagogically would also be sustainable.

From a sustainability perspective, the qualitative data gathered from this study has highlighted how crucial knowledge and values are to both policy and pedagogical change. To ensure an effective and sustainable delivery of such a policy change an investment in staff and resources is vital. A substantial investment was provided by the States of Jersey for the Primary Coding Project (2014) which provided initial support for the development of the primary computing curriculum; this was in conjunction with support, advice and training, where appropriate and requested, for the primary schools that were involved. To ensure sustainability and moreover quality of delivery, it would be shrewd to consider further investment in the Primary Coding Project (States of Jersey, 2014), to ensure that the

motivation and drive continues. This research has shown that participation in the coding curriculum, the intervention implemented by the Primary Coding Project (States of Jersey, 2014), increased the total score attained by children in the problem solving activity by 240.3 points; evidence that the recent change to the ICT programme of study is one to be positively received in relation to student outcomes. Supporting data from the staff surveys and children's focus groups also highlighted the motivation and enthusiasm that the majority of staff and children showed for the new curriculum. That said, challenges that may arise from any further investment will be highlighted in the next section.

From a knowledge perspective the data gathered from the surveys and focus groups showed that there was a spectrum of existing understanding and awareness of computing between both the staff and the children. De-mystification of the terminology around computer science was highlighted back in Chapter 1 as being a crucial factor in ensuring that people felt safe to embrace the curriculum change; I feel there is continued work to do here with future teachers, parents and children to support accessibility and avoid it becoming perceived as an elitist subject (Graham and Latulipe, 2003; Hoegh and Moskal, 2009). This should be considered at both policy level and within the classroom itself by creating a narrative that makes some of the more complex terms associated with computing accessible. For example, the curriculum language will and should be inclusive of technical terminology such as computational thinking, decomposition and iteration, but at the same time, emphasise the logic and common sense components of these terms and hence, computation. By identifying how these computing terms can support children developing skills, such as problem solving, will help to ensure that the policy change will be seen as valuable and worthy of investing in.

The 'Computing for Primary' website (<http://www.computingforprimary.co.uk>), that was initially set up to support the curriculum transition as a pedagogic and curriculum resource, could also be a valuable vehicle to continue to address challenges around accessible language, as this reaches parents as well as teaching staff. This resource could also be opened up to all primary children as an inclusive tool to share their learning, challenges and successes.

What also emerged from the data of this study was the need and desire for professional development, support, training and collaboration from the staff involved to support the

initiative and strengthen the transition towards the subsequent policy change. Some of this need and desire for continued training and support linked to trepidation of what was to come, however, other facets of the survey data clearly indicated a motivation and desire to embrace the policy change, to develop individual practice and take some ownership of the new curriculum. Harnessing this enthusiasm that was evident in the data, through professional development opportunities, is key to the longevity and success of the policy change and links back to the notion of developing a culture that embraces the change in philosophy and pedagogy (Papert, 1993). Scheduled training workshops and opportunities to share good practice would be the most obvious way to try and offer support, training and professional development opportunities, but this would require further financial resources.

In further reference to collaboration, there has been evidence of this culture emerging on Island through the organisation of coding competitions for primary school children, held and facilitated by the secondary teaching staff that engineered and delivered the Primary Coding Project (States of Jersey, 2014). To add a personal anecdote, I witnessed various primary school children attend one of these competitions that started at 9.00am and ran through until 2.00pm; all children were working autonomously from adults, but collaboratively within their teams, to complete a gaming challenge. As an early year's professional, I was not only impressed with their abilities to work creatively with their peers, but was also captivated by their perseverance and resilience when faced with problems in their designs, under timed conditions. For the duration of the session, which notably was quite long, the majority of children were completely engaged. However, this activity also required an investment in resources, so considerations as to how this momentum can be maintained would be expedient.

The previous anecdote leads into another aim that the 'Primary Coding Project' (States of Jersey, 2014) alluded to, which was to expose the new curriculum to a younger audience in the hope of enthusing "the next generation of developers" (States of Jersey, 2014). The children involved in this research were in Key Stage 1 (year 2) and although it would be an assumption to claim that the Primary Coding Project (States of Jersey, 2014) had achieved this, the majority of the data gathered from the children did suggest that the curriculum was well received.

The main research question was devised to find out if computer programming enhanced children's problem solving skills and it was found that after considering the effect of gender and maths attainment, participation in the coding curriculum, the intervention implemented by the Primary Coding Project (States of Jersey, 2014), increased the total score attained in the problem solving activity by 240.3 points. This goes part way to supporting the final aim outlined by the Primary Coding Project (States of Jersey, 2014) which was to "develop wider skills, including numeracy and problem solving". Evidence from both staff and children noted that computing had links with concepts both in the maths and science domains, however, to provide evidence from this research study, or make claims that the project has developed children's wider skills, including numeracy is more challenging and indicative of future research. That said, what has emerged from this study are some further insights in regards to transferable skills and important role of the teacher in nurturing these connections (Boylan, 2017).

Although not substantiated by this research data, on the basis of the literature, the fact that these children were developing their problem solving skills could suggest that they were developing these other skills, or attributes, that could then become transferable and contribute to the children's wider development, through supporting meta-cognition and developing positive habits of mind (Dewey, 2012; Claxton and Lucas, 2015 and Costa and Kallick, 2008). If this policy transition is successful then it could contribute to creating a culture where computing, or learning to code, is given the same level of value as learning to write (Wolfram, 1995) and computational thinking becomes a fundamental skill, offering a "framework for thinking" (Wing, 2014) for the 21st Century.

Following on from any curriculum reform, in this instance, the implementation of a new computing curriculum, it would be naive not to consider future challenges. Initial thoughts that emerged from the narrative were around longevity and the sustainability of the curriculum. For example, what would happen when the Primary Coding Project (States of Jersey, 2014) draws to a close? If trained staff move on, what, if any thought has been given to succession planning; or if any skills gaps remain, what support package, if any, can be accessed by primary teachers to plug these gaps to enable them to continue to be empowered and embrace the policy change? One proposal to be considered could be to have a specialist

computing teacher in every primary school, like the recommendation made for maths in the EPPE project (Sylva et al, 2004).

The longevity of programming, or coding as a valued skill also came to mind. From a personal perspective I had initially questioned the title of the project with its use of the term 'coding' rather than 'programming' as it could be argued that 'coding' might be perceived as a vogue or latest fad within the educational arena, compared to that of the term computer science, which could be viewed as a timeless discipline. There are however, two sides to this debate as if the term 'coding' creates attention and increased involvement, which links back to the coding explosion outlined in Chapter 2.5 (Wilson, 2014; Cellan-Jones, 2014; code.org, 2015), then this has to be acknowledged as a positive move. So in effect, the project name could be seen as been a catalyst into helping people to understand and implement the new curriculum.

Another challenge is around ensuring synergy between the primary and secondary computing curriculum so that the knowledge and skills acquired in primary are built upon in the secondary sector. For example, computing skills that were originally introduced to students in secondary school are now becoming embedded with the primary curriculum. This is exciting in regards to changing perceptions as to what young children are capable of, but at the same time could add pressure on secondary teachers who would not only need to revise their programmes of study but possibly have to upskill in the process. As discussed back in Chapter 1, this could have an impact on the recruitment of secondary computing teachers. Existing ICT teachers may feel out of their depth building on computing principles and concepts that are now been delivered within the primary curriculum and the alternative of trying to recruit computer scientists into a teaching career is a debate that probably sits outside of the realms of this study. That said, this could also be viewed as an opportunity, from the perspective that curriculum expectations have been raised, so in effect, what secondary teachers can hope to see in the future is students transitioning to secondary education with more established and refined computational thinking skills.

Further investment may need to be considered for the secondary sector so that the ground work of the Primary Coding Project (States of Jersey, 2014) does not end up falling by the wayside or becomes a lost investment. The notion that we have 'done programming now' and

swiftly moving on to what might be the next educational initiative, needs to be avoided (Rowland, 2015, p.43). Through the undertaking of this research I do believe that 'The Primary Coding Project' (States of Jersey, 2014) has been a vehicle to start the journey of positive pedagogical change but in order to validate change it is crucial that any changes to policy is evidenced based:

Evidence is a crucial tool which schools should use to inform their decision making and ensure that they identify the "best bets" for spending, but it must be acted upon... even where money is spent on strategies which research shows have not always been effective, evidence can help schools identify steps which make success more likely.

A profession that effectively evaluates what it does is critically important and it is hoped that through collaboration with Hautlieu School and the support of the States of Jersey Education Department (The Primary Coding Project, 2014) that this research study can make some contribution towards this.

8.2 Limitations of the study

Although not inherently a limitation, a necessary compromise of the study was the observational study method, which meant it would not be a true experiment. However, the opportunity that was presented that enabled this research to be undertaken, influenced the methodological decision taken here. On reflection, I still believe that that the approach taken was appropriate to interrogate the research question, explore the theory underpinning it and importantly, it aligned with the chosen philosophy of pragmatism.

There are a total of 22 States' primary schools in Jersey, 9 of which participated in the Primary Coding Project (2014) and this subsequent research study. Although full participation from all primary schools would have been the ideal representative of the Year Two population in Jersey, I feel the 9 schools that were involved enable the research to make some credible claims about Year Two Jersey pupils.

It could be argued that the results gleaned from the problem solving activity were context based, for example, exclusively gathered and attained in a programming environment (Pea, Hawkins and Sheingold, 1993). This could imply that the children just got better at programming rather than more explicitly, the act of problem solving. Although a bespoke test was created specifically for this study to ensure the children had not accessed it prior to the experiment, it could be claimed that certain characteristics of the design may have aligned with other software that the children could have been exposed to, though this could apply to both cohorts (phase 1 and 2) in the study.

Although there are notably some limitations with the problem solving activity tool in isolation, I believe it was a trustworthy method to address the core research question posed. However, what should be emphasised here is the necessity to look at the intervention in its broader capacity when attempting to draw any conclusions; it should be highlighted that the full intervention was the computer programming curriculum in its entirety, which was not always conducted within a programming environment, or even in connection with technology (see Appendix 1). For example, the early principles of algorithmic thinking were established “un-plugged” (Bell, Witten and Fellows, 2006) within the classroom and programming skills could be introduced on the classroom floor involving physical story boards for the children to interact with. Another tool that could be re-visited and potentially improved upon, is the constructed metric used to apply the range of penalties applied to individual students. As previously discussed, this was not based upon any pre-existing tools but informed from the knowledge and experience of myself and the Primary Coding team, driven by an emphasis on efficiency.

As with all studies of this nature there are limitations that are inherent to hypothesis testing, for example, the study assumes that the pupils are representative of a random sample of the Year Two population in Jersey. There is also the risk of type I and type II error in any inferential statistics, that is, detecting an effect that is not present (type I) or failing to detect an effect that is present (type II).

8.3 Recommendations for future research.

Having completed this research, I feel that there are three potential areas of study that would warrant further exploration. The first suggestion, which directly links to this research, would involve testing students again. Now the Primary Coding Project (States of Jersey, 2014) has ran its term and programme delivery has been handed over to primary schools it would be interesting to implement the same problem solving activity to the current Year 2 cohorts, applying the same conditions, but a year on. Gathering this data would enable an examination of average scores attained by current Year 2 children to be gathered, which could offer some insight as to how the new curriculum is being delivered and embedded. This could be aligned with further research in which the confidence levels of primary staff in delivering and embedding computer programming into the existing curriculum are re-visited.

Another avenue of research, undoubtedly from a longer term perspective, would be to examine future data on gender membership, to see if this curriculum reform encourages more females to stay within the computer science domain further down the line in their educational journey and ultimately, employment choices.

The final area of research that would warrant further exploration resides around the notion of problem solving and well-being. Although children's well-being is both a topical and well documented area of research (Bonnie, 1995; Townshend et al, 2016; Bradshaw, 2016), to capture rigorous data on "other good educational goals – like the habits of minds" (Claxton, 2015, p.144), for example, attributes such as perseverance and resilience, are not so easily measured, or therefore valued. The concept of problem solving is equally complex and problematic in regards to gathering and measuring data. However, further research that looks at problem solving, through the principles of computing, in relation to supporting well-being, could be a worthwhile venture and contribute to the broader debate around what skills children need for future learning.

8.4 Personal and final reflections of a ‘digital immigrant’

Having completed this thesis I have dual feelings of both relief but equally, privilege. At the start of the journey I was presented with the opportunity to examine a curriculum reform to ascertain if the re-emergence of computer science, specifically computer programming into the curriculum, would enhance children’s problem solving skills.

On reflection I am satisfied with the methods chosen, although the absence of any existing assessment tools for the problem solving activity posed a challenge. During the latter stages of writing a couple of studies have emerged that have faced, or will be facing similar issues (Werner, Denner and Campe, 2012; Boylan, 2017) so it will be interesting to see how these assessment tools evolve. What this does indicate though is support for research in this particular domain, suggesting that it is both current and purposeful.

With the benefit of hindsight, I would also have integrated activities into the focus groups. I could have explored a variety of nonverbal methods of data collection such as drawing, photography, using cards and playing games both to support the children’s concentration time, in addition to offering an alternative method to the children to express their thoughts. Equally, it could have helped to clarify meaning in the process of interpretation.

Demystifying some of the terms and gaining a deeper understanding of the philosophy and pedagogy has altered my own perceptions of what computer science and computer programming involves and although I will never become a computer programmer, I feel passionate about sharing this new knowledge.

Initially I struggled to align myself with a particular theoretical framework to provide structure to this study, but once this was established it became the scaffold for the research methodology but was equally relatable to the content of the study, with its focus on problem solving and interestingly, my own journey through the EdD:

“to maintain the state of doubt and to carry on systematic and protracted enquiry - these are the essentials of thinking” (Dewey, 2012, p.13).

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Appendices

Appendix 1: Jersey Computing Curriculum and examples of medium term planning to show examples of plugged and unplugged activities

JERSEY COMPUTING CURRICULUM (Published April 2014)

**This curriculum works alongside *Thinking Differently*
– *Vision for IT in Education 2013-2015***

One of the top priorities of the *Thinking Differently* vision is to provide:

“A new engaging computing curriculum for the 21st century with greater emphasis on employable skills that will be in demand in the future, with progression to industry; enthusing girls as well as boys.”

The strategy also states that this curriculum will focus on the long term success of every learner and provide opportunities to acquire key skills for learning, personal development and employability. The curriculum will:

- *Encourage creative use of technology in learning*
- *Introduce coding and computing in the primary school curriculum*
- *Inspire pupils, girls and boys, to be creative and innovative*
- *Ensure that pupils use technology routinely and discerningly to search for reliable sources of information, collaborate and publish their work*
- *Help pupils to learn to validate reliable sources of information, synthesise information, communicate, collaborate and problem-solve using the opportunities that technology provides*
- *Develop the wider skills required in the workplace such as creativity and business acumen and how to use and apply new knowledge and skills to problem-solving*
- *Educate and empower students to use technology safely and responsibly, both in school and in all aspects of their social lives with particular regard to their future reputations.*

Jersey Computing Curriculum

This document provides UK statutory guidance from Key Stage 1 to Key Stage 3.

It also provides Jersey schools with a framework for end of Key Stage expectations for the three strands;

Computer Science
Digital Literacy
IT Skills

These are minimum expectations: they do not place a ceiling on children’s achievement.

It is expected that experiences from the previous Key Stage will be consolidated as children move into the next Key Stage.

“This frame work is intended to support flexibility and discretion at the Institutional level; it is not a detailed prescription. Moreover the framework describes the goal we would like to achieve, not the journey for getting there. In practice we need to move in small steps towards these goals, and the route will differ between different providers depending on their respective strengths and priorities.” (*A Curriculum Framework for Computer Science and Information Technology*, Computing at School Working Group, pg 3, March 2012, available at <http://www.computingschool.org.uk> [accessed March 2014].)

This framework was written to focus on skill development rather than specific software, applications or operating systems.

Due to the evolving nature of IT this framework would need to be reviewed at least every two years.

Developed in February 2014 by the Computing Curriculum Writing Group:-

Alex Shea (Hautlieu)
Danny Doyle (Les Landes)
Jenny Pryke (St Martin’s)
Ozzy Parkes (Le Rocquier)
Rachel Crane (VLE)
Rory Steel (Beaulieu)
Sarah Briggs (St Martin’s)
Stuart Hughes (Hautlieu)
Jon Tarrant (ESC)
Sarah Johnson (ESC)

Colour Codes

(Used within this document to ease identification of strands and applicable age groups)

	Key Stage 1
	Key Stage 2
	Key Stage 3
	Computing
	Digital Literacy
	IT Skills

**Key Stage 1
Computer Science UK Statutory Requirement**

Pupils should be taught to;

Understand what algorithms are; how they are implemented as programs on digital devices and that programs execute by following precise and unambiguous instructions.

Create and debug simple programs

Use logical reasoning to predict the behaviour of simple programs.

**Key Stage 1
Computer Science Framework
Generic Skills for Computer Science**

Basic debugging strategies

Essential Skills	Key Stage 1 Expectations	What could it look like? Cross Curricular opportunities
Programming – algorithms	<p>Understand what an algorithm is and what it is used for.</p> <p>Set a sequence of instructions to achieve a goal. Use iteration to develop more efficient instructions.</p> <p>Plugged and unplugged activities.</p>	<p><i>The term “algorithm” should be introduced and understood but pupils are not required to use it.</i></p> <p><i>Make a sandwich</i></p> <p><i>Beebot and Scratch activities (See medium term planning documents A and B for examples)</i></p>
Control	<p>Use programming skills to control an external device.</p> <p>Use instructions to model control of a device. Anticipate the effect of adding a new instruction.</p>	
Hardware	<p>Identify external components and peripherals.</p> <p>Recognise different computerised systems/devices.</p>	<p><i>Keyboard, mouse, monitor</i></p> <p><i>Recognising wide ranges of devices e.g. washing machines</i></p>
Software	<p>No specific skills, apart from those in Digital Literacy and IT Skills strands.</p>	
Data Representation	<p>Understand that data represents information</p>	<p><i>Numbers, text, pictures,</i></p>

	and that it comes in many forms.	<i>sounds, videos</i>
Networking	Know the difference between networked and stand-alone devices and how connectivity affects use.	
Databases	N/A	

Medium Term Plan A – Developing algorithms

Year Group: Year 1

6 sessions

Key National Curriculum Objectives:

1. Understand what algorithms are
2. Create and debug simple programs
3. Use logical reasoning to predict the behaviour of simple programs.

Jersey Computing Curriculum:

1. Understand what an algorithm is and what it is used for.
2. Set a sequence of instructions to achieve a goal
3. Use programming skills to control an external device.

Overview: Children will extend their understanding of using Beebots in reception and creating and debugging algorithms for the Beebot. The children will begin to learn computing specific vocabulary such as ‘algorithm’ and ‘debug’ and learn to create and debug written forms of algorithms themselves.

Lessons are expected to last 45 – 60 mins

Children will complete a series of challenges using Beebots that will include predicting the outcome of algorithms.

Session 1 – Lego listening

Teaching points: The purpose of the first two lessons unplugged activities is to introduce the term **algorithm** and **debug** as well as their meanings. The children also learn that good algorithms are precise and sequential.

Independent activity: A Lego listening activity – children create a pattern using Lego or other blocks available in school. They relay the pattern to someone who cannot see their creation and use precise sequential language to provide an algorithm for their partner to create an identical Lego pattern.

Session 2 – Train my robot

Teaching points: A robot is controlled by a computer. A robot needs to be given instructions to complete a task. Algorithms can be recorded. Algorithms need to be precise and sequential.

Independent activity: Children learn about robots and how they need to be programmed to do tasks. Children begin to create and record pictorial algorithms to make a ‘robot’ complete a task. They use logical reasoning to debug their algorithms.

In pairs or small groups, children create pictorial algorithms to guide each other as ‘robots’ through a range of paths and round obstacles. Extension – a more developed robot pictorial code is available for advanced challenges.

Lesson 3 – Strictly Beebots dancing

Teaching points: Children learn how to use the Beebots by inputting instructions using the buttons. They write pictorial programs and debug their programs.

Independent activity: In groups, children begin by learning a whole class algorithm for Beebot to follow a dance sequence. The whole class choreograph their Beebots to make a dance sequence and record their sequence on whiteboards pictorially. Children then create their own dance sequences in groups and debug their programs to make two or more Beebots complete a dance algorithm together.

Lesson 4 – Beebot Maze

Teaching points: Continue to practice making good algorithms for Beebot to complete a task. Algorithms can be simplified by using a repeat number (iteration).

Independent activity: Children create written algorithms for Beebots to follow paths to a destination. Algorithms are debugged collaboratively. Numbers are introduced to simplify code.

Lesson 5 – Beebot Mats

Teaching points: Consolidation activities using mats and grids. – Previously learned concepts are applied to complete challenges using Beebots.

Independent activity: Beebot quiz questions using mats and grids. Children use logical thinking to answer questions and create algorithms to show their understanding of written algorithms and methods of debugging. E.g. jumbled algorithms, missing instruction in an algorithm, predict the destination or start from an algorithm.

Lesson 6 (optional) – Beebot Olympics, story activities

Teaching points: Create and debug algorithms efficiently, begin to simplify written algorithms by using iteration.

Independent activity: A carousel of Olympic events are created that test children's use of the Beebots and creating and debugging algorithms. E.g. Shooting – aim your beebot to stop in the centre of a target. Relay – go from one side to the other of a line and back – to the same place etc.

Alternatively – Story activities. Large sheets of paper can depict different points in a story that Beebot needs to visit sequentially. Children record the algorithms and tell the story to the rest of the class.

Developing algorithms – Lego Listening

Year Group	1	Lesson No	1 of 6
Links to curriculum		Learning intentions	
<ul style="list-style-type: none"> Understand what algorithms are Set a sequence of instructions to achieve a goal 		Must: Understand that algorithm means a set of instructions to complete a task Should: Create a verbal algorithm to complete a task Could: Explain how an algorithm could be improved	
Keywords	Algorithm <i>Prepositions</i> – on, next to, over, to the side, left, right, above, underneath <i>Colours</i>		
Resources	Lego, multilink, interlocking building blocks etc. Visual dividers e.g. cardboard boxes, screens etc.		

Whole class input

Explain the topic is about computing. Ask the children to tell me if they can see any computers in the room? *Usually they just identify the teacher's desktop PC*

Are there any other computers in the room? Identify that computers are used in lots of objects in school – PC, laptop, ipads, printers, projectors, phones, clocks etc..

Why do we have computers? They can do lots of tasks for us. *Children give examples*

Explain that computers can only do the tasks they do because they have been 'told' how to do the tasks by a programmer – somebody who makes the instructions for a computer to follow.

Introduce the new word, **algorithm**. Ask the children to say the word.

Explain that this is a word we use in computing and we are going to find out what it means.

Watch BBC KS1 Algorithm video <http://www.bbc.co.uk/guides/z3whpv4>

Reiterate that algorithm means a set of instructions to complete a task. Give some examples of algorithms we use to complete tasks every day e.g. journey to school, getting dressed, brushing teeth, etc.

Explain that you are going to tell the class the algorithm for how to create an object you are hiding from them. In a box or behind a dividing screen have a prepared multilink object of 4-6 multilink cubes.

Provide the children with multilink and give them the algorithm to create the shape. Each child tries to create the shape

Repeat with a child giving a new algorithm.

What words and phrases do we need to make our instructions clear? *Discuss prepositions and phrase used*

Do we need to give the instructions in the right order?

Independent activities

In pairs, the children create algorithms for shapes they have made with Lego or multilink cubes and take turn to instruct the other person to make their shape from behind a divider.

Evaluate

Reiterate the vocab used – what does algorithm mean?

What makes a good algorithm? *Refer to activity – in the right order, using clear meaning*

Developing algorithms – Train my Robot

Year Group

1

Lesson No

2 of 6

Links to curriculum

1. Understand what algorithms are
2. Create and debug simple programs

Learning intentions

Must: Create a written algorithm to complete a simple task

Should: Debug a recorded algorithm

Could:

Keywords

Algorithm
Debug

Resources

Whiteboards
Pens
Clear space
Counters/objects/cones to mark start and destination points
Obstacle course items, benches, bars etc..

Whole class input

Can anyone remember the new word from last week and what it means?

What makes a good **algorithm**?

Ask the children what a robot is. What does it look like? What does it do?

Look at some different robots, both fictional and real using the Powerpoint file supplied.
What do they do? How does a robot work?

Reiterate the idea that robots need to be ‘told’ what to do by programmers. The computer that controls them runs algorithms to complete different tasks. Explain that today we are going to be robots and create algorithms to show each other how to complete a task.

Demonstrate to the class the first independent activity. Start with ‘distance debug’. Put a counter some distance away from yourself and ask the children to give you the algorithm to pick the shape up. Explain that you can only follow one instruction at a time. Children should begin to instruct you to walk forward and finally pick up the shape. Show the children how to write the algorithm down as arrows for ‘forward one step’ and ‘pick up’ e.g. ↑↑↑•

Independent activities

In pairs children take turns to complete the distance debug activity. After 10 mins, call the children together and give another class example with a turn or a route around the room avoiding obstacles. Discuss using left or right. *Children could tap on the shoulder if this is difficult.*

Demonstrate writing out the algorithm on the whiteboards first before giving the instructions. Explain that we are going to **debug** our algorithms. Reiterate the terms debug and algorithm during the exercise

Using a range of objects and furniture create an obstacle course for the children to guide one another around. Ask the children to record their algorithms on whiteboards and debug them if necessary following the method shown previously.

Evaluate

Use the children's whiteboards as examples of recorded algorithms. Talk about how they changed their algorithms. Ask the children to define the words **debug** and **algorithm**

Developing algorithms – Strictly Beebots Dancing

Year Group	1	Lesson No	3 of 6
Links to curriculum		Learning intentions	
<ol style="list-style-type: none"> 1. Create and debug simple programs 2. Set a sequence of instructions to achieve a goal 3. Use programming skills to control an external device. 		<p>Must: Know what all the buttons on Beebot do</p> <p>Should: Write an algorithm for Beebot to follow.</p> <p>Could: Explain where errors are in an algorithm and debug it.</p>	
Keywords	Algorithm Debug Left, Right <i>(Beebot buttons)</i>		
Resources	Beebots – Preferably 1 between 2/3 Whiteboards Pens		

Whole class input

Class can start by a class dance e.g. Disneys under the sea - <https://www.youtube.com/watch?v=yw8xDUD4mYU>. Ask some of the children to give instructions to some of the moves they just danced. Remind them of the word **algorithm** and the meaning.

Introduce Beebot. What does she look like? Identify that she is part bee and part robot. Show the children the buttons and explain that the buttons give Beebot instructions for how to move. Talk through how and when we use each button. Emphasise that Beebot turns on the spot.

Also discuss how to keep Beebot safe (holding carefully, not picking up or dragging when moving)

Today we are going to teach Beebot to dance. We are going to create some dance **algorithms**.

Show the children a written algorithm on the whiteboard like the last lesson using arrows. E.g. ↑↑←←↑↑←← Choose a child to demonstrate how to use the algorithm to program Beebot to make a simple dance move.

Repeat with different children, creating different simple movements

Independent activities

Remaining as a whole class, pass out Beebots between the children to share, explain that we are going to show our Beebots how to dance together. In groups children put in the algorithm for a written routine you have scribed and all the children press go simultaneously. See if any of the Beebot's do a different routine and discuss how we need to debug the errors.

For 3 minutes, the children create a simple dance routine in their groups and record the algorithm on whiteboards using no more than 8 moves.

Come back together as a class and choreograph the different dance routines created together.

For more able groups set extra challenges e.g. Beebot needs to start and stop their dance algorithm in the same place. Every movement button needs to be used.

Evaluate

Show an algorithm and ask children how they would debug it to make Beebot come back to the starting place.

Question the children about the different buttons on Beebot and what they do. Review the vocab used and how to debug their algorithms.

Developing algorithms – A-maze-ing Beebots

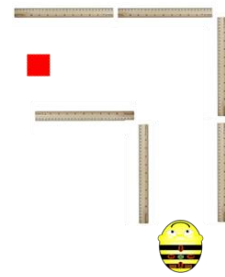
Year Group	1	Lesson No	4 of 6
Links to curriculum	Use iteration to develop more efficient instructions.		Learning intentions Must: I can write an algorithm for Beebot to follow a route. Should: I can simplify my algorithm using numbers to repeat actions Could: I can debug my algorithm to make it better.
Keywords	Repeat Algorithm Debug		
Resources	Beebots, Rulers, blocks etc. objects to make a route for Beebot to travel. Objects for Beebot to reach e.g. 2d shapes		
Whole class input			

Recap previous lesson and the Buttons on Beebot. Explain today we are going to write algorithms for Beebot to move along a route. Show how to make a simple route with rulers or blocks for Beebot to travel between.

As a class children practice writing the algorithm on the whiteboards like last lesson. Test and debug the algorithms using Beebot.

Are there any ways we can simplify our code? Show how we could use a number to repeat Beebot's move instead of repeating the same arrows

Eg. ↑↑↑ ← ↑↑↑ could be 3↑ ← 3↑



Practice as a whole class writing algorithms for simple routes or mazes using numbers to repeat commands.

Independent activities

Discuss with the children that they are going to work in groups to create different routes and write algorithms using numbers. Discuss with the children how they will share and divide up tasks making sure everyone has turns.

Children create routes using equipment for Beebot to follow.

Make sure children create their written algorithms first before they test them with the Beebot.

Children need to debug their algorithms before creating new routes and mazes.

Evaluate

Bring the children together. Missing instruction question:

Prepare a maze for a Beebot and show them a written algorithm that doesn't work because there is a missing instruction. Children in paired talk – Identify the missing instruction and rewrite the algorithm so it will work.

Developing algorithms – Beebot mats

Year Group	1	Lesson No	5 of 6
Links to curriculum	1. Create and debug simple programs 2. Use logical reasoning to predict the behaviour of simple programs.		Learning intentions Must: Write algorithms for Beebots Should: Debug written algorithms Could: Solve logic problems using Beebots.
Keywords	Algorithm Debug Left, Right <i>(Beebot buttons)</i> Repeat		
Resources	Beebots Mats (commercial mats or grids on large paper - 15cm size squares) Beebot button cards		

Whole class input

Use the mats to review how to create, record and debug algorithms to move Beebot to specified destinations.

Demonstrate some challenges with the children together:

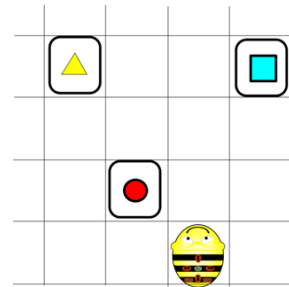
Example challenges:

Missing instruction – Show the children an algorithm to reach a destination with a single instruction missing – See if the children can spot and debug the instruction.

‘Broken’ button – Reach this destination without using a particular button. E.g. get to this destination without using ‘turn left’

Reverse Algorithms – One child turns away or is blind-folded, while

the others run an algorithm. “This is where Beebot ended, where did Beebot start?” Show the algorithm.



Independent activities

Lower – Use mats to create simple algorithms to move to different destinations.

Mid – Give the children some Beebot instruction cards *see resources*. Limit their algorithms to a certain number of cards.

High – Reverse algorithms – give the children an algorithm on white board and the end square. Children need to find the start square and test the algorithm

Evaluate

Review some of the activities as a whole class.

Developing algorithms - Beebot sports (optional)

Year Group	1	Lesson No	6 of 6
Links to curriculum 3. Create and debug simple programs 4. Use logical reasoning to predict the behaviour of simple programs.	Learning intentions Must: Write algorithms for Beebots Should: Debug written algorithms Could: Solve logic problems using Beebots.		
Keywords	Algorithm Debug (Beebot buttons) Repeat		
Resources	Beebots Hall or large area		

	Tape, chalk, markers or string to make lines on the floor Cones, ropes Equipment for different activities (see activities)
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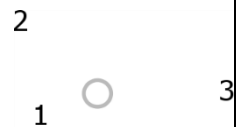
Whole class input

Show the children a carousel of activities and discuss the challenge for each activity

Independent activities

Activity 1 Bulls eye target

Put a 'bulls eye' target with different numbered start locations around the target. Children score a point and move onto the next number if they get Beebot to stop inside the target circle



Activity 2 There and back

Start line and 3 lines various distances away. Beebot must be programmed to get over first line and return to the start. Repeat for the other two lines

Activity 3 Maze

Use skipping ropes to design a simple maze
Pilot Beebot through by programming one section at a time

Activity 4 Beebot zigzag

Draw a starting circle with 4 cones in a line. Beebot to be programmed to zig zag around cones to a final destination

These activities are modified from this Olympics themed web resource:

<https://drbadgr.wordpress.com/2012/06/08/bee-bot-olympics-and-maths-project-design-an-olympic-stadium-ukedchat/>

Evaluate

Review some of the challenges and successes of the activities

Medium Term Plan B – Scratch Jr

Year Group: Year 1/2

4 - 6 sessions

Key National Curriculum Objectives:

4. Create and debug simple programs
5. Use logical reasoning to predict the behaviour of simple programs.

Jersey Computing Curriculum:

1. Set a sequence of instructions to achieve a goal.
2. Use iteration to develop more efficient instructions.

Overview: These lessons develop the children's understanding of creating and debugging algorithms that they have learned through the Beebot and unplugged activities. These skills are now applied in a software environment. Using ScratchJr, children begin by creating sequential algorithms to manipulate graphics and sound. Children then develop the idea of repeating sequences by creating loops to simplify their code. Finally, children look at how to make events occur through using messages in Scratch Jr.

In the last two sessions, children create their own animations and interactive scenes that apply the skills learned in the earlier lessons.

Lessons are expected to last 45 – 60 mins

Session 1 – Making objects move

Teaching points: Review previous lessons with Beebots – show an example of how to move Beebot around a small obstacle to reach a destination. Review how algorithms are written. Introduce Scratch Jr and the interface. Show similar commands for movement and how to make different characters move.

Independent activity: Children create a farm scene of no more than three characters and write sequential algorithms to make their characters move around the scene.

Session 2 – More than one command

Teaching points: Using an unplugged example activity of dance moves, the children explore the idea of having multiple commands simultaneously. Demonstrate how to use multiple lines of code blocks in scratch junior to make more advanced moves.

Independent activity: Children create a dance scene with multiple scripts per character

Lesson 3 – Repeating motion

Teaching points: Use human robots example to show how repeat commands can be used in written algorithms. Class instruct robot teacher to repeat an activity, e.g. collecting shapes off the floor. Introduce the repeat command in Scratch Jr and show an example to make a character move around in a circle.

Independent activity: Children complete a basketball activity with guidance from the teacher. <http://www.scratchjr.org/activities/card04-dribble.pdf>

Lesson 4 – Sending Messages

Teaching points: Play a secret message game – children receive an animal picture and must make the noise to the rest of the class. The class guess the animal. The teacher demonstrates the message feature of Scratch Jr that allows objects to interact. Children are also shown how to record sounds using scratch jr.

Independent activity: With teacher guidance, children create a story scene animation in the farmyard where the animals make noises (that the children have recorded) one after the other using the message feature.

Lesson 5 and 6 – Independent project

Teaching points: The interface and blocks in Scratch Junior are reviewed. The teacher explains the project theme based on a school topic and models how to create the first character using the drawing tools.

Independent activity: Children create a short animation using the movement blocks and repeat block. Higher ability children include messages in their code.

Scratch Jr. – Making objects move

Year Group

1

Lesson No

1 of 6

Links to curriculum

- Create and debug simple programs
- Set a sequence of instructions to achieve a goal.

Learning intentions

Must: Create a sequence of instructions using one movement block to make characters move in ScratchJr.
Should:
Could:

Keywords

Resources

Whole class input

Review previous lessons with Beebots – show an example of how to move Beebot around a small obstacle to reach a destination. Review how algorithms are written. Introduce Scratch Jr and the interface. Show similar commands for movement and how to make different characters move.

Independent activities

Children choose three characters for the farm scene and make short algorithms to make them move when the flag is pressed. Introduce each activity as whole class and then allow 5 -10 minutes to complete each activity.

Activity 1 Farmyard dash – Make animals move from one side of the screen to the other

Activity 2 Back and forth – Make animals move across the field and back to their starting location

Activity 3 – Square dance – Make a character move in a square returning to the original place.

Activity 4 – Experiment making animals move - different shapes etc.

Evaluate

Bring class together and review how to make a character move in a square using the move blocks.

Show the children an algorithm of an animal moving and in paired talk, see if they can predict the shape the animal will move.

Scratch Jr. More than one command

Year Group	1	Lesson No	2 of 6
Links to curriculum	<ul style="list-style-type: none"> • Create and debug simple programs • Set a sequence of instructions to achieve a goal. 		Learning intentions Must: Create code to make a character dance. Should: Create two simultaneous lines of code to make characters dance more complex routines Could: Use the repeat end block to make characters dance continuously
Keywords	Algorithm Code Blocks Debug		
Resources	Ipads (preferably one each) Apple TV link		

Whole class input

Begin by learning a dance song together like 'Move and Freeze'

<https://www.youtube.com/watch?v=388Q44ReOWE>

Ask the children to show you some of the different moves in the song.

How would you explain the instructions to someone using words?

Try to identify the different moves that need to be made simultaneously.

Show the children how to make a character dance in ScratchJr. Using the dance floor background and a person character. Remind children of the interface and how to build up lines of code blocks. Introduce the jump and turn left and right blocks.

Demonstrate how two algorithms can run simultaneously by using two sets of code blocks to make more complex dance moves like:

Jump to the left and jump to the right.
Lean (turn) to the left and lean to the right
Step forward-left, then forward-right

Independent activities

Children create some longer algorithms for characters to dance using more than one algorithm at the same time.

Lower ability can use a help sheet to help them -<http://www.scratchjr.org/activities/card02-dance.pdf>

Bring the children together and show them how to make the characters repeat their moves using the forever end block.

Give the children time to modify their code to include repeat end blocks to make their characters dance continuously.

Evaluate

Show the children a sequence of code blocks and ask them to predict in pairs what the character is going to do.

Show another sequence and explain that you want your character to return back to their starting place. How would we change the code for them to do this?

Scratch Jr. - Repeating commands

Year Group	1	Lesson No	3 of 6
Links to curriculum		Learning intentions	
<ul style="list-style-type: none"> Use iteration to develop more efficient instructions. 		Must: Use a repeat block to simplify code. Should: Use multiple repeat blocks to create a sequence. Could: Create multiple characters that use repeat blocks	
Keywords	Repeat Loop		
Resources	Ipads (preferably one each) Apple TV link		
Whole class input			

Revisit the 'human robot' activities from the Beebot unit. Remind the children how to instruct you to collect an object to off the floor. Review how to write the algorithm on a whiteboard using arrows. E.g. ↑↑↑↑

Show how the algorithm can be simplified with a number. 4↑

Now discuss with the children how to write the algorithm to collect a few objects off the floor evenly spaced in a row. Eg. ↑•↑•↑•↑•

Write the algorithm and then show the children how to simplify the algorithm using a number to repeat the sequence. 4↑•

Review the interface of Scratch Junior and the buttons used last week. Explain that today we are going to learn how to use a new block that will make our algorithms easier. Demonstrate the repeat block. Explain that the block creates a 'loop' that 'repeats'. Show the children how to use the repeat block to make a ball bounce 4 times and then roll.

Independent activities

Children complete the ScratchJr Basketball activity using help sheet if required

<http://www.scratchjr.org/activities/card04-dribble.pdf>

Evaluate

Review questions on ScratchJr worksheet:

Can you make the cat shoot the ball into the basket?

What else can you make with two characters moving at the same time?

Scratch Jr. – Sending messages

Year Group	1	Lesson No	4 of 6
Links to curriculum	<ul style="list-style-type: none"> • Create and debug simple programs • Use logical reasoning to predict the behaviour of simple programs. 		Learning intentions Must: Make two characters interact by using a message block. Should: Could:
Keywords	Message Sound Record		
Resources	Animal cards (see resources) Ipads (preferably one each) Apple TV link		

Whole class input

Play a secret message game – children receive an animal picture (see resources) and must make the noise to the rest of the class. The class guess the animal.

Children are also shown how to record sounds using Scratch jr.

Demo with the children how to record a sound for a duck and make a duck sprite play the sound when the flag is tapped.

Children use Ipads to record a sound for a duck and create a duck sprite that quacks when the flag is pressed.

Bring the class together. Demonstrate the message feature of Scratch Jr that allows objects to interact using coloured messages. Create a second farmyard animal and sound.

Independent activities

With teacher guidance, children create a story scene animation in the farmyard where the animals make noises (that the children have recorded) one after the other using the message feature.

Evaluate

Bring the class together and create 4 animals that send messages to each other to create a round of farmyard noises.

Scratch Jr. – Independent Project

Year Group	1	Lesson No	5 and 6 of 6
Links to curriculum <ol style="list-style-type: none">1. Create and debug simple programs2. Use logical reasoning to predict the behaviour of simple program3. Set a sequence of instructions to achieve a goal.4. Use iteration to develop more efficient instructions.			Learning intentions Must: Create an animation with a character using a repeat block. Should: Create an animation using multiple characters with repeat blocks and a sequence using one message. Could: Create an animation using multiple characters with repeat blocks and multiple messages.
Keywords	All previous terms used in the MTP Drawing tools e.g. fill, line, circle, rectangle etc		
Resources	Ipads (preferably one each) Apple TV link		

Whole class input

Discuss with the class the task: Using the class/school theme or topic, the children need to create an animation based on the differentiated learning intentions.

Begin by showing the children how to create artwork using the drawing tools on ScratchJr.

Next, model the planning of the project using a whiteboard to draw the images and symbols for the algorithms for each character in the animation.

Children could draw pictures to plan their animations.

Independent activities

Children create the animations. It might be good to guide the children through the process. Give time limits for each element of the process.

1. Create characters and artwork
2. Record sounds for each character
3. Create code for each character

Evaluate

Showcase the children's animations

Assess by differentiated learning intentions:

Lower: Create an animation with a character using a repeat block.

Middle: Create an animation using multiple characters with repeat blocks and a sequence using one message.

Higher: Create an animation using multiple characters with repeat blocks and multiple messages.

Appendix 2: Data from online surveys with Year 2 Primary teachers.

Question 1: Are you male or female?

Answer choices	Responses
Male	3
Female	7
Total	10
Answered: 10 Skipped: 1	

Question 2: What is your age?

Answer choices	Responses
18-24	2
25-34	3
35-44	5
45-54	1
55-64	0
Total	11
Answered: 11 Skipped: 0	

Question 3: What do you understand by the term computer programming?

Unique code	Response
F35-44-1	Giving instructions to make a 'piece of technology' work or do something.
F18-24-2	Programming a computer to tell it how to do different jobs. Telling the computer to follow a series of instructions.
M25-34-3	A few things really. Programming an icon/avatar on computer to move a set amount of spaces (then transfer into real world e.g. Bee Bots), this includes turns and amount of turn. Also creating algorithms to create something such as traffic light signals with timings. Also programming short and simple applications for use on computer using things like Scratch or using programmable devices such as Raspberry Pi.
M35-44-4	Typing in codes in order to command the computer to make or to do something.
F18-24-5	Creating instructions to command a computer to do something.
F35-44-6	You write a programme to make something do something.
F45-54-7	Programming objects to do something with a series of instructions e.g. Lego.
M35-44-8	Using a computer language (such as BASIC or JAVA) to create programmes of instructional code to run a wide range of computer software, e.g. banking systems, data systems and engineering systems.
F25-34-9	Sequences of instructions to enable a computer to do a certain thing.
F25-34-10	I understand the meaning of algorithms and how to provide opportunities for the children to learn what these mean both plugged and unplugged. We

	have explored the importance of clear instructions and the idea of 'input' to receive 'output'.
F35-44-11	Writing a script for the computer to operate and carry out a command/function.
Answered: 11 Skipped: 0	

Question 4: Have you experienced computer programming before this initiative?

Answer choices	Responses
Yes	5
No	6
Total	11
Answered: 11 Skipped: 0	

Question 5: If you answered No to question 4 then please move on to question 6. If you answered YES to question 4, which programmes/languages have you used?

Unique code	Response	
F35-44-1	Yes.	BeeBots.
M25-34-3	Yes.	Mainly Internet based programming such as HTML, CSS, java and so forth. Other simple programmes such as Scratch.
M35-44-4	Yes.	Respondent skipped the latter part of this question.
F45-54-7	No.	But respondent went on to comment that I have seen it happen in school – programmable Lego.
M35-44-8	Yes.	Respondent skipped the latter part of this question.
F25-34-9	Yes.	Scratch, hopscotch, various apps.
Answered: 4 Skipped: 7		

Question 6: What do you think are the possible benefits of introducing computer programming into the Key Sage 1 curriculum?

Unique code	Response
F35-44-1	Not sure.
F18-24-2	Children are able to sequence a series of instructions. Children develop a deeper understanding of how computers work.
M25-34-3	A great deal of benefit, sets the children up for the future, especially in this day and age where technology is an essential part of life. It also allows them to understand how, for example, sending instructions to make something move works.
M35-44-4	An application of maths skills, greater understanding of how computers work.
F18-24-5	Engaging, lots of opportunities for cross curricular learning.
F35-44-6	Yes. Staff getting training, older children peer tutoring younger children, logical thinking, problem solving, maths, having a purpose for use of ICT, enhance ICT skills.

F45-54-7	Vital – transition into KS2 and beyond. The future.
M35-44-8	Instructional writing should improve. Links to 3D modelling should make DT more engaging. Pupils can create own games or apps or effects and not just watch or play one already made. Pupils grasp idea of command language and how websites etc. are made.
F25-34-9	Lots of benefits. Logical/computational thinking etc.
F25-34-10	Children to understand how and why things work! And understand the role of the process rather than just being handed a product. Much more logical thinking, this is made explicit with the new curriculum.
F35-44-11	The younger you start with new initiatives the easier it is for children to acquire the skills and knowledge required.
Answered: 11 Skipped: 0	

Question 7: What do you think could be potential negatives to introducing computer programming into the Key Stage 1 curriculum?

Unique code	Response
F35-44-1	Not sure.
F18-24-2	Children may not develop other computer skills we normally teach during ICT.
M25-34-3	None that I can think of.
M35-44-4	A tricky concept to grasp. Teacher knowledge might be sketchy – I know mine would be.
F18-24-5	None.
F35-44-6	Computers not working therefore raising stress levels with small children having to wait for a long time. Staff need training. It's an addition to the curriculum that is already under a lot of time pressure.
F45-54-7	Children's lack of basic IT skills.
M35-44-8	Will suit pupils whose language skills are more developed. If you can't read or write you may be disadvantaged and get a wrong impression of the subject before being able to access it.
F25-34-9	Teacher knowledge – needs lots of training if never experienced any programming before.
F25-34-10	I don't see any other than the muddy stage of getting your head around change and ensuring curriculum coverage.
F35-44-11	Not having the infrastructure in place to support it.
Answered: 11 Skipped: 0	

Question 8: As a Key Stage 1 practitioner, please rate how confident you currently feel about delivering programming into the curriculum, with 1 being not at all confident through to 10 being extremely confident.

Not at all confident									Extremely confident	Total	Weighted average
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2	2	0	2	1	1	0	2	1	0	11	4.55
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Question 9: As a Key Stage 1 practitioner, please rate how confident you currently feel about embedding programming into the curriculum, with 1 being not at all confident through to 10 being extremely confident.

Not at all confident										Extremely confident	Total	Weighted average
1	2	1	2	1	1	1	1	1	0	11	4.64	

Question 10: As a Key Stage 1 practitioner, do you have any concerns in regards to implementing and embedding programming into the curriculum from September 2014? If you answered NO, please move onto question 12.

Answer choices	Responses
Yes	7
No	4
Total	11
Answered: 11 Skipped: 0	

Question 11: If YES, please identify your concerns using the rating scale below.

	Very concerned	Slightly concerned	Not concerned at all	Total
Personal Knowledge	3	4	0	7
Training	4	3	0	7
Assessing/tracking children's progress	4	2	1	7

Question 12: Please take the time to share any other concerns that you may have in the box below.

Unique code	Response
F35-44-1	I think, from looking into it myself, my concerns have stemmed from the language that has been used. When put into 'English' for those of us who are not 'technology geeks' it doesn't seem so bad!
F18-24-2	Respondent skipped this question.
M25-34-3	Respondent skipped this question.
M35-44-4	Respondent skipped this question.
F18-24-5	Respondent skipped this question.
F35-44-6	Respondent skipped this question.
F45-54-7	Will there be any other training or will our IT co-ordinators filter knowledge down and train in house?
M35-44-8	Feel that staff in KS2 will need to be skilled to a high level for it to be effective as we raise expectations further down the school.
F25-34-9	Respondent skipped this question.

F25-34-10	As the Key Stage 1 Manager, I need to ensure the rest of the team understand the curriculum and how to embed it. I need to create CPD opportunities for them as well as learn the material myself.
F35-44-11	Respondent skipped this question.
Answered: 6 Skipped: 5	

Question 13: Finally, what do you understand by the term computational thinking?

Unique code	Response
F35-44-1	Don't know. Would have to look it up. More jargon!
F18-24-2	Using computer science problems to complete problem solving.
M25-34-3	Problem solving.
M35-44-4	I've never heard this term before – perhaps something to do in the way you type in commands to make a computer appear to be thinking.
F18-24-5	Problem solving?
F35-44-6	It's a logical process that leads to a desired outcome, e.g. formulas in cells of a spreadsheet.
F45-54-7	Problem solving skills in IT.
M35-44-8	Logical and ordered thinking that can chunk tasks and problems into smaller steps to make them more attainable.
F25-34-9	Problem solving.
F25-34-10	I think this means to understand the steps and logic required to make something work. To know what to input to get a desired output.
F35-44-11	Respondent skipped this question.
Answered: 10 Skipped: 1	

Appendix 3: Data from focus groups with Year 2 children.

Tell me what you know about Computer Science	
Group 1 -2G and 4B	
G	B
'It's really cool' (G1)	'Because you get to like, you don't have to like write it, you can just type it on...' (B1)
'You can just click on stuff and its really cool because like Mr...showed us you can repeat it...normally you have to write it' (G1)	'That's quite boring' (B1)
Group 2 – 6G	
G	
'Kind of like it's changing stuff on the computer and learning about it and kind of like we learn about it cos we never knew it and then we start doing it, like sometimes I go on Scratch, but it never works really...' (G1)	
'There's a cat on it' (G2)	
I find it interesting when you collect the stuff...and you click the instructions and you put it on' (G1)	
'It's interesting when you know how to do it and you keep doing it...' (G3)	
'You can do lots of things on it, you can play and you can write on the words and...stop it' (G4)	
Group 3 – 3G and 3B	
G	B
'The Beebot program...when you have to get through these bits...' (G1)	'It's about Scratch' (B1)
'I found it exciting and interesting because sometimes we go on Beebot and we have to find out different things and then we get confused...and there's like a big mat and you have press forwards and backwards' (G3)	'Forwards, backwards...' (B3)
'And when you press forward it goes forward and when you press sideways it goes sideways and when you press the other side it goes side and when you press backward it goes back' (G1)	'In the middle there's a green button and it says stop' (B3)
Group 4 – 1G and 4B	
G	B
	'It means...cos debugging means, like you fix the computer basically' (B1)
	'We do Beebot activities and Scratch' (B1)

	'Scratch 1.4. What we're doing now is basically shapes and repeating and move 50 steps, turn 90...' (B2)
	'I found it interesting, when you could just start from the zero but you actually start from 90 and then you do 180, but you could do 10...' (B2)
	'Yeah, 90, 180, 360...' (B1)
Group 5 – 2G and 2B (1 B with SEN)	
G	B
'We do Beebot...they're like little arrows and you have to press them and tell them where to go' (G1)	'It's good...but with the Beebot it's hard to get to the finish line...' (B1) Facilitator: 'Aah, so sometimes it doesn't do the right instructions or have you told it the wrong instructions?' 'I've done something wrong...it makes you go back to the start and then it goes that way...' (B1)
'Scratch too...because on the first time I did Scratch...when I was doing a square it actually didn't work...' (G2) Facilitator: So what did you do? 'I just asked Mr....' (G2)	'Scratch...' (B2) Facilitator: And do you find that difficult? 'Yeah' (B2) Facilitator: What do you find difficult? 'Doing the triangles and squares...' (B2)

What sort of things do you do in these sessions? What do enjoy and what's challenging?	
Group 1 -2G and 4B	
G	B
'We go on Scratch 1.4 and we used to go on Beebot, we use this mat...was it you that was there?' (G1) Facilitator: Yes, that's right we came and use used the Beebots with you and we programmed them...'	
'No that's not really Computer Science...that's a game...' (G2)	'Played cool maths games...' (B2)
	'The FIFA pack opening on Scratch' (B3)
	'That's a game...' (B2)
And you get to play games and it's really fun the way you get to program...it's like you're making your own little thing...(G1)	'Like Computer Science (sigh), not a game...' (B3)
'But you also have to be careful...' (G1)	'You can go on Google and you can just type stuff in and you can look at pictures...' (B3)
Group 2 – 6G	
G	B
'Beebot activities' (G6)	

Facillitator: OK, what do you do with Beebot?’	
‘Er...you like move him...(G1)	
Facillitator: Physically move him? Pick him up and put him down?	
‘No. you do it on the compute’ (G6)	
‘Difficult following instructions’ (G1) ‘There’s one thing I’d like to say. I always be late on the computer and I don’t get on it...then the sessions maybe finished so I get a problem with the computer when it’s on Beebot’ (G1)	
‘I don’t even understand what he means half the time.’ (G1)	
‘I don’t even understand’ (G2) ‘I don’t ‘ (G4)	
Group 3 – 3G and 3B	
G	B
You get to find out some stuff on the computers (G3)	‘It’s fun because you can learn different things’ (B1)
How to make different shapes and stuff and one time when we could make like triangles, squares...fancy shapes... (G1)	
Group 4 – 1G and 4B	
G	B
	‘I think the good thing is that we have a new teacher in to help us with the computer...so we get used to new computers’ (B3)
‘No, 2 weeks we have left’ (G1)	‘I find it interesting about all the shapes and stuff cos we learnt a new one called the decagon, but it’s quite sad because we only have one more week left...’ (B2)
	‘Yeah, but when we’re in year 3 we’ll still get it won’t we?’ (B1)
Group 5 – 2G and 2B (1 B with SEN)	
G	B
	‘It’s good because you get to play really good games and you get to play like maths games or you can put music on...’ (B1)
‘You can choose anything you want on the computer but you have to be sensible with them so they don’t break’ (G1)	‘I like when we go on the computers for golden time’ (B1)

Do you think that what you are learning in the computer programming sessions helps you in other subjects in school?	
Group 1 -2G and 4B	
G	B
'And it also helps us with our maths, the way we do 90, 180, 270...' (G1)	'Yeah, because when we go into year 3 we might need to do it again, or have to remember...' (B1)
'And it's helped us with some shapes' (G1)	'9x4 is 360' (B4)
Group 2 – 6G	
G	
'Not really' (G3)	
'I don't even understand what he means half the time' (G1)	
'I don't even understand...' (G2)	
I don't...' (G4)	
Group 3 – 3G and 3B	
G	B
'Yeah...' (G2)	'No' (B3)
'Er, you get to know like other things you haven't known before...' (G3)	
Group 4 – 1G and 4B	
G	B
'ER, to say like Scratch, it's just a really good thing to help you learn with the computers' (G1)	'A lot...' (B2)
	'Yeah, it helps you...' (B1) Facilitator: Can you give me some examples?
	'Do you know when it says like 90 and 180...270 and 360...it helps you do your times tables (B2)
	'Yeah and your maths' (B1)
	'It's a bit like North, South, East and West but with numbers...' (B3) Facilitator: So a bit of geography and a bit of maths?
	'And science!' (B1) Facilitator: How does it help with science do you think?
	'Cos debugging is a lot like science...and stuff like that' (B3)
	'And you fix it...' (B1) Facilitator: so it's like trying to solve...
	'Problems!' (B3 and B1 together)
	'And it's science cos like it's basically not making up stuff, it's kind of telling us what

	to do and then we do it and make it up...' (B2)
	'I was just going to say that...erm...I think it's really special cos sometimes it makes me think that we're working for the program...of Scratch 1.4...' (B1) Facilitator: that's interesting, can you tell me a little bit more? 'Yes and plus, with Mr..., he teaches like, I think, year 9 and year 10 and I think it's really special cos they're...8 years older than us, so we're learning our 90 times tables and we're in year 2 and they're in year 10...but now we're learning what year 10's learn' (B1) Facilitator: Wow, so you're going to be super smart by the time you get to secondary.
	'When we're in year 10 we're going to be amazing at this...' (B2)
Group 5 – 2G and 2B (1 B with SEN)	
'Maths.' (G2)	'Shape...shape is in maths, cos we had to learn shapes and there's that thing where you can draw something and...pencils and squares, triangles, rectangles, squares, circles and you can draw all the shapes that are there...' (B1)

Have you shared what you have learnt in computer programming sessions in school with anybody else?	
Group 1 -2G and 4B	
G	B
'Yeah' (G1)	'Computers? I have to share with someone?' (B2) Facilitator: who have you shared it with?
'Friends...talk about it in the playground and with parents and family...' (G2) Facilitator: So you've talked about it to your parents? (Children then started to giggle and dis-engage so session was ended)	'Friends...' (B1)
Group 2 – 6G	
G	
'No, I don't really go on Scratch at home' (G3)	
'I don't have Scratch at home' (G5)	

'I can't go on Scratch if I don't have a computer...' (G1)	
'I've got a computer, but it's very old and it can't go that well, it's like 12 years old...' (G6) 'So I can't do it. So you click on something and then you just wait. I click a button and then it turns on. It loads really...and doesn't work that well' (G6)	
'I've got a new computer' (G4) Facilitator: And do you do anything at home like you do in Computer Science? 'I play Scratch' (G4)	
Group 3 – 3G and 3B	
G	B
No data gathered due to children indicating that they were ready to go back to class	No data gathered due to children indicating that they were ready to go back to class
Group 4 – 1G and 4B	
G	B
No data gathered due to children indicating that they were ready to go back to class	No data gathered due to children indicating that they were ready to go back to class
Group 5 – 2G and 2B (1 B with SEN)	
G	B
No data gathered due to children indicating that they were ready to go back to class	No data gathered due to children indicating that they were ready to go back to class

Appendix 4: University of Sheffield ethical approval.



The School Of Education.

Lynn Blakemore

Head of School
Professor Cathy Nutbrown

School of Education
388 Glossop Road
Sheffield
S10 2JA

17 March 2014

Telephone: +44 (0)114 222 8096
Email: edd@sheffield.ac.uk

Dear Lynn

ETHICAL APPROVAL LETTER

Does teaching computer programming within Key Stage 1 of the primary curriculum enhance children's problem solving skills?

Thank you for submitting your ethics application. I am writing to confirm that your application has now been approved, and you can proceed with your research.

This letter is evidence that your application has been approved and should be included as an Appendix in your final submission.

Good luck with your research.

Yours sincerely

Professor Dan Goodley
Chair of the School of Education Ethics Review Panel

CC Dr Rachael Levy

Appendix 5: Information sheet for Gatekeeper (Head teachers) and teachers of Year 2.



Information Sheet for Head teachers and Teachers of year 2 groups

Research Project Title:

Does teaching computer programming within key stage 1 of the primary curriculum enhance children's problem solving skills?

Invitation to take part in a research project -

You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

What is the project's purpose?

I am a student on the EdD Early Childhood Education programme with the University of Sheffield and just about to embark upon research for my thesis. An area of particular interest is that of the initiative of teaching computing within the Primary Curriculum which is currently being piloted within two Island primary schools. Given that all primary schools in Jersey will employ this initiative from September 2014, this thesis provides an ideal opportunity to evaluate the benefits of this initiative by collecting and analysing data over a two year period (2014-2016).

The focus of this research will be to elucidate on the current debate around the teaching and delivery of the ICT curriculum, with particular emphasis on pedagogy, policy and practice in the primary curriculum in Jersey.

Why have I been chosen?

You have been chosen to be part of this research project either as a Head teacher (and therefore gatekeeper to the potential research process) or as a teacher of a Year 2 cohort who will be experiencing the new computer programming curriculum from September 2014.

Do I have to take part?

Taking part in the research is entirely voluntary and any refusals to agree to participate will involve no penalties to you. All those involved in the research project may discontinue participation at any time.

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and you can still withdraw at any time without it affecting you in any way. You do not have to give a reason.

What will happen to me if I take part?

This research will be undertaken from June 2014 through to September 2016. As a year 2 teacher your class will be asked to take part in a problem solving activity in June/July 2014 so that we can gather some initial baseline data. This activity will form part of the computer programming curriculum that your class will be experiencing as part of their every day school experience. Some children will then be asked to take part in a focus group activity so that their thoughts/voices can be gathered in relation to their experience of the computer programming curriculum. Informed consent for this activity will be gained from parents/guardians at a later date.

Year 2 teachers will also be invited to complete a questionnaire regarding their perceptions of the computer programming curriculum. Data gathered from this questionnaire will be used for research purposes only and by filling in the questionnaire the researcher will assume that you are giving your consent for data to be used.

What are the possible disadvantages and risks of taking part?

The researcher sees no disadvantages or risks to taking part in this research that can't be managed appropriately. The computer based problem solving activity will be of a length of time that is appropriate for this age group therefore not putting any unnecessary stress or pressure on the children involved. Although the problem solving activity will be implemented by secondary teachers involved in the development of the computing pilot programme, the Year 2 teachers will remain in the classroom as the activity is completed by the children so that a familiar face is present at all times.

All participants will be reminded of their right to withdraw at any point during the research process. It is the responsibility of the researcher to ensure that no harm (either physical or emotional) will be intentionally caused. Should any child appear to become distressed during the computer based problem based activity then the activity will be stopped. As mentioned above, initial research activity will be embedded into the programming curriculum so no extra time commitment will be being asked of the children involved in the project.

Participation in the focus groups (children) and in the questionnaires (teachers) is entirely voluntary. Children will be able to withdraw from the focus groups at any time though it may not be possible to omit the data collected from the focus groups due to the nature of group discussion.

What are the possible benefits of taking part?

Whilst there are no immediate benefits for those people participating in the project, it is hoped that this work will inform the future development and implementation of the computer programming curriculum across primary schools within the Island.

What happens if the research study stops earlier than expected?

Should the research project should stop earlier than expected then all participants will be informed of this.

What if something goes wrong?

If you feel that something has not gone well and you need to report this then, in the first instance, please contact the researcher on:

Lynn Blakemore (Principal researcher)

Lynn.blakemore@highlands.ac.uk Tel: 01534 608535

Should you feel that your complaint has not been satisfied then please contact:

Dr Rachael Levy (Research supervisor)

r.levy@sheffield.ac.uk

Will my taking part in this project be kept confidential?

Any information that we collect about you during the course of the research will be kept strictly confidential. You will not be able to be identified in any reports or publications.

What will happen to the results of the research project?

Any data collected from the questionnaires will be used for analysis and for illustration in conference presentations and lectures. No other use will be made of them without your written permission.

A final report will be produced for the University of Sheffield and the States of Jersey Education Department. This will be made available on the States of Jersey website on completion. Data that has been collected during the course of the project might be used for additional or subsequent research.

Who has ethically reviewed the project?

This project has been ethically approved via The University of Sheffield, University Research Ethics Committee.

Contact for further information

Should you have any questions about this research project or wish to contact the researcher at any point during the research process please contact:

Lynn Blakemore (Principal researcher)

Lynn.blakemore@highlands.ac.uk

Tel: 01534 608535

Dr Rachael Levy (Research supervisor)

r.levy@sheffield.ac.uk

All participants will be given a copy of this information sheet and I thank you, in advance, for your participation in this research project.

Appendix 6: Information sheet for Parents of Year 2 children.



Information Sheet for Parents/Guardians of Year two children

Research Project Title:

Does teaching computer programming within Key Stage 1 of the primary curriculum enhance children's problem solving skills?

Invitation to take part in a research project -

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I am student on the EdD Early Childhood Education programme with the University of Sheffield and just about to embark upon research for my thesis. An area of particular interest is that of the initiative of teaching computing within the Primary Curriculum which is currently being piloted within two Island primary schools. Given that all primary schools in Jersey will employ this initiative from September 2014; this thesis provides an ideal opportunity to evaluate the benefits of this initiative by collecting and analysing data over a two year period (2014-2016).

Why have I been chosen?

You have been chosen to be part of this research project as a parent/guardian of a child in Year 2 who will be experiencing the new computer programming curriculum during this academic year.

Do I have to take part?

Taking part in the research is entirely voluntary and any refusals to agree to participate will involve no penalties to you. All those involved in the research project may discontinue participation at any time.

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and you can still withdraw at any time without it affecting you or your child in any way. You do not have to give a reason.

What will happen to me if I take part?

As parent/guardian you are giving permission for your child to take part in a focus group activity so that their thoughts/voices can be gathered in relation to their experience of the computer programming curriculum. This data will be collected for the purposes of this project and subsequent evaluation. If you are not happy for this data to be collected and evaluated then please contact your school to opt out of this activity.

What are the possible disadvantages and risks of taking part?

The researcher sees no disadvantages or risks to taking part in this research that can't be managed appropriately. The focus group activity will be conducted on the school premises, so familiar to the children. The activity will be held at a time that is agreed by the class teacher so as not to encroach on the curriculum or the children's free time.

It is the responsibility of the researcher to ensure that no harm (either physical or emotional) will be intentionally caused. Should any child appear to become distressed during the focus group then the activity will be stopped. Participation in the focus group activity is entirely voluntary. Children will be able to withdraw from the focus group at any time though it may not be possible to omit the data collected from the focus groups due to the nature of group discussion.

What are the possible benefits of taking part?

Whilst there are no immediate benefits for those people participating in the project, it is hoped that this work will inform the future development and implementation of the computer programming curriculum across primary schools within the Island.

What happens if the research study stops earlier than expected?

Should the research project should stop earlier than expected then all participants will be informed of this.

What if something goes wrong?

If you feel that something has not gone well and you need to report this then, in the first instance, please contact the researcher on:

Lynn Blakemore (Principal researcher)

Lynn.blakemore@highlands.ac.uk Tel: 01534 608535

Should you feel that your complaint has not been satisfied then please contact:

Dr Rachael Levy (Research supervisor)

r.levy@sheffield.ac.uk

Will my taking part in this project be kept confidential?

Any information that we collect about your child during the course of the research will be kept strictly confidential. Children will not be able to be identified in any reports or publications.

Will I be recorded, and how will the recorded media be used?

Any audio recordings of the focus group activities made during this research will be used for analysis and for illustration in conference presentations and lectures. No other use will be made of them without your written permission, and no one outside the project will be allowed access to the original recordings.

What will happen to the results of the research project?

A final report will be produced for the University of Sheffield and the States of Jersey Education Department. This will be made available on the States of Jersey website on completion. Data that has been collected during the course of the project might be used for additional or subsequent research.

Who has ethically reviewed the project?

This project has been ethically approved via The University of Sheffield, University Research Ethics Committee.

Contact for further information

Should you have any questions about this research project or wish to contact the researcher at any point during the research process please contact:

Lynn Blakemore (Principal researcher)

Lynn.blakemore@highlands.ac.uk

Tel: 01534 608535

Dr Rachael Levy (Research supervisor)

r.levy@sheffield.ac.uk

All participants will be given a copy of this information sheet and I thank you, in advance, for your participation in this research project

Appendix 7: Optimal move allocation for Problem Solving Activity.

Level	Optimal
1	2
2	4
3	5
4	5
5	8
6	8
7	6
8	5
9	6
10	2
11	3
12	4
13	5
14	4
15	4

Appendix 8: Re-coding of predictor variables.

Recoding of variables

	ENG	POR	POL	OTH
Old: FIRSTLANGUAGE	0	1	2	3
New: POR	Ref	1	0	0
New: POL	Ref	0	1	0
New: OTH	Ref	0	0	1

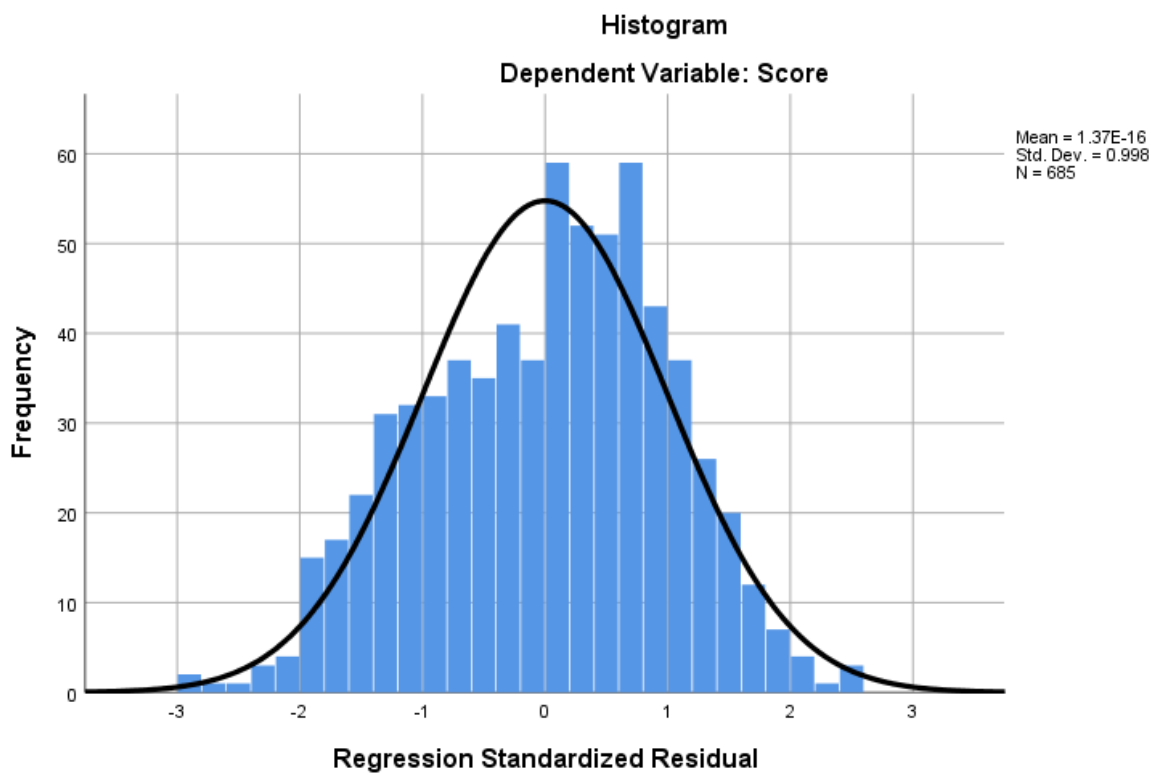
	NONE	SA	SAPLUS	STATEMENT
Old: SEN				
New: SA	Ref	1	0	0
New: SAPLUS	Ref	0	1	0
New: STATEMENT	Ref	0	0	1

	FIRSTTOWER	GROUVILLE	LAMOYE	MONTNICOLE	PLATDOUET	ROUGE	SPRINGFIELD	STLUKES	STPETERS
Old: SCHOOL	0	1	2	3	4	5	6	8	9
New: GROUVILLE	Ref	1	0	0	0	0	0	0	0
New: LAMOYE	Ref	0	1	0	0	0	0	0	0
New: MONTNICOLE	Ref	0	0	1	0	0	0	0	0
New: PLATDOUET	Ref	0	0	0	1	0	0	0	0
New: ROUGE	Ref	0	0	0	0	1	0	0	0
New: SPRINGFIELD	Ref	0	0	0	0	0	1	0	0
New: STLUKES	Ref	0	0	0	0	0	0	1	0
New: STPETERS	Ref	0	0	0	0	0	0	0	1

Appendix 9: Residuals statistics table^a and histogram of standardised residuals

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	-217.6201	1249.3468	658.9468	255.72561	685
Residual	-814.95276	853.55371	26.47352	248.06102	685
Std. Predicted Value	-3.856	2.431	-.099	1.096	685
Std. Residual	-3.757	3.935	.122	1.144	685

a. Dependent Variable: Score



Appendix 10: Pearson correlation co-efficient table

		Score	Y2Reading	Y2Writing	Y2English	Y2Maths	Y2Science	EnglishProgress	MathsProgress	ScienceProgress	AverageProgress
Score	Pearson Correlation	1	.430**	.434**	.445**	.531**	.448**	.110**	.258**	.057	.109*
	Sig. (2-tailed)		.000	.000	.000	.000	.000	.005	.000	.205	.015
	N	694	686	685	686	685	685	648	650	503	500
Y2Reading	Pearson Correlation	.430**	1	.886**	.975**	.808**	.791**	.349**	.289**	.226**	.286**
	Sig. (2-tailed)	.000		.000	.000	.000	.000	.000	.000	.000	.000
	N	686	686	685	686	685	685	648	650	503	500
Y2Writing	Pearson Correlation	.434**	.886**	1	.968**	.828**	.806**	.327**	.350**	.297**	.330**
	Sig. (2-tailed)	.000	.000		.000	.000	.000	.000	.000	.000	.000
	N	685	685	685	685	685	685	648	650	503	500
Y2English	Pearson Correlation	.445**	.975**	.968**	1	.842**	.822**	.349**	.328**	.268**	.316**
	Sig. (2-tailed)	.000	.000	.000		.000	.000	.000	.000	.000	.000
	N	686	686	685	686	685	685	648	650	503	500
Y2Maths	Pearson Correlation	.531**	.808**	.828**	.842**	1	.832**	.243**	.499**	.230**	.328**
	Sig. (2-tailed)	.000	.000	.000	.000		.000	.000	.000	.000	.000
	N	685	685	685	685	685	685	648	650	503	500
Y2Science	Pearson Correlation	.448**	.791**	.806**	.822**	.832**	1	.305**	.364**	.378**	.389**
	Sig. (2-tailed)	.000	.000	.000	.000	.000		.000	.000	.000	.000
	N	685	685	685	685	685	685	648	650	503	500
EnglishProgress	Pearson Correlation	.110**	.349**	.327**	.349**	.243**	.305**	1	.215**	.271**	.358**
	Sig. (2-tailed)	.005	.000	.000	.000	.000	.000		.000	.000	.000
	N	648	648	648	648	648	648	648	647	500	500
MathsProgress	Pearson Correlation	.258**	.289**	.350**	.328**	.499**	.364**	.215**	1	.326**	.597**
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.000	.000		.000	.000
	N	650	650	650	650	650	650	647	650	503	500
ScienceProgress	Pearson Correlation	.057	.226**	.297**	.268**	.230**	.378**	.271**	.326**	1	.662**
	Sig. (2-tailed)	.205	.000	.000	.000	.000	.000	.000	.000		.000
	N	503	503	503	503	503	503	500	503	503	500
AverageProgress	Pearson Correlation	.109*	.286**	.330**	.316**	.328**	.389**	.358**	.597**	.662**	1
	Sig. (2-tailed)	.015	.000	.000	.000	.000	.000	.000	.000	.000	
	N	500	500	500	500	500	500	500	500	500	500