AN EXAMINATION OF CHILDREN'S THINKING, LEARNING AND METACOGNITION WHEN MAKING COMPUTER GAMES

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Abstract

This thesis examines children's thinking, learning and metacognition when designing their own computer games. The study aims to understand more about what kind of learning takes place, and how it emerges whilst children are authoring their own computer games. The aim is to get an insight into the cognitive processes students exercise that activates the 'thinking for learning', in particular in relation to the role of the teacher and digital game making activities as a learning space.

Whereas mainly case studies and design-based research projects have been used as methodologies to study learning with digital game making, this study gives an ethnographic account by observing children's problem-solving activities from moment to moment. Field notes were collected by examining the language and the context children use for their 'self' explanations and group discussions, the gestures, the culture of their relationship with their teacher, peers and technology in their classroom settings. A metacognitive skills self-report instrument was created and used to investigate the metacognitive skills that children develop whilst working on their games. The data were collected for a period of eight months, through participant observations, in-depth interviews, informal conversations and video recordings of children's group discussions in a primary school in London. Learning logs and problem-solving sheets were introduced for the ten focus children to record their thinking when solving problems. During this research there were many opportunities to observe the changes in a child's reasoning over time, which provided an insight into children's mental activities.

The study found that game design activities have many learning benefits for children. The main themes that are emerged from the study include metacognitive awareness; CT; learning in curriculum subjects; and developing transferrable 21st century skills. Furthermore, the role of conversation in triggering thinking processes and self-regulated learning are discussed using data from the study.

Although the study provides insight into different aspects of learning during game design, it also highlights the difficulty in evaluating these different learning benefits. The results contribute to the growing body of knowledge about how to evaluate children's computational skills by providing a multiple evaluation model and a Metacognitive Skills Instrument (MSI) for measuring metacognitive skills that children develop whilst making their computer games. The challenges and limitations of these methods are discussed to form questions for the future studies.

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Glossary

21st Century skills refer set of skills and abilities that have been identified as being required for success in 21st century society and workplaces by educators, business leaders, academics, and governmental agencies. 21st-century skills can be organised into the following categories: literacies (literacy, numeracy, citizenship, digital, and media); competencies (critical thinking, creativity, collaboration); and character qualities (curiosity, initiative, persistence, resilience, adaptability, leadership).

Abstraction is the process of removing of all but the relevant data about an object or problem to facilitate focus on pertinent concepts

Alice, Alice 2.4 is a block-based programming environment for creating animations, building interactive narratives, or program simple games in three dimensions

AI artificial intelligence, is the ability of the computer systems to learn

Coding is the process of designing, writing, testing, debugging / troubleshooting, source code of computer programs

CSF Computational Sophistication Framework is an approach which is developed by Werner, Denner and Campe (2014) for evaluating students' games in an Alice programming environment

CAS Computing at School is a community of individuals who are passionate about giving our children a great education in computing

Computational Concepts refer to the programming constructs that are commonly used for completing tasks in programming environments such as sequences, loops, conditionals, and variables

Computational Thinking (CT) is a problem-solving process that includes characteristics such as logically ordering and analysing data and creating solutions using a series of ordered steps (or algorithms).

Conditional is an instruction in a program that is only executed when a specific condition is met

CFA is a statistical procedure that is used to verify the **factor** structure of a set of observed variables.

Conversational exchanges is a form of inquiry that engages learners in evaluating their thoughts, decisions and actions through conversations and dialogues with an 'invisible other' and other collaborators which are sometimes audible and / or sometimes visible through gestures

DES Descriptive experience sampling is a method developed by Russell Hurlburt, for the observation and description of inner experiences. The participants wear a an electronic 'beeper' in their natural environment and when the beep sounds at random times they report on their inner experiences.

Dr Scratch is a web-based application for assessing computational thinking concepts in games that are created in Scratch programming environment

Drag and Drop coding is a method of moving coding blocks from one place to another by clicking on them with the mouse and moving them across the screen

GCS Game Computational Sophistication is an approach for measuring children's learning of computational concepts in Alice programming environment

Game mechanics are the main elements of games which defines how players interact with the game

Gamestar Mechanic is an online game and community designed to teach the guiding principles of game design and systems thinking

Inner speech is the silent expression of conscious thought to oneself in a coherent linguistic form

Learning behaviours are the strategies, approaches and habits that have been exhibited by children whilst working on a task, which promotes learning

Likert Scale is usually a five (or seven) point scale which is used to allow the individual to express how much they agree or disagree with a particular statement

LOGO is an educational programming language, designed in 1967 by Wally Feurzeig, Seymour Papert and Cynthia Solomon

Loop is a sequence of instructions that are repeated until a specific task achieved

MAGICAL multilateral European project called Making Games in Collaboration for Learning, which was co-funded under the European Commission's Lifelong Learning Programme (KA3). The project set out to investigate the viability and added value of Collaborative Digital Game Making (CDGM) for learning, especially for supporting learners' transversal skills such as collaboration, creativity, problem solving and ICT literacy.

Metacognitive Activities Inventory (MCAI) is a questionnaire developed by Cooper and Urena (2009) for measuring awareness of chemistry problem-solving

Metacognition refers to a skill set which enables one to deploy and manage one's cognitive resources effectively to regulate one's thinking and learning

Metacognitive practices can be seen as the trigger and executive control for regulating cognitive activities, which includes planning, evaluation and monitoring

Missionmaker is a game-authoring software tool for making 3D videogames quickly with no specialist programming knowledge

MSI Metacognitive Skills Instrument is a Likert type self-report instrument designed to evaluate the metacognitive skills that children develop when creating their own games for this study

Neverwinter Nights is a third-person role-playing video game developed by BioWare

Object oriented programming (OOP) is a programming paradigm based on the concept of "objects", which may contain data, in the form of fields, often known as attributes; and code, in the form of procedures, often known as methods.

Operators are functions for both mathematical and logical expressions and it enables the use of both numeric and string operations

Parallelism is making events take place at the same time for different characters or for the same character

PISA the Program for International Student Assessment is an international assessment that measures 15-year-old students' performance in reading, Mathematics, and Science literacy every three years.

Private speech is speech spoken to oneself for communication, self-guidance, and self-regulation of behaviour

Pseudocode is a detailed description of what a computer program or algorithm must do, expressed in a formally-styled natural language rather than in a programming language

Scratch is a free programming language and online community where you can create your own interactive stories, games, and animations

Sequences are the series of steps for completing a task that can be executed by the computer

Syntax error is an error in the source code of a program. It can be seen as the small grammatical errors such as missing a semi colon or using an extra bracket at the end of a line.

Squeak Etoys is a child-friendly computer environment and object-oriented prototype-based programming language for use in education

Standard Deviation (SD) is a statistical term that measures the amount of dispersion around an average.

STEM stands for Science, Technology, Engineering and Mathematics.

Variables are a value, which can change depending on conditions. Variables used for holding on to a value to use it later.

Chapter 1: Introduction

1.1 Background

Since computer games have become an integral part of the daily lives of children (Gee, 2003; Granic, Lobel and Engels, 2014; Olson, 2010; Prensky, 2001), there has been interest in digital games for educational purposes (Denner, Campe and Werner, 2019; Ke and Abras, 2013). The review of the literature has shown that games can facilitate learning through increased motivation (Boyle et al., 2016; Connolly et al., 2012; Vos, Meijden, and Denessen , 2011; Wrzesien and Alcaniz Raya, 2010) and provide “immersive and compelling social, cognitive, and emotional experiences” (Granic, Lobel and Engels, 2014, p.1). A number of studies also highlighted the impact of game playing on children’s learning, suggesting that games can offer play opportunities that are very important for promoting children’s development in numerous areas including, Mathematics, literacy and critical thinking (Boyle et al., 2016; Evans et al., 2013; Habgood, Ainsworth and Benford, 2005; Shin et al., 2012).

Traditionally, many studies around games and learning have focused on game playing. However, recent influences of constructivist theories on technology-supported learning, where learners actively build knowledge through experiment and discovery, have led to an increasing interest in the potential learning benefits of children creating their own games (Denner, Campe and Werner, 2019; Kafai, 2012; Kafai and Burke, 2015). The ease of having access to a vast range of game design programs online and the ability to create digital games without any knowledge or technical skills also motivated this interest (Denner, Campe and Werner, 2019). Kafai and Burke (2015) argue that regardless of either the programming software that was used or the age of the learners, “making games proved to be a compelling context for learning computational concepts and practices and broadening participants' perspectives on computing and STEM overall” (p.13). They concluded that some studies in game making and learning mainly addressed the outcomes on children's learning in specific curriculum subjects and problem-solving skills, rather than investigating the relation between game making and development of metacognitive skills.

A few studies indicated that there are opportunities to teach 21st century skills through computer game design (Bermingham et al., 2013; Carbonaro et al. 2008; Jenson and Droumeva, 2016). According to the Organization for Economic Co-operation and Development (OECD) 21st century skills are "those skills and competencies young people will be required to have in order to be effective workers and citizens in the knowledge society of the 21st century" (Ananiadou and Claro, 2009, p. 8). Binkley et al. (2014) refer to 21st century skills as the learning and innovation skills which include critical thinking, creativity, collaboration and communication. Jenson et al. (2016) argue that designing and making digital games, "can provide an ideal framework for operationalizing 21st century learning" (p.111). Furthermore, Pinto and Escudeiro (2014), suggest that creating games using Scratch application can help children develop 21st Century skills such as creativity, problem solving, and augmented media literacy and critical thinking.

The literature also provides us with a few studies focusing on children developing their thinking skills through programming and game design activities. For example, Papert (1980) used programming as a way to promote learning general thinking skills. He described programming as a construction tool for personal expression and knowledge construction. Jonassen (1994) defined computers as cognitive tools and noted that when used with constructivist learning environments, computers can activate critical thinking and learning. Jonassen, Peck and Wilson (1999) described technology as "the designs and environments that engage learners" (p.12). They also talk about how learners learn the most when they become the designer of the learning materials, rather than just learn from them. Dyer (2008) focused on a number of games-making projects for primary school children explaining that creating digital games motivates learners to achieve; increases self-esteem; provides opportunities for collaborative learning; develops problem solving; develops students' ability to observe, question, hypothesize and test; and facilitates metacognitive reflection.

Whereas much has been written about the potential of game design as a learning tool, the empirical evidence is still limited. There is also a lack of focus upon developing an understanding of the cognitive process in students' minds that activates the thinking process in relation to the roles of teacher and technology. The question is not whether game design enhances learning; it is more about what kind of learning is supported, how it emerges and how it can be evaluated in a classroom setting. Kafai and Burke (2015) noted that in 55 studies they reviewed on making games, half of the learning took place out of schools and half in the classroom. This means game making is frequently integrated into classroom curricula and there is a need to develop methods to evaluate the learning outcomes. This will, therefore, be in the focus of this study.

1.2 Aims of the research

There are two main aims of this thesis:

- To examine children's thinking, learning and metacognition when designing their own computer games.
- To unfold the thinking and learning process in order to define the elements of learning in a game-design context.

In exploring these two main aims, the thesis will consider four research questions:

Q1. What is the educational value of children's game making activities in relation to thinking, learning and metacognition?

Q2. How can children develop computational thinking skills whilst making their computer games?

Q3. What is the role of conversational exchanges in metacognitive process and children's learning?

Q4. How can metacognition be measured in computer game design context?

1.3 Design of the study

A mixed method approach was adopted, where ethnography is used as a qualitative method alongside a self-report metacognitive skills instrument as a quantitative method to closely examine children's thinking and learning when making games in a classroom setting. Using a mixed method approach for the evaluation of children's game-authoring activities enhanced the contribution of both methods and provided richer data than that which would have been gained through using one method alone.

Data from participant observations, semi-structured interviews, field conversations, problem solving sheets, diary logs, game planning sheets, video recording of group discussions, interviews, children's completed games and metacognitive self-report instrument were used to investigate the children's learning, thinking and metacognition when authoring computer games.

1.4 Key issues that this thesis will address

It is very difficult to describe what exactly children learn by making digital games, as this will depend on the way digital game design is integrated into a learning environment, the teacher's approach and learners' resources. Furthermore, it is valuable to mention that most of the games-making activities that are mentioned in the literature are taking place in a controlled environment, mainly in after school clubs for a short period, where learners are willing to participate in the activity. Therefore, they are motivated from the beginning. How this would manifest in an ordinary classroom setting, where students have diverse skills, interests and needs, is another question. This will be investigated in this study in depth.

Another issue explored through this study is the question of children's learning in game design context. What can be defined as learning and what are the characteristics of these learning points and additionally how these learning aspects can be evaluated in a classroom environment will be investigated. The third issue explored is the role of metacognition in the learning process of children and how language plays a part in triggering and regulating these learning activities.

1.5 Personal interest

Since I became a primary school teacher in 2003, I have been curious about how children learn. What I mean by this is beyond achieving learning objectives that have been set for them, what actually happens in their minds. I have shown particular interest in finding answers to questions such as; 'how do children think?', 'what questions do they ask?', 'how do they trigger this thinking process?', and 'how do they come to know and /or understand something?'.

This interest became more defined during my MA studies where I looked at children's learning whilst creating games using Missionmaker software, which was created by Prof. Andrew Burn from UCL London Knowledge Lab. I observed children not only talking aloud with their peers, but also to themselves which is something was not visible during other lessons that I taught such as history or literacy. This led me to complete a pilot study prior to this research to investigate whether the process of children's thinking whilst making computer games was altered or not. The outcome was fascinating as it showed that children followed a different way of thinking when making computer games and, more interestingly, they were aware of it (Allsop, 2016).

I wanted to focus more on the metacognitive process that children go through when working on designing their games, especially the role of language in helping them self-regulate their learning. This includes talk with partners but also talk with self. I also wanted to highlight whether these metacognitive activities have any links to CT, as my experience of teaching programming to children has shown that programming is more than knowing and using programming constructs. In order to select and apply the correct coding scripts, students surely need to use other skills such as decision-making and evaluation. Therefore, I wanted to find out more about what other skills they use whilst creating their games and whether this can be transferred when learning in different contexts.

1.6 Overview of the thesis

Having introduced the research, I will give a brief overview of the remaining chapters of the thesis.

Chapter 2 looks at the overview of the studies relevant to the focus of this thesis. I start the chapter with discussing what learning is and how it relates to thinking processes. I look at studies about metacognition and its role in children's learning alongside conversational exchanges in educational contexts in detail as the main themes of this study. This is crucial for data collection and analysis because it is not possible to recognize characteristics of metacognitive skills without knowing what these are. The methods for measuring metacognition are also explored using recent studies which enabled me to create a framework and design a tool to measure metacognitive awareness in game design context. The second part of the literature review focuses specifically on learning that occurs whilst children work on their computer games. Themes included in this section are learning in curriculum subjects; developing 21st century skills; computational thinking; promoting metacognition. Furthermore, studies about measuring CT in game design context are examined in depth to develop an approach for evaluating children's learning of CT skills during this research.

Chapter 3 provides details of the research design and methodology, commencing with a rationale for adopting a mixed method approach, followed by an exploration of data collection and analysis techniques. I discuss the paradigm that encapsulates my personal approach to research, namely pragmatism. I explain why a mixed method approach was adopted, using ethnography as a qualitative method alongside a metacognitive skills instrument as a quantitative method to examine children's thinking and learning when making games in a classroom setting. The data collection methods were: participant observations, semi-structured interviews, field conversations, problem solving sheets, diary logs, game planning sheets, video recording of group discussions, children's completed games and a metacognitive skills instrument.

Chapter 4 is the first of four data analysis chapters. In this chapter empirical data are used to represent the skills and approaches that were visible whilst children were creating their computer games. Themes and categories that emerged from systematic data analysis process are discussed using data voiced by participants to give an insight into children's experiences. Curriculum subjects, collaboration, problem solving, computational concepts, communication, creativity and critical thinking themes are discussed in detail to illustrate the analysis of the learning process in game design context.

Chapter 5 presents the analysis process for investigating what CT constitutes and the ways to best evaluate it using both the support of literature and the data collected from this study. I use qualitative directed content analysis (Hsieh and Shannon, 2005) to examine the relevant studies for defining what CT is and what approach is best suited to its evaluation. I proposed a multiple evaluation approach for assessing CT process to demonstrate the full scope of learning through CT process which included four aspects: computational concepts, metacognitive practices, learning behaviours and context (game design). A guide for evaluating computational concepts in games that were created using the Alice and Scratch programming environments is shared. This guide is then used to assess computational concepts in two games that were created by participants using Scratch and Alice programs. I use detailed extracts from data to illustrate three other themes: metacognitive practices, learning behaviours and game mechanics (context).

Chapter 6 draws some conclusions about how children used different modes of conversation (conversational exchanges) to evaluate their thoughts and regulate their learning process. Using the data from semi-structured interviews, children's problem-solving sheets, participant observations and video recordings of group discussions, I was able to investigate the types of conversation that took place whilst children were creating their games. I use children's quotes to demonstrate their own experiences of using language for self-regulating their activities. I investigated the interaction between the different modes of conversation using both data from this study and relevant literature.

Chapter 7 is the last data analysis chapter. In this chapter I explore the issues around metacognition in a classroom context. In this study, in order to evaluate the metacognitive skills that children used when making games, I used participant observations, interviews, journal logs, problem solving sheets and a self-report instrument. The steps for designing a framework for metacognitive skills and an instrument for measuring these skills in a game design context are discussed in detail. The validity of the Metacognitive Skills Instrument (MSI) for Game Making is examined and suggestions to develop it shared.

In Chapter 8, I draw out some conclusions, issues and concerns raised about defining and evaluating children's learning in a game design context. I discuss the challenges around measuring metacognition and the role of the teacher in modelling metacognitive skills. Limitations of the research and suggestions for further investigation are offered. The contributions of this study to knowledge were also discussed. The thesis provides a platform for sharing the voices of students, which are evident in the data extracts that have been shared throughout the data analysis chapters.

Chapter 2: Review of the literature

This study investigates the link between learning, thinking and metacognition in a game design context. In order to provide an overview of the key literature, I begin with an introduction to children's learning and thinking processes in the context of school education. I then present an overview of the concept of metacognition and investigate the role of conversation in metacognitive processes. Finally, I discuss the educational benefits of children's game authoring activities under four headings: learning in curriculum subjects, developing 21st century skills, CT and promoting metacognitive awareness.

2.1 Thinking and Learning

Although there appears to be a general understanding of what the term learning means in education, there is no agreed definition of learning (Qvortrup et al., 2016). MacBlain (2014) noted that it is difficult to define learning as most of the studies in this topic were undertaken in the field of psychology. There seems to be lack of interaction between different fields such as psychology and education (Qvortrup et al., 2016) which makes it a challenging task for teachers to connect studies in the area of psychology to education practice. Thus, learning might be defined from different aspects depending on the researcher's field. The Oxford English Dictionary (2017) defines the term 'learn' as "The acquisition of knowledge or skills through study, experience, or being taught". It is not clear what this definition means by as 'the acquisition of knowledge or skills', as acquisition in different contexts can be at different levels and forms. For example, if a student is learning to play a musical instrument, how do we decide at which grade they acquired the necessary knowledge and skills to play an instrument? Atkinson et al. (1993) define learning as "a relatively permanent change in behaviour that results from practice" (p.227). Smith, Cowie and Blades (2003) emphasize the importance of the environment on changes in behaviour and suggest that, "the way an animal behaves depends on what it learns from the environment" (p.34). This might be useful for explaining the influence of an environment on observable behaviour, similar to the behaviourist tradition (Skinner, 1971); however, it provides no information about the process, in other words, the cognitive domain. Fontana's (1995) explanation based on Bruner's (1966) work about instrumental conceptualism provides the necessary clarification as he sees learning as something that people make happen "by the manner in which they handle incoming information and put it to use" (p.45). Ambrose et al. (2010) define learning as "a process that leads to change, which occurs as a result of experience and increases the potential for improved performance and future learning" (p.3). This idea of learning being a dynamic process is also supported by Piaget (1959) and Vygotsky (1978) who suggest that learning occurs when children are actively involved in constructing meaning by using their existing knowledge to make sense of new knowledge through social interactions.

The definitions of learning discussed above highlight that learning is not something we do to learners but is the outcome of how learners respond and interpret their experiences, in other words, how they make sense of their experiences through thinking. This is also supported by Perkins (1992, 2003), who notes that learning is a consequence of thinking and successful learning depends on making thinking visible to self and others. This shows that there is a strong relation between thinking and learning, overlapping at times. Thinking is a mental process to learn which happens through the inward and outward effects of one's actions in the physical world that constitutes the skills of enquiry, creative thinking, reasoning, information processing and evaluation (DfES, 2004). Similarly, learning also includes developing the ability to think critically and to be analytical; to use information effectively; to make decisions; and to think imaginatively, creatively and critically (Jessel, 2012). Piaget (1977) notes that thinking is an active process and it occurs as a result of learners' interaction with the world around them. Vygotsky (1986) discusses thinking from a social perspective and emphasises the importance of language for articulating thoughts and that enabling the organisation of these thoughts in a conscious way. This is supported by Bruner (1986) who argues that "language is a way of sorting one's thoughts about things. Thought is a mode of organising perception and action" (p.72). This suggests that thinking is used by learners for self-regulating their activities and is triggered by language (conversation).

As mentioned before, although learning and thinking can be argued to constitute similar skills, learning is extensively dependent on how well students can transfer and apply these skills to different learning contexts (Fink 2003; Perry, 1970). Bransford, Brown and Cocking . (2000) argue that the transfer of skills and knowledge is possible when learning involves more than simple memorisation or applying a fixed set of procedures. Foremost, students need to understand the concepts and become expert in the skills, then know how, and when, to apply the skills to new situations. Although these steps look very straightforward, they are only viable when one develops the ability to understand and reflect on one's own thoughts, in other words, develop metacognitive skills (Fisher, 1998; Flavell, 1979). Students can improve their learning by being aware of their own thinking and regulating their learning activities. This link between thinking and metacognition will be investigated further in the following section.

2.2 Metacognition and learning

In this section, I will provide an overview of metacognition and learning, focusing on methods for measuring metacognitive skills and the role of conversation in metacognitive process.

As a cognitive process, metacognition became a popular research field for many educators and psychologists in the mid1970s (Brown, 1987). Originally, Flavell (1979) described metacognition simply as 'thinking-about-thinking' and emphasized the role of metacognition in managing cognitive activities. Other studies explained metacognition as the process of monitoring or regulating first-order cognition (Kuhn, 2000) and some claimed that it refers to an individual's awareness and knowledge about their own cognition (Pintrich, 2002). First order cognition can be described as the "operations on single cognitive elements such as single sets or functions.

Second order cognitions are operators which hierarchically integrate two first order cognitive elements such as two sets or two functions” (Langer, 1993, p. 302). Over the years, many terms have been associated with metacognition, such as meta-knowing, metacognitive skills, metacognitive strategies, metacognitive awareness, higher order skills and self-regulation. Although there is no unified definition of metacognition, it is widely accepted that metacognition is important for learning (Kuhn, 2000; Pintrich, 2002; Krathwohl, 2002).

A majority of the studies into metacognition distinguished metacognitive knowledge (knowledge of cognition), from metacognitive control (regulation of cognition) (Baker, 1991; Brown, 1987; Jacobs and Paris, 1987; Schraw and Moshman, 1995). Metacognitive knowledge refers to what a person knows about his or her own cognition and it usually includes declarative, procedural, and conditional knowledge (Brown, 1987; Jacobs and Paris, 1987). Declarative knowledge refers to knowing ‘about’ things and it includes knowledge about oneself as a learner (Flavell, 1979; Schraw and Moshman 1995). It involves skills and strategies that are required to achieve a goal. Procedural knowledge is all about knowing “how” to do things and it refers to the execution of skills and the use of strategies for accomplishing tasks successfully in different contexts (Brown and DeLoache, 1978; Zimmerman and Risemberg, 1997). Conditional knowledge refers to knowing “why” and “when” to use cognitive strategies, procedures and skills (McCormick, 2003; Schraw and Moshman, 1995). Although Baker (1989) suggests that adults have more knowledge about their own cognition in comparison to children, Schneider (1985) notes that children aged 10-12 develop the ability to use cognitive strategies and regulate their learning by spending more time working on complex situations.

Metacognitive control refers to metacognitive functions and activities that help regulate and control one’s mental activities and learning. Planning, monitoring and evaluation are seen as the main regulatory skills (Baker, 1989; Jacobs and Paris, 1987). Planning includes the allocation of cognitive resources effectively and the selection of appropriate strategies for specific tasks. Being able to come up with a sequence of strategies to achieve a specific task is the core of the planning process, which can be seen as creating an algorithm in the context of Computer Science. Monitoring refers to being aware of how well one accomplishes the task. It may involve constant testing and checking for errors similar to debugging when programming. Evaluation involves assessing the learning process against the set goals and criteria from the planning process, followed by further planning if necessary.

Metacognitive practices allow learners to take control of their learning when completing a task or solving a problem. Flavell (1979) argues that metacognition is fundamental for learning in many areas such as oral communication, oral comprehension, reading comprehension, writing, memory, and problem solving; however, these claims are lacking empirical evidence. A number of studies also claimed that these metacognitive experiences also have an impact on students' academic achievements including reading, writing and Mathematics (Caretti et al., 2014; Dignath, Buettner and Langfeldt, 2008; Vula et al., 2017) and other researcher teams have suggested that students who are able to monitor and regulate their own learning are more independent and successful learners (Annevirta and Vauras, 2006). The heart of metacognition is the ability to think inwards and organize mental activities in the mind, by visualizing the steps through conversations with 'self'. For example, when a child is asked to come up with a narrative for their game design, they use their internal voices to talk with themselves about their ideas before sharing their choice with others.

Sternberg (1998) argues that metacognitive skills are driven by motivation, which activates learning and thinking skills; these then feed back into metacognitive skills, enabling one's level of expertise to increase. The crucial question is: 'can metacognitive skills be taught?' Although many studies in this area agree that metacognitive strategies can be taught (Garner, 1990; Sperling et al., 2004), they also highlight that it is a very challenging process to teach metacognitive skills. Flavell (1979) argues that "increasing the quantity and quality of children's metacognitive knowledge and monitoring skills through systematic training may be feasible as well as desirable" (p. 910). It is, however, critical to remember that facilitating metacognitive development requires more than just teaching students about metacognitive knowledge. It is essential to adopt an approach whereby students are exposed to metacognitive practices that incorporate both metacognitive knowledge and metacognitive regulation. This provides students with the knowledge of cognitive and metacognitive strategies and how to allocate them to monitor and evaluate their learning outcomes. Lester and Garofalo (1986) argue that teachers can facilitate the development of metacognitive knowledge through asking questions that encourage students to reflect on their own thinking processes.

One of the most important aspects of metacognition, as mentioned before, is that it enables students to self-regulate their mental processes which enables them to manage their own learning. This is important as a number of researchers suggest that there is a strong relationship between the level of self-regulative skills and academic success (Bouffard et al., 1995; Zimmerman, 1994). One of the reasons for this result might be that students who regulate their own learning have developed awareness that their learning is an outcome of their own attitudes and hard work. Knowing this also impacts on a student's motivation to achieve their goals. Still, in order to develop self-regulative skills, students need to be exposed to a learning context that would enable them to be actively involved in constructing their own understanding of concepts and gain experience of managing their own learning process.

2.2.1 Measuring Metacognition

The measurement of metacognition is extremely challenging, as individuals, especially young people, are not always aware of the metacognitive process. There are two different approaches to the measurement of metacognition. First, qualitative methods such as observations, learning journals, diaries and strategies such as think aloud can be used to capture the metacognition process (Rickey and Stacy, 2000). Whitebread et al. (2009) suggest that using observational methods, learners' behaviours can be recorded, which makes it possible to capture non-verbal behaviours. However, the metacognition process is a complex construct that is individual to each learner and not always directly observable (Sperling et al., 2002). Although these methods can provide in-depth information about children's metacognitive awareness, it might not be appropriate with very young children "whose verbal ability and working memory capacities are incompletely developed" (Lai, 2011).

The second approach to the measurement of metacognition is self-report questionnaires or rating scales that enable learners to describe or rate their use of specific strategies. Questionnaires can be used with a large group of learners and evaluated more quickly. However, it is not always clear if the students fully understand the questions. Another issue with questionnaires is that they do not provide the opportunities for in-depth investigations that interviews offer. On other hand, teachers have to set time aside to undertake interviews as it is not usually possible to integrate these into the daily routine of a classroom environment. As there is no single method available for measuring metacognition (Schraw, 2009; Tobias and Everson, 2002), any tool should be designed around the purpose required and involve a blend of appropriate mediums appropriate for the age of the learners.

A few studies have investigated the instruments that can be used for measuring a learner's metacognitive awareness, mainly focusing on domain-specific metacognition. Cross and Paris (1988) investigated children's metacognitive reading skills using The Reading Awareness Interview. This instrument included 33 Likert Scale items and 19 open ended questions. Sperling et al. (2002) used the Junior Metacognitive Awareness Inventory with students in grades 3-9 (8-15 years old). Version A was aimed at younger children and had 12 items with a 3-point scale. Version B was designed for students in grades 6-9 (11-15 years old) and contained 18 items with a 5-point Likert scale. The items asked about the metacognitive strategies that each student had used. Kramarski and Mevarech (2003) developed a metacognitive questionnaire to measure general metacognition and domain-specific metacognition, in their case

Mathematics strategies. Students were asked to rate strategies that they used from a given strategy inventory using a 5-point Likert scale that ranged from ‘never’ to ‘always’. Karamarski and Mevarech (2003) found that students who received metacognitive instructions were able to use metacognitive strategies that are specific to Mathematics such as mathematical reasoning, representing concepts in many different ways, and transferring skills to different tasks. This also shows that they were successful at using a Likert scale to measure metacognitive knowledge. Cooper and Sandi-Urena (2009) developed the Metacognitive Activities Inventory (MCAI) to assess students’ metacognitive awareness during chemistry problem solving, although the items included are relevant to many problem-solving situations. Schraw and Dennison (1994) developed the Metacognitive Awareness Inventory, which included 52 items such as “I am good at organizing information,” “I summarize what I’ve learned after I’ve finished”. One of the main concerns with using these self-report instruments is that it is not clear whether they measure metacognitive knowledge in a specific domain, rather than the quality and suitability of strategies that have been selected and applied by learners. Another issue is that metacognition includes different components such as planning, monitoring and evaluation. Therefore, it may require different procedures for measuring these different aspects of metacognitive skills.

2.2.2 Conversational Exchanges

Before proceeding to explore the role of language in the metacognitive process, it is important to discuss how conversation differs from dialogue. Conversation takes place between two or more participants and is a communication process where an understanding of someone’s perception is developed. It can be seen as a spontaneous debate to explore ideas and share viewpoints without a pre-set intention. Dialogue, on the other hand can be simply defined as a focused conversation with the purpose of negotiating meaning. Bakhtin explains dialogue as ‘conversation and inquiry’ (Bakhtin 1986, quoted in Alexander, 2000, p.520). This suggests that dialogue is more structured and includes elements of questioning.

Bruner (1986) describes language as 'a way of sorting one's thoughts about things.' (p.72). This is relevant to metacognition because, as previously described, the heart of metacognition is to be able to think inwards and organize mental activities in the mind. This is a very important point as, when we ask a child to 'think', it basically directs them to use their internal voice to talk with their 'self'. Asking questions to either 'self' or 'others' does not aim to evaluate what a child already knows, rather, it enables them to analyse, reflect, share and extend their understanding and thinking when performing a task. Articulating their thoughts through language, learners regulate their mental activities when designing solutions, making decision and classifying-selecting appropriate strategies to accomplish a task. This conversation element makes 'thought' more visible and manageable. In this domain conversation becomes a function to negotiate meaning, rather than a tool to communicate.

A number of theorists have explored the function of children's self-talk, namely private speech, egocentric talk and self-directed speech (Flavell, 1979; Mead, 1934; Piaget, 1959; Vygotsky, 1978). Piaget (1959) uses the term 'egocentric' to describe speech that is not directed to a listener other than the child and argues that it appears in the spontaneous conversations of children aged five to six and disappears with age. He claims that private speech is the sign of a child's inability to distinguish their own perspective of events from those of others and would be replaced by social communication from the ages of eight to nine years. According to Piaget, the reason young children use private speech is their unwillingness to socially interact and share information with others. He posited that, although the child might talk next to another person, they are not interested in whether this person either hears them or understands their perspective. Flavell, Beach, and Chinsky (1966) argue that 'private speech' occurs when a child is alone or in a social setting in a form of non-communicative speech. Piaget (1959) uses the term 'collective monologue' to describe this as a category of private speech and suggests that the child may not expect to be acknowledged by others and continues to talk to self without collaborating with their audience. I agree that during private speech, a child may not direct their conversation to other collaborators, but this does not mean that private speech will not lead a social interaction. It is possible that the child might receive some reaction or response from other children and adults around even though this was not intentional. This changes the form of conversation from lone to unintentional social communication.

The use of language for regulating mental activities is also supported by Vygotsky (1978), who sees the interaction between thought and language, that is, private speech, as the main link between social and cognitive experience. He suggests that young children use language not only as a tool for communication with others, but at the same time to self-regulate their own activities through planning and monitoring. He agrees with Piaget's view that private speech is visible among children aged five to six years old and declines with age. However, he was opposed to the idea that it is replaced by social communication. According to Vygotsky, private speech goes underground, transforming into a cognitive function (self-regulating) and becoming a verbal thought called 'inner speech', generally from the age of seven.

Vygotsky (1978) claims that the regulation of this cognitive process depends on a person's ability to reflect on their activities through internal and external verbalisation of their thinking. He states that language and thought dwell together and, in order to raise awareness of mental activities, one needs to know how to articulate one's thoughts. He saw dialogic exchange as an essential skill, which can transform the way in which children think and learn. For metacognition to occur, one should have the ability to transfer and apply metacognitive knowledge and skills to a specific problem-solving context. Vygotsky (1978) argues that inner speech or private speech can support the transfer and the application of these strategies as 'it promotes higher order reasoning about the relationship between the problem, the problem-solving process, and the solution' (Tarricone, 2011, p.23). Inner speech, referred as inner dialogue or verbal thinking, is also said to have an impact on self-regulative learning (Diaz and Berk, 1992; Vygotsky, 1986), and metacognition and self-awareness (Morin, 2005).

According to Diaz (1992), there is a correlation between the use of private speech and children's task performance. She suggests that if a child has the level of competence that is necessary for completing a task, the child would be able to accomplish the task without the need for private speech. While this might be a valid point for some situations, other aspects that would impact on the task performance should also be considered. For example, a close-ended task that requires selecting an option from presented solutions may not motivate a child to use private speech as much as an open-ended task that requires exploring ideas, creativity and making decisions. If a task is too challenging or easy, the child would be disengaged which would diminish the need for private speech. The challenge level of the task would, therefore, have an impact on the usage of private speech (Behrend, Rosengren and Perlmutter, 1989; Kohlberg, Yaeger and Hjertholm, 1968). The context and the purpose of the task can be designed to maximize or minimize the use of self-talk for self-regulating. This is supported by Vygotsky (1978) who suggests that the use of private speech by children will vary by the activity type and social context. Likewise, Berk and Garvin (1984) claim that children use private speech when they are engaged in problem solving or a goal-directed task as these situations places high levels of self-regulatory demands on them. Other studies also found that working alone (Martlew, Connolly, and McCleod, 1978) or having the support of an adult as a facilitator (Goudena, 1987; Diaz et. al., 1992) encourages the use of private speech.

The review of the literature, focusing on young children and private speech utterances, presents different approaches for identifying the type of speech that is being used. Copeland (1979) analysed children's private speech data using nine categories: exclamations, nonwords (e.g. erm), description of self, description of the environment, self-reinforcement, planning, commands, questions and inaudible vocal sounds. Rubin and Dyck (1980) used seven categories for coding private speech discourse: analytic statements (involves reasoning), comments about the objects, comments about the activity, directions to self, feedback, questions and other for any private speech characteristic that does not fit into previous six categories.

Kraft and Berk (1998) used six categories for analysing private speech data: affect expression (e.g. wow!), word play and repetition, fantasy play speech such as role play, describing one's own activity (planning, thinking aloud), and inaudible mutterings (lip movements, silence). This scheme seems to be more appropriate for younger children and for isolated activities rather than game making which facilitates collaborative work.

Girbau (2002) analysed subcategories of private and social speech of eight to nine years old children's dyadic communication while playing with Lego sets. For coding private speech utterances, she used three categorisation units: audible words and sounds (external verbal production), communicative gestures that represents verbalisation, and silence (a pause of 2 or more seconds). For social speech, she listed ten conditions and suggested that at least one of them should be met. These were: eye contact with a partner; expecting action or response from a partner; giving information to a partner; repeating or reformulating a previous message to a partner; requesting a partner's attention using words or physical contact; replying to a partner's request; completing a partner's sentence; and contributing to a conversation using short answers, e.g. yes, no or laughing. She also adopted a categorization unit related to the information shared by the partner before or after that categorization unit, and further categorized both private and social speech according to whether they were audible and task relevant. She also coded change of turn and category change (private, inner, untraceable), which is useful for describing the relation and progression between different forms of speech.

With the exception of Girbau's (2002) study, the coding schemes discussed above were specifically designed for analysing children's private speech utterances. The studies about inner speech are limited, especially in comparison to studies about private and social speech. I think the main reason for this is the difficulty of observing inner speech, which is necessary for empirical studies. According to Alderson-Day and Fernyhough (2015), asking people to report whether they experienced inner speech using questionnaires is simplest way of evaluating inner speech utterances. They added that this is also useful “for investigating inner speech frequency, context dependence, and phenomenological properties, although their veridicality has often been questioned” (p.4). I agree that asking people to describe their inner speech experiences is a valuable method. However, I am not sure from what ages this would be able to provide valid data, as children may not always be able to identify their experiences, especially if they are unsure about the characteristics of speech utterances. Another method mentioned by Alderson-Day and Fernyhough (2015) was experience sampling, which investigates the occurrence of inner speech randomly using a diary or other recording methods. As part of sampling process, they discussed descriptive experience sampling (DES) that involves participants first taking brief notes of their inner speech utterances and then being interviewed to share the accounts of their experiences. Although I like the idea of providing young people with a diary for them to keep a record of their experiences, this might be challenging for those who are not very confident in writing. Furthermore, they might have limited ability to understand their own inner experience (Flavell, Flavell and Green, 2001) and trying to record everything that happens might be very difficult while they are also trying to complete their task. Providing participants with a template to record specific speech utterances during a set short task or a problem might be a more valuable practice.

My study aims to investigate different modes of conversations that take place while children are working on their games including social, inner, and other uncategorised speech types, as well as private speech utterances. Furthermore, as discussed above, the majority of existing studies focus on private, social or inner speech separately. This makes it difficult for researchers to study the interaction between different modes of speech and how these impact on the task performance. Nonetheless, this is important because it is likely that in some situations several types of speech were taking place during the same interaction, overlapping at times. Therefore, it is very difficult to use one coding scheme to measure each speech utterance that occurs in interaction while children are working on their games. In the following section, I will discuss learning in the context of game making.

2.3 Computer Game Design and Learning

In this section, I will discuss the learning benefits of computer game design activities for children from different aspects. In this thesis the term 'computer game design' is used to describe children's game making activities which offers "opportunities for children exercise a wide spectrum of skills (such as devising game rules, creating characters and dialogue, visual design, and computer program- ming) to create a complex artefact" (Robertson and Howells, 2008, p.562). The artefact they create may not always include a narrative, but it will have the playability element embedded into the design using a software tool.

Recent years have seen many game-making applications and programs that are designed specifically for educational purposes. Additionally, in parallel to the popularity of tablet devices in education, the focus on developing apps to teach children how to program and make their own games is also on the rise. As schools use these programs and apps more than ever, further studies have focused on how programming and game-making activities can impact on children's learning (Denner, Campe and Werner, 2019; Hainey, Baxter and Ford, 2019; Kafai and Burke, 2017; Ruggiero and Green, 2017). A worldwide interest in encouraging young people to learn how to code, supported by both the education and technology community and industry, has also had an impact on this level of interest (Sterling, 2016).

It is extremely difficult to draw all the studies about learning through game making under one category as they explore very different aspects of learning. This was also the experience of Kafai and Burke (2017) who reviewed 55 studies about children's game making activities and found that the focus of these studies was very diverse. They reported that out of these 55 studies, 44% focused on developing computational strategies for problem solving; 34% looked at children's learning of computational concepts; 27% focused on programming skills; 34% examined metacognitive skills (children's own sense of learning); and 16% investigated children's learning in a specific curriculum subject e.g. Mathematics, Literacy.

There have been numerous studies into children's game-design practices and their impact on learning over the last two decades. These have mainly addressed the outcomes on children's learning in specific curriculum subjects. Some studies explored children's game making practices focusing on the impact on specific learning areas such as literacy skills (Dyer, 2008; Howells and Robertson, 2012; Robertson and Howells 2008; Robertson, 2012, 2013) or skills in the areas of Mathematics, Science, Art and Computer Literacy (Ke, 2014; Yatim and Masuch, 2007); others studied games design as part of game literacy, teaching students to learn to be critically, creatively and culturally accomplished individuals (Buckingham and Burn, 2007). As a result of the growing emphasis on teaching children 21st century skills, a few studies have explored transferrable skills such as collaboration, communication, and problem solving that children develop when they design their own computer games (Bermingham et al, 2013; Ching and Kafai, 2008; Denner and Werner, 2007). Simultaneously, the popularity of teaching children how to code has inspired researchers to think about the relationships between computer game making, CT and metacognitive awareness (Games and Kane, 2011; Vos, Meijden, and Denessen, 2011). Thus, empirical research into facilitating CT through game design, or using game making as a space for children to develop metacognitive skills, is still limited, which is why I have chosen to make it the focus of this study. The review of the studies above highlights that computer game design activates can provide learning opportunities in many different areas. Therefore, this study will look at learning through computer game design in four areas: learning in curriculum subjects, 21st Century skills, computational concepts, and metacognitive awareness.

2.3.1 Learning in Curriculum Subjects

Digital game making is a powerful tool for storytelling through which students can manipulate objects, backgrounds and characters to create narrative elements for their games, moulded by their creativity. In 'The Game Maker Workshop', Robertson and Good (2004), explored children's narrative development through game authoring. They used the 'Neverwinter Nights Toolset' for the game authoring activities. Face-to-face storytelling sessions were used together with a game creation task using a computer. The sessions included various steps such as a group discussion about the games, a trial of the Neverwinter Nights game, character design including creating a 3D character model; plot planning and storyboarding with digital cameras; game authoring using the Neverwinter Nights toolset; and finally reflecting on their progress and planning further steps. The study found that the children most enjoyed creating their characters, followed by designing a background setting for their story. Robertson and Good (2004) suggest that character design and area design have similarities to the design of plays and other types of drama. Children also reported that they found it difficult to write their stories in advance and that allowing their stories to evolve as they designed their game was easier. Robertson and Good (2004) suggest that the greatest educational benefit gained from this workshop was its motivational power, which can be used to raise standards of literacy in schools; however, the evidence for this is limited.

When evaluating the educational value of games, it is crucial to mention the work of Kafai (1998) who was involved in the early development of the Scratch educational programming language. She was one of the first researchers who studied the design of computer games as a context to understand how girls and boys think when playing and designing games (Kafai, 1998). She describes how students spent long hours working to design their own games, where they not only used their creativity, but also evaluated and revised their designs constantly. Through this constant self and peer evaluation, learners share and develop their ideas and then test them to check if they have designed a solution for a problem. Kafai (1995) noted:

> *Learning through design considers programming not only valuable for its computational and technological knowledge, but also supportive of other learning. It proposes an environment in which the computer becomes a tool that allows children to express their personal thoughts and ideas in the form of a product (1995, p. xvii).*

This again emphasises the importance of how design makes programming more meaningful for learners by enabling them to reflect their individuality within their design.

Yatim and Masuch (2007) investigated children's learning when designing games using Squeak Etoys, an educational programming language tool that uses visual development. They asked children to create a competitive game that can be played by two people. The children were taught how to use the game authoring tool. The study suggests that, by creating games, the children developed transferable skills in the areas of Mathematics, Science, Art and Computer Literacy. Yatim and Masuch (2007) saw game creating activities as creative because of the involvement of children’s imagination and originality. They explained that creativity requires critical judgement and cannot be seen as just creating new solutions, but also creating better solutions.

The 'Making Games' Project (Pelletier, Burn and Buckingham, 2010), which was supported by Immersive Education, aimed to develop a game authoring software to use in education, the result of which was Missionmaker. The project continued for three years and 100 young people, aged 12-15 were involved in the project as part of their media education course. They made their own games using a prototype version of the tool. Missionmaker was developed and used by media educators, who realised the importance of the relationship between the changes in digital technology and young peoples' culture of constructing meaning and who wanted to try different ways of implementing game literacy into education. Their aim was to create a program where children would be actively creating games instead of just playing. Their effort had a very positive impact on secondary schools focusing on media education the UK. They have, however, received little attention in primary schools.

Buckingham and Burn (2007) explain that their focus with Missionmaker was to develop a model of game literacy based on researching the students' existing experiences of games and their creative authoring practices. They investigated the potential of game making as a creative cultural expression and its role in developing students' critical understanding of the medium. Furthermore, they suggest that creativity is a combination of children's imaginative acts and conceptual thinking. This, of course, involves learners' experiences of games with both narrative and ludic elements. When their interactions with these elements of the game are combined with their imagination and conceptual thinking, they create a new gaming culture based upon their experiences. In the 'Making Games' project, students were primarily taught how to analyse a text through marketing and packaging materials. They were then allowed to design an action adventure game. The design process involved making decisions such as choosing characters, objects and locations, and also creating rules for actions. The children worked collaboratively and developed technical skills and an interest in games. They reflected upon what they had learned about their own game and from others' games, which enabled them to analyse their games and modify them if necessary. They discussed their ideas, sharing them with other game makers, which developed their speaking and listening skills.

Howells and Robertson (2012) used Adventure Author, a computer game design tool for children aged 10-14 that allows children to create an interactive game and add story text to objects to tell the narration. They found that the children did not necessarily use their storytelling skills from their traditional writing tasks when making games. The authors suggest that the reason for this could be that children did not see games with heavy-text as successful and focused more on the action of the game. I think deciding the story for a game, selecting characters and backgrounds are crucial part of storytelling, and helping children master using these elements in game design context would offer opportunities for development of literacy skills.

Ching and Kafai (2008), studied 5th grade (10-11 years old) students' game development where the students were asked to generate ideas for computer games to teach fractions. They found that game-making activity provided an authentic and meaningful learning experience for students to connect their mathematical thinking with their real lives by allowing them to include elements from their personal interest. This outcome was also supported by Ke (2014) who studied middle grade students' learning while creating maths games using the Scratch programming application. The participants comprised both boys and girls and had different levels of maths competency. Observation, interviews and a pre and post-game-making Mathematics attitudes survey were used for collecting data. Ke found that the students' attitudes towards Mathematics were significantly more positive after computer game making activities. Furthermore, the study indicated that integrating maths content into Scratch games helped students to engage with mathematical thinking. To conclude, Ke (2014) suggested that "computer game making provided a powerful learning environment or a 'microworld' for children to actively explore, represent, and test their domain knowledge and skills." (p. 37). The review of the studies above shows that computer game design activities can support children's learning in curriculum subjects especially in Mathematics and literacy. In the following section I will discuss the studies that focused on developing 21st century transferrable skills through game making, rather than learning in curriculum subjects.

2.3.2 Developing 21st Century Skills

Recent developments in communication technology have not only changed the way young people communicate with each other, they have also transformed the way they understand the world around them. Children's interaction with the media, either through watching videos or playing games online has started to shape the learning culture of the individual. Today, young people communicate, socialise and search for information differently (Allsop 2016; Gibbons, 2007; Liao et.al, 2016). They use making and sharing media such as music, animations, films and games as a way of communicating their ideas and concurrently developing their cultural identity through "claiming membership of particular social groups" (Burn and Durran, 2007, p.3). This transformation of the daily lives of youth through emerging technologies requires the development of a new set of skills and capabilities that can be either transferred or applied to any situation in both informal and formal education settings. Such new capabilities and skills are called transferrable skills or 21st Century skills and are seen as necessary to succeed in learning and work (Trilling and Fadel, 2009). It is arguable that, as some of these skills have been around for centuries, it is inaccurate to introduce them as new competencies. Nonetheless, the manner in which they have been applied to different activities, in particular involving digital technologies, has encouraged educators to re-think learning and the education system in general.

Defining what constitutes 21st Century skills and competencies is a very challenging task. Several reviews include critical thinking and problem solving; collaboration; creativity; communication; and information and communication technologies (ICT) in their frameworks (Trilling and Fadel, 2009; Binkley et al., 2012; Voogt and Pareja Roblin, 2012). These framework

reviews posed a question about what pedagogical approaches are needed to teach these skills to learners. The constructionist (Papert, 1991) approach to learning, based on the fundamentals of constructivism (e.g. Bruner 1960) is widely regarded as the main pedagogy as it accommodates collaborative, problem-based learning where learners are actively involved in constructing their knowledge and understanding of the world around them. From a constructionist perspective, learning is seen as reconstruction rather than knowledge transmission (Papert, 1991). In constructionist learning space children draw their own conclusions through active experiments and teacher's role is to create conditions for invention, rather than providing ready-made knowledge. I see game making as a constructionist activity because as it allows students to learn through interacting and building digital artefacts (Papert, 1980).

Game making as a constructionist form of learning can provide learners with interactive, learner-centred activities by engaging them with problem-solving tasks. However, there are limited studies investigating the impact of computer game making on developing transferrable or 21st Century skills (Bermingham et al, 2013). Bermingham et al. (2013) explored the use of collaborative game making as a pedagogical model. This study differed from previous ones as the focus was not purely on digital game making, but had a blended approach, where non-digital game making was used to scaffold a student's knowledge and understanding of the game design process through collaborative and hands-on tasks. According to this study, "game-making can also support the development of 21st century competencies like creative problem solving, collaboration, ICT literacy, systems thinking, and positively affect engagement in STEM subjects" (p.46). The study also discussed the complexity of the game-making task individually or collaboratively and how this requires higher-level ICT skills. Bermingham et al. (2013) explain that collaborative game making as a 'learning by doing' activity could provide learners with opportunities for problem solving, which includes 'representing, planning, executing, and self-regulating' skills (Mayer and Wittrock, 2006, as cited in Bermingham et al., 2013, p.48). The study did not focus on communication and critical thinking. However, as working in pairs or as a team requires learners to discuss and communicate their ideas, collaborative game making does provide a space for learners to apply and develop their communication skills.

Liao, Motter and Patton (2016) studied how girls can be engaged with 21st Century learning skills through digital artmaking including creating animations and video games. The students used GameMaker and My Avatar Games software to tell stories and create games collaboratively. The study found that, through making games, the students learned 21st century skills such as critical thinking and problem solving. These examples highlight that game design activities can be used as a teaching tool to facilitate the development of 21st Century competencies.

2.3.3. Developing Computational Thinking Through Game Making

The recent inclusion of programming concepts in primary school curricula in many countries, including England, have raised interest in teaching children how to code. As a result, educators started to explore methods of engaging learners with programming activities. The terms ‘coding’ and ‘programming’ are used interchangeably, however, this creates confusion as programming includes “many other skills, such as getting specifications, planning and debugging” (Duncan, Bell and Tanimoto, 2014, p. 62). According to Duncan, Bell and Tanimoto (2014) coding refers to “the last stage of the process of programming, translating a designed program into programming expressions and typing/entering these into a computer” (p.62). They define ‘programming’ as the activity of formulating a problem then implementing a program to solve it. This study also agrees and adopts the same definition when discussing children’s programming activities in game design context.

An overwhelming number of applications and apps for teaching programming have been developed and made available, for free, to anyone; these include Scratch and Alice applications. These developments have produced an environment where programming is seen as a skill that is easy to teach and learn (Marcelino et al., 2018; Papadakis and Orfanakis, 2016; Plaza et al., 2017). However, while young people might be interacting with digital technologies on a daily basis, having basic technical skills does not guarantee that they would be able to cope with the cognitive demands of a programming task. Furthermore, children use technology outside of the school environment mainly for a purpose that has a meaning for them. Therefore, we cannot expect that students’ attitudes to using technology would be the same in a classroom environment where learning for pleasure is replaced with learning for a curriculum objective that is mainly shaped and controlled by a teacher. Resnick et al. (2009) suggest that children’s interaction with digital technologies does not necessarily make them fluent with new technologies. Only when they start using new media to design, create, and basically, make things, do they reach ‘digital fluency’. Although I agree with this statement, I think that we need to direct our attention to the design, making and evaluation process where the majority of learning occurs, rather than the coding alone. Some researchers have suggested that computer game design is a fun and effective way of introducing programming concepts (Basawapatna, Koh and Repenning, 2010; Denner, Werner and Ortiz, 2012) as it includes this type of design, making and evaluation routine. Hainey, Baxter and Ford (2019) developed a coding scheme for analysing primary school children's games that were created using the Scratch application which they focused on both the programming and design aspects of children's learning. They concluded that after just four lessons, the children were able to develop a working game and learn programming and design concepts in the process.

Another important issue is the readiness of teachers to plan, teach and assess children's learning when they teach programming. Teachers might be able to describe the terminology relating to Computational Thinking (CT) or teach programming using lesson plans and instruction sheets that are available online without mastering the concepts. However, this does not mean that they would be able to recognise CT skills when they assess children's work. There are some automated web-based applications for assessing programming concepts in children's games, such as Dr. Scratch (Moreno-León and Robles, 2015), but these programs provide little information about the learning process that children go through and the extent to which they are able to develop and use CT skills when solving problems in different contexts. There are also limitations around the generalisation of these applications as they are specific to one programming environment. In order to gain a better understanding of how computer game making activities can facilitate development of CT skills, it is important to discuss what CT is. In the following sections, I will investigate what CT is, how it can be best taught and approaches to assessing CT skills.

2.3.3.1 Defining Computational Thinking

There is no common definition of Computational Thinking (CT) and its characteristics. While Papert (1980; 1991) did not discuss CT directly, he did come up with the idea of CT by focusing on the procedural thinking that children develop through programming in a LOGO environment. Wing (2006) championed this idea and emphasized that CT is not just about coding; it is a skill set for understanding human behaviour using fundamental concepts from Computer Science. In 2010, she reintroduced the term ‘computational thinking’ as “the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent” (Wing, 2010, p.1).

A number of studies highlight CT as a cognitive process (Selby and Woollard, 2014; Sung et al, 2016) and some describe it as a problem-solving approach (Cuny, Snyder, and Wing, 2010). The role of metacognition in the CT process is also emphasized (Brennan and Resnick, 2012; Kafai and Burke, 2015). Furthermore, how CT is different to other ways of thinking has been explained by focusing on the automation of information when computers execute repetitive tasks efficiently (Aho, 2012; Lu and Fletcher, 2009). This highlights the link between CT and Artificial Intelligence (AI). AI can be defined as the ability of computer systems to learn, think and perform tasks that require complex decision-making (Gadanidis, 2017). At the core of this repetitive task automation are algorithms and abstractions, which are also key elements of CT (Yadav et. al., 2014).

Aho (2012) explained CT as the thought processes involved in formulating problems so that “their solutions can be represented as computational steps and algorithms” (p.832). From a psychological perspective, forming a mental representation of a problem (formulating problems); planning and choosing appropriate strategies for a solution (formulating solutions); checking for errors (evaluating) and debugging them; and thinking about how to improve work (monitoring) are components of metacognition (Davidson, Deuser and Sternberg, 1994).

Lu and Fletcher (2009) describe CT as a “full set of mental tools necessary to effectively use computing to solve complex human problems” (p1). The effective allocation of these mental tools for completing a task requires one's own knowledge of these tools and knowing how to use them for executing a task, namely metacognition. Several researchers also highlight the relationship between metacognition and CT. Resnick (2007) suggests that constructive learning environments, where learners are given opportunities to design solutions iteratively and reflect on their own learning processes, are required to facilitate the learning of CT skills. This was also supported by Papert (1980) who argues that creating programs encouraged learners to be more aware of the strategies they used for debugging problems and think about ways of improving them. Kafai and Burke (2015) discuss the benefits of constructionist game making and emphasised the learning beyond coding. They claim that a constructionist game-making space supports children to think about their own thinking and learning namely "reflection or metacognition" (2015, p.10).

The Barefoot Computing Programme (2014) consider computational thinking from the concepts and approaches aspect. They list tinkering, creating, debugging, persevering and working collaboratively as the main approaches that pupils apply and develop during the CT process. Brennan and Resnick (2012) discuss questioning, connecting and expressing under the term "computational perspectives". In a model for CT created by the Somerset E-Learning and Information Management team (2014), making mistakes, perseverance, imagination CT process. Furthermore, other studies have found that, while working on their games, pupils have opportunities to apply and develop skills such as collaboration, creativity, communication, critical thinking, tinkering, and persevering (Akcaoglu, 2014; Bermingham et al, 2013; Denner and Werner, 2007). All these approaches, perspectives and attitudes can be described as learning behaviours since these are the strategies for promoting behaviours that are 'necessary for learning' (Ellis and Tod, 2013, p.53). Powell and Tod (2004) suggest that learning behaviours reflect pupils' social, emotional and cognitive development and depend on their prior learning experiences; patterns of development would, therefore, vary for each pupil.

As discussed above, the CT process offers a wider scope than just learning of programming constructs. Informed by the discussion about CT in relevant literature, I propose the following definition of CT, which:

- is a cognitive process;
- is regulated by metacognitive practices;
- involves the application of a series of computational concepts;
- includes the utilization of learning behaviours;
- aims to design solutions to problems that are susceptible to automation.

The definitions shared above include problem solving, thinking in an abstract manner, formulating problems, formulating solutions, automation, higher order thinking, cognitive skills, planning, evaluation, improving and decomposition. The definition also emphasises the functional relationship between metacognition and CT that highlights the executive role of metacognitive practices in the CT process, which should be considered when evaluating the development of CT skills. It is evident that metacognition is an integral part of the CT process, although it is not limited to computational practices. It enables learners to think about their own thinking and learning in different scenarios across disciplines. Perhaps, rather than taking ownership of concepts and skills from other disciplines under CT, a multi-dimensional approach to the analysis of the computational process would be more constructive. This approach will be discussed in the next section using the current models from literature.

2.3.3.2 Assessing Computational Thinking in Computer Games

Before discussing the studies that focused on measuring CT skills in children’s computer games, it might be useful to clarify the terms ‘assessment’ and ‘evaluation’. Although people usually use the terms ‘assessment’ and ‘evaluation’ interchangeably, they do refer to different processes. Evaluation as a term is used for describing and providing some form of judgement on the quality of the present work rather than focusing on attainment (Baehr, 2010). Whereas assessment is not concerned with the quality of the work, rather on how to improve the quality level of the work for future performances (Ibid). In this study I used evaluation to determine whether the children were able to use programming concepts rather than an assessment tool to provide feedback on their strengths and weaknesses for future improvement. This evaluation step can be seen as part of the wider assessment process but not enough to determine the performance of students alone.

A number of studies have suggested that, if supported with appropriate teaching strategies and game making tools, game design can help children develop and demonstrate the learning of CT skills (Pelletier, Burn and Buckingham, 2010; Robertson, 2012; Robertson and Howells, 2008; Werner, Denner and Campe, 2014). Several studies have been conducted to measure the CT skills that children develop when creating their own computer games (Brennan and Resnick, 2012; Werner et al, 2012; Werner, Denner and Campe, 2014).

Werner et al. (2014) proposed a three-level assessment model called Game Computational Sophistication (GCS) for measuring children's computational learning in an 'Alice' programming environment. The first level is about coding blocks that are crucial for programming or making games. At the second level, students use coding blocks to create patterns. The next level involves a combination of programming constructs and patterns, namely, 'game mechanics'. They identified 15 patterns and 11 game mechanics in the games that the students had created. Although the clear structure of their game mechanics and pattern model makes it easier for investigating evidence of CT skills in the games that were created by the children, it is crucial to remember that CT includes both concepts and approaches (Barefoot CAS, 2014). Therefore, other methods should be used alongside this model to provide a more detailed overview of the CT skills that learners develop when making computer games. Using programming constructions to evaluate learners' games tells us whether they used CT concepts, but it does not provide information about whether they were able to transfer and apply these concepts when solving different problems. It is also difficult to gain an insight into the challenges they faced and/or how they managed their thinking and learning processes by just looking at the programming constructions that they used. Furthermore, it does not provide information about the strategies they selected and employed for identifying and debugging the errors in their games, or the interactions with their friends and the programming environment and how this would impact on their ability to think critically and solve problems.

Werner et al. (2012) used a three-stage model called Use-Modify-Create to evaluate students' progression in CT skills. In the first stage, students were required to complete a series of self-paced instructional tasks. During the second stage, students were asked to create their own games. Finally, in the third stage they were told to complete Fairy Assessment, which is an Alice game with built-in tasks to measure the CT skills that the students apply whilst they modify the programming code to complete these pre-set tasks. One of the limitations of this model is that it is difficult to generalize these tasks to other programming environments directly as the tasks would be specific to the Alice programming application.

Brennan and Resnick (2012) proposed a model for measuring CT skills when children develop games in a 'Scratch' programming environment. They suggested a framework with three dimensions: computational concepts, computational practices and computational perspectives. Computational concepts include sequences, loops, parallelism, events, conditionals, operators and data. CT practices involve focusing on the thinking and learning process, namely, how students planned their games, how they solved problems, which strategies they used and so forth. Although the CT practices were defined in relation to a Scratch Programming environment, it can be applied to activities when using other gaming applications. This dimension can be seen as a metacognition of programming as it involves metacognitive skills such as planning, evaluating, modifying, monitoring, reflecting – in other words thinking about thinking.

Brennan and Resnick (2012) define the design process as an adaptive process because it is not always a sequential practice Instead, children will modify their design whilst creating in small steps. Similarly, in the pilot study that I have completed prior to my PhD study I also found that children's thinking sequences when making digital games had a similar pattern. However, when children were asked to draw the way they thought when making games, they drew their thinking process as a circular continuous cycle that had the flexibility to allow them to move between different steps as they needed. This adaptive process involved functions such as engaging, exploring, engineering, experimenting, eliciting and error checking / evaluating (Allsop, 2016).

The final dimension of Brennan and Resnick's (2012) model for measuring CT skills is called the computational perspective and is all about children's "understandings of themselves, their relationships with others, and the technological world around them" (p.10). They suggested three approaches to assess computational concepts, practices, and perspectives: project analysis, artefact-based interviews and design scenarios.

One interesting point about Brennan and Resnick's (2012) model is that it regards computational practices as similar to the metacognitive process in that they involve focusing on the thinking and learning process: how children planned their games, how they solved problems, which strategies they used and so forth. Metacognition in the CT process can be seen as the executive function that "involves the ability to monitor and control the information processing necessary to produce voluntary action" (Fernandez-Duque, Baird, and Posner, 2000, p.288), in other words, the process that coordinates cognition.

In a recent large-scale empirical study Hainey, Baxter and Ford (2019) investigated the issues around teaching programming using the games-based construction learning (GBCL) approach. They defined GBCL as "an innovative learning approach that uses appropriate tools in order to allow games to be constructed to support learning and teaching" (p.2). They developed a coding scheme to analyse 178 games that were created by 384 children between levels 4 and 7 in primary education (7-11 years old) using the Scratch application. The coding scheme included programming and design categories that were divided into 29 categories to code each game according to “the presence of each element or to the extent that the element was utilised within the category”(p.5). One interesting point about this coding scheme was, it analysed the games from both programming and design aspects rather than focusing only on programming constructs to provide a full view of children’s learning activities in game design context.

The definition of CT that I proposed highlights the complex structure of computational thinking and the interaction between the elements of AI, computer, cognitive, learning and psychological sciences, while providing a foundation for defining the multiple aspects that the evaluation of CT skills should include. This multiple means of assessment approach was also supported by Brennan and Resnick (2012) who highlighted the necessity of focusing on the process that children go through rather than only their codes. Similarly, Grover (2015), after reviewing different assessment approaches to CT, recommended that Conley and Darling-Hammond’s (2013) ‘systems of assessment’ would provide a more comprehensive view of children’s learning of CT skills. I agree with this view, as it is not possible to use one single method to evaluate the interaction between the elements of computer, cognitive, learning and psychological sciences. Adopting a multiple means of assessment approach would not only provide more in-depth information about children’s understandings of computational concepts, but also gather evidence of children’s individual skills development, especially during pair programming activities. In this context, I use the term ‘assessment’ to represent the evaluation of children’s learning rather than a formal assessment tool.

In Chapter 5, the dimensions for assessing children’s CT skills will be discussed in detail using analysis of the data collected for this study.

2.3.4 Promoting Metacognition

The empirical research about children's cognitive and metacognitive process when making computer games is very limited. Kafai (1998) was one of the first researchers who studied children's game design activities to understand how girls and boys think when playing and designing games. She asked children in their fourth grade (9-10 years old) to create 2D games using the LOGO programming language. She found that children developed not only domain specific skills, such as programming and Mathematics, but at the same time they used metacognitive skills necessary for planning and monitoring the game design task. Kafai (1998) suggested that when making games the students evaluated and revised their designs constantly. Through this constant self- and peer-evaluation, learners share and develop their ideas and then test them to check if they have designed a solution for the problem. Kafai (1998) emphasised the importance of how design makes programming more meaningful for the learners by enabling them to reflect their individuality through their design. In a more recent meta-analysis, focusing on constructionist gaming and its benefits for learning, Kafai and Burke (2015) describe 'learning about learning' as one of the educational benefits of game making and suggest that game making allows learners to learn about their own thinking and learning, in other words, metacognition.

Robertson and Nicholson (2007) proposed a model of the creative process of computer game authoring. Their model included exploration, ideas generation, game design, game implementation, game testing and evaluation stages. As the stages are not fixed, the designer can return to any stage as they develop their ideas. Although they concluded that the analysis of meta-cognitive skills demonstrated by the children is ongoing, their evaluation of children's game authoring activities using a creative process provides us with clues into this field. Exploring ideas, engineering ideas, testing their design and evaluating can all be seen as metacognitive strategies that are used for regulating children's game design activities. However, it is important to explore how children actually managed the application of these strategies. Interestingly, they asked children to record their interactions into a 'Designer's Notebook', which may provide an opportunity to find out about the strategies they selected when creating ideas, debugging problems, evaluating their games and executing them.

Dyer (2008), focuses on game-making projects for primary school children that aimed to develop, students' storytelling and writing skills based on the curriculum. The project involved schools and four different game authoring software programmes: Missionmaker, Thinking Worlds, Gamemaker, and Neverwinter Nights. Dyer (2008) argues that creating digital games from a perspective of learning motivates learners to achieve; increases self-esteem; provides opportunities for collaborative learning; develops problem solving; develops a student’s ability to observe, question, hypothesise and test; facilitates metacognitive reflection; and makes school an exciting place. Dyer (2008) also analyses the outcome of the children's game authoring activity from the perspective of games literacy. She suggests that after game making activities, children were more aware and critical of games.

Games (2010) studied the language and literacy practices of middle-school children during their game authoring activities using Gamestar Mechanic. He used participants’ conversation and think-aloud interview data to examine the changes in children’s design and thinking strategies over time. He suggests that during this activity, children started to use more sophisticated metacognitive strategies when addressing design problems and debugging. He sums up his findings as follows: “the tools at hand (Gamestar mechanic) allow the learner to think in function of systemic interactions and establish metacognitive strategies” (p.16).

Vos, Meijden, and Denessen (2011) studied the effects of constructing and playing an educational game on student motivation and deep learning strategy using a sample of 235 pupils: 128 designed their own game (a version of Memory), and 107 (a control group) played a Memory game. They found that learners who were involved in game design activities were better motivated and engaged in deep learning strategies. They suggest that the ‘constructing’ element of gaming might provide a more authentic, meaningful and complex learning experience, which might require the use of deeper strategies such as critical thinking and self-regulated learning. Metacognition and critical thinking are deeply connected as critical thinking happens when one uses metacognitive skills and strategies to achieve an outcome (Magno, 2010). Self-regulation as a metacognitive function also is a crucial element of the metacognitive process, as was mentioned earlier in this chapter. Although Vos, Meijden and Denessen (2011) share some important points, they were not able to provide an insight into the students' learning process as they did not use any structured qualitative data.

In conclusion, the studies that have been discussed in this section contributed to the design of my research in a number of ways. Although the main focus of my research is the metacognitive skills that children develop when authoring their own games, it is clear that this cannot be investigated independently from learning and thinking processes. The review of metacognition and game making research illustrate how children apply metacognitive strategies to regulate their learning. However, it does not present enough information to form a model of metacognition. This literature review also highlights the wider spectrum of learning benefits of game making activities from metacognitive awareness, curriculum subjects, 21st century skills and CT perspectives. Evaluating the data collection methods of these investigations was also valuable, as it revealed the limitations of using only quantitative methods to gain insight into children's thinking and learning processes. This critical evaluation of research designs of relevant studies was useful when forming my methodology and selecting data collection tools. The research approach of this study will be discussed in detail in Chapter 3: Research Design.

Chapter 3: Methodology

In this chapter, I will outline issues related to the research design and methodology and discuss the research approach taken within the context of educational research. The research techniques that have been adopted are presented with regards to each research question and the ethical issues associated with this research are reviewed at the end of this chapter.

As discussed in Chapter 1, this study aims to examine children's learning, thinking and metacognition when making computer games. The research questions for this study are:

Q1. What is the educational value of children's game making activities in relation to thinking, learning and metacognition?

Q2. How can children develop computational thinking skills whilst making their computer games?

Q3. What is the role of conversational exchanges in metacognitive process and children's learning?

Q4. How can metacognition be measured in computer game design context?

3.1 Mixed method approach

Before discussing the method, a quick explanation of game design as a medium is necessary. Although game design seems to be a simple activity using coding, it is in fact a complex process requiring understanding of a wide spectrum of skills and knowledge domains. Game design involves the process of developing a concept, a thought in mind, and then actualising it through a physical design. It is mainly based on hypothesizing an idea, which can be seen as problem setting, whilst the activity itself involves developing solutions, or problem solving. The difficulty is that children will perceive problems differently and their solutions will also be dissimilar. Therefore, the focus of the methodology should not be the problems or solutions themselves, but on the interpretation of the learners' actions and their ongoing dialogue with both their 'self' and 'others' in the learning space.

For the purpose of this study, a mixed method approach was adopted, where ethnography, as a qualitative method, was used alongside a metacognitive skills instrument, a quantitative method employed to closely examine children's thinking and learning when making games in a classroom setting. As described below, using a mixed method approach for the evaluation of children's game authoring activities enhanced the contribution of both methods and provided richer data than that which would have been gained through using one method alone.

Whereas, previous empirical work in the area of children's game design activities were mainly adopted case studies (Kafai, 2005) or design-based research (Robertson and Howells, 2008) as their methods, ethnographic accounts of young children's thinking and learning with digital game making are still relatively new. There are only a few ethnographic studies into student's learning with technology. McNeil and Diao (2010) used ethnography to explore how undergraduate students used technology in their everyday lives, and Satwicz (2006) used ethnography to analyse children's video gaming practices.

Denzin (1997) describes ethnography as a "form of inquiry and writing that produces descriptions and accounts about the ways of life of the writer and those written about" (p.xi). Ethnographic research can be used to predict and explain the behaviour of the members of the group being studied. Researchers using this method, look beyond what people do and know, to explore the meaning of the behaviour and their feelings. Ethnography aims to "discover their culture, to learn to see the world from their perspective" (Hicks, 1976). Making extensive field notes of the children's designs and problem-solving activities and listening to how they viewed their learning enabled me to understand the social and cultural context around children's thinking and learning, which provided a more detailed description than using a single questionnaire or interview.

Ethnography not only enabled me to blend different data collection methods but also provided me with a rich written account of the children's learning process. By being in the classroom for a long period of time to observe what children are saying and doing, I was be able to monitor the changes in children's reasoning over eight months, which provided me with detailed understanding, and a very personal level of experience.

Using ethnography to investigate metacognition is a challenging task as thinking is not always visible. According to Perkins (1992, 2003) learning is a consequence of thinking, and successful learning depends on making thinking visible. Balka and Miles (2011) talk about ways that visible thinking manifests itself within classrooms. Students share their thinking orally; listen to and articulate others' thinking; participate in discussions whilst forming their understanding; record their thinking by completing projects, problem solving and keeping journals; and demonstrate their thinking through the use of technology. Observing the children's problem-solving activities as they happen in real-time, the language that they used for their individual explanations and group discussions, the gestures they made, and their use of technology provided a detailed insight into their thinking. There are, however, some limitations of ethnography.

Ethnographic research requires a substantial amount of time spent in the field collecting data. This may be a problem where researchers have limited time. As Fetterman (1998) explains, "Ethnography is more than a 1-day hike through the woods" (p.ix). This wasn't an issue for my study as I had 28 weeks to study children's learning when making computer games. This provided me with enough time to observe the changes in children's learning over a long period.

There is also danger of researchers bringing their previous experiences and preconceptions about cultures with them, which makes ethnographic research subjective. However, this can also be beneficial, as knowing the studied culture well may help the researcher to unfold meanings that are not visible to others. As a Mathematics and technology teacher, I have had the opportunity to work with many different classes within the school, therefore, the children did not see me as an outsider, and this helped to make the role of participant observer easier. Furthermore as Jessel (2012) stated “Innovation arising from new technologies makes a variety of demands upon the role of the teacher” (p.28). At the time I started data collection, ICT was replaced with Computing and teaching programming was included in the Primary Computing Curriculum (Department for Education, 2013). This sudden change of the computing curriculum meant that teachers had to develop their subject knowledge of programming before they could plan and teach in the classroom. Although I felt confident enough to teach programming using the Scratch application, there were times when I couldn’t answer the students’ questions directly and on many occasions I had to explore possible answers collaboratively with the students. It can be said that the changes in the computing curriculum had an impact on my role in the classroom and as a result during this study I adopted the role of a researcher, a teacher and a co-learner. This was useful in terms of getting an insight into the students’ learning processes as I was an active part of their discussions and problem-solving activities. Again, this new role helped me to document the culture, the perspectives and practices of students in a classroom setting which is the central aim of ethnography (Hammersley, 1992; Reeves, Kuper and Hodges, 2008).

The success of ethnographic research, as for any research, relies on the researcher. Collecting credible data, then writing about it in a persuasive way is a skill that the researcher needs to develop. There are also discussions around the reliability and credibility of ethnographic research (Hammersley, 2006; LeCompte and Goetz, 1982). One of the criticisms is the generalizability of results, as it is limited to statements about the specific group studied (Hammersley, 2006; Small, 2009). Although this is true, in-depth, detailed descriptions can provide a good context for theoretical contributions.

3.2 Research Paradigm

In this section, the research approach for this study will be examined, including the research paradigm and methods. According to Greene and Caracelli (1997) a paradigm “frames and guides a particular orientation to social inquiry, including what questions to ask, what methods to use, what knowledge claims to strive for, and what defines high-quality work” (p.6). Morgan (2007) defines paradigm as ‘‘Systems of beliefs and practices that influence how researchers select both the questions they study and methods that they use to study them’’ (p. 49). Paradigm is a tool that researchers can use for framing their approach to their research problems and design some solutions to address these based on their beliefs about the world. In research, ontological assumptions, which relate to one’s view of reality, informs epistemological assumptions, which is how one acquires knowledge (Cohen, Manion and Morrison 2007). This, in turn, shapes methodology and data collection techniques. Together, ontological and epistemological assumptions (Crotty, 1998) make up a research paradigm, which can be seen as beliefs and feelings about the world and how it should be explored and studied (Denzin and Lincoln, 2003). Grix (2004) argues that ontological assumptions represent the way researchers view the world and understand the nature of reality which impacts on the research questions that they select to study a research area.

A critical factor in this research is that I am adopting a mixed methodology. This means it is particularly important to explore the paradigm issues around mixed methods. According to Tashakkori and Teddlie (1998) mixed methods is the combination of “qualitative and quantitative approaches in the methodology of a study” (p.ix). Some have suggested that for a researcher to take a stance for combining qualitative and quantitative data through two incompatible paradigms is problematic (Guba and Lincoln, 1994). As a solution to this problem different approaches have been presented (Tashahori and Teddlie, 2003).

The first option suggested by Tashahori and Teddlie (2003) is to adopt and -a-paradigmatic stance, which suggests that paradigmatic issues should be ignored. This becomes problematic when a researcher is interpreting research data as epistemology plays a role in the method that has been selected for collecting and interpreting data. I therefore rejected this option for my research.

The second options suggested by Tashahori and Teddlie (2003) is to use multiple paradigms within one research study. In my case, it may have been possible to take this approach by using a positivist paradigm for the MSI self-report instrument whilst using an interpretivist paradigm for the ethnographic aspects of the study. The positivist paradigm typically focuses on proving or disproving a hypothesis using scientific method and statistical analysis. The ontological assumption of positivism is that the reality is external to the researcher and can be observed by the senses and predicted. The epistemological position of positivism is that knowledge is drawn from a hypothesis and the evidence should be verifiable and should be the result of direct observation that allows for testing. According to Bryman (2008), in this paradigm the researcher tests theories, and typically uses quasi-experimentation and non-experimental methods such as questionnaires and surveys.

One of the main criticisms of positivism is that it makes it difficult to conclude an absolute truth as people will perceive and interpret events differently.
The ontological position of interpretivism, on the other hand, is relativism. This means that reality is regarded as subjective and constructed differently by different people (Guba and Lincoln, 1994). The role of the researcher is to, “understand, explain, and demystify social reality through the eyes of different participants” (Cohen, Manion and Morrison 2007, p. 19). The epistemological position of the interpretivist paradigm is that the world does not exist independently, that is, without people’s knowledge of it (Grix, 2004). A research methodology based on this approach focuses on understanding events through one’s perception and studying the interaction between individuals in connection to their cultural and historical ties. Case studies and ethnography are examples of typical interpretivist methods. One criticism of this paradigm is that it is difficult to generalize results. Whilst

it may have been possible to take this approach of mixing paradigms within my study, I decided not to take this option because, as Tashahori and Teddlie (2003) point out, there is no any clear information about how paradigms might can be combined, and which paradigms can be mixed together. In addition, this "dual epistemology tends to discourage mixing qualitative and quantitative methods in single studies by encouraging epistemological and methodological purism among both qualitative and quantitative researchers" (Alexander, 2006).

I therefore decided to adopt the third approach suggested by Tashahori and Teddlie (2003) and Somekh and Lewin (2005), namely, to use a single paradigm approach, pragmatism, which lends itself to the use of both quantitative and qualitative methods in one research study. Johnson and Onwuegbuzie (2006) suggest that the aim of pragmatism is to find and strengthen the weaknesses in a study using a mixed method approach. Pragmatism focuses on the outcome product of the research (Biesta, 2010; Johnson and Onwuegbuzie, 2006). According to Creswell (2003), the pragmatic paradigm enables researchers to select research methods that are appropriate for their research questions, i.e. linking their research approach directly to the research purpose. The quantitative approaches usually associated with the positivist paradigm engages with data collection strategies that typically result in numeric data, whilst the qualitative approaches, most frequently associated with the constructivist paradigm, employ strategies that usually result in open-ended textual data. A mixed method approach, typically, associated with the pragmatic paradigm enables the researcher to collect data in a simultaneous or sequential manner, using strategies from both quantitative and qualitative approaches to address the research questions in a best fit approach (Cresewell, 2003). The main advantage of using a mixed method approach for research design is, researchers can use all of the data collection techniques that are available, rather than being limited to qualitative or quantitative research. This provides them with diversified findings that can be used for interpreting different viewpoints.

My personal approach to the selection of a research paradigm is closely aligned with pragmatism as the primary philosophy of my mixed methods research. This paradigm allows me to investigate the phenomenon that I am focusing on from different angles using many data collection tools to gain a more in-depth understanding of reality. In a mixed method research approach, the findings from one method can lead the researcher to use another method to ask and study further questions; or they might choose to use two methods side by side to strengthen the validity of their results. In this study, the findings from studying the metacognitive skills that children develop when making computer games using qualitative methods led me to ask the same question using a quantitative method, namely a self-report instrument to gain an understanding of the students' perspectives. I linked the data collection method directly to the question and purpose of this study. Using a self-report instrument enabled me to verify the findings of previous data collection methods with a study results from a defined population (Creswell and Plano Clark, 2007:121).

Taking the position of pragmatic approach enabled me to be flexible with the selection of my methods, as I did not want "be the prisoner of a particular method or technique'' (Robson, 2002, p. 291). Furthermore, the different methods and techniques that I used informed and supplemented each other as they helped me to address the questions from different aspects (Teddlie and Tashakkori, 2009). For example, while participants observations were used for understanding the processes of how children learn and use programming constructs to create their games, their completed games were analysed to establish which programming constructs they were able to include in their games and at which level. Analysing children's games qualitatively and quantitatively allowed me to evaluate how well the children could use programming constructs.

Feilzer (2010) states that "pragmatism is a commitment to uncertainty, an acknowledgement that any knowledge ''produced'' through research is relative and not absolute" (p.14) which helps researchers to be flexible and open to unexpected data occurrences. One example of this can be that whilst reviewing the literature to define metacognitive skills that children developed, the role of language in metacognitive process appeared as a theme. Therefore, I analysed the data to understand how language relates to children's thinking processes. In a way pragmatic approach helped me to be adaptable and focus on what I wanted to know using methods that have the potential of answering my research questions. In the following section I will discuss these data collection methods and techniques in more detail.

3.3 Participants

A class of 30 children aged ten and eleven (Year 6) were included in this study, however the Metacognitive Skills Instrument was administered with 223 children aged nine to eleven (Year 5 and 6) as they were all learning about making games in their computing lessons. Using the MSI (Metacognitive Skills Instrument) with a larger group size was vital in order to evaluate its validity.

Ten children were selected as focus children in order to provide an in-depth analysis of children's learning activities when making games. I wanted to observe if there was any link between children's game making activities and learning in Mathematics, therefore the children were selected from my top set Mathematics group as I only taught Mathematics to Year 5 / 6 top set groups and did not have access to other classes. Eight were boys and two were girls. Although parents sign a generic declaration giving permission for the school to study their child's learning, because this research was for my PhD study, I sought consent from each child and their parents by giving them a consent form. Although all the children chose to be part of the study, only 14 parents agreed that their child could be interviewed, could keep a journal, and could take part in group discussions. This was the reason for having only two girls, as these were the only children whose parents ticked the statements to allow their child to be a focus child. The focus children will be referred in letters throughout this PhD. Below is the brief information about each child. In order to ensure anonymity, I used random letters instead of their names or initials.

Child A was female and ten years old. Her spoken language at home was not English. She was in the top set Mathematics group, but she achieved lower grades in comparison to the rest of the class. She had a very good knowledge of calculations, but she had issues solving problems with 2 or more steps. In English, she was receiving additional support. The main reason for this was identified by her class teacher as the lack of confidence. She reported that she does not enjoy playing computer games. During breaks she played outside with her friends.

Child B was male and ten years old. English was his first language. He was in the top set group for Mathematics. He received support for English as he was achieving below the expected level. He was very confident and good at articulating his thoughts. He loved playing commercial games. He did not enjoy making games or working on robotics projects. He preferred playing football during breaks.

Child C was male and ten years old. He was in the top set groups for both Mathematics and English. English was his second language. He liked playing commercial games with his friends. He had a confident personality and expressed his ideas easily. His parents could not speak English. During breaks he worked on robotics projects in the Computing Lab.

Child G was male and aged 11 years old. English was his second language. He was in the top set Mathematics and English groups as he achieved above expected levels in both subjects. He had an interest in game playing and he played commercial games daily. He was very confident and good at expressing his ideas. During breaks he played football.

Child H was male and ten years old. He was in the top set Mathematics group; however, he was struggling with the level of the work. English was spoken at home alongside his mother tongue. In English, he received additional support as he was achieving below the expected level. He had confidence issues which meant that he found it hard to express his ideas and only wanted to work with Child K. Their families were originally from the same country and they lived very close to each other. During breaks he played football.

Child J was male and 11 years old. His spoken language at home was English. He was in the top set group for both Mathematics and English. He was very confident and good at expressing his ideas. During breaks he worked on robotics projects in the Computing Lab.

Child K was male and ten years old. English was his second language. He was born in the UK, but English was not spoken at home. He was in the top set Mathematics group. In English, he was working at the expected level. He enjoyed playing commercial computer games, especially with his dad, and making games at home using Unity. He was very confident and sometimes was described as dominant by his friends. During breaks he worked on robotics projects in the Computing Lab.

Child M was male and ten years old. His home language was English. He was in the top set group for both Mathematics and English. He was interested in robotics and electronics. He liked playing commercial games with his friends. Whilst he was very articulate at sharing his ideas, he only talked when he was asked a question rather than voluntarily. He spent his breaks working on robotics projects with Child S.

Child S was male and 11 years old. English was his second language. He spoke English and another language at home. He loved playing commercial games with his friends and was interested in robotics. He was in top set Mathematics group, but he received extra support for English as he was not achieving at expected level. He was very confident and spent all his breaks working on robotics projects in the Computing Lab.

Child T was female and ten years old. She was in the top set Mathematics group as she achieved high levels in this subject. English was her first language. She was achieving at the expected level in English. She was very shy and found it hard to talk in front of the class. She was better able to express her ideas in a written format than verbally. She loved playing Sims on her phone. During breaks she worked on robotics projects in the Computing Lab.

3.4 Data collection techniques

The data were collected for eight months using participant observations; semi-structured interviews; informal conversations; group discussions; learning journals and problem-solving sheets; the metacognitive skills instrument; and children's planning sheet for their game design and completed games. Table 2 shows the data collection methods in relation to when it was used, and which participants were involved.

Table 2: Data collection methods

	When	Participants
Participant observations	Every session	The whole class
Semi-structured interviews	At the end of the study	Focus children
Informal conversations	Every session	Focus children
Group discussions	Three times (November, January and March)	Focus children and their partners
Learning journals and Problem-solving sheets	Every few sessions	Focus children
Children's game plans and completed games	At the beginning and at the end of Scratch and Alice projects	Focus children
Metacognitive Skills Instrument	At the end of the study	All of the Year 5 and 6 children (223 in total)

Below data collection strategies that were used for this study will be discussed in detail.

3.4.1 Participant Observation

My aim as a researcher was to find out what was happening when the children were making games in a context of thinking and learning. According to Patton (2002) the "participant-observer employs multiple and overlapping data collection strategies: being fully engaged in experiencing the setting (participation) while at the same time observing and talking with other participants about whatever is happening" (pp. 265 – 266). The difficulty I faced, however, was that having both the role of a teacher and of a researcher, sometimes had an impact on the students' interaction with me as their teacher. Hammersley and Atkinson (1995), talked about the danger of the researcher having too close a relationship with the people being observed which may affect their objectivity. Although there was a risk of subjectivity that I could not dismiss, I feel that having a prior knowledge of the children and the class culture helped me to convey their meanings better. Knowing me may also have helped the children to feel comfortable with my presence, which would not affect the natural state of the group adversely.

I have found that the key for participant observation is to write down brief notes straight away as soon as something significant happens, then write up full notes at the latest by the end of the day. Notes must be clear, so that they can be understood easily at a later date. Although it is important to give a detailed account, recording every single event in the setting can be challenging and can also be a distraction as the children might pay more attention to my notes than the activity. Therefore, I kept in mind the research focus and wrote down only simple bullet points when undertaking observations. Field notes were collected by examining the language children used for their 'self' explanations and group discussions; their gestures; and the context of their relations with their teacher, their peers and the technology in their classroom setting. My field notes before editing after each session were around 30 A5 pages. Through editing my notes, I expanded some points, therefore at the end I had around 40 A5 pages of data. I think maybe it would have been useful to use a sound recorder after the session to record my thoughts on the points that I had written down, as I realised that it was difficult to remember everything that I had observed afterwards.

3.4.2 Informal conversations

During observations, I used informal or conversational interviews with the focus children, which allowed me to discuss issues that arose, or question the children on significant events as they occurred. Because they were not formal interviews, this helped the children to feel more comfortable and open in giving their answers. Informal conversations are more than just observing the children's interactions; it is the process of allowing the children to reflect on what they are doing or saying that relates to the research purpose. It is a way of revealing and making their thinking visible whilst making games. This data collection tool allowed me to be aware of my students' experiences. There were 26 informal conversations were recorded in my field notes during participants observations.

3.4.3 Semi-structured interviews

I interviewed the ten focus children at the end of the project individually. The interviews were recorded using a sound recorder and transcribed. Each interview was around 8-12 minutes long. Semi-structured interviews were used to unfold the student's 'deeper self' and collect 'authentic data' (Marvasti, 2004). Having one-on-one contact with the students for a longer period enabled the children to reflect on their learning and thinking processes. By giving a 'walking tour' of their digital game design and their notes in their learning journal, I had the opportunity to clarify any unanswered questions about how and what they had learned when making their digital games. As I used semi-structured interviews, there was the flexibility for probing and using follow up questions. By talking about their design process and problem-solving activities, children were able to reflect on their own thinking and learning. These interviews were audio recorded and transcribed.

3.4.4 Learning Journals

In addition to studying the children's behaviour and actions in the classroom, documenting their individual thinking when solving problems was necessary. For this purpose, ten focus children were given a notebook to record their problem-solving tasks when making their games. By encouraging them to be aware of their own thoughts and then share them in either drawing and/or written form, I managed to get extensive data about the children's individual problem-solving activities. In other words, the learning journals provided an insight into their thinking processes. As some children found it difficult to decide what to record in their journals, I decided to provide them with a template to record their activities when solving problems. This problem sheet included questions and a space for the children to draw their problem as an alternative to writing down their comments. Some children completed these problem-solving sheets for each session, some every few sessions. Altogether, 27 problem solving sheets were completed during Scratch sessions and 34 during Alice sessions.

3.4.5 Group discussions

Group discussions with the focus group children and their partners from their class, took place every two months where the children had an opportunity to share their thinking with both their peers and with me. These discussions were video-recorded and transcribed to re-visit the children's perspective of their learning and interactions when making games. Video recording the discussions allowed me to study not only the students' answers, but their body gestures and facial expressions when interacting with their peers through conversation. In total, three group discussions were video recorded and transcribed; each was around 30-40 minutes long. It is important for the ethnographer to be aware of the sensitive issues surrounding working with young people in order to provide a safe space for dialogue. Although the group discussions provided me with some information about the students' learning when making computer games, the students were able to expand their explanations during the individual semi-structured interviews described above.

3.4.6 Metacognitive Skills Instrument

Although other data collection tools that were used for this study provided me with an insight into metacognitive skills that children developed, I decided to develop a Likert type instrument to collect further data to gain an understanding of how children describe their behaviours that represented metacognitive awareness when making computer games. Measuring metacognition using one approach is challenging; therefore, it is valuable to employ different tools to understand how metacognitive skills are applied in a game-making context. Class teachers and students were involved in the design of a Metacognitive Skills Instrument (MSI). The statements (items) were decided using the analysis of the data that had been collected by utilizing the other data collection methods. I administered the instrument in groups of six students. The students completed the self-report instrument anonymously on a paper. Although many children read the items themselves, I read out the statements for those students who had reading difficulties. Altogether 223 students completed the instrument. The process of creating MSI instrument will be discussed in section 7.3 in more detail.

3.4.7 Children's game plans and completed games

The children's game plans allowed me to see how well children could predict the outcome of their written scripts and use resources from the game environment to express their ideas.

The children's completed games were studied to examine the CT process that the children went through whilst they were working on their games. In total, I analysed 18 games that were created using the Scratch application and 15 games that were created using Alice 2. I mainly looked at the programming constructs and game mechanics that the children had used in their code scripts. One of the challenges of this process was, because a majority of the children had worked in pairs, it was difficult to decide which children were able to apply the specific skills or use constructs successfully. Another issue was my ability to recognize programming constructs in children's completed games. Although I am confident in my subject knowledge of these concepts, it might have been better to moderate this evaluation process to ensure the quality.

3.5 Data collection

The data were collected, over a period of eight months in a primary classroom setting in London. The school is larger than the average primary school with approximately 900 students. The school has a high proportion of pupils from minority ethnic backgrounds. There is also a high proportion of pupils who speak English as an additional language. The proportion of pupils with special educational needs is above average. The students mainly come from disadvantaged backgrounds, so the proportion of the children registered as eligible for free school meals is high.

In the first session, the elements of computer games were discussed with the class of 30 children. The question ‘what makes a game a game?’ was asked and the children were told to discuss this in pairs. They fed back their ideas, which had answers such as; ‘reward, timer, lives, points, aim, people, animals, story, characters, places and challenge’. They were then asked to explain the difference between a game and an animation. The common answer was ‘you can’t play an animation; you just watch it’. The children were told that during the game-making project they were free to:

- Move around in the classroom and look at what others were doing or share their work.
- Have discussions with their partners or other students
- Sit however they felt comfortable
- Provide feedback to their friends about their work.

For this study, Scratch 2.0 and Alice 2 applications were used for teaching computer game design. Scratch 2.0 is an online editor with a drop and drag 2D programming environment for creating animations and games. Scratch has instruction palettes in different colours for different functions that include coding blocks. These coding blocks can be dragged and dropped on the coding area to write scripts to make things happen. Scratch has a built-in image, sound and background library, but also allows users to create custom built ones or upload images from their computers.

Alice 2 is a 3D drag and drop object-based programming environment. Alice uses three-dimensional objects that can be programmed in the virtual world by dragging and dropping coding blocks that represent instructions in logical structures. The language structure that Alice uses is very similar to Java language and it allows syntax-free programming which prevents any typing errors that might occur in a text-based programming environment. In Alice, 'objects' are anything that can be programmed. Objects have names and properties and can perform actions called methods that are written in code. Although objects in Alice have pre-built methods for main tasks, new methods can be developed by programmers. Functions in Alice can be described as the messages that return information.

The children (16 boys, 14 girls) in a Year 6 class aged 10-11 years old used the Scratch application between September 2013 and January 2014 for four months, once a week, for an hour as part of their weekly computing session. This totalled 14 hours of programming. Although all 14 of the girls decided to work in pairs, only 10 of the boys chose to work in pairs and six of them opted to work alone. All of the focus children chose to work in pairs. They also worked with the same partners during Alice sessions. Table 1 show the peering for the focus children. There were, however, occasions where focus children worked with another focus child, non-focus child or alone because their partners were away. For instance, Child K worked with Child B during one of the Scratch sessions and created a game together as Child K's partner Child H was not in school. The children were allowed to explore the application at their own pace and look at some examples on the Scratch website. After a brief introduction to the Scratch Interface, they were given some example projects that they could complete themselves. They were then asked to discuss and plan their animation or game in pairs. Some children used the template for planning their project, but others decided to use blank paper.

Table 1: Peering for the focus children

<table>
<tr><th>Child</th><th>Age</th><th>Gender</th><th rowspan="6">PARTNER</th><th>Child</th><th>Age</th><th>Gender</th></tr>
<tr><td>Child T</td><td>10</td><td>F</td><td>Child A</td><td>10</td><td>F</td></tr>
<tr><td>Child C</td><td>10</td><td>M</td><td>Child G</td><td>11</td><td>M</td></tr>
<tr><td>Child K</td><td>10</td><td>M</td><td>Child H</td><td>10</td><td>M</td></tr>
<tr><td>Child M</td><td>10</td><td>M</td><td>Child S</td><td>11</td><td>M</td></tr>
<tr><td>Child B</td><td>10</td><td>M</td><td>Child J</td><td>11</td><td>M</td></tr>
</table>

A similar process was repeated for the game-making project using Alice 2. The children worked on their games between January 2014 and April 2014 for four months, once a week, for an hour as part of their weekly computing session. This also totalled 14 hours of programming. Similar to the Scratch project, the children were first allowed to explore the program and look at examples. They found the Alice programming environment very challenging; I therefore decided to model some projects that would help them to understand the structure and the functions of the application. In the first session, we discussed the interface of Alice 2 and I modelled some simple actions, such as inserting an object from the gallery and making object parts move. They were then left alone to try these out and play around with objects and functions. In the second session, I provided them with instruction sheets for making animations. Some used these, but some children decided to look on YouTube and the Alice website for other ideas. In the third session, I asked the children to plan their game. I had a storyboard printed out for them, but ten children (five pairs) preferred not to use these. The difficulty of the program might have had an impact on this as to program even the simplest action one needed to write relatively complex script in comparison to Scratch. For example, as a 3D program Alice allows students to program individual body parts; therefore, to make a character run, each part of the body should be programmed individually. The limitations of the program, such as having no option for creating custom built characters or backgrounds, also made the children change their stories couple of times.

3.6 Data analysis

I started the data analysis using a form of qualitative content analysis where initial coding started with previous research findings (Hsieh and Shannon, 2005). In content analysis using a directed approach researcher begin by identifying the key categories from existing studies (Potter and Levine-Donnerstein, 1999). Drawing on concepts from previous studies at the beginning of data analysis was very useful (Berg, 2001), especially for identifying the relationship between existing themes, data and emerging categories.

I used methodological triangulation, which can increase the validity of studies (Denzin and Lincoln, 2012). Although collecting data using many different methods provided me with a better understanding of emerging themes, I found it challenging to analyse the vast amount of data that I collected. In order to tackle this issue, as suggested by Miles and Huberman (1994), I organised the data into manageable units through constant comparison and coding to answer each focus questions separately. Focusing on research questions helped me to analyse the data in a more structured way as it was easier to identify categories from literature that is relevant to individual questions. I focused on the key themes and investigated similarities and relationships between categories, which helped me to make sense of the data. In order to make the coding process more efficient during constant comparison process, I created a table to record which data was relevant for answering specific questions. Each data segments from participant observations (PO), informal conversations (IC), semi-structured interviews (S-SI), Scratch games (SG), Alice games (AG), Scratch problem solving sheets (S-PSS), Alice problem solving sheets (A-PSS), Children's game plans (GP), group discussions (GD) and Metacognitive Skills self-report instrument (MSI) was numbered and mapped to the specific questions (Table 3).

Table 3: Mapping the data to specific questions

	RQ 1	RQ 2	RQ 3	RQ 4
PO (40 A5 pages)	1, 4, 8-12, 21-28, 30-40	4, 6-14, 17-26, 29-40	1-7, 11, 14-25, 28-40,	1-5, 7, 9-14, 16, 19-23, 25, 29-40
IC (26 records)	2, 8, 14-17, 22, 24-26	2, 4, 7-12, 15-19, 22-26	1-26	1-26
S-SI (10)	1-10	1-10	1-10	1-10
SG (18 games)	1-18	1-18	______	______
AG (15 games)	1-15	1-15	______	______
S-PSS (27)	1-27	1-27	1-27	1-27
A-PSS (34)	1-34	1-34	1-34	1-34
GD (3)	1-3	1-3	1-3	1-3
GP (31)	1-31	1-31	______	1-31
MSI	______	______	______	√

I analysed the data abductively, deductively and inductively, individually at first, then I moved back and forth between different data sets using the knowledge produced by each one of them. I then brought the data from different methods together which enabled me to interpret the data from a multidimensional perspective. The data was sorted again through constant comparison to refine the existing themes under each question and identify the emerging categories. As a result, each data set was informed, questioned, and enhanced by the others. I did not use any computer application for analysing the data, rather adopted a traditional approach where pen and paper were used as data analysis tools. In the following section I will explain the focus of each question with respect to data collection and analysis techniques.

RQ 1: What is the educational value of children's game-making activities in relation to thinking, learning and metacognition?

This question creates a frame to explore the learning benefits that game-making activities may offer and the link between thinking, learning and metacognition in game design contexts. The literature review provided information about what children could learn through game making and also the skills that they might develop, such as computational concepts; metacognitive skills; and 21st century competencies including problem solving, collaboration, communication and creativity. These themes were used to make sense of educational benefits of children's game making activities using the support of the data. The existing themes and data collection techniques used to address this question are summarised in Table 4 below.

Table 4: Data collection techniques and themes used for evaluating the educational benefits of game authoring activities

Educational benefits of children's game-making activities	
Categories from literature	**Data collection methods**
• **Learning in Curriculum Subjects** • **21st Century Competencies** (Critical thinking, collaboration, creativity, communication, problem solving) • **Computational Concepts**	• Problem solving sheets • Participant observations • Children's game plans • Children's group discussions • Semi-structured interviews • Children's completed games

The coding was completed in the format of 'open coding process' (Strauss and Corbin, 2008), where I read and annotated each interview script, field notes, children's problem-solving sheets and their completed game designs. I highlighted and labelled concepts on each data text (Appendix 1 and 2). As I continued to code, themes and categories that were different from previous studies emerged. For example, when analysing the data from the interviews, problem solving sheets and the field notes; 'Talking to self", ‘Talking in mind, in the head’ for managing learning were repeated many times. Therefore, conversation for regulating learning although can be seen as part of communication, was included as an additional category. I refined and grouped individual data segments around key themes which was very useful when discussing the findings. Table 5 shows the key themes that were identified when answering RQ 1 using data.

Table 5: Data analysis process for RQ 1

	Data segments	Existing	New
Learning in curriculum subjects	• PO 1, 8, 22, 32-36 • IC 8, 22, 15 • S-SI 1, 3, 6-10 • GD 1-3 • GP 1-31	√	
Collaboration	• PO 8, 11, 23-26, 32, 35, 37-40 • IC 2, 8, 22, 24-26 • S-SI 2, 5, 7-10 • S-PSS 1-27 • A-PSS 1-34	√	
Problem solving	• IC 14, 16-17, 24-26 • S-SI 1, 3, 5-10 • S-PSS 1-27 • A-PSS 1-34 • GD 1-3	√	
Computational concepts	• IC 8, 14, 25 • S-SI 1, 5. 7-10 • SG 1-18 • AG 1-15 • GP 1-31	√	

Communication	• PO 1, 4, 8-12, 21-28, 30-40 • S-SI 1, 3, 5-10 • S-PSS 1-27 • A-PSS 1-34	√	
Creativity	• PO 8, 22, 24, 27 • S-SI 1-10 • SG 1-18 • AG 1-15	√	
Critical Thinking	• S-SI 1-10 • S-PSS 1-27 • A-PSS 1-34	√	
Conversation for regulating learning	• PO 4, 8-10, 21, 23, 27-34, 40 • S-SI 1-10 • S-PSS 1-27 • A-PSS 1-34 • GD 1-3		√

RQ 2: How can children develop computational thinking skills whilst making their computer games?

The second research question investigates whether students can develop computational thinking (CT) skills through game making activities. Although this is briefly explained when discussing the educational values of children's game making activities, it is crucial to explore this area further to provide a sound understanding of the link between game making and CT. Computational Sophistication Framework for assessing children's learning when using Alice (Werner, Denner and Campe, 2014) and Scratch assessment package (Brennan and Resnick, 2012) were explored in depth to understand how game making activities facilitate CT skills. Case studies of 2 Scratch and 2 Alice games created by the students were shared to display the process for assessing the children's games in relation to CT skills.

The following table presents the existing themes and methods for data collection.

Table 6: Data collection techniques and themes used for investigating how game making can facilitate learning of CT skills

Computational Thinking skills	
Categories from literature	**Data Collection methods**
Assessing Computational Thinking Skills • Computational concepts • Learning behaviours • Metacognitive practices • Game mechanics	• Children's completed games • Participant observations • Problem solving sheets • Children's game plans • Children's group discussions

In order to evaluate the thinking process that the children went through when making games, their problem-solving sheets were analysed for patterns of CT skills. For this, I first formed a definition of CT to describe what CT consists of using the literature review in Chapter 2. I then looked at the programming constructs that the students applied when creating their computer games using both the Alice 2 and Scratch applications.

I examined the learning behaviours that students exhibited using the data from participant observations, group discussions and interviews. Finally, I studied the data from their problem-solving sheets, planning documents, participant observations and interviews by looking whether the students mentioned or displayed meta cognitive skills (planning, monitoring, evaluation, self-questioning, choosing and applying). The coding process was similar to data analysis for RQ 1. I reviewed each data segment to refine the existing themes and identify the emerging categories. Table 7 displays the data and the key themes for RQ 2.

Table 7: Data analysis process for RQ 2

	Data segments	Existing theme	New theme
Computational Concepts	• SG 1-18 • AG 1-15	√	
Learning Behaviours	• PO 4, 6-14, 17-26, 29-40 • IC 2, 4, 7-12, 15-19, 22-26 • S-SI 1-10 • S-PSS 1-27 • A-PSS 1-34		√
Game Mechanics	• IC 7, 8, 11 • SG 1-18 • AG 1-15	√	
Metacognitive practices	• S-SI 1-10 • S-PSS 1-27 • A-PSS 1-34 • GP 1-31		√

RQ 3: What is the role of conversational exchanges in metacognitive process and children's learning?

The third research question examines the role of conversational exchanges in metacognition. Firstly, the link between game making and conversational exchanges was explored using the findings of the literature review from previous questions. It was important to define what 'conversational exchanges' refers to and how it can be identified through different data collection techniques. The participant observations and children's group discussions were used to analyse the visible form of conversational exchanges. However, this was limited to what I could see and hear, and what the children included in their group discussions. To gain more in-depth information, a question was added to the children's problem-solving sheets and they were asked to record any conversation that they had with their friends, teacher, computer or their ‘self’. Semi-structured interviews were used to unfold the student’s ‘deeper self’ and collect ‘authentic data’ (Marvasti, 2004) about their conversations and how this shaped their thinking. The existing themes and data collection techniques used to address this question are summarised in Table 8 below.

Table 8: Data collection techniques and themes used for examining the link between conversational exchanges and game making

Conversational Exchanges	
Categories from literature	**Data Collection methods**
Types of conversation • Private speech • Social speech • Inner speech	• Participant observations • Children’s problem-solving record sheets • Children’s group discussions • Semi structured interviews

Participant observations were used to identify when and how children’s thinking became visible. Additionally, the children’s learning journals and problem-solving sheets were analysed to see whether the children used conversational exchanges in their problem-solving process. The learning journals and the problem-solving sheets that the children completed were also useful for making their thinking visible as children kept a written record of their strategies for solving problems and explained the process that they went through. Table 9 shows the data segments and the key themes for RQ 3.

Table 9: Data analysis process for RQ 3

	Data segments	Existing theme	New theme
Private speech	• PO 1-7, 11, 14-25, 28-40 • IC 1-26 • S-SI 1-10 • S-PSS 1- 27 • A-PSS 1-34 • GD 1,2,3	√	
Social speech		√	
Inner speech		√	
Unintended collaborative talk			√

As discussed in section 2.2.2, there is no an agreed system of analysing children's speech practices, and many studies focus on private speech. In contrast, this study aims to examine the children's utterances from private, inner, social and other uncategorized perspectives.

RQ 4: How to measure metacognition in a computer game design context?

The final research question considers approaches to the measurement of metacognition. To answer this question, firstly, the data from participants observations, children's learning journals and group discussions were used to determine the metacognitive skills that were visible whilst the children were working on their games. Secondly, the data analysis from previous research questions and the relevant studies were used to define a framework for metacognitive skills that would be useful for measuring metacognition. The existing themes and data collection techniques used to address this question are summarised in Table 10 below.

Table 10: Data collection techniques and themes used for measuring metacognition

Measuring Metacognition	
Categories from literature	**Data Collection methods**
Metacognitive skills • Planning • Monitoring • Evaluating	• Participant observations • Game design planning sheets • Children's learning journals and problem-solving sheets • Semi-structured interviews • Children's group discussions
Measuring Metacognition • Qualitative methods (e.g. Observations and learning journals) • self-report questionnaires / rating scales	MSI self-report instrument

In this research, in order to evaluate the metacognitive skills that children used when making games, participant observations, interviews, journal logs, problem solving sheets and a self-report instrument were used. Table 11 displays the purpose and issues of the methods that were used for assessing metacognition in this study.

Table 11: Methods used for assessing metacognition

Method	Description	Benefits	Issues
Semi-structured interviews	Children were interviewed after the game design project and asked to share their thoughts about their experience.	-Opportunities for probing -Detailed explanation	-Difficulties with remembering every detail from the learning experience -Issues with verbal reporting -Time consuming

Journal logs	Children were asked to keep a record of their mental activities.	-In depth data -Time to reflect	-Not being confident in writing -Confused about what to record -Too much data to analyse -No opportunities for probing -Lack of time for writing -Distraction from the task
Problem solving sheets	Children were given a template to keep a record of their problem-solving activities.	-Structured so it provided support for a focused explanation -Making thinking visible -Giving information about the process	- Issues around writing -Probing is not possible -Time consuming
self-report questionnaire	Children were asked to describe the metacognitive strategies that they used by rating statements.	-Easy to use with a large group -Structured	-They may not understand the statements -They may select the answer to please the teacher
Participant observation	Children's interactions were observed when making computer games and ethnographic records were kept.	-Non-verbal -Opportunity to observe the process	- Time required -It might distract the learners -Difficult to observe a large group

In order to discover the children's perception of the metacognitive awareness that they developed when making computer games at a larger scale, a metacognitive skills self-report instrument (MSI) was developed and used with the 223 children. A Mixed Anova (Question as the repeated measure, class and gender as independent-samples factors) and with Greenhouse Geisser correction was used to analyse the interaction between question and class; and gender and year group. When using Likert-type scales, it is necessary to calculate and report Cronbach's alpha coefficient for internal consistency reliability (Brown, 2011; Gliem and Gliem, 2003) therefore, factor analysis and Cronbach's alpha were used to measure the validity and internal consistency reliability of the instrument. More detailed analysis of the instrument and the conclusion drawn can be found in Chapter 5.

The detailed analysis of the methodology and data collection and analysis techniques that are discussed for each question illustrates that different qualitative and quantitative data collection and analysis techniques have been used as part of this research. The next section of this chapter considers the ethical issues associated with the research.

3.7 Ethical Considerations

In research, informed consent needs to be sought and may be withdrawn at any time, and it is also important to use direct talk regarding the continued willingness to participate (Cassell, 1982). Although the school had a generic form signed during the child's registration to allow the school to study the children's work, because this was part of a PhD study, I created an information sheet and a consent form in line with BERA (2011) ethical guidelines for both parents and the children (Appendix 3 and 4). A permission letter regarding observing children working on their game designs; interviewing them; and studying their written learning log, photos, videos and audio was prepared. I listed the data collection activities on the consent form which included: taking part in the study, being observed by the teacher, keeping a journal, participating in audio recorded interviews, and taking part in video recorded group discussions. All of the parents agreed for their children to take part in the activity and be observed. Fourteen out of 30 parents agreed to permit their child to take part in all data collection activities. All ten of the focus children were selected from this list. I only selected ten focus children, as the size of the sample would be large enough to provide me with extensive data. Sixteen parents selected some of the data collection activities on the list. I provided all of the parents with an information letter and asked them to discuss this with their child. This also allowed parents to find out about the topic of my study and their children's involvement in the research process.

BERA (2011) guidelines suggest that participants' identities should not be revealed, and their names should be changed. In my data analysis when I mention children, I use names such as 'Child T' and 'Child A'. I also covered their names on their planning and problem-solving sheets. When transcribing group discussions, whenever a child mentioned the name of another student, I again changed this using the 'Child T' format. I did not use any extracts from the videos or audio recordings in my presentations about this study.

Fisher (1993) suggests that when children are old enough to understand the purpose of the research, they need to be asked for informed consent, in addition to parental consent. He also talks about how children's thinking enables them to understand scientific principles and researchers should respect and enhance this by giving a full explanation of the research project in child friendly language. In line with this, I explained the purpose of the study to the children verbally, so that they were aware of the aims of the research project and then gave them a consent form. I also informed them that their participation was voluntary and that they may withdraw from the study at any time. As Flewitt (2005) suggested, it is difficult to regulate ongoing consent, but I wanted to make sure that the children were happy to take part in all of the stages of this study. However, as the activities took place during our computing lessons this made it more difficult for them to withdraw from the activity. If there was any situation when a child did not want to participate in the study, but continue with the activities, I would then exclude them from the data collection process. It would be difficult to send them to another class, as this task is part of their curriculum targets, which they needed to complete. I gave the children information about the research procedure so that they knew what to expect during the study. The children did not ask any questions about the study.

Before the group discussions and interviews, I asked the children if they were happy to be included. I had been their teacher for years and I believed that they felt safe with me and were therefore able to establish an open dialogue. One example of this was when on one occasion, one of the children did not want to take part in the group discussion because he felt very tired. I specifically had the group discussion sessions at the end of the day where children were allowed to select an activity of their choice. I let this child to join another class (the same age group) and take part in a reading activity which was his choice. I discussed this with the class teacher prior to the session.

During the video recording of children’s group discussions, the camera was positioned in an angle that would reduce the filming of children’s faces. The school’s camera was used for filming three group sessions as the school’s use of technology policy does not allow filming using personal devices. The video file was transcribed directly and the file itself was kept in an encrypted computer in the school. This was also the case for the audio files. I used school’s devices to record the interviews with 10 focus children and transcribed them directly. I deleted the both the video and audio files when I left working at the school as this was the requirement of the school’s policy.

During this project, I had to constantly meet the demands of two roles: being a teacher and being a researcher. This might have had put a pressure on the participants to take part in the study (Ebbs, 1996) because of their concerns around how their refusal might impact on their relationship with me as their computing teacher. This might look unethical, however, as Edwards and Chalmers (2002) argued, the research can be carried out ethically if this pressure on participants can be managed. I explained to the students (and also included in the information sheet for parents and children) that they are free to decide whether they would like to take part in this project and there will be no negative consequences if they decide not to participate. I also explained that if they are not included in the study, they will be completing the same game design activities with another class that is not part of this study. They knew that I would be teaching other classes too.

Another issue that I discussed with children was the confidentiality of the data. I explained to children (and also included in the information sheets) that neither their identifies nor the raw data would not be available to others. Although I mentioned that I will use direct quotes from the data, I would ensure that this will not jeopardise the anonymity of the participants. However, confidentiality during group discussions was tricky as the children needed to know that they could not share the data from their group discussions with others that were not part of the focus group. Having a discussion with the students about risk and benefits of this study before the project was very useful in this respect.

In summary, in this chapter, I have discussed my personal approach to research paradigms and provided detailed information about data collection techniques that I used for collecting data. I shared information about the data analysis process and explained how I coded the data in relation to each specific research question. Ethical issues were considered and challenges around taking a dual role of teacher and researcher were clarified. The existing themes and new categories identified in this chapter will be discussed in the next four chapters to show how findings from the data of this study was used to answer the research questions.

Chapter 4: The educational value of children's game making activities

This chapter aims to answer RQ 1:
What is the educational value of children's game making activities in relation to thinking, learning and metacognition?

In Chapter 2, a literature review was carried out to identify the skills and competencies that children developed whilst making their own computer games. In this chapter, the data from the children’s completed games, game plans, problem solving sheets, participant observations, group discussions and semi-structured interviews are examined in detail to identify existing and emerging categories in relation to children’s learning in computer game design context. These themes are then discussed using examples from the data to explain the educational benefits of children’s game design activities.

As discussed in Chapter 2, there have been a number of studies that explored children’s game making activities focusing on their impact on children’s learning (e.g. Denner, Campe and Werner, 2019; Kafai and Burke, 2017; Ruggiero and Green, 2017). Some studies addressed is the impact of game making on children’s learning of specific curriculum subjects such as literacy and Mathematics (e.g. Ching and Kafai, 2008; Howells and Robertson, 2012; Ke, 2014). Other studies explored the relationship between children’s game design activities and skills such as collaboration, communication, problem solving, critical thinking and creativity (e.g. Akcaoglu, 2014; Bermingham et al, 2013; Liao, Motter and Patton, 2016). The recent focus on teaching children how to code has also encouraged researchers to explore how game making provides opportunities for teaching CT concepts (e.g. Denner, Campe and Werner, 2019; Kafai and Burke, 2014). Only a few researchers have focused on the link between game making and metacognition (e.g. Games and Kane, 2011; Vos, Meijden, and Denessen, 2011).

As outlined above, the literature was useful to identify existing themes in relation to educational benefits of game design activities. The categories that emerged from the literature were: learning in curriculum subjects; 21st century competencies (Critical thinking, collaboration, creativity, communication, problem solving); and computational concepts. Below, I will discuss the findings under each category.

4.1 Curriculum subjects

This study did not aim to investigate children's learning in any specific curriculum area, although the task itself provided opportunities for developing literacy and Mathematics skills. Children sometimes planned their games on paper first, and sometimes developed their games as they went along whilst making their games. Eight students mentioned writing during the interviews. They suggested that game design encourages them to write, just like writing a story, as they needed to plan the narration script for their game before they start creating it. Child T expressed this as:

> *"First I write a piece of script like how the steps, then I think to myself, 'how can I make it better?'"*

Child B mentioned using writing for planning and also for problem solving;

> *"I write down the steps for my game as a list, so I won't get mistakes in my game then I make. If I have a problem, I write the steps down too, because it helps you to solve it quicker."*

Other students also shared similar comments about how they use writing for planning their games and organizing their ideas as they did in literacy lessons and explained how this helps them with identifying their errors before start creating the game.

> Child C: *"First you have to write down your ideas on paper to see what you are going to do, and then when you finished, you get a laptop and you look at your ideas and then put it on Scratch".*
>
> Child M: *"Writing steps helps you to think about what you going to do. It is a bit like story telling really".*
>
> Child H: *"I like writing on a paper, it helps you to see mistakes you made that you wouldn't normally see".*

Child J: *"For me, it is like writing a story. You have to have characters, a story, and actions, climax. We use planning like this one in literacy lesson too".*

Children's planning sheets also showed that children used writing to plan their games, including characters, background and storyline. Some children wrote down the detailed actions and records of the conversation that should take place between characters during their games. Figure 4.1 shows one example of this. The children had many opportunities for writing during game design activities; they used writing as a medium for organizing their ideas before creating using a computer program. This might have had an impact on their language development as Robertson and Good (2004) found in their study. However, it is difficult to identify the scale of this as the children would have received support towards the development of these skills during other lessons. Additionally, it would be very difficult to measure the change in children's writing skills without evaluating these prior to the game design activities.

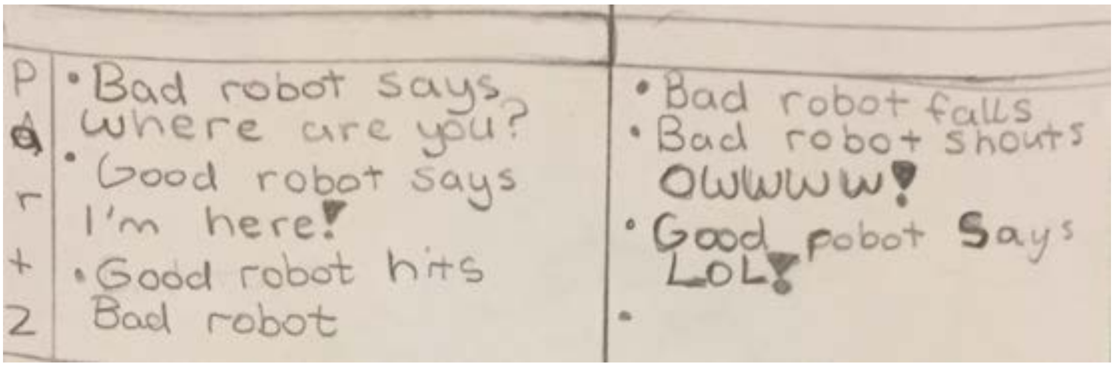


Figure 4.1: Records of a dialog in a game design sheet

There were rare occasions where children shared how game making helped them to solve Mathematics problems. During a maths lesson, when discussing the strategies that children used for solving Mathematics problems that involves transferring patterns from cubes to nets, Child C reported that he visualised the cube as it was on the Alice 2 screen. He added that he continued to visualise where the pattern would appear. He mentioned the 3D feature of Alice 2 allowing him to visualise the cube, as it is also a 3D shape. He recorded this in his game journal (Figure 4.2).

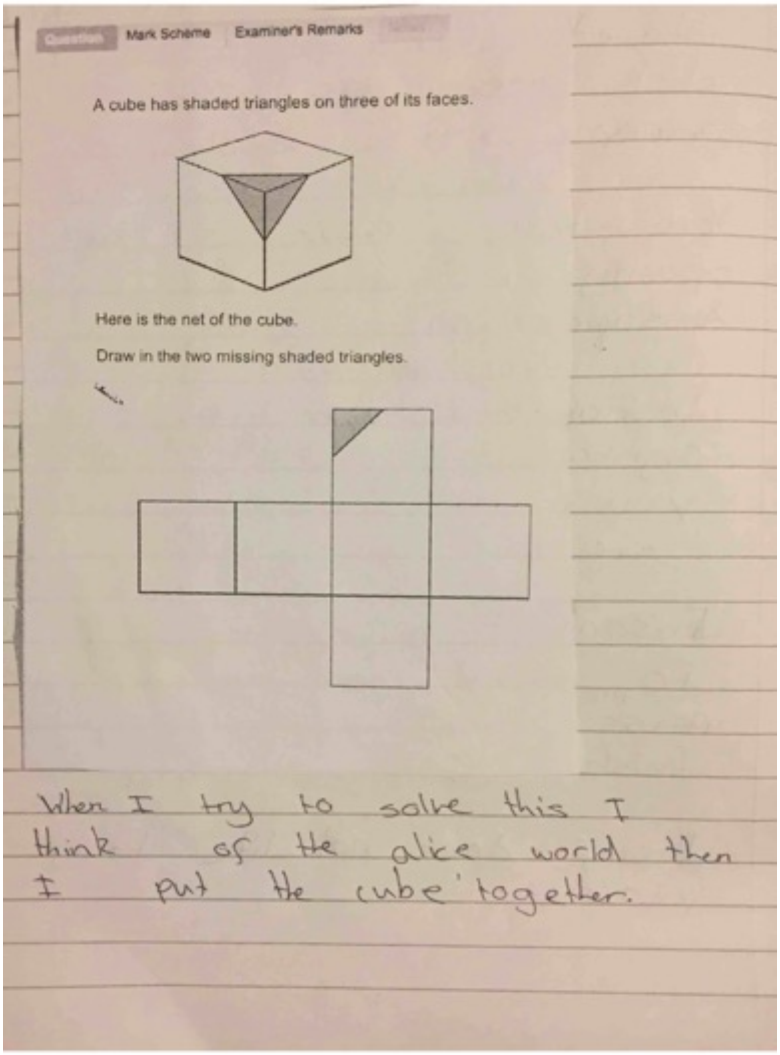


Figure 4.2: Child C's log entry of mathematical problem

He was able to use mental folding which is a spatial visualisation ability (Linn and Petersen, 1985; McGee, 1979) to imagine where the pattern on the cube (3D object) would look like when it was transformed into a net (2D shape). This example illustrates that game making can help children to develop skills that will help them to solve problems in other curriculum subjects, in this case Mathematics.

Learning about Mathematics was mentioned during interviews by four children. They talked about how they had to use their knowledge of degrees and coordinates; negative numbers; decimals; different functions such as smaller and bigger; and estimation to program their sprite in Scratch. For example, Child H said:

> *"You see when we were exploring with Scratch, I didn't realise that the bottom of the screen was negative, and the top was positive. My sprite kept appearing in the wrong place. Then I asked my partner and he told me it is like coordinates. So, I put the correct numbers for x and y in the go to code and it worked. My car moved to the beginning of the screen. It wasn't in the middle anymore". (Extract from Interview transcription)*

Child M talked about how he used his knowledge of shapes and angles to complete a task:

> *"You kind of need to know some maths. Because let's say you are going to draw a square, you can't do if you don't know that it has right angle, that is 90 degrees. But it was difficult to daw a triangle. We tried 60 degrees, then 72, it didn't work. But I then thought of the pattern and I knew that it had 120 degrees. That was a bit hard, but you try and learn"* (Extract from Interview transcription).

Sharing a similar experience Child T referred to issues around using operators and x /y coordinates:

> *"I forgot which one was bigger and which one was smaller, so apples were falling from wrong places. I tried again again and then it worked…The same happened when I was changing x for apples, I thought x was for top and bottom position not left and right. So, apples were coming from left of the screen, not falling from top. My partner said change the y not x. I tried it and yes, she was right".*

During the interviews six focus children shared examples of applying their Mathematics knowledge to create their games using Alice. They explained that in Alice there are many options for objects such as height, width and distance between them. They also discussed these properties can be set using built in functions within the program or their own ones (custom).

Child C commented:

> *"It is a bit tricky to make your character do something because in Alice, you get many options to choose from, if you want to program*

your object. Like let's say you want to move your character, it will ask you first up, down, left, right, forward etc. Then you need to select the amount like 1m, 0.5 m or you can choose math and enter your own. It is kind of good too, because you can decide. But is a bit hard I think" (Extract from Interview transcription).

Child K said:

"You know you can decide where to place your character. Like how far from another object or from the edge of the screen. This is good because you decide the distance and you can use your own number. But when I moved the body of my character, something went wrong and the arm did not move, it stayed. It was funny. Then I had to program the arm. That took time." (Extract from Interview transcription).

Another four children also mentioned using maths to set heights, widths and position of their characters. Although this shows that they used mathematical operations and expressions; angles; and decimals, it is not clear whether the program helped them to learn any mathematical concept. It seems likely the program provided them with a space to apply these skills. However, I would suggest that even if they did not know how to use these mathematical functions before the project, they were able to use them through try and error during this project. The children were not assessed on their knowledge of mathematical concepts prior to this study; therefore, it would be very difficult to make a case that creating games using Alice and Scratch helped them develop their skills in Mathematics.

4.2 21st Century Competencies

In addition to core subjects such as Mathematics and literacy, in the recent years, curriculum developers have been focusing on skills and strategies that would prepare children for their future learning and careers (Alismail and McGuire, 2015; Lombardi, 2007). Many studies listed 4Cs; creativity, communication, critical thinking and collaboration as the main 21st Century skills (Kivunja, 2015; Reeve, 2016; Romero, 2015). Below, I will discuss whether or not game making activities provide opportunities for children to develop these four main skills. I will combine problem solving with critical thinking because of the overlapping nature of these two skills.

4.2.1 Collaboration

Vygotsky (1978) described learning as a collaborative activity and argued that social interaction was central to learning and development. This has been supported by other theorists who suggested that learners construct meanings through their interactions with others (Ernest et al, 1991; Prawat and Floden 1994). Working collaboratively with peers, students practise skills such as sharing ideas, making decisions and solving problems, which can be facilitated through collaborative game making activities. Bermingham et al. (2013) discussed this collaborative element of game making when they explored the use of collaborative game making as a pedagogical model. They found that "game making can also support the development of 21st century competencies like creative problem solving, collaboration, ICT literacy, systems thinking, and positively affect engagement in STEM subjects" (p2).

When I asked the children to decide whether they would like to work either with a partner or alone, some chose to work alone, but they still walked around and had different forms of interaction with other children in the classroom. For example, some asked for help; some looked at others' work and asked questions or made comments; and some shared their work and asked for feedback.

One interesting point raised from the field notes was that those who worked with a partner also had conversations with other children in the classroom. This shows that game making as an activity can encourage children to share and discuss their work, whether or not they chose to work in pairs or alone, and that working in a pair did not limit interaction to the other in the pair. One factor that could have impacted on this was the way that I facilitated the game making activities. For example, adapting a flexible approach to movement and interaction within the classroom allowed the children to walk around the classroom to look at others' work, give feedback and ask for help.

The field notes demonstrated that, although most of the children usually worked directly with their partner, on many occasions they also walked around the classroom to look at others' work to either make suggestions or get some ideas for their own games. Some children asked for help from others. There was a constant discussion between the pairs and other game designers, which enabled them to evaluate and reflect on their own work and to re-organise their ideas. This collaborative approach to game making had motivational power by providing support for the children from their peers when they needed it. This brings a question to mind as to whether not having this support from their partner would disengage some of the children from the activity.

The records from the participant observations showed that some children did give up when faced with a challenge, but others persevered and did not stop until they had found a solution to their problem. The following record from participant observations shows the interaction which took place between three children during one of the games-making sessions demonstrates the importance of the collaborative element of game design activities in encouraging children to find solutions to problems.

> *Child T and Child A were making a game together using Alice application. They had a problem. They couldn't stop spacemen becoming smaller as they got closer to the spaceship. Child T looked for information on Google, but she couldn't find anything. It was apparent from her facial expressions and body gestures that she was getting very annoyed. Child A suggested that they should re-start their work, however, this did not solve their problem. At this point Child T started to become disengaged. She did not answer Child T's questions, she just looked at the screen. Child A called Child K to help them. He wanted to quickly fix the problem, but Child T wasn't happy with this. She asked Child K to show how to stop the*

spacemen becoming smaller. Rather than just doing it, she then took the mouse from Child K and completed the task. Child T was disengaged with the activity when she couldn't solve a problem. Her partner suggested that they should re-write the script, but she didn't show any interest in this. It was only when another child offered to help them with their problem that she engaged with the game making activity again (Extract from fieldnotes).

This shows the importance of allowing children to face challenges and giving them the opportunity to work collaboratively with their peers. This was also highlighted by Ryan and Deci, (2000), who noted that "intrinsically motivated a person is moved to act for the fun or challenge entailed rather than because of external prods, pressures, or rewards" (p3). We might assume that those children who persevered to complete their tasks without any external reward found game making an intrinsically interesting activity. This was visible in their behaviours during game making sessions. The following example from participant observations shows how children thought that game making project was different than ordinary sessions.

Child K left his partner and went to look at the game of Child B and Child J. They were creating a football game using Scratch where the players get a point for scoring a goal. Child B was unhappy as he argued that whenever he hits the space bar to kick the ball, the game doesn't directly execute the code and it takes time for the ball to move to goal. Child J agreed with him. Child K told them that this is similar in FIFA game and he suggested that there is a glitch in the game. Child J and I agreed with Child K and went on the Internet to search if other people had the same problem. Whilst they were searching on the Internet, Child B said that it is nice to be able to decide what to do when there is a problem rather than asking to a teacher or waiting for permission. Child K responded "Yeah, and it is nice that we are doing something we like". Child J and Child B agreed with him and Child J replied as "Yeah, it is fun, isn't it?". Child K and Child B agreed with him (Extract from fieldnotes).

One reason for this might be that many of the children in the classroom are interested in playing games, therefore making games that they can play or can be played is relevant to them, making learning more meaningful. Their comments also show that they see the game making sessions as different than their other lessons. During the semi-structured interviews children were asked if learning with game making was different than learning in other lessons. Child H answered this as:

> *"It puts your brain into focus. Because, people think maths and literacy is really boring, when it comes to game design it is really exciting, so they focus more".*

Ryan and Deci (2000, 2016) argue that many activities in schools are not designed to be intrinsically interesting and creating activities that would motivate children to self-regulate their activities is a challenge. An important question at this point is whether those children who were not engaged with the game making activity could be extrinsically motivated using praise or rewards.

During the interviews Child A stated;

> "*We learned how to use our imagination and how to cooperate because we worked in a pair. If you work by yourself you may not do much, because two heads are better than one. It is also good for revising; you can go over with your friend*".

This brings another question to mind: can the enjoyment and achievement that children gained by working with a friend contribute to intrinsic motivation, or is it best defined as an external award? Furthermore, can students become more intrinsically motivated in a flexible learning space that offered during game making projects? This will be discussed in conclusions, in Chapter 8.

Children's problem-solving sheets had many records of how they worked collaboratively with their partner, especially when they could not solve a problem. Child M expressed this;

"*I discussed with my friend how to save it because we might lose it".*

Another child reported, *"I discussed with my friend how to open the web gallery".*

Children's problem-solving sheets also provided many examples of how having a specific issue encouraged them to have discussion with their peers. Some of these specific problems were:

Child A: *"What the next steps was and how you get objects in your world".*

Child G: "*Where to put the objects?"*

Child T*: "How are we going to make the robot say boo?"*

Child B: *"How can we make score and timer"?*

Child H*: "How we can change the size?"*

Child M*: "Where is the hide and show button?"*

Child S*: "How are we going to make characters move"?*

There were also a few comments about having more generic discussions with partner/s rather than focusing on a specific problem, which shows that children constantly shared ideas with their peers and made decisions collaboratively. Some of their reflections about what they talked with their peers were:

Child M: *"How to keep up with the tutorials"*

Child A: *"What actions to use for each sprite"*

Child T: *"Which game we can make together"*

Child S: *"What should be our game about?"*

Child H: *"Shall we use characters from films?"*

Child K: *"Could we sell our game?"*

Talking to a partner and making decisions together was also mentioned during individual interviews. Child K explained this:

"You see, if I can't think of something, then I start talking to my partner. We decide on things together".

Child C mentioned of getting less frustrated during game design activities because having a partner was like a helpline service:

"I get frustrated when I can't do something and sometimes, I just stop because I can't be bothered anymore. But I have a partner for this, so think like having a helpline just to yourself, that is very helpful".

Other students also mentioned having fewer worries and less frustration because of working with a partner*:*

Child H: *"I think if I didn't have my partner, I would give up because sometimes it is frustrating, when you can't make the code work how you wanted."*

Child C: *"I am not worried much because if I can't find the error, I can ask my partner or another friend. Some you tube videos are also good, it shows you how to do things."*

The data analysis shows that game-making activities support children working collaboratively with their peers, especially when they are solving a problem. Additionally, the data illustrate that working with partners motivates children to continue to look for solutions rather than worrying and getting frustrated. It is also important to remember that game design does not automatically provide a collaborative learning environment; it is the teacher who will decide how the classroom organized when children create computer games. For example, if children in this study were not given an option of working with a partner or having the freedom to ask questions to peers in the classroom, then their experience and conclusions might be different.

4.2.2. Critical thinking and Problem solving

Kivunja (2015) describes critical thinking as "an individual's ability to use a number of his or her general cognitive processing skills which fall into Bloom's (1956) high-order thinking levels of analysing, evaluating and constructing new ideas or creating" (p.4) and he suggests that critical thinking is a 21st Century skill because it encourages learners to think at a deeper level and to formulate many different solutions for unfamiliar problems (Kivunja, 2015). According to Trilling and Fadel (2009), critical thinking is an essential skill for problem solving as it enables learners to make logical judgements and decisions. Sternberg (1986) explains critical thinking as “the mental processes, strategies, and representations people use to solve problems, make decisions, and learn new concepts” (p. 3). Critical thinking involves having discussions about ideas and problems, and the ability to share viewpoints with justifications. It requires the ability to be aware of your own strategies and organise and apply these to manage cognitive activities such as decision making and problem solving, at the right time. From this perspective, critical thinking can be seen as a form of metacognition (Kuhn,1999; Kuhn and Dean, 2004). Furthermore, it sets the foundations for learners to use range of digital tools to present their original ideas.

Critical thinking is a crucial part of the problem-solving process as, without critical thinking, learners would not be able to evaluate their own or others’ ideas and formulate solutions. Previous research has suggested that children learn problem-solving skills through game making (e.g. Akcaoglu 2014; Bermingham et al., 2013).

In my study, both participant observations and children’s problem-solving sheets showed that constant problem solving was at the core of the game making activities. The children’s problem-solving sheets, where they recorded some of the challenges that they faced and how they solved them, provided me with detailed information about types of problems that they had. When using the Scratch application, most of the problems were related to the coding of the game, although some were about the design of a character or background. When using the Alice 2 application, the children’s problems were all about the coding of the game. The reason for this might be that Alice 2 does not allow the children to design their own characters and backgrounds; they were limited to what was available in the application library and did not need to spend time on creating their backgrounds and characters like they did using Scratch. When analysing children’s problem-solving sheets, this was also visible in the problems that the children recorded when making their games. In Scratch, the children solved problems related to script, such as creating a variable. However, they also had different problems, such as making sound work, locating sound files, duplicating a character, and finding a costume. When designing a game using Alice 2, the children's problems were mainly writing the code to make an object do something, for example, how to add a score, move an object by itself, add a timer (variable), or move a left arm or right leg (of a robot).

In their problem-solving sheets all of the ten focus children reported helping others to solve problems or asking for help from their friends. One example of this was shared by Child K on his problem-solving sheet:

> *"We didn't have any problem, but our friends did. They didn't know how to open the gallery. Some of them did but they did not have some of the characters*."

Child M reflected:

> *"I had a problem with finding the ramp which my friend helped me with, and she told me it was in the skate park section."*

Eight students wrote about asking for help. Child A expressed this:

> *"My problem was how to get to duplicate I solved it by asking a friend."*

Child B reported as:

> *"We tried to solve it with (Child J) but, he didn't know it. So, we asked (Child K). He is really good. He knows how to make games. He solved it so fast. He said he will teach us more stuff".*

This shows that collaborative problem-solving activities were taking place whilst children were working on their games. It also illustrates that children were able to identify and formulate problems, which can be seen as critical thinking. Some children also mentioned solving problems by talking to self. Child H explained this as:

> *"My problem is how to make the sound work. I worked this by talking to my self and not giving up."*

Child B also expressed a similar point:

> *"I tried everything, but the variable didn't work. So, I said, I ask myself and think more, then I did the correct one and it worked".*

The data from participant observations shows that identifying and debugging coding errors and solving problems related to the design of the games were also observed during game making. The children tested their code frequently to check that it worked. When it did not, they tried to identify the problem - sometimes alone, sometimes with others - and then designed solutions. The written records of informal conversations with the children highlighted that they evaluated their work and checked for errors during game making more than for any other lesson. Child K reported the reason for this is as;

> "*You can find your mistake very easy when making games because if the code is wrong, game doesn't work*".

In another record from participant observations during a Scratch session, Child A and T had a conversation about problem solving.

> *Child A was frustrated as their game wasn't working. Child T shared some solutions, but Child A did not want to try. She told Child T that there are always problems and she is fed up. Child A assured her that they will solve it and their game will work. Child T complained that they are always something that not working. Child T told her that they have managed to solve them all and they will work it out (Extract from fieldnotes).*

During the interviews, when asked what they think they learned by making games, seven children mentioned 'problem solving' as one of the skills that they developed. Child H described this as:

> *"I think I learned imagination and a lot of skills. Designing, imagination, problem solving. I learned to do it by myself, not always many people around to help".*

Child K stated:

> *"When I had a problem, I would try new things to see if I could make it work or think about adding more things to improve it. I think I am*

getting better at solving problems because I solved so many and helped other people too".

Child M commented:

> *"I solved, I think, maybe 100 problems. I helped others too. But it wasn't hard because you could test and find what is wrong yourself. Once you know why it is not working, then you start thinking about solutions. I can code better now so I have less problems".*

Child A expressed her frustration:

> *"It wasn't easy. Always something did not work. We could solve some problems, but some of them were very hard, we had to ask for help. I didn't like it that much. It is ok. Maybe creating a story would be ok. Variables were very hard. The timer did not work. But we made it work later. We didn't add it for all variables, so it didn't work. I guess I am getting good at it now".*

The findings of data above show that the children solved many problems during game making project. It also highlights the importance of working with a partner who will be able to provide support and keep each other on task. Some children also mentioned getting better at problem solving because they had to tackle many problems.

4.2.3 Communication

Many studies list communication as one of the main 21st Century skills (Binkley et al., 2012; Kivunja, 2015). With the development of the digital technology in the recent years, digital communication specifically has come to be seen as a skill that is essential for 21st Century (Griffin, Care and McGaw 2012). Communication is all about understanding ideas and then exchanging these using different mediums such as speaking, writing, coding, typing using a computer or presenting using an application. Piascik (2015) suggests that communication involves "sharing thoughts, questions, ideas and solutions" (p. 1). Listening is also an important part of the communication process of course. During game design activities, communication can take different forms. For example, it may involve children sharing their ideas with their peers, but also can mean children communicating their ideas with the computer by writing the script to turn their ideas into a game.

The field notes from my observation show that the children constantly communicated with their friends. They talked about their storylines, characters, backgrounds, code errors and rules. They discussed their solutions and actions to solve problems before they put them into practice. They gave feedback to each other and made suggestions for improving their work. This shows that communication was a core part of their game making. During the data analysis, I focused on six actions that represent communication activities. These were: talking about what went wrong; telling their story/narrations to a friend; making suggestions; asking questions; discussing (what to do next, what to change); and playing each other's games and making comments about it.

Eight children mentioned asking for help during their interviews. For example, Child H suggested that he first tried to solve a problem himself, but if he could not, he asked his friend. He explained this as follows:

> "*What I do is, if I have a problem, like the character is in the wrong place, I will try to move to different place by changing the code, but if it doesn't work, I will ask my friend".*

Child K talked about how they changed their game because they had some very useful feedback from another friend:

> *"We asked people to play our game and tell us what they thought. Most of them just said, it was nice, but Child A said having a timer would make it more interesting. So, we tried and created a timer variable; I think it is better now".*

Child M made an interesting point during the interviews, he stated that during game making it seemed easier to talk to people and help each other because you do not get told off for talking:

> *"You see, let's say literacy, yeah, you can't just tell people about your story, the teacher asks you to read at the end, but not everyone, some, yeah, you write quietly, but here you can play some one's game and tell them what you think, you don't get told off for it".*

Again, this brings the question of whether classroom organization and teaching approach also play a role in increased communication and collaboration activities during a game-making project. Likewise, children's problem-solving sheets also had records of children talking to their friends about problems they faced whilst making games. Child B stated:

> *"I tried to make a character create kind of stamp of itself and then disappear, but it didn't work. I tried long time. So, I asked Child J, he didn't know but we talked and solved it".*

Child T shared:

> *"I was annoyed because the game wouldn't work, tried couple of times, then I almost stopped, but then I said why not ask someone, my partner was ill, so Child K gave me some feedback, then I tried different things and it worked".*

Both examples show that communicating with another peer, whether for asking help or feedback, helped children stay on task and try different solutions, which can also be seen as helping them to develop persevering skills.

4.2.4 Creativity

Robinson defines creativity as "the process of having original ideas that have value" (2009, p.114). Compton (2007) lists enquiry, evaluation, ideation, imagination, innovation and problem solving as the components of creativity. Buckingham and Burn (2007) explain creativity as "a combination of children's imaginative acts and conceptual thinking". I therefore define creativity as the process of presenting ideas and thoughts in a product using imagination and brainpower. This product could be a game or a poem, for example. I call it a process because it is not a simple one step action: it involves tinkering and experimenting with ideas, making decisions, solving problems and visualisation.

I did not ask children about how creative their games were during this study. However, it is visible from their completed games and field notes that they were experimenting with ideas that involved decision-making, critical thinking, problem solving, and designing solutions, which can all be seen as part of creativity. The task of character and background design also provided the children with an opportunity to develop creativity skills, as this allowed them to express their own ideas using technology. During the interviews, children were asked about what they learned by making games. Child K replied, *“my imagination”.*

When I asked how, he answered:

> *“Because like it expresses your imagination different points and it tells you, you can come up with good things to say*”.

Child H suggested that game making makes you more creative:

> *“It makes you more creative. I see the problem in my head, then I try to figure out how to solve it and then that helps me to solve the problem”.*

Child M said:

> *“In game design we also need imagination, because you can’t just have a game that is not fun or doesn’t make sense because people don’t want to play it”*

This emphasises the link between game making and creativity. There was mention of pair work and how this had an impact on creativity. Child H reported:

> “*We learned how to use our imagination and how to cooperate because we worked in a pair. If you work by yourself you may not do much, because two heads are better than one*”.

This shows that some children may not be able to express their ideas alone and might need the input or support of a friend. There might be different reasons for this. For example, the child may not feel confident, or maybe they lack knowledge and skills that would support them developing ideas. They might also have issues with articulating their thoughts (hinking and language); or organising and managing their own thinking process (metacognition), which can present barriers for sharing their ideas with peers. The link between imagination, creativity and brainpower was articulated by Child H who suggested that:

> “*Having a wide imagination means, thinking a lot harder, harder you think, more intelligent and more creative you get*”.

Similarly, Child T reported:

> "*It kind of makes you think a lot. You think what character you should use. Then you think about your story and what your character should do. Maybe glide or dance. Yeah. But you think first, don't you, then you create".*

It is clear that children were able to analyse creativity in their game design activities from different aspects, including imagination, thinking and intelligence.

Kivunja (2015) suggests that creativity involves learners engaging in challenging activities and using digital tools to create a product such as a digital story. The data from participant observations demonstrates that a game-making project was seen as a challenging activity by learners because it was a new skill for them to learn and involved constant problem solving. The following interaction between Child C and F shows that, although they were eventually able to solve problems, they found game making very challenging when using Alice 2.

> *Child C was frustrated because him and his partner couldn't make the bird fly. Child F suggested that maybe birds just don't fly in this application. Child C disagreed with him as he told Child F, because they don't know how to do it, it doesn't mean it can't be done. Child C complained that they had really good ideas but only some of them they could include in their games because they didn't know how to make it happen. Child F told him that they just started to learn this, once they try things, they will know what to do, maybe they need to come up with some other ideas (Extract from fieldnotes).*

This example shows that when children faced challenges, they refined their ideas and produced new ones they formulated new solutions, which can be seen as the application of creative skills. There were records of four similar interactions between children with reference to changing or refining ideas because of a lack of knowledge. The importance of having a good knowledge for creativity was also mentioned by Adams (2006) who argued that knowledge, critical thinking and motivation are three components of creativity (p.4). The scenario shared above also highlights that not having a good knowledge of the Alice application limited the ideas that children could implement in their games, thereby restricting their creativity.

4.3 Computational concepts

The recent focus on teaching children how to code has focused attention on teaching children computational concepts and strategies through game making. In a large-scale study, Werner, Denner and Campe (2014) analysed middle school (11 to 14 years old) students' games that were created using Storytelling Alice. They found that children used both key concepts such as loops, variables and conditionals, and more complex ones such as abstractions and event handling. Likewise, Kafai and Peppler (2011) examined 500 Scratch gaming projects that were created by children during a two-year period. They noted that the children used programming concepts such as loops and conditionals more frequently in the second year of the project. However, they did not use more complex concepts such as variables as often as the basic constructions.

In my research, the analysis of children's completed game designs showed that children used computational concepts such as loops, conditionals and variables. This can be explained in more detail with examples in figure 4.3 and 4.4. One interesting finding was that most of the children were able to use variables such as a timer and speed in their game when using the Scratch programming application; however, only two children created variables using the Alice 2. application. Also, whilst the children were able to create games using Scratch, their creations using Alice 2 were mainly animated stories rather than games.

Figure 4.3 shows a two-sprite script from a two-player game that Child T and Child A created. They used conditional 'if' to set a rule for their 'diver sprite' and created a loop for their 'start button sprite'. No variable was used. The two 'diver sprites' had the same script.

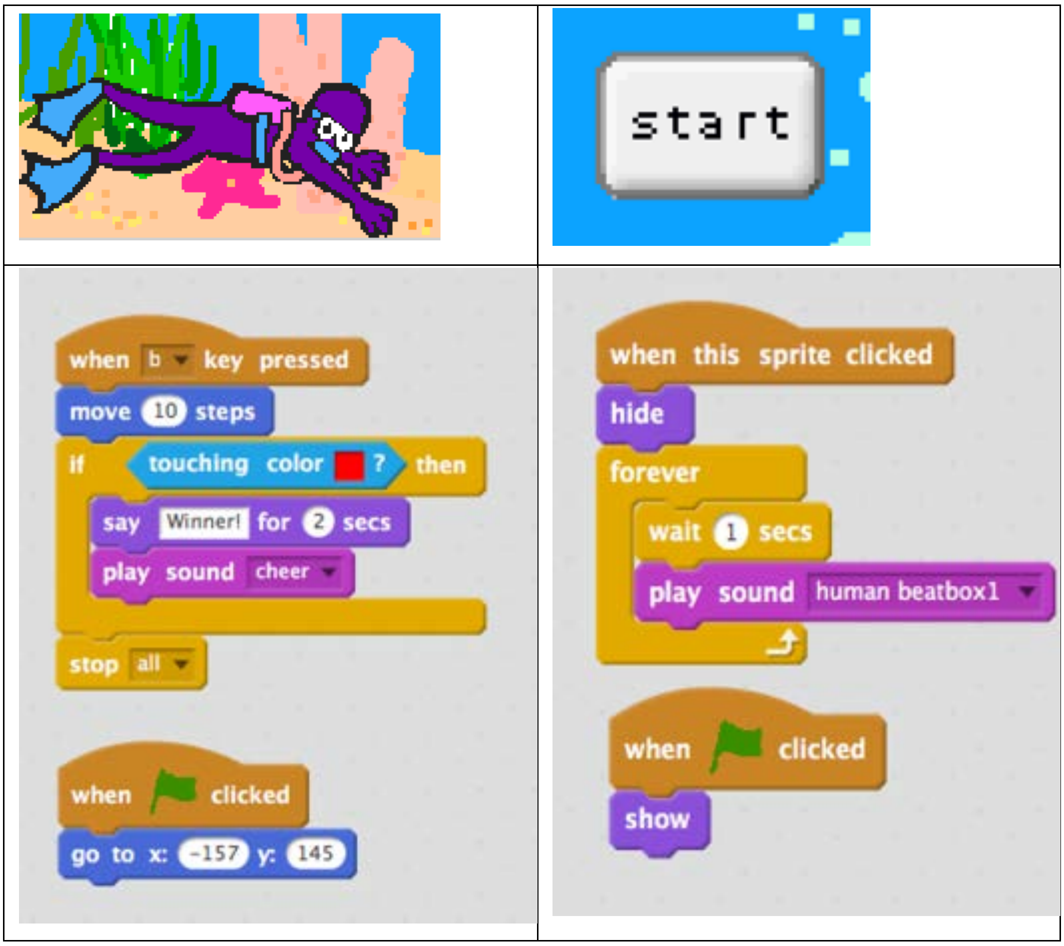


Figure 4.3: Scratch Scripts

The data from the transcripts of the interviews with children show that they found Alice 2 more interesting, not only because it is in 3D, but also because it is more complex in terms of programming to make something happen. Child H explained this as:

> *"Yeah, well scratch is easier than Alice, Alice has more complex way to do it. Scratch. Imagine ermmm, as Alice you can move hands, move your legs, in Scratch you can't do those stuff".*

Child J suggested that Scratch is too easy for him. He then added:

> *"I prefer Alice because more complex, allows you to make complex games".*

Child T stated this as:

> *"Well, I think, Scratch is mainly created for youngers, Alice is for more mature people that knows games".*

I think the reason that they thought that making games using the Alice application was more complex was because they knew that if they wanted to move a sprite in Scratch, they can drag the ‘move… steps’ code and make the whole object move. When they tried to move a character in Alice 2, they realised that they needed to write a script for each part of the body for example arm, leg, or head. This meant that they had to spend a longer time creating their script to program their character in Alice 2 than in the Scratch programming environment.

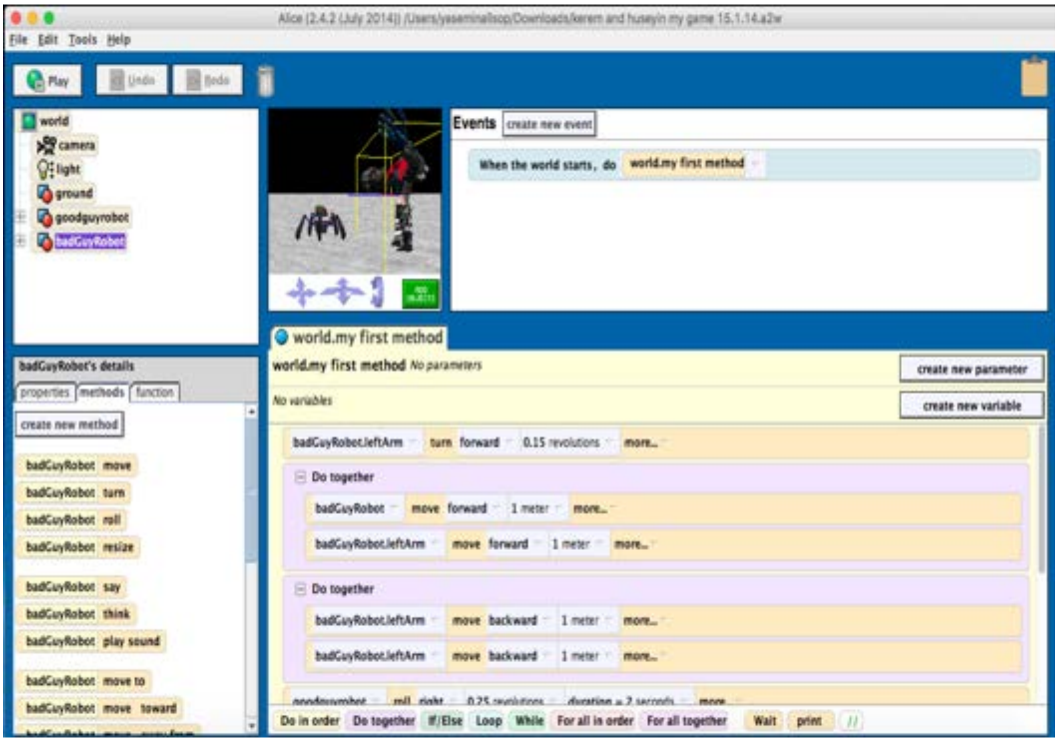


Figure 4.4: Alice coding

Figure 4.4 shows the script for Children K and H's ‘BadguyRobot’ game. They were able to code different body parts of each character. The number of codes that are needed to make a character move is much greater than the Scratch programming application.

The children experimented with computational concepts through programming using the Scratch and Alice 2 applications when making their games. They designed algorithms, created loops, and used variables to manipulate objects to do something. Child K reported an example in his journal:

> "*Well, today was an extremely frustrating day…I had to do an if/else with a score, then I had to print another few sentences. I then researched on how to make a game score. You have to make a variable and then choose number, then set number to 0".*

It was apparent from both the problem-solving sheets and the interviews that the children found coding in Alice 2 more challenging, as they needed help more often than when coding with Scratch. The coding part of game making posed more challenges for the children as they had to think critically to design solutions (algorithms) for problems. Learning to code using different applications and designing their own characters and backgrounds provided opportunities for them to develop their technology skills, although it is not the aim of this research to identify the progress they made in this respect. The computational concepts that children develop when making computer games will be discussed in Chapter 5, in more detail.

4.4 Conversation for self-regulated learning

Singer and Bashir describe self-regulation as "a set of behaviours that are used flexibly to guide, monitor, and direct the success of one's performance" (1999, p.2). Barkley (1997) noted that self-regulation is an essential element of metacognition and crucial for learning and achievement in schools (Singer and Bashir, 1999). Self-regulated or self-organised learning involves being aware of own thoughts and actions and reflecting on these through engaging in conversations with self and others (Thomas and Harri-Augstein, 1985). Language is the core of metacognition as, in order to use metacognitive strategies to self-regulate learning, "students must learn to talk to themselves about what they are doing and how they are doing it" (Singer and Bashir, 1999, p.3).

The children's' problem-solving sheets and my observational data showed that they constantly identified, decomposed and debugged problems, sometimes alone and sometimes with their friends, using different modes of conversation. Some of these behaviours were visible, either through the observation of their dialogue with each other or gestures or were recorded on problem-solving sheets. The following example from my field notes illustrates this.

> *Child H and K had constant dialogue with each other when making their game. When they faced a challenge, they first identified what exactly they wanted their character to do. They wanted to make their character (robot) move just like in Temple Run game. They tried a couple of scripts, but they did not work. So, they looked at examples on the Internet and watched some videos online. They found out the reason why their script did not work. They realised that they needed to write a script not for the whole body, but for the different parts of the body if they wanted their character to walk just in real life. They wrote a script for the legs, arms, head and the neck. This constant dialogue helped them to identify and debug the problem in their game.*

In another example, Child H reported on his problem-solving sheet that he had experienced a problem with making the sound work. He solved his problem by talking to his 'self' and not giving up. This again shows the role of conversation, whether with a partner or self, in managing learning activities.

During the interviews, children were asked to explain some of the points that they had mentioned on their problem-solving sheets regarding talking to 'self'. Child H reported that whilst making games he talks to his brain. He said:

> *"Can I do this, it is like my brain says 'yes' and give me the answer, thing like solving in my mind".*

Some students noted that they use 'talking to self' to check and evaluate their work before sharing with others. Child K explained this as:

> *"Before let people see, I would ask myself 'are you sure it is alright?' When I was making the robot fighting game. I wanted to see, I talked to myself 'how would make it more interesting and more detailed. To make it more like movement, maybe add voice. I just say in my mind.*

What shall I do to fix this?' if something is wrong. This makes you think if you ask and repeat".

Many children mentioned use of self-talk for improving and regulating work. *Child K explained this as:*

"Ermmm I just, when I am making game, what I ask myself, for example, how can I make this, what do I have to put in to make it better, how can I improve it. It helps me mmm, like, focus".

The detailed analysis of children using different modes of conversation during game design activities for different purposes, including self-regulating their learning, can be found in Chapter 6.

In summary, in this chapter the educational benefits of children's game making activities has been explored and the skills and the competencies that the students developed during the game design process discussed. The data analysis shows that the children used and developed skills and competencies, such as communication, problem solving, working collaboratively, creativity, computational concepts, and conversation for self-regulation. There were also some examples of children's learning in relation to curriculum subjects such as literacy and Mathematics. However, it is difficult state what knowledge and concepts they exactly learned when making games because of the difficulty in knowing their prior knowledge and measuring the progress they may have made during this project.

Chapter 5: Developing Computational Thinking Through Computer Game Making

This chapter aims to answer RQ 2:
How can children develop CT skills whilst making their computer games?

In Chapter 2, I reviewed the literature to define what CT is and what it constitutes. In this chapter, I present a multiple assessment model for assessing CT skills, which I use to identify the main themes for data analysis. The categories emerging from this model are: computational concepts, learning behaviours, game mechanics and metacognitive practices. In order to examine the computational concepts that the students used/developed, I describe each programming construct and share examples of what it looks like in Scratch and Alice programming environments. Following this, I present two case studies to illustrate how to recognise and assess programming constructs in children's games. I then use this as a guide to analyse all of the children's completed games in Scratch and Alice.

I use data from participant observations, semi-structured interviews, Scratch and Alice problem solving sheets to investigate the learning behaviours that were visible when children were working on their games. I use data from children's completed games and informal conversations to describe the game mechanics that children applied in their games. Finally, I analyse the data collected from problem-solving sheets, planning documents, participant observations and interviews to find whether the students mentioned or displayed metacognitive skills (planning, monitoring, evaluation, self-questioning, choosing and applying).

5.1 Towards a multi evaluation approach for assessing CT

As discussed in Chapter 2, it is not feasible to use one single method to evaluate the children's learning of CT skills. Therefore, it is important to adopt multiple means of assessment that provide more in-depth information about children’s understandings of computational concepts. I examined previous research findings on defining and assessing CT skills, which helped me to form my definition of computational thinking and a multiple assessment model for evaluating CT skills. The terms from my definition of CT (see 2.3.3.1) which represent the interaction between different sciences, were used to evaluate learners’ CT skills from three aspects: ‘computational concepts’, ‘metacognitive practices’, and ‘learning behaviours’. In order to investigate these dimensions within a game-making context, computer game design was also included in the evaluation model. The model is semi-flexible as it is possible to exclude and replace the game design dimension when evaluating CT in a different context to computer game design, for example, app development. Figure 5.1 presents the overview of the Multiple Evaluation Approach to CT skills in a computer game design context.

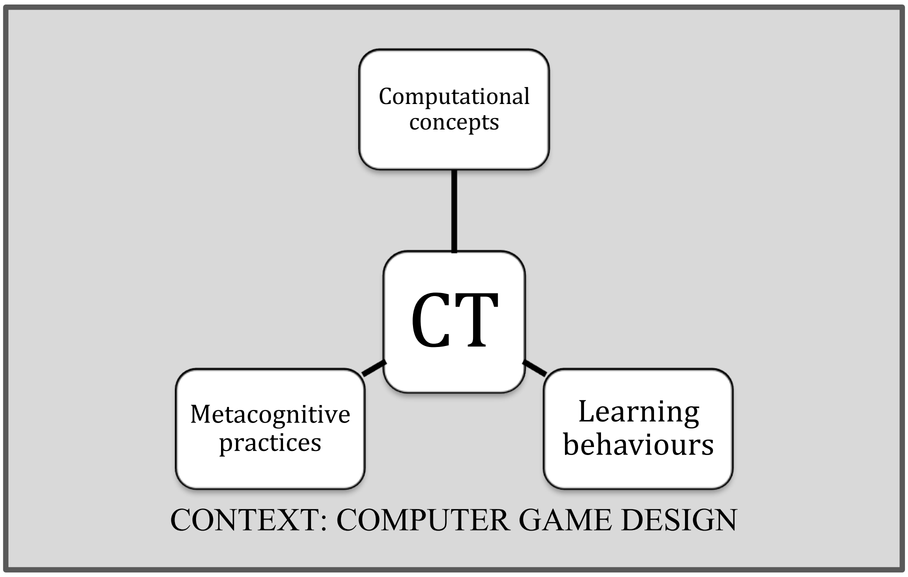


Figure 5.1: Multiple Evaluation Approach to CT skills in a computer game design context

5.2 Computational Concepts

Computational concepts refer to the programming constructs that are commonly used for completing tasks in programming environments such as sequences, loops, conditionals, and variables. Motivated by Werner et al.’ (2014) Game Computational Sophistication Analysis Procedure and the CT concepts developed by Brennan and Resnick (2012), I included sequences, loops, events, parallelism, conditionals, operators, variables and abstraction as the programming constructs that represent computational concepts in this study. Table 12 presents a brief description of these constructs.

Table 12: Programming constructs

Construct	Description
Sequences	The series of steps for completing a task that can be executed by the computer.
Loops	A sequence of instructions that are repeated until a specific task is achieved.
Events	One action causing another action to happen
Parallelism	The function of making events take place at the same time for different characters or for the same character
Conditionals	An instruction in a program that is only executed when a specific condition is met.
Operators	Functions for both mathematical and logical expressions and it enables the use of both numeric and string operations.
Variables	A value, which can change depending on conditions. Variables used for holding on to a value to use it later.
Abstraction	The process of removing or reducing details from a complex object to facilitate a focus on relevant concepts

In order to make the analysis process more efficient and reliable, I created a guide where I described each programming construct and then showed an example of what it looks like in both the Scratch and Alice environments (Figures 5.2 – 5.11). This is useful for educators as it would help them to identify the programming constructs in children's games. I then used this guide to create case studies where I exemplified the programming constructs in two games that were created by children using the Scratch and Alice applications.

The guide for programming constructs

Sequences can be described as the series of steps for completing a task that can be executed by the computer. In Scratch, an example of this could be a script to program a sprite to move across the screen. In Scratch, any object that can be programmed is called sprite. In Alice, consecutive sequences for one object are created using a ‘do in order’ block. For more than one object, a ‘For all in order’ block is used. This command will execute an operation on each object in a list one at a time, beginning with the first object in the list and completing the list in order. Figure 5.2 shows what a sequence looks like in Scratch and Alice environments.

<table>
<tr><td>Scratch</td><td>Alice 2.4</td></tr>
<tr><td>This instruction sequence programs the ball sprite to move across the screen and then play the sound ‘pop’.


</td><td>Using ‘Do in order’ statement in Alice, it is possible to run the codes in a consecutive order for an object.


</td></tr>
</table>

Figure 5.2: Sequences in Scratch and Alice

Loops involve the repeated execution of a sequence of statements. They make code writing more efficient by using the repeat function instead of creating a long script that would describe the same actions. For example, in Figure 5.3, I created a script that makes the ball sprite move across the screen. A more efficient way of writing this would be repeating the ‘move 100 steps and wait 0.2 secs’ code blocks three times rather than using six coding blocks. An instruction in Scratch can be repeated for a specific number of times, or infinitely which is the forever block. In Alice a ‘Loop’ block is used for repeated actions. Figure 5.3 displays the script using the repeat function in Scratch and Alice.

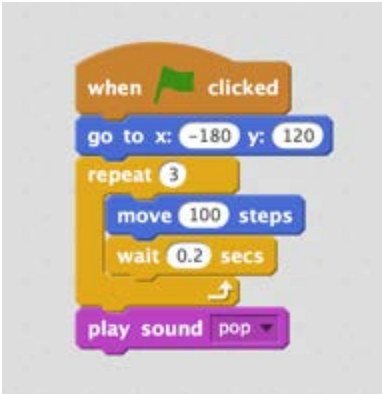
Scratch	Alice 2.4
	

Figure 5.3: Loops in Scratch and Alice

Events refer to one action causing another action to happen. In Scratch, there are different ways an event can produce an action. For example, when the green flag is clicked or when a key is pressed. In Alice, creating a new event to produce an action is possible by clicking on the ‘create a new event’ tab which has options such as when the world starts, when a key is typed, when a variable change or when the mouse is clicked on something. Figure 5.4 shows some of the ways that events can produce actions in Scratch and Alice.

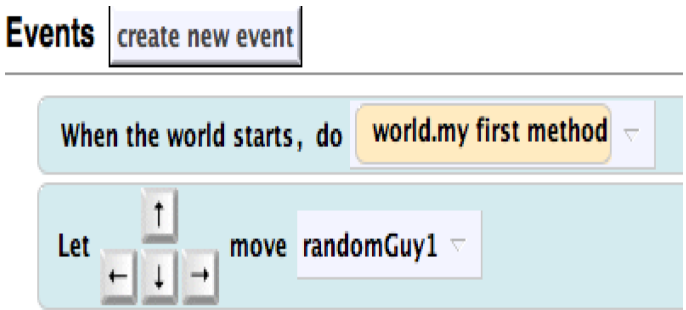
Scratch	Alice 2.4
	

Figure 5.4: Events in Scratch and Alice

Parallelism is making events take place at the same time for different characters or for the same character. In Scratch, this is done through using the same event block for different actions. For example, you can make a character have a think using speech bubbles, change costume and play sound all at the same time 'when the green flag' is clicked. In Alice parallelism is supported using 'Do it together' block. 'For all together' block is used for performing an operation on all the objects in a list at the same time. Figure 5.5 displays how parallelism is supported in Scratch and Alice.

Scratch	Alice 2.4
	

Figure 5.5: Parallelism in Scratch and Alice

A 'conditional' is an instruction in a program that is only executed when a specific condition is met. In the Scratch application, a conditional is defined using the 'if block'. For example, in Figure 5.6 the condition for the ball sprite to play the 'pop' sound is to touch the apple sprite. In Alice, conditionals are set using 'if / else' block and it allows actions to be performed when a Boolean expression is true. For example, 'if the car is within 1 metre of the tree, the car will play the doorbell sound'. There is also the while statement which repeats the instructions inside a loop as long as the Boolean condition is true.

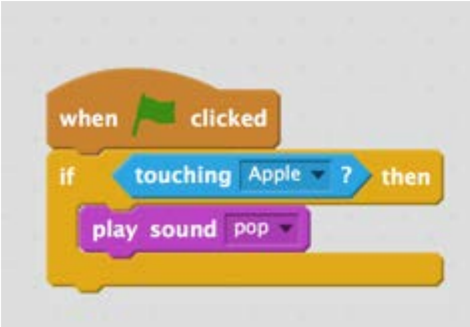
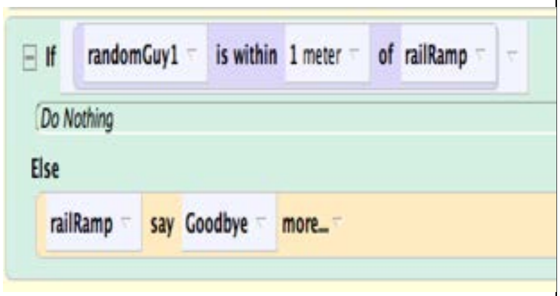
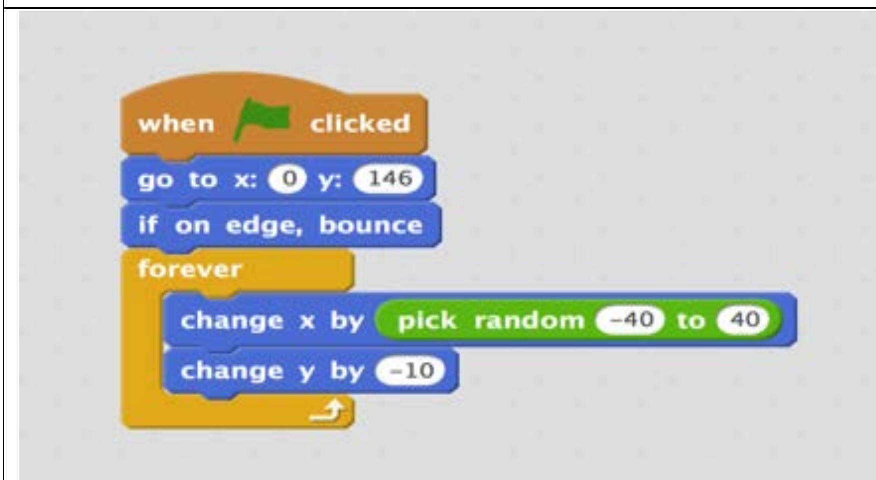
Scratch	Alice 2.4
	

Figure 5.6: Conditionals in Scratch and Alice

Operators (Figure 5.7) are functions for both mathematical and logical expressions and enable the use of both numeric and string operations. In Scratch this is done using the codes inside the 'operators' palette. In Alice, logical operators such as 'not a', 'both a and b', 'either a or b, or both' are used for connecting comparisons to form more complex Boolean expressions. Relational operators, such as equal to, greater than, less than, are also used for forming comparisons. Mathematical expressions such as addition, subtraction, division and multiplication are also used in the Alice 2 programming environment.

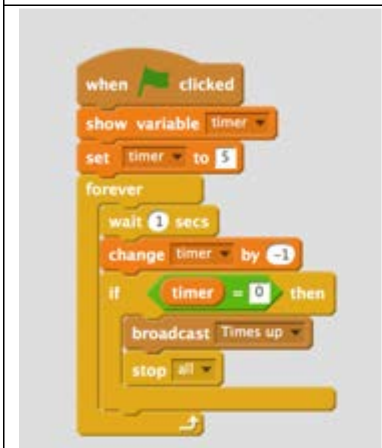
Scratch


Alice 2.4

Figure 5.7: Operators in Scratch and Alice

Variables are the placeholders for information which can change depending on conditions. The common use of variables in Scratch and Alice is creating score or a timer for games. In Scratch, variables are created using a 'Data' block'. In Alice, variables are created using the 'Create a new variable' tab and it includes data as numbers, objects, Boolean (true and false) or string. Variables in Alice 2.4 can be created for a method (local variable), to hold an argument (Parameter variables), for a specific object (Class-level) or for all objects in a world (World –level variables). Figure 5.8 shows scripts for timer variables in both Scratch and Alice.

Scratch



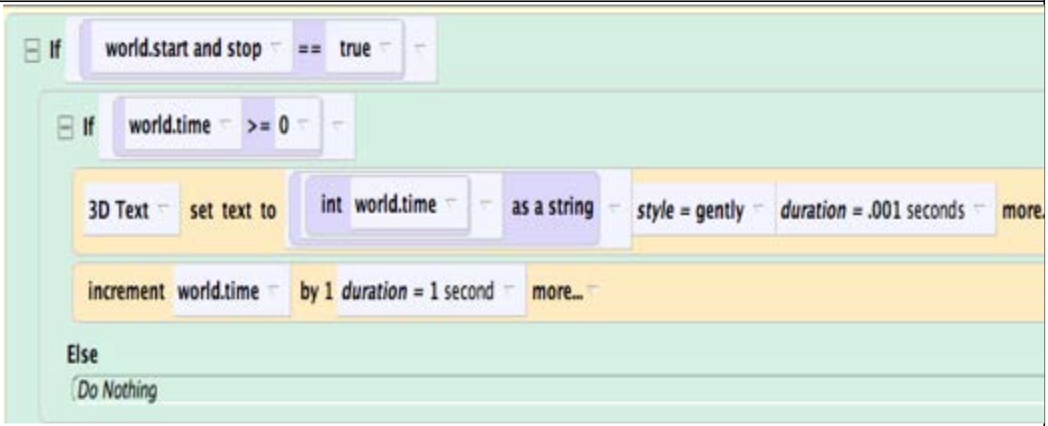
<table>
<tr><td>Alice 2.4</td></tr>
<tr><td>
</td></tr>
</table>

Figure 5.8: Timer variable in Scratch and Alice

Abstraction is the process of removing details about an object to reduce complexity and increase efficiency. In Scratch, this can be seen as organising instructions into code stacks based on their functions using user defined blocks. The example for Scratch in Figure 5.9 defines the script for drawing a rectangle. In Alice, abstractions are performed through methods as they include actions that can be executed by objects in the world when they have been requested. In Alice, methods can be defined at either character level (applying to one object only) or at world level (applying to many objects).

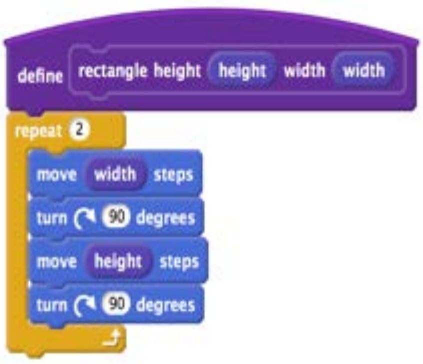
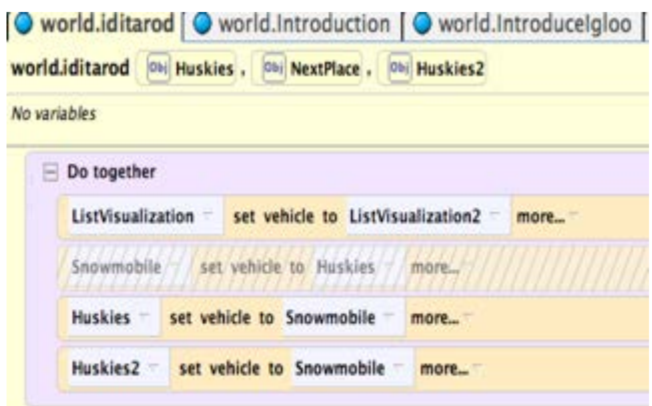
<table>
<tr><td>Scratch</td><td>Alice</td></tr>
<tr><td>
</td><td>
</td></tr>
</table>

Figure 5.9: Abstraction in Scratch and Alice

Using the programming constructs discussed above, I evaluated the children's completed games. In the following section, I will share the findings of this evaluation process and identify the programming concepts that the students were able to apply when creating their computer games.

A three-step analysis process, as described by Werner et al. (2014), was used to analyse each game that the children created using both Scratch and Alice 2 applications.

- In the first stage, the code was analysed to identify the programming constructs that were used.
- The games were then played to check if the programming constructs were executed correctly.
- The final step looked to define whether the code was either built-in or created by the student.

5.2.1 Computational concepts in Scratch

For this study, the students used Scratch 2.0 online editor with a drop and drag 2D programming environment for creating animations and games. All of the focus children chose to work on their games in the classroom with their partners although they were allowed to choose to work with a partner or independently. However, the students each created an online account on the Scratch website, which allowed them to access their work from home if they wished to. Eight children reported that they created a copy of their shared work to try some of their ideas at home without changing the original game. The children were reminded about the responsible use of technology both at school and at home at the beginning and during the project. This aimed to eliminate some of the issues that may occur e.g. deleting, editing partners' work without discussion.

Individual Case study: Child B and J

The individual case study of one game created by two boys below will illustrate the programming constructions that some children used whilst creating their games and animations. The reason for choosing this game was that it included more sophisticated coding structures than the other games, therefore it makes it possible to illustrate the range of programming concepts that the students used whilst making their game.

The game selected for this individual case study was called ‘Kick about’ and it was created by two boys (B and J). The aim of ‘kick about’ game is to stop the ball sprite (character or object) that is coming from the top of the screen by moving the kicker sprite vertically using the left and right arrow keys. The kicker sprite stands on a red line and if the ball touches this line, then the kicker loses a life. Once all of the five lives have been used, ‘game over’ text appears on the screen and the game stops. If the kicker sprite can stop the ball before it touches the red line, the player gets one point as a score. Figure 5.10 displays the game interface.

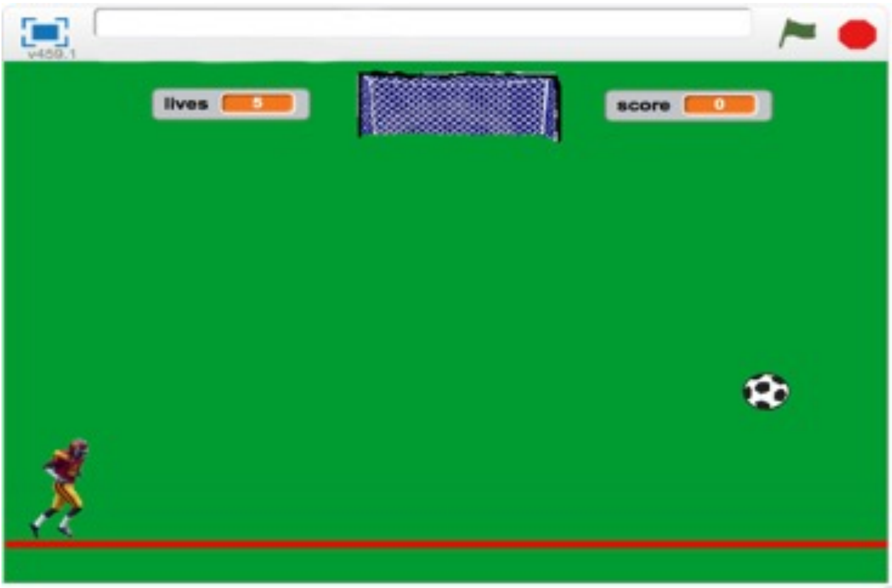
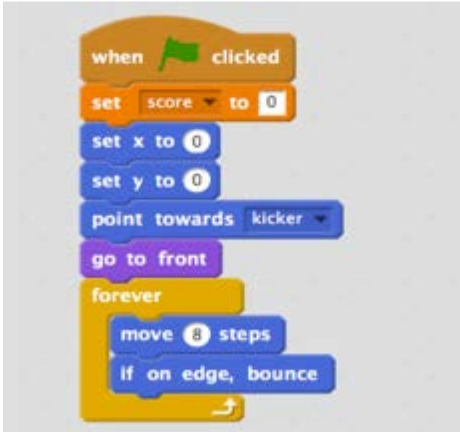
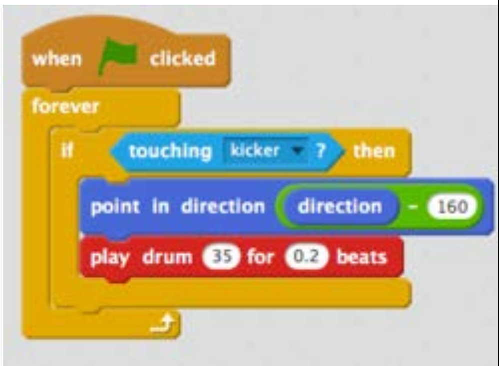
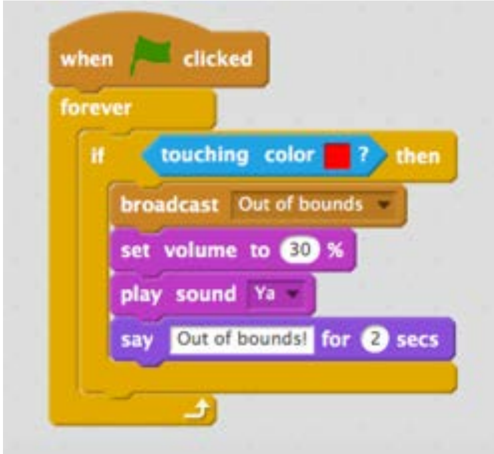


Figure 5.10: Kick about game interface

Children B and J created the game collaboratively. They used programming constructions, for example, sequences, loops, parallelism, conditionals, operators, variables and events, to create their game. The students did not use any custom-built blocks to define a new instruction or any other method of abstraction. One reason for this might be that they did not need any action that would require the creation of a new function; therefore, they were able to complete their task with pre-built code blocks. Another possible reason is that they may not have had sufficient knowledge to create new functions as I only modelled this once in the classroom. However, they could have used the Internet to develop their understanding in this area as they did use online videos often when they did not know how to do something. Table 13 shows 'Kick about' game programming constructs.

Table 13: Scratch Case Study

	'Kick about' game programming constructs	
Sequences	For the ball sprite students first set the score to zero, then defined the position of the ball using series of codes.	
Loops	Forever block was used to repeat the movement of the ball sprite for 8 steps and make it bounce when it reaches the edge of the screen.	
Parallelism	Three sets of script were written for the ball sprite and they were all executed at the same time when the green flag was clicked.	
Conditionals	If statement was used to define the behaviour of the ball sprite when it touches the 'kicker' sprite.	

		 Scripts for ball sprite
Operators	The condition for the ball sprite had a statement that used minus (-) operator. If the ball touches the kicker ball it should point ‘direction less 160’ (direction – 160). This script sets the direction for the ball sprite when it meets the condition, which is touching the kicker sprite.	
Variables	Data Score for the ball and lives variables for the kicker sprite were used for this game.	
Events	When the ball sprite broadcasts game over, then the hidden game over text (sprite) appears on the screen and the whole game stops.	
Abstraction	The students did not use abstraction for this game.	

Overall data analysis of programming constructs

Out of the 30 children, 24 worked in pairs and six worked alone; therefore, 18 games were included in the data analysis. Although, at first, I used Dr. Scratch (an online application for assessing children's Scratch projects) created by Moreno-León and Robles (2015) to analyse the students' games, I then manually evaluated each game as I wanted to be able to use specific examples from the students' game script to explain how well they were able to use the programming constructs rather than the generic examples that were presented by this tool. This was very useful when giving individual feedback to the students by using examples from their own game scripts. The children were not given information about how their games were graded. They were. however, given feedback about the areas that they were good at and areas that they need to develop. This was done using examples from children's completed games at the end of the game-making project. The reason for this was because, as part of the school's assessment policy, the teachers used learning conversations to discuss children's learning in different subjects and identify the areas that children need to work on. As the Computing leader who was responsible for teaching computing to all of the Year 5 (9 - 10 years old) and Year 6 (10 - 11 years old) classes, I used learning conversation to discuss children's progress in computing.

The programming constructions were graded using a simple point system similar to the Dr. Scratch assessment tool. If the programming constructs were not used within the game, the student received 0 points; if they were used in a simple form, the students received 1 point; and if more sophisticated programming constructs were used, the students received 2 points.

Although this manual evaluation approach was useful for finding out whether the children were able to use each of the programming constructs, it was very time consuming. For the children who had worked in pairs, it was also, difficult to identify which were able to apply their knowledge to create code as the decisions were mainly taken collaboratively. Another challenge is that this manual evaluation method requires the knowledge of how programming structures look in Scratch, in other words, very good subject knowledge was needed. Therefore, the analysis is limited to my knowledge and understanding of what each programming constructs would look like in the Scratch application. It would probably have worked better if a team had completed the evaluation of the games in order to moderate the scoring process, but this approach was not feasible within the constraints of this study.

If a student had used all of the programming constructions at a sophisticated level, they would have received 16 points in total, which is 100%. Once I had graded each game, I calculated the mean value to define the average level of use for each programming construct in the Scratch environment. This was useful for identifying the computational concepts that the children were struggling with and those concepts that they were using efficiently. Table 14 displays the mean score for each programming construct.

Table 14: Mean scores for programming constructs

	Mean score N: 18	Percentage % of games containing this	Standard Deviation
Sequences	1.9	97.2	0.2
Loops	1.3	66.7	0.7
Parallelism	1.6	77.8	0.5
Conditionals	1.5	75.0	0.6
Operators	0.7	33.3	0.7
Variables	1.1	52.8	0.8
Events	1.3	66.7	0.6
Abstractions	0.0	0.0	0.0

As illustrated in table 14, the mean score for using an abstraction construct was zero, meaning that no one used custom built functions. The mean score for sequences was 97.2% with a standard deviation of 0.2; this shows that almost all the games included sequences at a complex level. The use of operators was low, at only 33.3% with a standard deviation of 0.7. This means that either the children did not know how to use operators, or it was not necessary for their game design. Parallelism and conditionals were used confidently with mean scores being 77.8% (SD: 0.5) and 75% (SD: 0.6) respectively. Loops and events were used in 66.7% of the games. Variables such as timer, score and lives were used by 52.8% (SD: 0.8) of the games.

Although pair-programming made it difficult to compare individual students' understanding of CT concepts, single sex pairing made it possible for some gender-based comparisons. There were 14 girls who worked in pairs to create their animations and games. The analysis of the games that were created by these seven pairs of girls showed that they were able to use sequences very well; however, they struggled with the application of variables. Only one group of girls in comparison with boys was able to use variables to create a game with a score and a timer. The remainder created simple animations without any variables. The students' prior experiences of game playing might have had an impact on this; however, there was no data to support this claim as the students were not asked about their previous experiences of either playing or making games. This was interesting because at the beginning of the project we had a class discussion about games. Many children mentioned that games have variables such as timer or points. Although I did not ask children to use any specific programming structure, they were aware that to create a playable game using a reward system they needed to use a variable. The gender-based comparison for other programming structures did not have any significant patterns; both boys' and girls' groups had some issues with using operators, conditionals and loops.

The comparison of the six games that were created by individual children with 12 pair coded games provided me with some information about the impact of pair programming on students' use of programming constructs.

Table 15: Comparing pair coded and independently created games

	Pair coded Games			Independently coded games		
	Mean score N (Number of games): 12	%	Standard Deviation	Mean score N:6	%	Standard Deviation
Sequences	1.9	95.8	0.3	2.0	100.0	0.0
Loops	1.5	75.0	0.6	1.0	50.0	0.6
Parallelism	1.6	79.2	0.5	1.5	75.0	0.5
Conditionals	1.7	83.3	0.5	1.2	58.3	0.7
Operators	0.8	37.5	0.7	0.5	25.0	0.5
Variables	1.3	66.7	0.7	0.5	25.0	0.5
Events	1.5	75.0	0.5	1.0	50.0	0.6
Abstractions	0.0	0.0	0.0	0.0	0.0	0.0

As displayed on table 15, the use of variables in the games that were created by the children who worked alone was only 25%, but 66.7% in the games that were coded by pairs. The students who worked collaboratively used loops, conditionals and events constructs by almost 25% more than the games that were created independently. It is very difficult to describe the factors that might have had an impact on the level of using programming constructions. Students' prior experiences of these constructs and programming with Scratch; opportunities for talk and discussion; and accessing the work from home can be listed as some of these; however, there is no data to support or explain this statement. The use of sequences and parallelism were very similar levels for both pair-coded and independently created games.

5.2.2 Computational concepts in Alice

Individual case study: Child K and E

The game that was selected for this case study was called Badguyrobot. It was created by two boys, both aged ten. It is an animation with two characters: badguyrobot and goodguyrobot. This game was selected because it included many of the programming constructs; therefore, it was appropriate to illustrate these using example scripts from the game. The scene background is space. Figure 5.11 shows the selected animation screen.

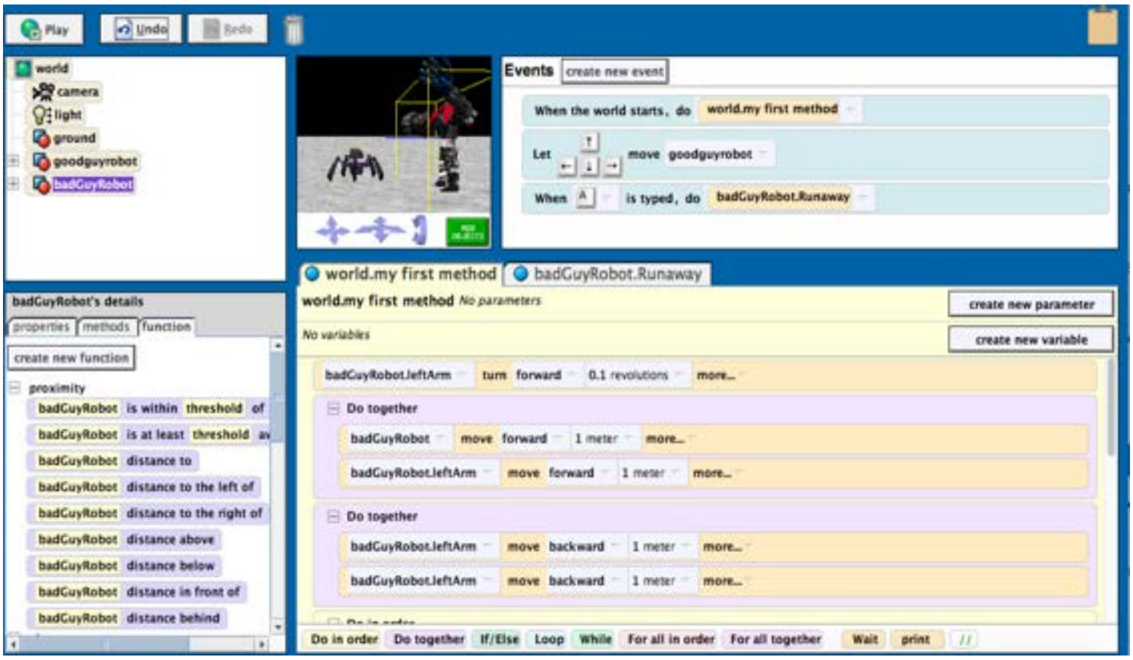
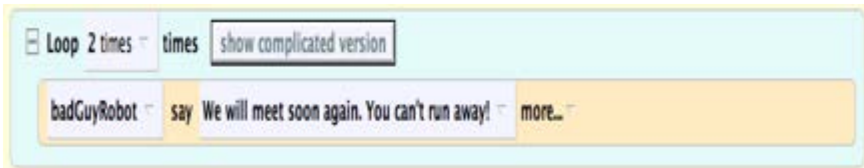


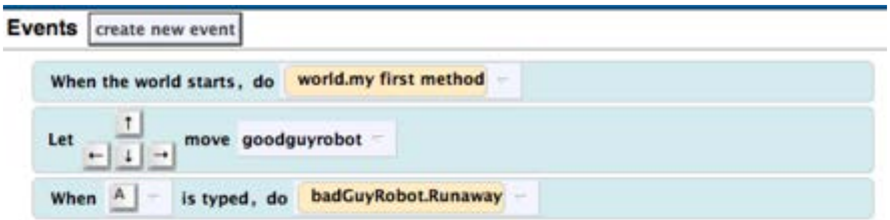
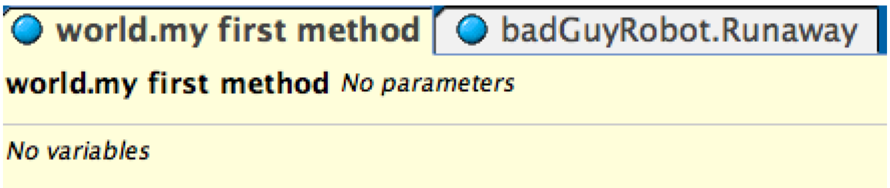
Figure 5.11: Badguyrobot and Goodguyrobot animation screen

The students used both built-in methods and created their own ones. They started by programming the left arm of the badguyrobot character to point forwards by specifying the turn revolutions. They used a few ‘Do together’ constructions to make both characters move at the same time. They used ‘Do in order’ statements to program the goodguyrobot character to complete 4 actions simultaneously. A ‘Loop’ was used for making the goodguyrobot say goodbye if the position of ‘badguyrobot is within a metre of goodguyrobot’ is untrue. In the events section, the students had their first method called ‘when the world starts’. They then had another event to control the goodguyrobot with arrow keys. They created a new method called ‘runaway’ and an event handler to run it when ‘A’ letter key is pressed on the keyboard.

The students did not create any variables or parameters when creating the ‘Goodguyrobot and Badguyrobot’ animation. They used the built-in ‘say’ construct for creating a dialogue between the two characters. They used constructs to manipulate subparts of the objects e.g. left arm. They recorded their own voices and used these for each character. They were able to create and use new methods, which illustrates that they were able to apply abstraction to complete their task. They used conditionals and relational operators (numerical and logical expressions) to define the behaviour of the characters. Their programming constructs were tested, and they worked as expected. Table 16 displays the Alice case study.

Table 16: Alice Case study

	Goodguyrobot and Badguyrobot animation programming construct
Sequences	‘Do in order’ statement 
Loops	Loop statement 
Parallelism	‘Do together’ statement 

<table>
<tr><td>Conditionals</td><td>If/Else statement
</td></tr>
<tr><td>Operators</td><td>Relational operators
</td></tr>
<tr><td>Events</td><td>Something that occurs while an Alice program is running
</td></tr>
<tr><td>Variables</td><td>Variables
None</td></tr>
<tr><td>Abstraction</td><td>Methods
</td></tr>
</table>

Overall data analysis of the games

Werner et al. (2014) listed Alice programming constructs in four levels of difficulty. They placed basic constructions for creating sequences and simple event handlers in level 1; use of built-in functions and more sophisticated event handlers in level 2; creating methods, variables, if/else, loop and while statement in level 3; and parameters, student-created functions, list variables, nested if/else statements, more sophisticated sequence and parallelism constructions in level 4. Using their analysis scheme, I created a simple rubric that would help me to evaluate the games that students created using Alice 2.4. I first listed the blocks under points 1 and 2 to differentiate their difficulty level. This can be seen as level 1 and 2. Then I mapped each block and action in Alice to a programming construction to make it easier to compare the level of use. As discussed by Werner, Denner and Campe (2014), both if/else and while statements are based on simple Boolean expressions; therefore, they have been listed under the 1-point section. If the student did not use the programming construct, they received 0 points; if they used the simple constructions as listed in Table 17, they received 1 point; if they used more advanced programming constructs, they received 2 points.

Table 17: Scoring system for Alice programming constructs

	0 point	1 point	2 points
Sequences	Programming construct hasn't been used	Do in order	For all in order
Loops		Loop statement While statement	Nested loop
Parallelism		Do together	For all together
Conditionals		If/Else statement	Nested If/Else
Operators		Mathematical expressions	Relational and Logical Operators
Variables		Non-list variables	List variables
Events		Event with single action	Event with multiple actions
Abstractions		Built in methods Simple event handlers Built-in functions	Student created Methods Sophisticated event handlers Student created functions

Similar to the Scratch games analysis, if a student used all of the programming constructions at the sophisticated level, they would receive 16 points in total, which is 100%. I calculated the mean value for each programming construct to define the average use in the Alice environment. This helped me to see the computational concepts that the children were able to apply at a confident level. Table 18 displays the mean score for each programming construct.

Table 18: Mean scores for programming constructs

	Mean score N: 15	Percentage %	Standard Variation
Sequences	2.0	100.0	0.0
Loops	0.9	46.7	0.7
Parallelism	1.6	80.0	0.5
Conditionals	1.5	73.3	0.5
Operators	1.2	60.0	0.4
Variables	0.2	10.0	0.5
Events	1.3	66.7	0.5
Abstractions	0.9	43.3	0.6

As illustrated by Table 18, the mean score for the sequences construct was 100%, meaning everyone was able to create a set of instructions to program the behaviour of an object at a sophisticated level. 80% of the games included more than one event for an object that would happen at the same time (parallelism). The mean score for the uses of operators was 60% with a standard variation of 0.4, showing that the students used this construct more than they did when programming with Scratch. Abstraction was used in 43.3% of the games and loops in 46.7%. Students used conditionals well, as 75% of the games included this programming construct. Variables had the lowest mean score (10%) as only one student used this construction at a complex level, when he created a timer and a score. Another student attempted to create a variable, but there was an error, so it did not work correctly.

Gender comparison of the games that were created using Alice shows that both boys and girls used sequences in their games. Boys were more successful at using almost all the programming constructions including loops, parallelism, conditionals and events. This does not mean that the girls did not use these constructs in their games, but they used them less often and used fewer complex constructs in comparison to boys. It is possible they might have tried using them at a complex level, but they did not work correctly. Variables seem to be problematic for both boys and girls, as girls' games did not include any variables and only one pair of boys included variables in their game. Another pair also tried to use a variable but did not work properly. Abstractions were used in 50% of the boys' games in comparison to 35% in girls' games. The data used for gender comparison of the games can be seen in Table 19.

Table 19: Gender comparison of children's games created using Alice

	Boys			Girls		
	Mean score N: 8	%	Standard Deviation	Mean score N:7	%	Standard Deviation
Sequences	2.0	100	0.0	2.0	100.0	0.0
Loops	1.3	62.5	0.7	0.6	28.6	0.5
Parallelism	1.9	93.75	0.3	1.3	64.3	0.5
Conditionals	1.8	87.5	0.4	1.1	57.1	0.3
Operators	1.3	62.5	0.4	1.1	57.1	0.3
Variables	0.4	18.75	0.7	0.0	0.0	0.0
Events	1.5	75	0.5	1.1	57.1	0.3
Abstractions	1.0	50	0.7	0.7	35.7	0.5

5.3 Metacognitive practices

I define metacognition as a skill set that enables an individual to deploy and manage his or her cognitive resources effectively to regulate his or her thinking and learning. Sternberg (1998) listed planning, evaluating, monitoring problem-solving activities and allocating cognitive resources appropriately as the main abilities for managing the metacognitive process. Flavell (1979) described exploring; setting goals; organizing; planning; self-questioning; choosing and applying; monitoring; and managing thinking as metacognitive skills. A number of studies also described planning, monitoring and evaluation as the main metacognitive skills (Fisher, 2005; Schraw, Crippen and Hartley, 2006; Whitebread et al., 2009). Metacognitive practices can be seen as the trigger and executive control for managing cognitive activities, which include planning, evaluation and monitoring.

I am arguing that at the core of metacognitive practices is the conversational exchanges that take place between ‘others’ and ‘self’. Vygotsky (1986) also mentioned the role of private and inner speech (conversation with self) and social speech (conversation with others) in self-regulation, stating that language is not only used for communication, but also for self-regulation through planning and monitoring. Likewise, other studies also describe this conversational exchange with self and others as an instrument for managing planning, monitoring, thinking and learning processes (e.g. Rohrkemper and Bershon, 1984; Zakin, 2007).

The findings of my study show that, although the methods were different, planning was a skill used by all of the children who participated in this research. Some children planned using text and some used images, while others preferred to blend images and text to communicate their ideas. Appendix 5 shows some examples of the children’s planning sheets. One interesting outcome was that only four children decided to use the planning sheet that I had prepared for them (Appendix 6), suggesting that children preferred to share their ideas using their own planning methods rather than a pre-set one. The majority of the children reported that the game design activity helped them to use planning skills more than other learning activities.

Another finding of this study showed that children used language as an instrument, in different forms of conversation, to make decisions, evaluate and regulate their activities. When the students were asked to record what they asked / talked / thought to themselves on their problem-solving sheets, they shared the questions that they asked in order to solve a problem, make a prediction, or make a decision before they took an action. For example, Child K reported this as:

> *"I asked and talked about how we are going to work out to move the robot and the space men?"*. Another one wrote, *"I thought to myself how I am going to make the witch move around the screen?"*

There were more questions written in this section by children asking about how to complete a specific task and also broader questions to check if they were doing things correctly. This will be discussed in Chapter 6, in more detail.

Monitoring and evaluation is another metacognitive skill that was visible during children's game making activities. The children constantly tested and evaluated their games to identify if there were any errors. They debugged their errors by deleting, modifying or adding new lines of codes. This monitoring and evaluation of activities continued throughout their game design process. The more detailed data analysis of children's metacognitive practices can be found in Chapter 7.

5.4 Learning behaviours

I explain learning behaviour as the strategies, approaches and habits that promote learning, and which have been exhibited by children whilst working on a task. Powell and Tod (2004) listed engagement, collaboration, participation, communication, motivation, independent activity, responsibility, disaffection and problems as the main behaviours for learning. In a DfES White Paper about Education and Skills for 14-19 years old pupils, enquiry, creative thinking, information processing, reasoning and evaluation were included as learning behaviours (2005). Although he did not mention the term 'learning behaviour', Claxton's (2002) theories around building learning power seem to focus on similar attributes that schools should focus in order to help children learn. These attributes are resilience, resourcefulness, reflectiveness, and reciprocity. He argues that these attributes promote learning.

The findings of this study also found that, whilst working on their design and programming scripts, pupils worked collaboratively; thought creatively and critically; debugged errors; tinkered with ideas; and communicated these ideas using different modes of conversational exchanges. Each of these behaviours will be discussed in more detail below.

Collaboration

My field notes showed that although most of the children usually worked directly with their partner, on many occasions they also walked around the classroom to look at others' work, where they either made suggestions or got some ideas for their own games. Some children asked for help from others. There was a constant discussion between the pairs and other game designers, which enabled them to evaluate and reflect on their own work and to re-organise their ideas. This collaborative approach to game making had motivational power by providing support for the children from their peers when they needed it. The relation between game making and collaboration is discussed in section 4.2.1.

Perseverance

One other interesting learning behaviours shown by many pupils was perseverance. When children identified their script error, they tried different solutions to debug it. Sometimes this was a simple action, but sometimes they had to spend a very long time trying different options until they found how to make it work. The records from the participant observations of the children working on their games showed that some children did give up when faced with a challenge while some persevered and did not stop until they had found a solution to their problem. The record of the interaction which took place between three children during one of the games making sessions, which I shared on page 93 demonstrates this.

Whilst working on their games, Child A was disengaged with the activity when she could not solve a problem. Her partner Child T suggested that they should re-write the script, but she did not show any interest in this. It was only when another child (Child K) offered to help them with their problem that she engaged with the game making activity again. Interestingly, there were four other situations where Child A was disengaged with the game making task when facing a challenge and it was only because of the support of her peers that she was able to keep on task and complete her project. This highlights the importance of providing opportunities for children to work collaboratively or even have the flexibility to move around and ask for help if needed.

Another interesting point was made by Child G during the interviews. He talked about how playful elements of game making actually motivated him to persevere. He explained this:

> *"I think we try again again, until it works, because it is a game. Something you can play. You know, we like it. Not sure if I would check my story in English again again (He laughs). I should really, but it is not the same is it?"*

When he was asked to explain what means by 'it is not the same' he replied:

> *"Well, I don't solve a problem when I am making a game because you ask, I do it, otherwise we wouldn't be able to play, right? Let's say I wrote a story, it is not that easy to find your mistake and you also ask to yourself, why shall I check it again again, who will read it. You know, the teacher will read it, but that's it. You can't really play". So, you think, what is the point? (He waves his hands around)."*

This shows that he is aware of his perseverance skill, and he decides when to use it depending on the lesson context. Game making seems to encourage him to persevere to solve his problems because it is an activity that he found it meaningful as he links it to his game playing activities outside of the school. During interviews, Child K also made similar comments. He said:

> *"Yeah, I will try to find a solution because the game won't work, will it. So how can you play, if it doesn't work? (His right hand was up waving around)".*

When he was asked if he persevered to solve problems in other lessons, he replied:

> *"It depends. Ermm. Like if it is a maths problem, I try to solve because I like maths, maybe not as long as I do when I code. Sometimes in science too. Ermm. I am not sure about English. Hard to say what is wrong, so. Yeah. As I said you have to make your game work, so it can be played".*

Again, this example also shows that children persevere when working on an activity that they like. It also shows that being able to identify problems quicker using computers also encourages them to focus on solving these. Both students mentioned not persevering during English lessons because of difficulty in identifying the problem and also not seeing any purpose in completing the task other than meeting the objective. Similar reasons were shared by the other eight focus children who talked about how important it was for them to ensure that their game had fully worked and could be played by others.

Communication

The field notes from my observations of the children have shown that they constantly communicated with their friends. They talked about their storylines, characters, backgrounds, code errors and rules. They discussed their solutions and actions to correct problems before they put them into practice. They gave each other feedback and made suggestions for improving their work. This shows that communication was a core part of their game making. Many children mentioned asking for help during their interviews. For example, Child K suggested that he first tried to solve a problem himself, but if he could not, he asked his friend. He explained this as:

> “*What I do is, if I have a problem, like the character is in the wrong place, I will try to move to different place by changing the code, but if it doesn't work, I will ask my friend”.*

Likewise, children’s problem-solving sheets also had records of children talking to their friends about problems they faced whilst making games. Section 4.2.3 presents a detailed discussion of how children used communication skills whilst working on their games.

Debugging

Identifying and debugging coding errors or solving problems related to the design of the games were also observed during game making. The children tested their code frequently to check that it worked. When it did not, they tried to identify the problem, sometimes alone, sometimes with others, and then designed solutions. The written records of informal conversations with the children highlighted that the children claimed to evaluate their work and check for errors during game making more than for any other lesson.

One interesting point was that, as children moved on with the game making project, they needed less help with debugging their errors. This was visible from their problem-solving sheets. Children used these sheets to record their problems and how they debugged them. They completed these forms regularly in the first five or six sessions of the Scratch and Alice game making project, but after this, they only completed a few where they wrote what they asked to themselves, rather than explaining what their problem was and how they solved it. This does not mean that they did not use their debugging skills. I think they became more expert in debugging and solved their problems without realising. Another factor that could impact on this is that, as children develop their subject knowledge of Scratch and Alice applications, they would have made less mistakes, meaning less debugging was required.

During the interviews seven out of ten focus children made comments to support this. Child K said (Talking about his experience of programming with Alice):

> *"It was a bit hard first, so we kept making many mistakes and spent all our time looking for some answers on YouTube. I was a bit annoyed. I even thought maybe we won't be able to make a game. But after, ermm, I think sixth session we got better at it. Not very good still, but we didn't have too many problems. We couldn't make the robot run, that was a bit hard".*

Child H, who worked with Child K, explained his experience of programming with Scratch and Alice as:

> *"I think Scratch was ok, not hard but a bit like, for younger children…We had some problems but only at the beginning, then it was fine. I guess we learned to use it very quickly. You do it a few times, then you solve some problems, you kind of get better, right? I liked Alice, but that was hard. Like, we couldn't make the robot run, we spent a whole lesson. We solved it later and then we didn't have many problems".*

This shows that it is important to give time for children to explore the programming applications so that they can develop their subject knowledge, which is necessary for debugging problems. It also highlights that having opportunities to solve problems constantly actually helped children to make less mistakes as they progressed with their games.

Creativity and Tinkering

I did not asked children about how creative their games were during this study. However, it is evident from their completed games and field notes that they were experimenting with ideas that involved decision-making, critical thinking, problem solving, and designing solutions, which can all be seen as part of creativity. The task of character and background designs also provided the children with an opportunity to develop creativity skills, as this would allow them to express their own ideas using technology.

During the interviews, children were asked about what they learned by making games. Child T replied:

"It is a bit like writing a story really, you have to imagine first in your head, what characters or background you will use. Then you think how to code that".

Child S replied as:

> *"I guess you use some imagination".*

When asked to explain how, he answered:

> *"I pictured what I was going to do, I imagined it. Then I draw some, not everything. Because I wanted to try it first."*

Child B reported:

> *"I planned it with my friend. We thought in our head then, he told me his ideas. Then I told him mine. And we created it together".*

This shows that some children may not be able to express their ideas alone and might need the input or support of a friend. The link between using imagination, creativity and thinking skills was proclaimed by Child S who suggested that:

> "*Having a wide imagination means, thinking a lot harder, harder you think, more intelligent and more creative you get".*

The impact of game making activities on children's creativity is discussed in detail, in section 4.2.4.

Problem solving

During the interviews, when asked what they thought they learned by making games, every single child mentioned 'problem solving' as one of the skills that they developed. Child K stated that, during game making sessions when he had a problem, he would try new things to see if he could make it work or think about adding more things to improve it.

Both participant observations and children's problem-solving sheets from this study showed that constant problem solving was at the core of the game making activities (Appendix 7). The children's problem-solving sheets,where they recorded some of the challenges that they faced and how they solved them, provided me with more detailed information about examples of problems that they had. When analysing children's problem-solving sheets, this was also visible in the problems that the children recorded when making their games. In Scratch, the children solved problems related to script, such as creating a variable, but they also had different problems, such as making sound work, locating sound files, duplicating a character, or finding a costume. When designing a game using Alice 2, the children's problems were mainly writing the code to make an object do something e.g. How to add a score, moving an object by itself, how to add a timer (variable), moving a left arm or right leg (robot). The detailed discussion about children's problem-solving activities during game making project can be found in section 4.2.2.

5.5 Game mechanics

Lundgren and Björk (2003) explained game mechanics as the rules that players need to employ when they interact with a game. Aleven et al. (2010, p.71) described the mechanics of a game as "the basic components out of which the game is built: the materials, rules, explicit goals, basic moves, and control options available to the players". Hunicke, LeBlanc and Zubek (2004) noted that mechanics involve actions, behaviours and control mechanisms. This complex structure of game mechanics makes it difficult to create a set of evaluation criteria for pupil-created games. Weise (2011) suggests that writing game mechanics in a verb form, basically as actions that are accomplished within the limits of game rules, is a technique that can be useful for creating a framework. Werner, Denner and Campe (2014) used a similar technique to assess game mechanics in computer games that were created by children using Alice 2. They listed actions such as collecting, shooting, racing, guessing, hitting moving objects, and exploration as game mechanics. Additionally, they included puzzles, hidden objects, navigation, levels and avoidance in game mechanics. I will use Werner and colleague's framework for evaluating the game mechanics in children's completed games in this study.

At the beginning of the study, we had a class discussion about 'what makes a game, a game'. The common answers that were given by students were:

> *Games is something you can play", "It has rules, you get rewards", "It has score", "It needs timer", "You get points if you win", "You lose*

lives if you don't play well", "You have different levels", "Many games have stories", "It has goals".

My notes of informal conversations with children during the class discussions illustrates that they distinguish a game from animation mainly by its playability function. Child K explained this as:

"*You play with games, but animation, you just watch them, don't you?"*

Child B reported:

"You need to get some points or some rewards. Maybe have lives, if you don't want points. Otherwise what is the point of playing, right?"

Child T mentioned how the game they created can be played but there was no reward.

"Well, you can drive the car. Two players, like each control one car. One could use space bar and then one could press arrows. If you go to the finishing line, then you win. But you don't receive any point. But you can play with your friend".

This comment was interesting as she was correct that her racing game with her partner was a game that could be played. Her question was, 'does a game have to have some form of reward system to be categorised as a game?': I think I should have made it clearer at the beginning of the sessions that, as long as it can be played, it is a game, as I could see that couple of children had similar confusion.

I analysed 18 games that were created using the Scratch application and 15 games that were created using Alice 2. I used Werner, Denner and Campe's (2014) study to examine game mechanics in children's games. I added other visible actions and elements that represent game mechanics for each game and then looked for repeated patterns, first in Scratch games, then Alice games. Finally, I compared the results of the two separate analyses to provide an insight into game mechanics that were used by the children whilst making their games and how this relates to their learning, especially the development of CT skills. Table 20 shows the actions and elements that the children included in their games.

Table 20: The actions and elements that children included in their games

Mechanic	Description
Timer	Player is given a time limit to complete the task
Levels	Player is allowed to move to different stages when completing a challenge or reaching a target
Avoiding objects	Player avoids objects to complete a task. This is done sometimes by controlling the object using a mouse or arrow keys on the keyboard.
Clicking objects	Player is given points/ reward when clicking the objects
Moving objects	Player moves the objects by using mouse or keys on keyboard
Racing	Player moves objects to the finishing line. This sometimes involves time limit.
Guessing	Player completes a quiz by typing answers
Catching objects	Player controls an object to catch other falling objects. This is done using mouse or keys on the keyboard.
Points / Score	Player receives points or score for completing tasks.
Lives	Player is given a number of lives for completing a task. In many games, when the player runs out of lives, the game stops.
Speed	Player is given a number of speed options for different levels of challenge, engagement and interaction with the game.

Analysis of the 18 Scratch games that were created by the children showed that timed challenge and score/point were the most commonly used mechanics as these were included in 11 games. Levels and lives mechanics were used only in two games. Seven games contained the challenge of avoiding objects by controlling a sprite using either mouse or arrow keys on the keyboard. Three games included an action of clicking on the objects that were appearing and hiding on the screen in order to get points. Two games were basic racing games where two players were expected to each move a character to a finishing line; however, this task did not have any visible forms of reward. One game included speed for objects (apples) dropping from top, which was a range of random numbers.

During participant observations I asked Child B what the reason was for using speed, Child B replied:

> *"This made my game more challenging because players have to be ready for speed that changes all the time".*

Child K explained that he tried to create a real game:

> *"You need to have all that stuff, like levels, score. We got levels, right, let's say you practice, get better, then you can move onto next. You can't play the same one again again, it gets boring".*

These examples from informal conversations show that children used different mechanics in their game, which they thought had an impact on the level of players' engagement with their games.

The analysis of the 15 children's games created using Alice showed different results from those of the Scratch games. The most commonly used game mechanic in Alice was moving objects, where children created events to control the objects using arrow keys. Only one game included a timed challenge and score. Two groups tried to create a boat racing game but had issues with creating the score and timer. Another pair created a simple race game by moving objects to a specified position using arrow keys. Most of the games which the children created using Alice 2 were in a format of animation rather than a game. When the children were asked why they did not include mechanics in their games, they mentioned how difficult it was for them to create a timer and score using Alice 2. When I provided them with an instruction sheet for a game with a timer and score, they were then able to add these to their games. This showed that they needed more input and practise to create games using Alice 2.

In summary, this chapter explored what CT constitutes and the ways to best evaluate it using both the support of literature and the data collected from this study. After a thorough literature review, I proposed a definition of CT which highlights the interaction between computation and the elements of AI, computer, cognitive, learning and psychological sciences. This was also used to create a framework for evaluating different aspects of the CT Process, which can be listed as 'computational concepts', 'metacognitive practices', 'learning behaviours' and 'Context', in this study this wascomputer game design. I conclude that a multiple evaluation approach should be adopted to illustrate the full learning scope of the CT Process.

Evaluation of children's completed games demonstrated that, although a few students found using variables and abstraction challenging, children were able to use programming constructs including sequences, loops, parallelism, conditionals, operators and events. The gender-based comparisons showed that there were differences between the girls' and boys' use of programming constructs both in Alice and Scratch. In the Scratch environment, all except two girls created animations without using variables. There were no significant differences in the use of other programming constructs. In the Alice environment, variables were found challenging by both girls and boys and only 35% of the girls' games included abstractions in comparison to 50% of the boys' games. Analysis of the children's problem-solving sheets, observation records, informal conversations and semi-structured interviews illustrates that planning, monitoring, and evaluation were the main metacognitive skills that the children applied and developed through metacognitive practices when making computer games. Monitoring through constant testing and evaluation was also evident in all of the children's work, showing that metacognitive practices were used for controlling and regulating programming activities. The findings also indicate that learning behaviours such as collaboration, communication, persevering, problem solving, and creativity were visible whilst children were coding games. Furthermore, the findings of this study showed that the children used different modes of conversation to make decisions, evaluate and regulate their activities. The role of conversation in children's learning will be discussed in the next chapter.

Chapter 6: Conversational Exchanges

This chapter aims to answer RQ 3:
What is the role of conversational exchanges in metacognitive process and children's learning?

As discussed in Chapter 2, I defined 'Conversational exchanges' as a form of inquiry that engages learners in evaluating their thoughts, decisions and actions through conversations and dialogues with an 'invisible other' and other collaborators which are sometimes audible, sometimes visible through gestures. This chapter will examine if and how children use conversation whilst working on their games and how this relates to metacognition.

Firstly, what constitutes conversational exchanges and how this relates to game making is explored, using the findings of the literature and data analysis of semi-structured interviews, children's problem-solving sheets, participant observations and video recordings of group discussions. This is useful for describing the characteristics of different types of conversation that took place when children were working on their game designs. I then discuss the interaction between different modes of conversation that took place during children's game authoring activities, using data from this study to clarify the role of conversation in metacognitive process and children's learning.

6.1 Conversational exchanges: an overview

The data from participant observations clearly show that the children were constantly having spontaneous conversations with themselves and more focused dialogues with their 'self' and their friends. Although some of their self-talk was aloud and audible, they did not always expect a reply from their partner. This does not imply that they were not interested in their partner's perspective, but rather that their private speech had a different function than social communication (Vygotsky, 1986). They used self-talk for a different purpose whilst designing computer games, specifically, for clarifying things for themselves in the process of making decisions and problem solving, in other words, self-regulating. There were occasions where they wanted to have the opinion of their partners; therefore, they asked questions aimed directly at them. The following exchange, recorded through participant observation of Child K and Child H, illustrates this use of language for different purposes during the sixth game making session:

> *Child K and H were sitting next to each other and sharing a laptop. They had created a game called 'Robot fights' using Alice 2. Child H was happy with what they had accomplished and wanted to create another game. Child K was not pleased with their work and wanted to continue to work on it. They agreed to spend half of the session on their robot fight game and the other half on creating a new game.*

Figures 6.1 and 6.2 shows the entrance and the main fight scene from their Robot Fights game design on their computer screen.

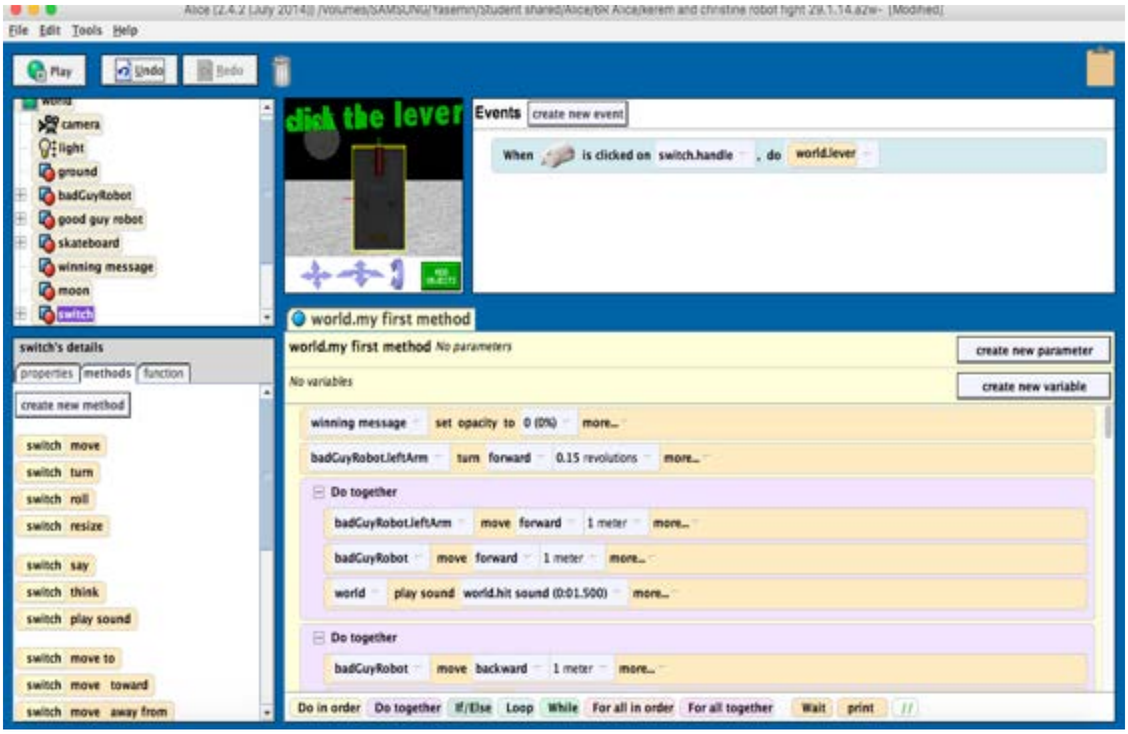


Figure 6.1: Child K and H's Robot fights entrance scene

Child K was controlling the laptop and as soon as he opened the game, he said, 'let me see what it looks like' and then he played it 3 times without making any comments, looking directly at the screen.
Child H: (Looking at the screen) I like it. I think it is done.
Child K: Don't know.
Child K: (pointing at the object tree of the small robot on the left-hand side) Why is he flying?
Child K: (Without waiting for a reply) I think I know why
(He then deleted some codes and added new ones).
Child H: Maybe we could add score, so if you win you get something.
Child K: (ignored Child H's comments, sat back and looked at the codes on the screen) Maybe BadGuyRobot can go down and then turn around, small robot could go up and down, like teasing, right? (Pointing at the BadGuyRobot on the screen)
Child H: Yeah, but it is not a game is it?
Child K: It is because you can win at the end.
Child H: But always BadGuyRobot wins. You can't play, that is what I am telling you.
Child K: Yeah, I know that. Hmm, what shall we do then?
Child H: I am not sure (He paused around 30 seconds, looking on the screen).
Child K: I know (loud), we can use keyboard keys to control them, like 2 people use different letters or arrows.
Child H: How do you do that?
Child K: I don't know.
Child K: (Sat back, put his hands over his head) Oh man, this is going to take forever.

Child K seems to focus on developing the fight scene, as he was not happy with the movement of the small robot. He asked questions, but he did not acknowledge his friend's replies (audible private speech). He answered his own question and then put this into action by adding and deleting codes.

Child H was not worried about the movement of the small robot; he was thinking about whether this was a game or not. He was displeased that he could not play the game because it had a fixed ending. A moment later, Child K acknowledged Child H's comment on BadGuyRobot always winning. He tried to interact with Child H by asking what they should do (Social speech). He then, again, answered the question himself by making a suggestion about using the keyboard arrow keys as a controller.

Figure 6.2: Child K and Child H's 'Robot fights' scene

Whilst it is certain that some forms of conversation took place between these two children, the purpose was more than just for communication. Each question they asked, replied, or discussed led to another action that helped them to decide and control their next action. It was also interesting that when asking questions or making remarks, Child K touched the codes or characters on the screen, as if he was interacting with them. After he had suggested that writing a script for controlling the robots will take a very long time, he paused a few seconds and then directly went to YouTube to explore tutorials for this task. This means he had thought about how to create this script (inner speech) and then this led to the action of exploring YouTube. On his problem-solving sheet, Child K stated that he had asked and talked to himself about:

“How are we going to work out how to move the robot and the space man?”.

This is significant as he used ‘we’ instead of ‘I’ which can be seen as his acknowledgement of his ’off-and-on’ interaction with his partner in his thought process. He also added that he discussed with his friend how to make the robot say ‘boo’. Other children in their problem-solving sheets also reported this type of focused dialogue with their partner on a specific problem, question or task.

Vygotsky (1978) shared Piaget’s (1959) view that private speech is visible with children aged 5-6 years old and declines with age; however, he was opposed to the idea that it becomes replaced by social communication. According to Vygotsky, private speech goes underground, transforming into a cognitive function (self-regulating) and becoming a verbal thought called ‘inner speech’, generally from the age of seven. During this study, although it cannot be assumed that all of children’s thoughts were audible by others, there were records of many occasions when children’s self-talk happened out loud. Whilst they were having a conversation with their ‘self’, they were touching the screen - not in a random way but aiming at specific characters and objects. Their private speech did not gradually become social speech or replaced with inner speech; rather they used private, social and inner speech continuously in different sequences as they needed to. They would talk to their ‘self’ and ask questions without expecting to be acknowledged by another person, and then they would ask the opinion of their partner on either the same thought or something else. Later on, they would start talking to their ‘self’ again both loudly and quietly. Notably, when the children used inner speech, this was visible in their gestures, facial expressions and their interaction with the game design through touching with their fingers on the screen as mentioned above. Furthermore, their thoughts, articulated through inner speech, helped them to make decisions regarding their games as their thoughts resulted in action. This can be demonstrated in the following example (recorded through participant observation) of Child T trying to solve a problem with her game during one of the Scratch game design sessions:

Child T had created a 2-player racing game with 2 characters, 1 background and a button object to start the game using the Scratch drag and drop 2D web-based game design application. In order to start playing the game, a player should click on the green flag, then the start button on the screen and this should hide the button so that players can control the characters using the letter b and the up arrow on the keyboard. The problem she described on her problem-solving sheet was that she couldn't make the button disappear once the player had started to move the characters. She had a partner, but on the day her partner was ill, so she worked alone. Figure 6.3 shows the Child T's game design.

Child T (touching on the start button on the screen constantly): "ohhh, it is not disappearing, why?" She then said "Maybe" and clicked on the events tab and dragged and dropped the 'When green flag clicked' block onto the script area. She looked at the script and put the 'hide' block under the 'When green flag clicked' block. While she was moving the 'hide block' she said, "I think this would make it work" (audible private speech).She sat back and said, "I did try that, doesn't work" (as if she was having a conversation with her 'invisible self') (audible private speech and inner speech).

When her solution did not work, she got annoyed, said "off", then stood up and went to Child K. After 4 minutes she returned with Child K and she told him that she is trying to make the button disappear when the players start moving their characters. He looked at her script and he said, "I know why", he them moved the 'hide' code above the forever block. They tested it and the script worked. She said, "I thought of that too". Child K told her that if you put the hide under the 'When green flag clicked', you are telling the computer to hide the character. He said, "you should show it at the beginning", so *he dragged the 'show' code under 'When green flag clicked' block (social speech).*

During this session, Child T started the execution of game design task alone as she asked questions to her 'self' when she faced a challenge. She made remarks as she moved the code blocks on to the script (audible private speech). After she tried a solution and failed, it appeared as though she was having a conversation with her 'invisible self', telling it that she did try that (as though she had thought of another suggestion to solve her problem). The level of challenge that she experienced might have had an impact on her using audible private speech (Berk and Landau, 1993). When she could not come up with an answer, she asked for help from a friend. It was interesting that, after Child K helped her, she asked him to explain his solution. Looking at her interaction with both her 'self 'and others, she used private speech that was audible by others where she talked as she moved the code blocks, social speech when interacting with Child K, and inner speech when she was evaluating a solution in her mind. These different forms of conversation enabled her to continue to engage with her task and manage her activities.

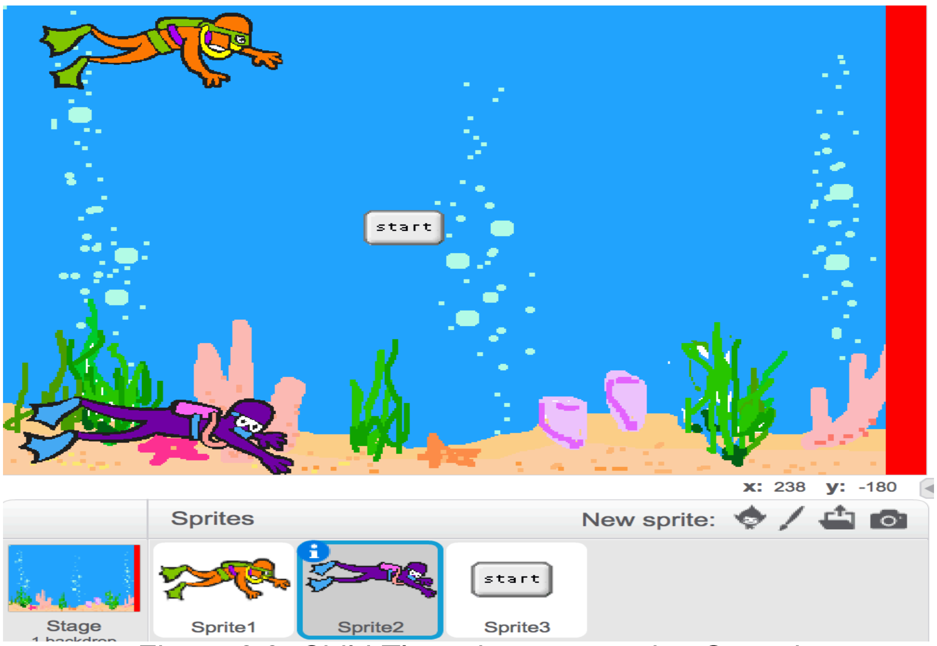


Figure 6.3: Child T's racing game using Scratch

As previously stated, the data from this study illustrates that, whilst making games, the children constantly had spontaneous and focused conversations with their ‘invisible self’ and ‘others’. During the semi-structured interviews Child M, aged 9 remarked:

> *“First, I write a piece of script like how the steps, then I think to myself, how can I make it better? I try to understand or sometimes decide by asking myself. I usually do this when I don't understand what I am doing, when I just check it or revise it I talk to myself. In other lessons I do it, but I don't do it a lot. Not as often as game design.”*

It is apparent from this comment that Child M used language in a form of a thought for asking himself for help when he does not understand something or is making a decision. It is interesting that he is aware of a self-talk function and he states that he uses it in other lessons, but not as often. By asking how he could make it better, he is activating the thought process for evaluating and planning. Child H also made similar comments, but this time with a justification, suggesting that listening to a teacher in other lessons limits the use of self-talk. This might pose a question as to whether or not too much ‘teacher talk’ would have an impact on both children’s private and inner speech.

> *“I ask myself shall I do that, shall I do this, trying to make a decision. It kind of helps me to make sense of things. I do it in other lessons too but not that much. Because you have to listen what teacher is saying”.*

Child J also mentioned:

> *“I guess I do use it (self-talk) in other lessons too, but I don’t really think about it. Maybe not that much because I kind of have to listen my teacher too. Then you have to finish your work, write and stuff like that”.*

When Child J asked about why he uses self-talk, he replied:

> *“When I talk to myself, I decide what to do better. It is like asking questions to yourself. Shall I do this and that. Then you answer it yourself, but you don’t really realise that. Because it is like thinking in your head. You hear yourself (He smiles)”.*

Child H's and Child J's purpose of using self-talk is comparable to that of Child M's; all mentioned making decisions and making sense of things. They noted that they are both aware of self-talk as a function and pointed out that they use it more often during game making. This might suggest that the application of conversation as a function could be task-related and the context of how the learning was facilitated might have had an impact on the use of conversational exchanges by children.

When the children were asked to complete the sentence "I asked/talked /thought to myself' on their problem solving sheets, some of them replied: "If I did it right", "How we could improve our game", "How my game should be set up", "That I should check the game", "I asked myself if I put this… to make plan work", "About the mistakes we were making". When they were asked to report on what they had discussed with their partner or friends, their comments exhibited different forms of dialogue with a more specific focus. They made comments such as "How to open web gallery", "How to put the alien behind the ramp", "How are we going to make the score work", and "Which character we should pick". This shows that they used both self-talk and social talk to check if they were doing the task correctly and/or to make decisions related to specific problems with different focusses.

Video recordings of the children's discussions provided a deeper insight into how and why they used different forms of conversation when making their games, especially self-talk. A few of them reported that talking to their 'self', made them think, which emphasizes the link between language and thought. Child K explained this as:

> *"I think when you talk to yourself, it makes your brain like, you, you think yourself, like you don't ask someone else with different brains to yourself. So, you see, like, was in your own brain, you know what you are capable of, what you are good at".*

Child K's comment also highlights how he used 'self-talk' to evaluate his own ability to do something. He also connects self-talk to the mind by adding:

> "*I think when you talk to yourself, it expresses your mind, makes you think what you want to think, not anyone else".*

By suggesting that he does not ask someone, it can be assumed that self-talk took place in his mind (inner speech) and was not audible by others; however, this was not clear.

Child M's comments also suggest that he was able to distinguish self-talk from talking to others and define its purpose. Child M noted that talking has a purpose of asking someone for their opinion. He said:

> "*I think talking to yourself is that, it is different than talking to other people because you don't really ask their opinion, you ask your opinion, like what is in your head. It makes you think, what you wanna do, like independent, more independent than talking to someone else to see what they think*".

This view was supported by Gallagher and Crisafi (2009) who claim that "when we are explicitly trying to think through a problem, we conduct an inner conversation where we may represent one side of the issue against the other side" (p.6). They also noted that conversation with others can also serve the same purpose and thinking is often conducted by such conversations.

Child A shared another purpose for self-talk. He suggested that it helps him to organize things. He explained this as:

> "*I think that the purpose of it is like to make you a bit more organised. Like if you couldn't bother to like, write down everything you are going to do today, your brain, you could store it inside your brain. Like a phone, you store stuff in your phone*".

'Organising your brain' means using self-talk as a function to regulate self-behaviour (Ford et al., 2004).

It is very difficult to count the number of these speech utterances that have occurred at the end of this project as I was not able to observe every single focus child at the same time during each session. However, it still provided me with an insight into what type of conversations they were using it and for what purpose. I will discuss this in the following section.

6.2 The modes of Conversational Exchanges

It is clear from the data analysis that (as discussed in section 6.1) sometimes learners had spontaneous conversation with themselves out loud, which were random (unplanned) and aimed at 'self' with an intent of exploring their ideas and solutions randomly (Private speech). Sometimes they focused on a specific problem during their conversation as they answered their own questions and/or had unintentional dialogue with others (Unintended collaborative talk). In some situations, they had focused dialogues with their friends in which they tried solving problems collaboratively, which can be seen as shared thinking (Intentional social discourse -social speech). On other occasions, they had conversations with self that were only visible through actions and/or gestures as they internalized their thoughts (tacit inner dialogue).

In order to have a clear picture of conversations styles and their purposes in game design context, I first listed all the conversations that children had: random self-talk, unintended collaborative talk, intentional social talk and inner dialogue. I wrote the characteristics for each conversation style by using the data from my observation notes, group discussions and semi-structured interviews (Table 21). This was useful for identifying the different types of conversational exchanges that took place whilst children were working on their games, and their purposes. This process contributes to the literature as it provides a clear list of children's speech utterances and their characteristics in computer game design context. There were 28 interactions recorded in total. Some of these interactions represented more than one type of conversational exchange. For example, in record 15, Child

T was having a conversation with self, but then she moved onto talking to her partner, Child A, and then went to speak with Child K. Therefore, she used private, social and also inner speech in the same interaction. Out of 28 interactions; 11 records were private speech, six records were unintended collaborative talk, 21 were intentional social discourse and seven were tacit inner speech occurrences. I believe that there were more inner speech activities included in almost each interaction; however, I was not able to keep a record of these through visible behaviours.

Table 21: Modes of conversation in game design context

Modes of Conversations in game design context	
Mode 1: Spontaneous audible conversation (private speech)	Mode 2: Unintended collaborative talk (with 'self' and 'others')
• Random • Aimed at 'self' • Directed at an object • Self-remarks • Visible via audible talk • Intent of exploring	• Focused on specific problem • Aimed at 'self' and 'others' • Asking questions to 'self' • Answering own questions • Unintentional dialogue with 'others'
Mode 3: Intentional social discourse (Focused dialogues with others)	Mode 4: Mode 4: Tacit inner speech (Thought)
• Aimed at 'others' • Focused dialogues • Negotiating meaning • Collaboration • Shared thinking • Asking questions to a partner • Answering questions of a partner • Eye / Physical contact • Requesting partner's attention	• Internalization • In the form of a thought • Visible through actions or/and gestures • Making sense with 'self' and 'invisible self' • Self-regulation • Silence

A more detailed account of the different modes of Conversational exchanges is given below using data from participants observations.

Mode 1: Spontaneous audible private speech

The analysis of the participant observations shows that out of 28 recorded interactions involving the focus children, 11 included interaction with 'invisible other', namely private speech. The children had spontaneous conversations that were related to any part of their game design task. This communication was aimed at their 'self' with a main function of 'exploring'. Some children made remarks about the characters and the backgrounds that were included within the game design application, while others asked questions without any expectations of an answer from other pupils. The children did not communicate any information directly to others, although some of them had a partner nearby watching their actions. They rarely acknowledged the responses from their partners and their interactions with their 'self' were visible through their facial expressions, gestures and audible speech. The record of participant observation in the following example presents the use of self-talk by Child T who was working with a ten-year-old boy (not a focus child). This was the second session of using the Scratch application when the students were exploring the program and planning their games. She normally was partnered with Child A, but on that specific day Child A was absent; therefore, she worked with another child. The observation commenced 12 minutes after the students started to work on their games.

> *What! That is ugly trousers, will draw a new one (Looks at a female character in Scratch library). Maybe I can draw my own? Let me see how you do that (Clicks on the Scratch drawing area). Should have black hair, right, or dark brown maybe? (She draws a circle then adds mixture of black and brown hair). Aha, cool (she smiles). It looks similar; oh I forgot the hair clips (she looks at her drawing on her paper then uses black felt tipped pen to over go the lines on the hair clips of the female character on paper). Red pencil please, who has it? (She shouts, then leaves her seat for a few seconds and picks up some coloring pencils from other tables). (She starts colouring the*

female characters clothes on her planning sheet in red), ba pam ba pam bam pa… (She hums a rhythm while she is working). Shoes, himmm! (She looks at the colouring pencil for a short while then starts colouring the shoes of her character in red too). Looks ok. I know what, I think the hair should have red (She colours the hair below the hair clip in red. (Looks at her drawing on the paper, then looks at the screen on her computer, she repeats this a few times, then she starts drawing on her screen). Ah, why is it not working? (She gets cross because the eyes she draws on screen character are not the same size). (Her partner says 'silly, silly, silly' and then adds 'use the circle silly'). (She looks at the screen) Where? (She asks). Oh, silly me (She smiles, finds the circle drawing tool). (She erases her character on screen and then draws it again using the shapes drawing tools. She uses circle for drawing the head and the eyes).

In the example above, Child T used private speech when making decisions and finding solutions to problems. Sometimes she used a non-word (e.g. himm…), excitement word (e.g. ah, aha) or a muttering in a form of humming a song, and sometimes she made a sentence or asked a question, but these were all related to her work, meaning her conversation with 'self' helped her to control her behaviour and focus on the task. These dialogues also engaged her in collaborative problem-solving activities with 'invisible self' (Vygotsky, 1979) by helping her to appropriately select and use cognitive strategies. One example of this was when Child T did not like the character in Scratch library, so she decided to draw her own one. She then started to think about whether she could draw exactly the one that she wanted. She used her knowledge of Scratch to open the drawing pad and tried to create an on-screen version of her drawing from her paper. She guided herself for this activity and constantly monitored her progress by comparing her on screen drawing with her paper based one. Diaz (1992) suggested that there is a correlation between the use of private speech and children's task performance. According to her, if a child has the level of competence that is necessary for completing a task, the child will be able to accomplish this without the need for private speech. This was supported by

Fernyhough and Fradley (2005) who noted that private speech is initiated especially when facing challenging tasks. I believe that this might be the case for some children and situations, but in this case Child T did have the competence to complete the task. The task was open-ended and required her to use her own ideas and creativity to explore and make decisions, and it was this which encouraged the use of private speech. Johnson (2004) supported this by suggesting that private speech supports children to solve complex problems by providing them with metacognitive tools such as guiding, monitoring and planning of tasks.

Observation of Child K during a Scratch session provides further detail about the use of private speech for self-regulating. This observation took place halfway through the session 6. His partner, Child H, was away and he did not want to work with someone else. He also did not want to work on their shared project, so he decided to create a car game.

> *(He was testing his code for making the car start with a speed and then gradually gets faster). Hmmm… (He looked thoughtful and unsure; he placed his hands behind his head, sat back on his chair and looked at the screen). (He dragged an operation (+) block and tried to place it onto move block), ah what, why did I do that? Ok, let me think. X is like, like vertical line (he moves his hands, holding them vertically, then he goes on Google and writes x vertical or horizontal, clicks on the enter). (He reads the first web page, then returns to his game screen), ah now I got it, it is horizontal (he laughs). (He drags the 'change x by' block to the coding space. The then places 'When the green flag clicked' block above and clicks on the flag. He drags the repeat block and moves the 'change x by' block inside. He programs the code to repeat 10 times. He is using the cat sprite, the cat moves, he looks annoyed). (He puffs) so annoying man. (He then searches on Google 'changing the speed of a sprite Scratch'. He opens a website and reads the instructions. He starts laughing) Oh man, that is easy, just need a variable. (He creates a speed variable, then he drags 'change speed by' block inside 'forever' block).*

In this example, Child K uses self-reinforcement words ‘I got it’ to express the point that he now knows the problem. He asks question to himself “Why did I do that?” to evaluate his own action. He plans his next action by thinking about and searching for the position of X, whether it is vertical or horizontal. He again plans by suggesting that he needs to get a variable. Although Child K was frustrated in a few situations, this did disengage him with his task, but encouraged him to think ways of finding a solution to his problem. He planned his actions and evaluated them through questioning, which is the important part of self-regulated learning and successful cognitive performance. As mentioned in Chapter 2, this semi-structured problem-solving task motivated him to use private speech (Berk and Garvin, 1984). Furthermore, the task was challenging at times, which might facilitate the use of private speech more than usual (Kohlberg and Yaeger, Hjertholm, 1968; Behrend, Rosengren and Perlmutter, 1989).

Mode 2: Unintended collaborative talk (with self and others)

There were six records of this type of conversation written down in field notes. In this mode, the children focused on a specific question, problem or task execution. Although their dialogue was aimed at their ‘self’ and they mainly answered their own questions, there were cases where they had a quick exchange of thoughts through dialogue with their partners on a shared topic or question. It was significant that none of the parties involved in dialogue was interested in negotiating a shared meaning or finding out about each other’s perspectives. Although they were in the same environment: sitting next to each other, focusing on the same activities, looking at the same computer screen, they were just sharing their own thoughts without an expectation of acknowledgement from each other.

The Child T example from Mode 1: Spontaneous audible private speech section can also be used to explain this mode of conversation. During the participant observations, Child T switched between having a conversation with ‘invisible self’ and interacting with her partner. When she asked questions or made comments about her actions, she did not look at her partner or try to involve with her. When she could not come up with a solution, although she did not ask for help, her partner who has been watching and listening to her quietly, decided to become involved and suggested using the circle tool to draw the character's eyes. The interesting point was that, although the interaction between two children started at that point, they both continued to use private speech. This shows that they did not replace one form of conversation with another; rather, they used them for different purpose and situations.

The following exchange between Child M (Focus child, 10 years old boy) and Child N (not a focus child, 10 years old girl) illustrates the main elements of this mode of conversation. The observation took place during the third session of Scratch gaming project. The children were still exploring the application and developing their game plans. Child M's partner was away so he worked with Child N. They had a planning sheet in front of them. They drew pictures and used text for their planning. They did not colour the pictures; they only used black pencil to draw the characters and the background for their game. They were sitting next to each other, but not sharing a computer; each had their own laptop.

> *Child M: (Looks at the planning sheet) I need a police officer. (He opens the Scratch library) Oh no! (He places his hand on his mouth, and then moves it away, he smiles).*
> *Child N: (Looks at the planning sheet, smiles, opens the Scratch library, clicks on the people tab. She doesn't respond to Child M.)*
> *Child M: I can't draw. I am rubbish! Hmm. (He opens the drawing pad on Scratch, draws a head (He laughs). Oh God, rubbish innit? (He still doesn't look at Child N).*
> *Child N: (Opens the drawing pad and starts drawing a person). (She looks at Child M's laptop screen, starts laughing, they both laugh). Mine rubbish too (She continues to draw).*

Child M: (He looks at Child S laptop screen who is also a focus child). That's good, actually really good. That's it! (He closes the cover of his laptop and sits back, stares at Child N laptop).

Child M did not start his task with an intention of working with his partner, even though they were sitting next to each other. They could share a laptop from beginning like many pairs, but they decided to have their own. There might be many reasons for this, such as they may not get enough turns using the laptop, or they might want to search on the Internet. Child M began interacting with himself, focusing on a specific aim: creating a police character for their game. He evaluated his work and did not like the quality of what he created; he shared his self-criticism aloud but not directed to his partner. Child N did not acknowledge her partner's conversation or actions until he comments on his own picture. After this, they start interacting and commenting on each other's work. It is not possible to simply define this interaction being a 'Collective Monologue' as Piaget suggested (1959, p.17). He noted that in this form of private speech the child may not expect to be acknowledged by others and continues to talk to self without collaborating with his/her audience. He might have intended to describe this form of private speech in relation to very young children rather than the students that took part in this study. In this episode, Child M started his conversation with himself without expecting any answers from his partner. However, his out loud comments triggered a conversation with Child N and they mediated their ideas to form a solution for their game project. They moved from working alone to collaborative interaction through conversing, although this was not continuous as they switched between working alone, talking to self and talking to each other. Their conversation was not aimed at anyone specifically; rather, conversing both with self and each other occurred unintentionally.

Another interaction took place between Child B and J during one of the Alice sessions:

Child B and Child J were sitting together. Although they were working on their game on Child B's computer, Child J also had logged onto *his computer. Child J was on You Tube looking at some videos. Child B asked himself if he should make the boat bigger (His hand was on the mouse). Child J replied as "I am not sure". He was still keeping an eye on his screen. Child J then opened a video and said "Yes" (looked very excited and happy). Child B was still working on re-sizing the boat object. Child B suggested that it (the boat) looked better now. Child J looked at the boat very quickly and said "Yeah, I think so". He (Child J) then looked at his screen and said, "This is cool, but looks a bit hard". Child B only looked briefly to Child J's screen and smiled. The You Tube screen showed a boat race on Alice with a timer at the top. I left the students and moved to another part of the classroom. When I returned maybe 5 minutes later, Child B was looking at Child J's screen. They watched the video together; they stopped the video at certain times in order to follow the step-by-step instructions (Extract from fieldnotes).*

This example shows that although the children worked on the same task, their conversation was always aimed at each other. Sometimes they asked a question to themselves and sometimes they acknowledged a comment that was made by their partner although this was not expected of them. Still, they were having a conversation on the shared task unintentionally which brought them together later on to work collaboratively. While they did not have a purpose of solving a problem together or finding an answer, through speech, they evaluated each other's ideas and focused on investigating their own ideas at the same time.

Mode 3: Intentional social discourse (Focused dialogues with others)

'Intentional social discourse' refers to the social interaction that is based on a shared task, challenge or question. Conversation in this form has the function of negotiating, meaning that could trigger an evaluating, planning or monitoring process. There were 21 records of the children having focused dialogues with either their partner or others in the room for both communicating their ideas or/and asking questions. They engaged collaboratively with a problem, challenged, questioned or executed tasks through focused dialogues that led to a shared thinking. When analysing the data to identify social speech, the focus was not only on the verbal communication that took place between children, but at the same time the physical contact and/or eye contact that they made. The following examples from observations present intentional social speech practices that took place during game-making activities.

> *Child K and Child L (10 years old, not a focus child). This interaction took place during the 3rd session of Alice game making project. Child K's partner Child H was away.*
>
> *(Child K clicks on the green flag to run his code, it doesn't work. He looks at his partner, Child M. His partner raises his eyebrows, looks at the screen and waits in silence for about 6 seconds).*
>
> *Child M: Let me do it then (Sounds like he is not happy).*
>
> *(Child K moves back, Child M clicks on the green flag to run the code, it doesn't work).*
>
> *Child M: Why did you put this?*
>
> *(Child M moves the pointer to a code, he deletes a code and then drags another one, and he is humming a tune at the same time, Child K watching him).*
>
> *Child K: Ah now I know, wait.*
>
> *(Child M stops and looks at him).*
>
> *Child M: What? I am making it*
>
> *(Child K moves forward and takes over the control of the laptop; he pats Child M on the shoulder)*
>
> *Child K: Yep, yep, I know now.*
>
> *(Child M looks very annoyed, folds his arms and sits back, still looking on the screen).*

Although Child K did not directly ask for help of his partner, by looking at him he triggered the communication using eye contact. They do not seem to work on the problem together; rather, they try to solve it alone. Nevertheless, they responded to each other's verbal comments and actions. This made the conversation ongoing and kept them on task. There were moments were the students were silence whilst their partner was using the laptop, but this did not disengage them from the activity, or stop the social interaction. Rather, they seem to be thinking about their next action, as a verbal comment or physical movement often followed this silent moment.

Another example of this was observed between Child A , Child T and Child K. This interaction took place during sixth session of Alice game making project, 34 minutes after the session had started. Child A and Child T are partners, creating their game together. Child K has a different partner; however, during the observation of this specific interaction he was sitting with Child A and T.

Child T: Yeah, done that, tried it (Looking at Child A)

(Child A nods)

Child K: Hmm, let me see, emm, what about (He is controlling the laptop, moving some codes).

Child T: Can you see it (Looking at Child A)

(Child A nods her head)

Child T: Sure?

Child A: Yes (Nods)

(Child K, working on the script, he deletes some codes and drags some new codes).

Child K: You could create a procedure, you know, it saves time, you don't keep adding code.

Child T: Yeah, we tried, haven't we (Looking at Child A).

Child A: (Nods her head) didn't work.

Child K: Let's see; let me run it, yes (He raises his fist above his head, 'Yes' comes very loud).

Both Child T and A are smiling (they look relieved).

Child T: Can you show us though?

Child K: Your variable, yeah, you need to create it for this sprite, you see what I mean (pointing at the code)

Child A: I did say (Looking at Child T)

Child T: We did that, I am sure we tried that (Looking at Child A, expecting a response).
Child K: You did for all of them, not just for this sprite
Child T: oh, I see, well.

I am assuming Child A and Child T could not make their code work, so they asked Child K for help. Child A was very quiet; she mainly nodded her head and made very only two short verbal comments. This is unusual as she is normally very chatty and dominating. She does not get on well with Child K, so this might impact on her involvement level. Child K is very good at coding in both Scratch and Alice environments. The students always ask him for help. Although Child A did not say much, it was clear that she was engaged with the conversation through eye contact and physical gestures. Child T always used plural form for verb (we), reflecting that the game was created collaboratively. She also requested Child A's attention by looking at her for a response or asking her question directly. The interaction between Child T and Child K was more than asking for help; Child T wanted to find out what their error was and how they could solve it. She asked Child K for further explanations, in other words, she constructed her understanding through social interactions with Child K. They used social speech to evaluate the script, identify the error and create a solution, which involved some form of planning, although this was not always visible.

One interesting point is that the children's social speech was not always audible. As presented in this example, the use of eye contact or physical gestures which are not audible were also part of this mode of interaction. It is not possible to suggest that Child A did not have necessary resources for using social speech, as there might be many reasons for her silence such as not having a good relationship with Child K. Another interesting point was that the conversation between children became more intensive when there is a problem. In both episodes, the social speech was taking place because the children could not find a solution for their problem and they needed help; in other words, social speech was triggered by a problem.

In another example, Child C and G solved a problem which involved creating a variable for one character. Child C was holding the mouse and he deleted the variable. Child G became upset and told him off for deleting the variable.

> *Child C: So, what, we can create it again (not happy with Child G's reaction)*
>
> *Child G: Wait man, just wait. You don't know what was wrong though, do you? (He looked cross).*
>
> *Child C: (Passing the mouse to Child G) Fine, you do it (he folded his arms).*
>
> *Child G: (Clicked on make a variable, then he created a score variable) Here it is.*
>
> *Child C: Test it, come on*
>
> *Child G: (Tested the game) Offff! (He looked at me as if he was expecting me to help, I turned my head other way as if looking at another child).*
>
> *Child C: Did you click on the apple?*
>
> *Child G: I think, oh no, background. I know what to do. Just select this (apple sprite).*
>
> *Child C: Yeah, told you (smiling).*
>
> *Child G: For this or for all (clicking on the make a variable tab)*
>
> *Child C: Make it so if click on strawberries you lose points. So, you need to have one more for that one.*
>
> *Child G: This is for apple (created a variable).*
>
> *Child C: Yeah.*

Once the variable for the apple sprite worked, they both looked happy. They basically identified and solved the problem together. In this scene, they used conversation as a tool to communicate, but also to think of solutions for a problem, then evaluate these through testing. In a sense, Child C guided Child G by offering hints which can be seen as indirect support through social conversations that can help with their cognitive development (Bodrova and Leong, 1996). This was supported by Tobin (1998) who suggested that language-based interactions enable students to negotiate meaning (in this example evaluating and formulating solutions) which can contribute to both social and cognitive development. Furthermore, these language-based social interactions are essential for learners to self-regulate their learning (Tobin, 1998; Vygotsky, 1978; Schunk and Zimmerman, 2011). One important point is when Child C and G were having a conversation, they were also making comments that directed at self. For example, when Child G wanted to create a variable, he talked to himself; “for this or for all”, “just select this(apple)”, “this is for apple”. There were many similar interactions where private and social speech were used together. Kraft and Berk (1998) reported that when children worked collaboratively with their peers, they used private speech more often than when they were alone. I cannot make any claims as all the students in this study had social interactions either through working with a partner, or walking around and exchanging ideas, or both.

Mode 4: Tacit inner speech (Thought)

Inner speech can be simply defined as dialogue with oneself (Bakhtin, 1986). It is very difficult to observe when and how children use tacit inner speech (thought) as it is not audible by others, but it is sometimes visible through children’s actions that reflect their decisions. Child A’s explanation during interviews illustrates this:

> *“When trying to find out, like when I was trying to make the character move, I was thinking how can I make the character move? Let me look around the place. I kind of explore in my mind. If you say it in your head, you can think more, focus on it and learn more. Sometimes I do it in maths and science”.*

In this episode, Child A used tacit inner speech to find a way to make his character move. He suggests that if you say it in your head (inner speech), it can enhance your learning. Tacit inner speech (thought) mainly took place after one of the other modes of conversation in the form of a ‘pause’ and ‘silence’. This moment of silence enabled children to make sense of their conversations with both their ‘self’ and ‘others’ through evaluating and negotiating meaning in their mind. This ‘making sense’ process would lead to decisions, followed by an action. In some cases, this action was going back to explore some more ideas or modifying the planning or the game design.

Some of the children used tacit inner speech to evaluate their decisions and actions and to plan their next steps, some to formulate solutions. The example I shared in the previous section where Child G and Child C were having an issue with creating a variable. They tried out different solutions to debug their errors. They used social speech to discuss their ideas and private speech to evaluate their own thinking. Every time they had language-based social interaction, their social and private speech gradually internalized and became silence (inner speech) (Winsler and Naglieri, 2003). Ford et al. (2004) suggest that the purpose of inner speech is to control thought and behaviour. Although it was silent, inner speech became visible through Child C's and Child G's private and social speech practices as they constantly made decisions and evaluated these. In the following section, I will discuss the interaction between these four types of conversation.

6.3 The interaction between the modes of conversation

The data from participant observations, children's interviews and the problem-solving sheets show that the children used modes of conversation in different sequential order. During the interviews, Child G explained his 'talk' activities as:

> *"Depends on what my problem is. Sometimes I think in my head and that works, sometimes I will talk to Child C or other people. Yeah, and solve it together".*

He moved between talking to his 'self' and friend to find an answer to his problem. He compared his inner speech to talking to his brain, which could be seen as 'invisible self'.

Child T also described her interaction using different modes of conversation. She said:

> "*First, I try to make a plan in my head, think what I want my characters to do, how I want my characters to look, what shall I do, how shall I*

do it? Then, I start talking to my partner. We decide on things together".

Child J explained:

> *"Well, of course, I first think in my head, right, and ask how, how I can solve it. If I got the answer then it is ok, I tell my partner, or if it was too hard, then I would ask for help".*

Participant observations shown that Child A started her task by planning in her head (inner speech) then discussing these with her partner (social speech) to decide together. It appears as though some children decided to start having a conversation with their partner directly to plan their games rather than their 'self'. Other children chose to explore some ideas on their own by looking at examples on the Internet and making remarks to their 'self' whilst analysing these. There were some students who wrote notes on paper as they talked to their 'self' during mode 1 and thought to their 'self' during mode four. As they moved between the modes, they used conversation to trigger, apply and control different cognitive and metacognitive strategies (Johnson, 2004). Figure 6.4 shows the interaction between the different modes of conversational exchanges.

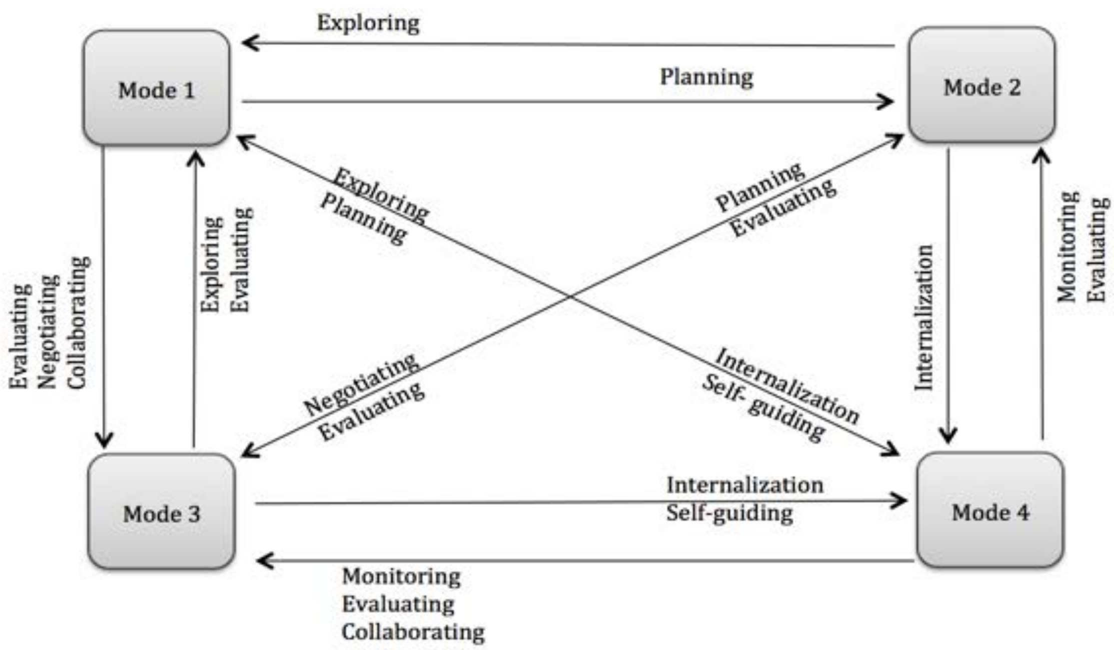


Figure 6.4: The interaction between the different modes of conversational exchanges.

According to Tomasello et al. (1993), the core of internal dialogues of self-regulation is social interaction. They argued that the child could only be engaged in internal dialogues of self- regulating speech after they have managed to understand others' thoughts and perspectives. I agree that dialogue through social interactions can lead to internalization of thoughts, in other words, inner speech. However, the data from this study shows that the internalization of audible private speech is also possible as children negotiate the meaning through self-talk. Vygotsky argued that "Inner speech is not the interior aspect of external speech - it is a function in itself" (Vygotsky, 1986, p. 149). Assumptions around inner speech occurring automatically as a consequence of social speech are therefore misleading.

Vygotsky (1978) also suggests that, alongside its cognitive function, private speech also indicates one's ability for self-communication, similar to social speech demonstrating one's capacity for social communication. The interpretation of 'self' in self-communication makes this statement more understandable. Self in this process acts as 'invisible self' with a function of regulating by providing another perspective for negotiating meaning, just as we do in social communication. This dialogue between 'self' and 'invisible self' leads internalization of language as thoughts (Inner speech). Child A's comments from interviews illustrates how communication with 'invisible self' enables one to adopt two different roles that enable social-like dialogue. She explains:

> *"I think about what I want to do in my game or animation. Then I plan it out. First in my mind, then on a paper. After I finished planning then I start talking to my brain, finding out what makes this thing move and actions, like how do you make it stop at certain times. I ask, and my brain answers me. If it doesn't work, I try different things, sometimes I ask my friend or teacher but most of the times I talk to myself, because it helps your mind to think about the steps you need to follow. I do it more in game design, because game design is more complicated. You have to improvise it; you have to find new things."*

Child A expressed her interaction with ‘invisible self’ by stating that she talks to her brain and her brain answers back. She also explains that when she talks to herself, this helps her mind to think about what to do next. She moves between talking to brain, talking to self and talking to friend/teacher. All these modes of conversation share a common feature, that of social interaction. Self-talk is also a form of social interaction in this scenario, as this enabled Child A to negotiate answers for her questions with herself.
During the group discussions, the children used different words to represent ‘invisible self’. Child A explained this as talking to a ghost. She said:

> “*If you can't really remember it, you ask yourself and it answers back. It is like a ghost; it is inside you*”.

Child B mentioned having two different people in her brain:

> *“it is like I have 2 different people in my brain. One is me; one is the part that is saying, do this, do that”.*

The data from this study suggests that the children’s use of different modes of conversation were neither based on a developmental stage nor related to age. The children used some or all of the modes of conversational exchanges in different sequential orders. This might have been determined by many different factors. The children may have been lacking the awareness or skills that are necessary for using different modes of conversation for regulating their own mental activities. They might not have the emotional readiness for interacting with friends. The teachers may not have an understanding of the role of self-talk in learning and how they facilitate this process in the classroom. The game-making task may not be interesting for all of the children or might be too challenging for some.

In summary, children used conversations to think and regulate their planning, decision-making and evaluating activities. In a sense, these conversational exchanges are metacognitive conversations because they act as a trigger for evoking metacognitive process. This idea is supported by Mead (1934) who agreed with Vygotsky that speech and thought could be in the form of a dialogue that allows children to make sense of their own actions when they discuss the meaning with others. In the next chapter, I will discuss metacognition and tools for measuring metacognition in more detail.

Chapter 7: Measuring Metacognition

This chapter aims to answer the RQ 4:
How to measure metacognition in a computer game design context?

In this chapter, I first evaluate the data from the participant observations, game design planning sheets, children's journals and problem-solving sheets, semi-structured interviews and group discussions to gain an understanding of the metacognitive skills that children apply and develop when making their computer games. I than propose a framework for metacognitive skills using the support of relevant studies in this field and the data from this study. Finally, I report on the development of the Metacognitive Skills Instrument (MSI) based on the framework for metacognitive skills in game making context: a self-report instrument for pupils to measure their perception of metacognitive awareness whilst authoring their own games. The development and the use of this tool can be seen as a way of checking the validity of the metacognitive framework that has been shared.

It is clear from my discussions in section 2.2.2. that measuring metacognition is very challenging and in order to cover all the components of metacognition, it is crucial to employ different procedures for measuring metacognitive skills from different aspects. The complete list of the methods that were used for identifying the metacognitive skills that children applied during game making activities can be found in Chapter 3, Table 11.

7.1 Data analysis of Metacognitive skills

It is a very difficult task to describe the metacognitive skills that children apply when making computer games, as their mental activities are not always visible. Their game designs could give us information about whether they were able to use the software to create a game. However, it does not explain the underlying functions they used in the control and monitoring of their cognitive process, such as, how they solved the problem, the strategies they used, whether they had previous knowledge which helped them with the task, how they selected the information they used, how they knew it was the right choice and so forth. This section tries to answer these questions by analysing the findings from the participant observations, game design planning sheets, children's journals and problem-solving sheets, semi-structured interviews and group discussions, in conjunction with the literature in metacognition.

As explained in section 2.2, metacognition is simply described as 'thinking-about-thinking' (Flavell, 1979). Claxton (1999) explains metacognition as a way of supporting people to manage their minds more productively, which enables them to use their resources more effectively. It is clear that metacognition involves self-regulating, monitoring activities and skills to manage these processes. Therefore, I define metacognition as a skill set which enables people to deploy and manage their cognitive resources effectively to regulate their thinking and learning. A number of studies describe planning, monitoring and evaluation as the main metacognitive skills for learners to regulate their learning whilst completing a task (Fisher, 2005; Perry et al., 2018; Schraw et al., 2006; Whitebread et al., 2009; Zepeda et al. 2018) and these will be used as a starting point for examining metacognitive skills that children applied whilst working on their games.

Several studies suggest that collaborative game making provides a context for children to solve problems which requires planning, executing and self-regulation skills (Bermingham et al., 2013; Kafai; 1996). In my study, I also found that planning was a skill used by all of the children throughout the activity for different purposes such as making predictions; managing resources and time; and selecting and allocating strategies. At the beginning, the children used different methods and styles to plan their games when using both the Scratch and Alice applications. This involved making predictions about which codes that would help them achieve their goals and allocating the resources that would help them to create their games (characters, backgrounds, sounds). On their planning sheets, some children preferred only drawings as a tool to communicate their ideas; some used both text and pictures; and a few used only texts to present their thoughts.

Most of the children's planning sheets had a title, characters and background information. They included a story or narrative, but not necessarily game elements such as variables. Although their finished games included some variables such as a timer, score and levels, some of the children did not have any records of this on paper. During the semi-structured interviews, many children talked about how they went over their work and changed their games constantly. Again, this was visible when their finished games were compared with their paper versions. However, there were no alterations made on the planning sheet. It therefore seems as though they used their planning sheet purely as a verbal review tool and made the changes on the actual design rather than on paper.

A majority of the children planned their games in multiple parts. One of the interesting points was that, when they designed their work in parts, most of them listed each action that will take place as a bullet point. This task is very abstract for young people and requires organizing, predicting, visualising and sequencing skills. Coming up and tinkering with ideas and then visualising how these ideas would transform into a game through planning in mind (visualising) and discussions with partners were common behaviours that were recorded, both during participant observations and interviews.

The data from the semi-structured interviews also suggests that game design activities helped the children to use planning skills more often for other activities as well. Child S reported this:

> "*I used to be like, let's do this, but never planned for anything. But game design made me to do stuff freely, like independent. And then suddenly my thinking has changed. Now I plan everything out".*

Child G explained:

> *"I kind of got used to doing it, then I start doing in other lessons. I don't have to, but, erm, like you know it helps me remember things, or I write steps down, so I know what to do next".*

Using their early planning sheets, I created a planning template for them to use if they wanted to (Appendix 6). Some children preferred to use the ready-made template to organize their ideas, but most continued to plan using blank sheets. There were only a few children who preferred to just plan on-screen as they went along rather than planning on paper in advance. Those who used the template seemed to include more-detailed information and spent more time on drawing and colouring the scenes. The template had two pages. The first page was in the form of a diagram for the children to just write down some words to express their ideas. The second page had simple instructions to tell them what they need to focus on (Figure 7.1). I tried not to include too many instructions, as I did not want to affect either their ideas or the methods that they used for recording their thoughts. One of the most interesting points was on the first page of the template, which had small circles for the children to write down some ideas, some children preferred to just draw rather than use text. Not defining the form in which children should present their ideas enabled them to think using different methods to organize and share their designs, which requires deeper thinking.

Scripting	Drawing
Write down the main events as a list to help you with your planning	How would your game / animation look like?

Figure 7.1: Headings for the game planning template

Flavell (1979) listed 'exploring' as a metacognitive skill. Before starting to plan their games, a majority of the students first explored the Scratch and Storytelling Alice programs and investigated what it is possible to do using these programs. Although I wanted to help them to get familiar with the Alice interface through modelling a simple animation, all except two of the children wanted to just explore the program for themselves. I changed the structure of my lesson and worked with those two children who wanted more help with using the application. The rest of the class spent the session trying out different elements of the Alice program. This ‘exploring’ activity had occurred in two different ways: learning about the mechanics of the medium (interface) and knowing what they could manifest with it (design). They looked at the characters and backgrounds that are available within the application and found out about how to draw their own objects. They also needed to visualise and predict how their sentences would translate into code to form actions in their design in order to identify the next steps. Although it looked as though they are very different activities, all are required for the planning process. The planning sheet for their game design using Scratch (Figure 7.2) had more detailed drawings than Storytelling Alice. One reason for this might be that after exploring the capabilities of the programs, they knew they would not be able to create their own characters using the Storytelling Alice programs; therefore, they did not spend much time on designing it, but used a stick figure or a simple drawing (Figure 7.3).

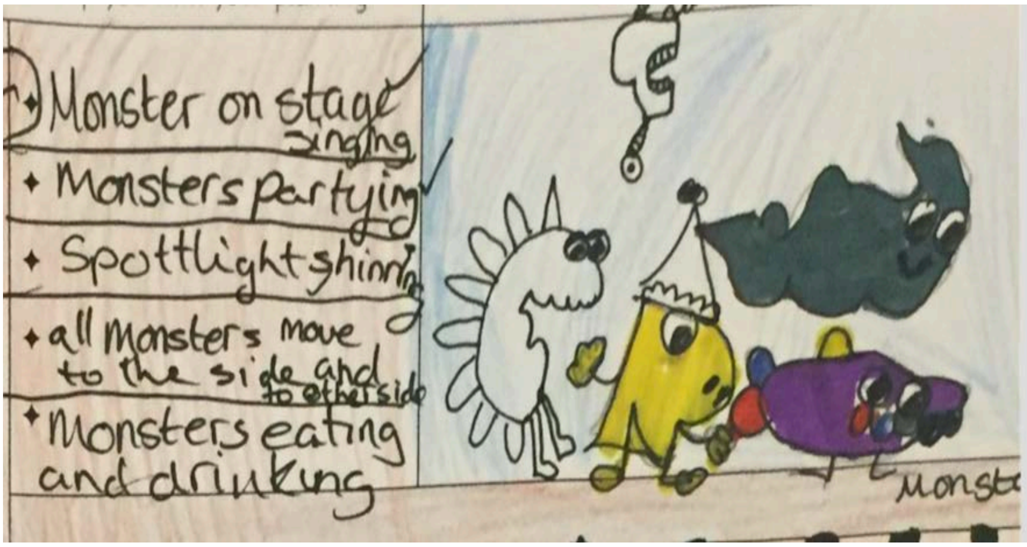


Figure 7.2: Planning example for making game using Scratch

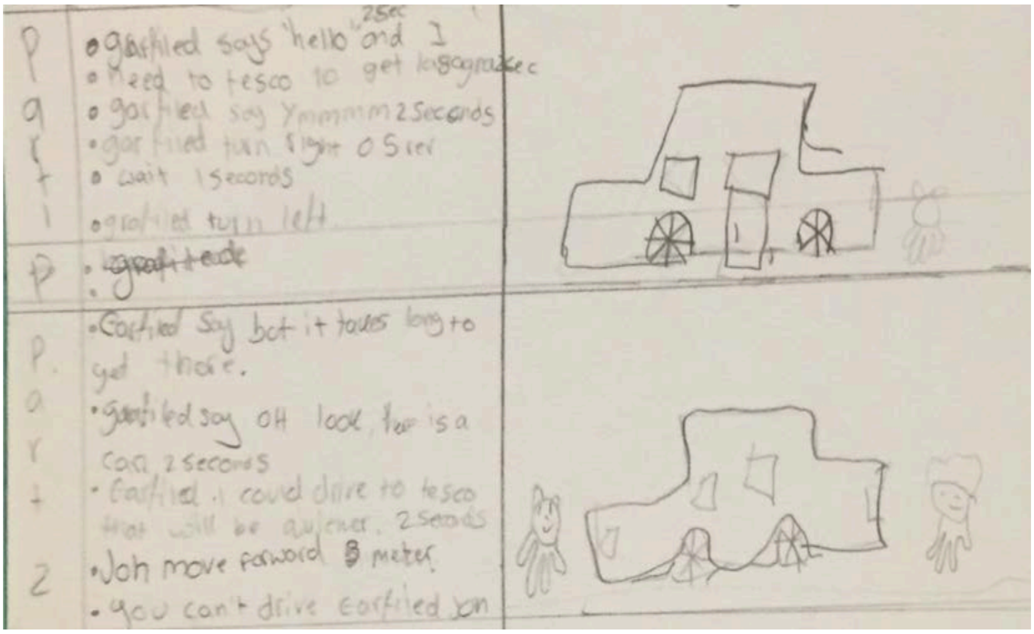


Figure 7.3: Planning example for making game using Alice

Monitoring is another metacognitive ability that was included as a main metacognitive skill in many studies (Brown, 1987; Fisher, 2005; Tobias and Everson, 2002; Whitebread et al., 2009) and it refers to “one’s awareness of comprehension and task performance” (Schraw and Moshman, 1995). It involves making decisions about when to change strategies and use new ones to solve issues when performing a task. The monitoring process for problem solving activities was visible in students’ learning logs, but not always recorded in detail. Some students explained how they solved their problems with their partner or other friends in depth. Many students mentioned asking for help or receiving help from others. This shows that there was constant interaction taking place between the students when they came across a problem. During one of the sessions, one group had a problem changing the position of a character when they were using the Scratch application. They asked for help from the class and another student came to model it for them. I found this behaviour interesting, as the children seemed to be more comfortable at asking for help during their game design activities than in other lessons. This made me think about the reasons the way I organized and managed the classroom during the different activities.

I realized that during game design activities, I adopted a less structured, more flexible approach to classroom management that might help the children to feel more comfortable about moving around and having a conversation with their friends.

The children were able to identify their errors and explain how they solved them, which can be seen as both a ‘monitoring’ and an ‘evaluating’ skill. Schraw (1998) defines evaluation as “appraising the products and efficiency of one’s learning” (p.115). Child T explained that they found their mistake, which was *‘naming the variable wrong and corrected it’*. She also added that both she and her partner learned to:
“*sort stuff out and how to correct their mistakes in game design*” (figure 7.4).

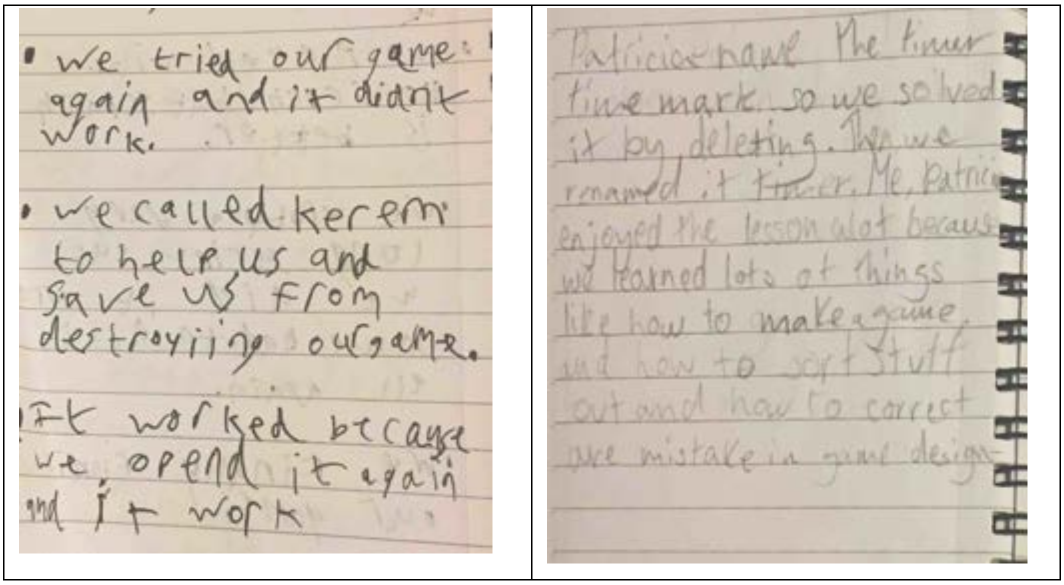


Figure 7.4: An example journal entry of monitoring activity

Child C explained their problem-solving activity as:

> “*We couldn’t change the colour of the tombstone, we went on You Tube and followed the instruction, and we had to put down a lot of methods*”.

This shows that this student was able to evaluate the quality of his game to identify the error and then use a different strategy to solve this. Child J recorded their problem-solving activity as:

> “*We test it and it doesn’t work…I then figured out that the lollipop must be behind, so we add another net which is behind it. BINGO! It works*.”

All these activities can be seen as demonstrations of self-directed learning because if had they stopped when they could not immediately solve a problem, the learning would also have stopped. Rather the children used different strategies to help themselves to continue to look for solutions for their problems. This involved testing, evaluating, communicating, working collaboratively, making decisions, experimenting with ideas and selecting strategies.

The participant observations showed that the children constantly tested their game design and checked their code for errors when it did not work as they expected. They deleted lines of code or added new code blocks to make their designs work, in other words, debugged their errors. This constant evaluation activity continued throughout the design, not just as the learners developed their games, but also at the end as a final check-up activity. The children also helped each other to evaluate their games by giving one another feedback. They walked around the room, played with their friends' games and gave verbal feedback. Some students analysed their game and provided feedback to their 'self'. For instance, Child B looked at his design at the end then started to touch the screen and talk to his 'self'. He said:

> "*This works (pointing at a car, good. The sound 'pop' doesn't go with this. Maybe I could use (he clicked on the sound tab and explored different sound effects) this one (chomp)*".

Findings from the semi-structured interviews also demonstrate that, although the children made decisions throughout the design process, they did not elicit their final game design ideas until towards the end. They constantly reviewed their work and modified it. Many of them reported that they could not always come up with the correct script to turn their idea into a design, so they decided to re-design it in order to make it work and complete their game. Child T explained his reason as:

> *"I tried to make it like, you have three lives and if you lose them you need to repeat the game. But it didn't work. Levels didn't work.*

I asked my partner, she didn't know. So, we said, maybe we won't use levels just have points. That worked better".

As discussed in Chapter 2, evidence of learning is extensively derived from how well students can transfer and apply their learning and thinking skills to different learning contexts. An incident that demonstrates this notion occurred during a problem-solving activity in a Mathematics lesson where some of the focus children were present. Child C shared how he used the game design program Alice 2 screen to visualize a solution for a Mathematics problem. I asked him if he could also record his explanation in his journal later on, which he did. Figure 7.5 shows his explanation. He also drew a diagram to explain how logic is used for problem solving both in Mathematics and game design sessions. He was able to think about his learning and reflect on it by using his prior learning experience to construct the new knowledge. He was able to transfer and apply the visualisation skill that he developed during his game design activities when solving a mathematic problem. Additionally, he was aware that he had this skill and was able to decide when and how to apply it to a new learning situation, which can be seen as part of self-regulation process.

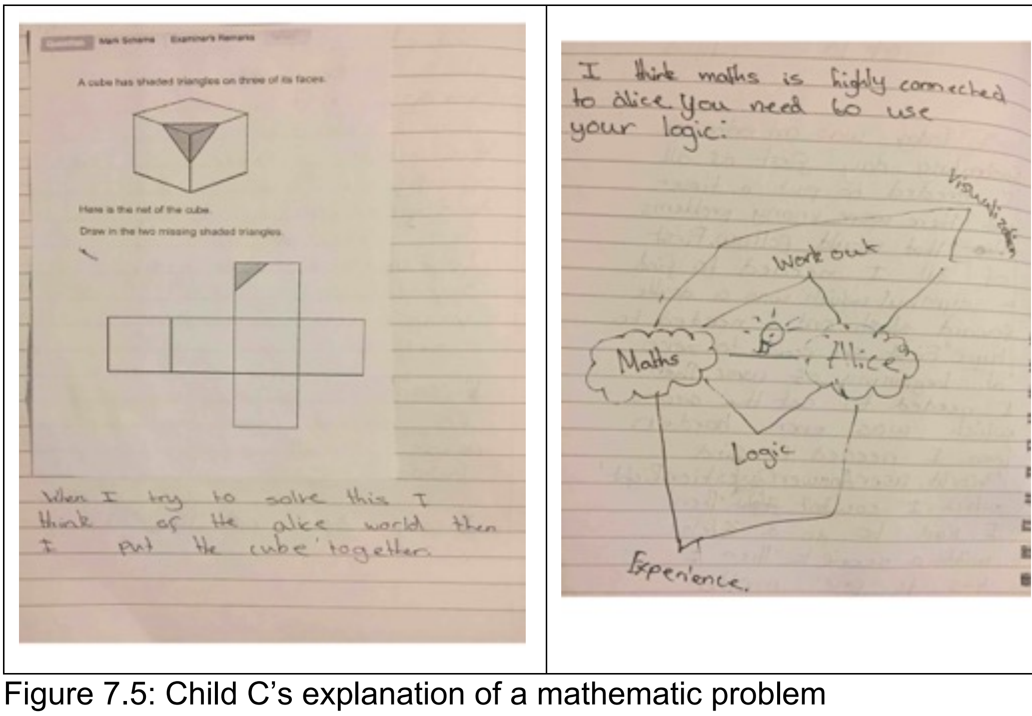


Figure 7.5: Child C's explanation of a mathematic problem

According to Dyer (2008) game making facilitates metacognitive reflection. Candy, Harri-Augstein and Thomas (1985) define metacognitive reflection as the "specific approach to enable learners to examine their own learning in a systematic manner and uncover their own assumptions and constructs about what they are doing as a means for learners to identify and question their own strategies" (pp.16-17). During the metacognitive reflection process, first learners think about their prior learning and experiences related to the new concept. They then use these beliefs and attitudes to re-evaluate their values that enable them to be aware, and to select and apply the appropriate strategies for learning. The following example of Child K provides an account of metacognitive reflection:

> *Child K was working in a pair with Child M as his usual partner Child H was not in. They were creating a game called 'Chase the dog' using the Scratch application. The aim of the game is to click on as many dogs that appear on the screen as you can before they disappear. For each dog clicked, the player receives a point. Child K suggested that they use the beach background so that they can have dogs appearing over the sea. Although they had played around with the Scratch application, they had not created a fully functioning game before. They selected a dog character from the Scratch library and then started to discuss their code. Child M wanted to duplicate the dogs. Child K explained that they should duplicate once the code is completed so that they wouldn't have to program each dog individually. Child M asked if this was possible. Child K replied as "Like the witch game that miss showed us". Child M agreed with him and they decided to write the code. Child K decided to plan the code in plain writing on paper before actually working on the screen. Child M wanted to play around with the codes and try it on the screen, but Child K suggested that this is like solving a problem in Mathematics: first they need to decide what they want to do and then think about*

how they can do this. He then tested his solution on screen to check that it worked.

It is clear from this example that Child K was aware of different strategies that he had developed through previous activities and was able to appropriately allocate them to complete the new task. Child M, on other hand, did not recognize that his prior knowledge would help him with his new learning experience. This could mean that game making does not automatically make children reflect metacognitively, but it does provide a space for them to think and engage with their learning at a deeper level. Furthermore, it encourages children to use and apply metacognitive skills such as planning, monitoring and evaluation, allowing them to self-regulate their learning activities.

Some of the learners reported that they were confused and were not sure what to record or how to record the way they solved a problem. I thought that it would be useful to have a template for planning and recording problem solving activities for those who may have difficulties with writing or organizing their ideas. Appendix 7 shows an example of a learning log that was completed by a focus child when making a game. The section titles were decided after analysing the findings from the journals, participant observations and semi-structured interviews. During the semi-structured interviews, some children mentioned asking questions or talking to their 'self' or sometimes the computer itself. They were aware of their discussions with their friends but showed less knowledge of their interaction with their 'self'.

By including a section 'I asked / talked / thought to myself…' sub-heading in their problem-solving sheets, I aimed to encourage them to think and reflect about their conversations with their 'self', others and the 'computer'. This would be an instrument in unfolding the role of language in regulating mental activities that take place whilst making their computer games.

The templates were available in the classroom for each session and the children were told that they do not have to use the template; if they preferred, they could continue to use their journals. All of the focus children decided to use these templates. During the interviews I asked them the reason for this. The answers were:

Child A: *"easier to share what I think".*

Child G: *"helps me to remember".*

Child B*: "I don't have to worry about what to write".*

Child M: *"I just answer the question, quicker to complete".*

Some of the children answered the questions on the template in a few words, whilst some provided a more detailed explanation. There might be many reasons for this. The child might want to spend more time on the game design and forget to keep a record of their activities. There might be issues around being able to express their ideas and feelings in a written format. Although we discussed each question from the template to make it clear, some children might have found it difficult to understand what the question is actually asking and what type of answer it requires as the questions were open-ended.

Under the 'I have learnt to…' section, they mainly shared how they learned to complete a specific task such as uploading a file, resizing objects, creating new moves and objects, making characters speak, adding objects, using a gallery, duplicating and adding variables. These showed that the students were aware of their own learning and evaluated what they were actually able to do. They also reported how they learned to make objects look more realistic, be precise about the script, create games that look real, or make their game better. This implies that they thought about how to improve both their design and the coding of their games.

The template had a box for the children to explain how they solved a problem. Some children shared more than one problem, whereas some only wrote down one specific problem that they had solved. Some reported on their friends' problems and how they helped them to come up with a solution. The main problem reported was finding where the specific objects and characters were in the Scratch or Alice program. Child A expressed the problem as:

> "*My problem is how to make the sound work I worked this by talking to myself and not giving up*".

During the interviews I asked the student to explain this statement further. Her answer was:

> "*Sometimes we need to try different things to make something work. I usually ask myself to decide what shall I do now, which button I should touch, which code I need to use for this to happen*".

When the students were asked to record what they asked / talked / thought to themselves, they shared the questions that they were asked in order to solve a problem, make a prediction, or make a decision before they took an action. For example, Child H reported this as:

> *"I asked and talked about how we are going to work out to move the robot and the space men"*.

Child B wrote:

> *"I thought to myself how I am going to make the witch move around the screen"*.

There were more questions written in this section by children asking how to complete a specific task and also more general questions to check if they were doing things correctly.

The data from the interviews also demonstrated that the conversations with both their 'self' and 'others' were taking place when the children were regulating their problem-solving activities. Child S stated that he would use dialogue with his 'self' to check and evaluate his design before sharing it with others:

> *"Before let people see, I would ask myself; are you sure it is alright? When I was making the robot fighting game, I wanted to see, I talked to myself how I would make it more interesting and more detailed. To make it more like movement, maybe add voice. I just say in my mind,*

what shall I do to fix this? if something is wrong. This makes you think if you ask and repeat".

Child G also explained:

> *"It is hard to explain. Like, I say it to myself in my head, then I tell my partner, then ask myself, and my partner. It is like, I am talking all the time".*

When he was asked about what kind of things he usually talks about, he said:

> *"Not sure really, sometimes, when I have a question or can't decide something. Sometimes, ermmm, let's say the game is not working, so I would ask myself, what is wrong, if I can't debug, then I would ask my partner".*

This social interaction between self and 'invisible self' (Private speech), fits into Vygotsky's notion of language and thought. According to Vygotsky (1986) language and thought dwell together. He believed that, in order to raise awareness of mental activities, children need to know how to articulate their thoughts. He saw dialogic exchange as an essential skill for children to manage the way they think and learn. Whitebread et al. (2009) also noted that social interactions allow children to evaluate their ideas with their peers through metacognitive dialogues. Johnson (2004) argued that private speech provides children with tools such as planning and monitoring that promotes metacognition while Morin (2005) shared similar thoughts for inner speech, emphasizing its role in metacognition. Zakin also concludes that, "Learning activities based on inner speech allow students to become more aware of their thought processes in general and their cognitive decision-making in particular" (2007, p.10). Several other studies also argue that private speech emerges from interaction with self or others, transforms into inner speech and is crucial for both metacognition and self-regulation (Berk and Winsler, 1995; Winsler, Diaz, and Montero, 1997). The examples above show that the children used both private, inner and social speech to plan, monitor and evaluate their activities such as debugging errors and making decisions. This highlights the important role of conversational exchanges in metacognitive process as a metacognitive skill.

7.2 A framework for metacognitive skills

Defining a framework for metacognitive abilities requires the ability to distinguish cognitive from metacognitive. However, as Flavell (1979) pointed out, separating cognition from metacognition is not always a straightforward task. Cognitive strategies are usually used to help one to achieve a specific objective such as designing a computer game. On the other hand, metacognitive strategies are used to ensure that the objective has been met. For example, questioning could be observed as either a cognitive or metacognitive strategy depending on the purpose it is used for. Similarly, when solving problems, an understanding of the problem may be seen as a cognitive process, and the monitoring of this understanding process may be seen as metacognitive activity. The difficulty is that, in some cases, cognitive and metacognitive strategies overlap. Identifying metacognitive strategies might be a useful approach to understanding the distinction between cognitive and metacognitive.

As mentioned before several studies describe planning, monitoring and evaluation as the main metacognitive skills for regulating learning whilst completing a task (Fisher, 2005; Perry, Lundie and Golder, 2018; Schraw, Crippen and Hartley 2006; Whitebread et al., 2009; Zepeda et al. 2018). This study agrees that planning, monitoring and evaluation are the main metacognitive skills for managing mental activities; however, I would like to highlight the role of conversational exchanges (discussed in Chapter 6) in metacognitive processes.

The data analysis of children’s problem-solving sheets, learning journals, participant observations and interviews demonstrates that, whilst making games, children used their mind as a lab where they developed and tested their ideas, through conversations with ‘self’ and ‘others’ before turning these into a game using software. Manning et al. (1994) suggested that “private speech reflects children's future potential for cognitive self-direction to plan, guide, and monitor their goal-directed activity” (p.3). There are other studies that also described private speech as an instrument for planning, monitoring and managing the thinking and learning process (Berk, 1986; Manning, 1991; Rohrkemper, 1989). Research also shows that alongside private speech (Johnson, 2004), social speech (Whitebread et al., 2009) and inner speech (Morin, 2005; Zakin, 2007) provides children with tools to self-regulate their learning.

As discussed in detail in Chapter 2, Chapter 6, and section 7.1, children's language-based interactions (Conversational exchanges) with self or others acted as an executive function which evoked and directed the application of metacognitive skills such as planning, monitoring and evaluation whilst children were creating their computing games. To represent these language-based interactions for regulating activities, it is crucial to include 'Conversational exchanges (Metacognitive conversation)' as a metacognitive skill alongside planning, monitoring and evaluating. However, in order to manage their learning, children need to be conscious of different modes of conversation and know how to use them for different purposes. Figure 7.6 shows a conceptual framework for metacognitive abilities.

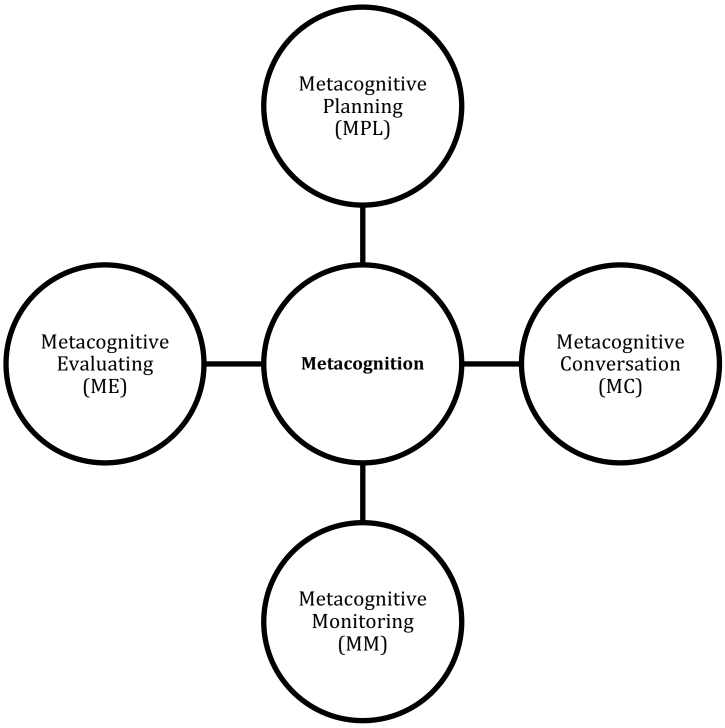


Figure 7.6: A Framework for Metacognitive abilities

The steps for designing a framework for metacognition:

To define the framework for metacognitive abilities, first I reviewed the literature and issues around the current metacognition frameworks (see Chapter 2). I then recorded the cognitive (C) and metacognitive (MC) skills that were illustrated through data analysis next to each component. To link this information with the data, I listed the visible behaviours that represented these abilities for each strategy alongside the information about when they were adopted during the activity. Finally, I explained each component with regard to the game design context. Table 22 shows the metacognitive skills and abilities that were visible when the children were making their own computer games.

Table 22: A framework for metacognitive skills

Metacognitive Skills/ abilities		When adopted	Behaviours
PLANNING	Exploring (C) or (MC) Designing (MC) Engineering (MC) Visualisation (MC)	Beginning of the task and during monitoring when required	Randomly looking at the characters/ backgrounds (Scratch software) Coming up with ideas Partner discussions Planning first in head Planning on paper Drawings of scenes (game ideas) Game script in bullet points
CONVERS	Focused dialogues with others Audible conversations (Private speech) Inner speech	Beginning and during and at the end of the task	Talking / asking questions to 'self' Discussing with partners Deciding ideas Deciding which character, background and code to use

A T I O N	Unintended collaborative talk (with 'self' and 'others')		Making sense of what is not working Designing a solution Trying out things to make it work
M O N I T O R I N G	Self-regulating (MC)	During the task	Making game better Making game more interesting Checking if the game is working Thinking about what is working well Changing the game in design Changing the planning on paper
E V A L U A T I N G	Testing (C) and (MC) Debugging (C) and (MC) Feedback (self and peer) (MC) Analysing (MC)	At the end of the task and during monitoring when required	Testing the game Checking codes Debugging Looking for problems Deleting codes Adding new codes

Metacognitive planning (MPL)

Planning skills help children to formulate their actions in order to reach their goals. It provides learners with a base for analysing their approaches to a task before they actually start working on it. Planning involves exploring, predicting, analysing, visualizing and tinkering (experimenting with ideas). In a game design context, students may think about the title of a game, their narration, characters, backgrounds so forth. One issue that was visible during game making activities was, children's planning activities were not always verbalized or presented on paper. Sometimes children planned their activities in their mind whilst developing their games and did not necessarily record these on their planning sheets or problem-solving templates. It was possible to get some information about this through interviews, but not in detail, as they could not always recall the changes they made. They may ask questions such as: 'What is my task/my goal?' 'What do I need to know?', 'What strategies do I need to use?' 'What are the steps for making a computer game?' 'Which character or/and background shall I use?' and 'What is my game about?'.

Metacognitive Conversation (MC)

According to Harri-Augstein and Thomas (1991) meta-cognitive strategies such as planning, monitoring, self-testing does not automatically lead to learning. They suggest that learning is derived from both internal and external (group) 'conversations', where learners negotiate a meaning through dialogue with others. I argue that, in this domain, the conversation becomes a skill of its own to negotiate meaning, rather than a tool to communicate. Conversation has a key role in monitoring and evaluating processes where children reflect on the success and the difficulties that they had when solving problems, as well as acting as a mediator for developing an understanding that leads to learning. In a game design context, computers can also become a 'learning partner' where children have a dialogue in order to make decisions or check, revise and reflect on their mental activities. Learners may ask questions regarding the execution of strategies to manifest an outcome: Which strategy shall I use? What is the problem here? How can I solve this problem? What does my partner think?

What do you think about my solution? Will this solution work? Which characters shall I use?

Metacognitive monitoring (MM)

Monitoring refers to the learners' ability to manage their own cognitive skills while working on a task to identify problems and modify their planning as needed. It is a difficult strategy to develop and use, even by adult standards, as it requires one's awareness of one's own progress. According to Delclos and Harrington (1991), monitoring skills develop with training and practice. During the interviews, many of the students reported that, because of their game design experience, they started to keep checking their work in other lessons. In a game design context, the children are constantly testing a sequence of codes to check if their game works. This can be seen not only as use of the monitoring skill, but also it links to debugging, a CT concept. When the children were working on a task in another subject such as literacy, they could need support with identifying mistakes in their writing as they may not even be aware that they had done something wrong. In game design, they can diagnose their errors directly when testing because if there was something wrong, the program would stop working. The questions learners might ask are: Am I on the right track? Do I understand the task? Am I working towards my goals? Is my plan working? Do I need to make any changes to my planning?

Metacognitive evaluating (ME)

"Evaluating refers to appraising the products and efficiency of one's learning" (Schraw, 2001, p.5). The evaluation skill is all about the learners' reflection on their own progress by checking the final outcome against their objective. It involves auditing the solutions they have designed and the strategies they used to execute their planning for a specific goal. Their aim is to determine whether the strategies they used were successful in supporting them to achieve their goal. It is especially useful when identifying errors in their solutions.

The questions that may be asked by the learner are: Have I reached my target? Which strategies worked? Which methods didn't work? What could I do to make it better? What could I do differently next time? What other problems can I use this strategy for?

7.3 Metacognitive Skills Instrument (MSI) for Game Making

The MSI (metacognitive skills instrument) self-report instrument was constructed for use in computer game design context; however, it could be used in different contexts with modification. It is intended to be used to gain an insight into children's own perceptions of the metacognitive abilities that they develop or apply whilst creating computer games.

The development of MSI was guided by several efforts:

- A comprehensive review of literature on metacognition, and metacognitive skills.
- Insights gained from existing self-report instruments for measuring general and domain specific metacognition
- A review of recent literature on the role of conversations in metacognitive process and learning.
- The data analysis of children's conversations whilst making their computer games.
- Input from four colleagues and seven focus children in terms of clarity and readability of the items.
- The use of factor analysis to examine the validity, reliability and the structure of the self-report instrument

The definition of metacognition had an impact on how it has been measured. My definition described metacognition as a skills-set that is used for managing the thinking and learning processes. The data analysis of children's conversation found that conversational exchanges (Metacognitive conversation) is a crucial component skill for metacognitive process (Chapter 6). Therefore, the MSI was constructed as a list of skills with four components; planning, monitoring, evaluating and conversational exchanges. Typical behaviours that represent metacognitive skills for each component were listed as statements in a table (Table 23).

The initial collection of 28 statements were discussed with four colleagues and seven focus children to avoid repetition and to ensure that they are understandable by young learners. The teachers focused on evaluating whether the item represented the specific skills and readability, where children checked if the items were confusing and /or expressed using a clear language. The review resulted in elimination of eight items mainly due to repeated statements. Students suggested that it might be useful to include examples for some of the statements, and these were added to the instrument. Some of the items were written in a more generic form to assess metacognition, whereas others were worded specifically for computer game making activities. For example; ‘I write down my ideas’ is a statement that can be used for evaluating metacognitive planning in different domains. However, ‘I start making my game as soon as I open the game design program’ item focuses on the learner’s behaviour whilst designing their computer game. This can be useful if the instrument is to be used for measuring metacognitive skills in different domains, as it can be easily adapted.

Twenty items, five for each component of metacognition, were retained for initial testing in addition to a short section asking students for their age, gender and year group. Appendix 8 shows the MSI for game making contexts. All of the 20 statements were formed positively as negative comments could confuse young learners. Table 23 was used to construct a five-point Likert-type instrument (1= Never, 2=Seldom, 3=Sometimes, 4=Often, 5=Always) and students were asked to circle the answer that best described their behaviour when authoring their own computer games. Age and gender were also included in the instrument to evaluate the relationship between these variables and learners’ ability to regulate their own learning.

Table 23: Items pool for Metacognitive Abilities

Metacognitive Skills		When adopted	Behaviours
PLANNING	Exploring Designing Engineering	Beginning of the task and during monitoring when required	I start making my game as soon as I open the game design program I write down my ideas I check if it is similar to anything that I have done before I make a plan of what I need to do I discuss/share my ideas with others
CONVERSATION	Focused dialogues with others Audible conversations (Private speech) Inner speech Unintended collaborative talk (with 'self' and 'others')	At the beginning, during and at the end of the task.	I talk/ask questions to myself to make sense of my thoughts I design solutions to solve problems using different methods (such as linking up what I know or breaking down the problem) I make notes of what works well and doesn't work to develop my game further (such as; loop statements) I discuss my work with others during the task I make decisions to manage my learning

MONITORING	Self-regulating	During the task	I ask myself whether I am on the right track I check to see if my plan is working I think about other ways of making my game design better I look at the work that I don't understand I make changes to my planning during the task
EVALUATING	Testing Debugging Feedback (self and peer)	At the end of the task and during monitoring when required	I test my design to see if it works I correct my errors I ask my friends their opinion of my design I share with my friends what I think of their designs I think about what I could do better the next time

Finally, the Metacognitive Skills Instrument (MSI) for game making was presented to a total of 223 children, aged 9-11, in Year 5 and 6 classes; 117 (52.5%) of the learners were female and 106 (47.5%) were male. Before administrating the instrument, the students were informed that this was not a test to level them and they would not receive any reward for scoring high on the MSI for game making. They were advised to read the statements carefully and those who had reading difficulties were allowed to ask me to read for them. Learners completed the MSI independently in groups of six supervised by me, rather than as a whole class. There was no time limit for completing the instrument, as having a set time can cause the students to associate the MSI with a test.

Results

When using Likert-type scales, it is imperative to calculate and report Cronbach's alpha coefficient for internal consistency reliability for any scales or subscales that one may be using. Therefore, factor analysis and Cronbach's alpha were used to measure the validity and internal consistency reliability of the instrument. The internal consistency of the Metacognition Skills Instrument for game making is 0.788, indicating a reasonably reliable measure of metacognitive skills.

Exploratory factor analysis was used to identify common factors for the MSI 20 item instrument as this would be useful for identifying any item that might be deleted or refined. Before the factor analysis, it is necessary to check the suitability of the data for factor analysis. Individual KMO statistics were all > 0.6 and the overall KMO statistic was 0.767. Bartlett's test of sphericity was significant, $p < .001$. These outcomes suggest that a factor analysis for the data can be undertaken. The factor structure of MSI was investigated using SPSS to evaluate if there was empirical support for the four factors (components) of metacognition and identify any items that might be removed from the instrument. The Principal Component Analysis (PCA) using Principal =axis factor analysis on the 20 items of the MSI indicated support for a 5-factors solution. Principal-axis Factor Analysis (PFA) was used as a method of common extraction, with Promax rotation with Kaiser Normalization, which allows for inter-correlation among factors. Rotation is useful for improving the interpretability of factors as "it maximizes the loading of each variable on one of the extracted factors whilst minimizing the loading on all other factors." (Field, 2005, p.3). Figure 7.7 presents Metacognitive Skills Instrument (MSI) for game making scree plot graphic from exploratory factor analysis using the SPSS program.

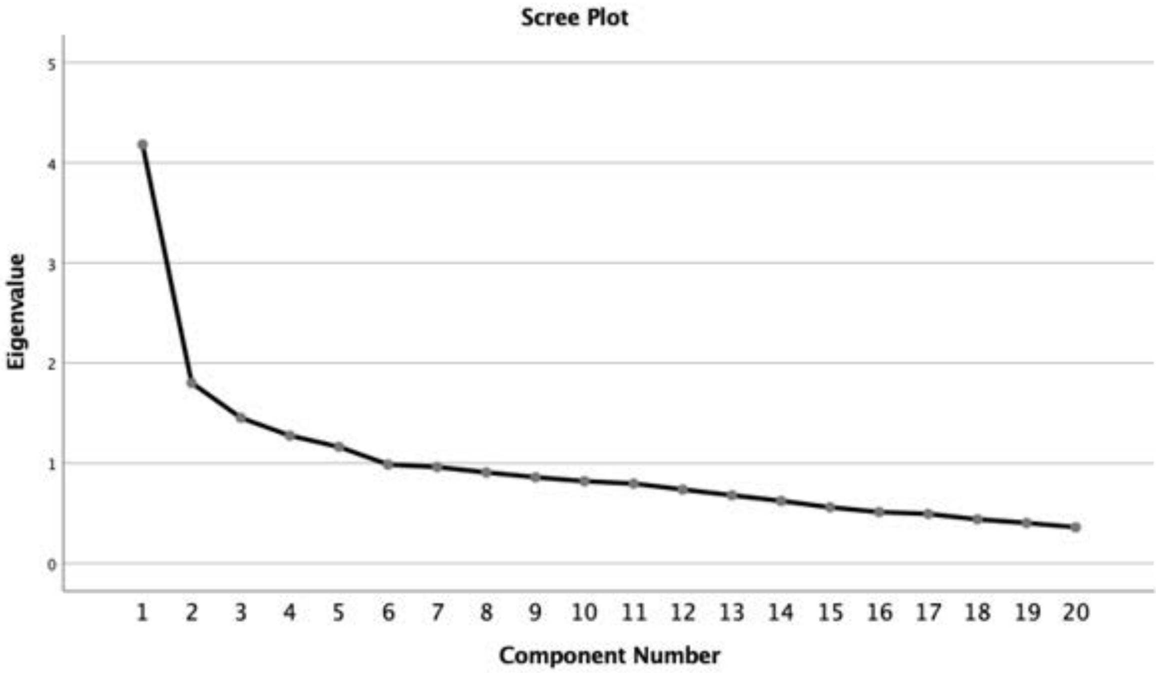


Figure 7.7: Scree plot graphic from exploratory factor analysis

One of the selection criteria known as Kaiser-Guttman criterion suggests that all the factors with eigenvalue of ≥1 should be retained. The factor analysis of the MSI instrument showed that four factors clearly met this criterion. Another method is making the decision using the scree plot which shows the eigenvalues on the y-axis and the number of factors on the x-axis (Cattell, 1966). The point where the scree plot levels and the curve start to disappear indicates the number of factors that should be included in the analysis. As it is displayed, the graph expands horizontally after the fourth item and after this there is no significant decrease. Although there is a slight slope after factor 5, the first four factors explain large amounts of variance (40% of total variance) and factors after 4 explain only small amounts of variance. Therefore 20 items then underwent another principal-axis factor analysis under four factors.

There is no set answer to which loading factors should be retained in the pool (Comrey and Lee, 1992). However, it has been suggested that the items that load onto one component strongly and maybe show small or nil loading to other components should be included in the item pool (Matsunaga, 2010). Setting a priori determined cut off value seems to be a common approach that has been utilized by researchers. In many cases, items with a factor loading of .40 or greater is retained. All of the items loaded were above .40, meaning they can be retained in the item pool.

Confirmatory factor analysis can be used for explaining patterns of relationship between different latent structures. It is not intended to confirm previously built structure, but to define the current structure using the data set. The structure of the MSI for game making and item factor loading can be seen on Table 24. At the beginning the items in the instrument were categorised under four components:

- Items 1, 2, 3, 4, 5 were listed under the 'planning' component
- Items 6,7,8,9,10 were listed under the 'Conversation' component
- Items 11, 12, 13, 14, 15 were listed under the 'monitoring' component
- Items 16, 17, 18, 19, 20 were listed under the 'Evaluation' component

Confirmatory factor analysis (CFA) shows that although some of the items fall into the same categories, there are some that do not.

- Items 1, 2, 4 can be listed under 'planning'
- Items 3, 6, 7, 8, 10, 11, 14, 15 can be listed under 'conversation'
- Items 12, 13, 16, 17, 20 can be listed under 'monitoring'
- Items 5, 9, 18, 19 can be listed under 'evaluating'

Table 24: The Structure of the MSI and Item Factor Loadings

	Components			
	Planning	Conversation	Monitoring	Evaluating
Q1	-.437			
Q2	.688			
Q4	.664			
Q11		.667		
Q8		.627		
Q6		.596		

Q7		.522		
Q10		.521		
Q3		.491		
Q14		.453		
Q15		.412		
Q17			.733	
Q16			.657	
Q12			.639	
Q13			.596	
Q20			.575	
Q19				.666
Q5				.666
Q9				.652
Q18				.576

Loading values for the factors varied between .412 and .733. Although all of the items had a loading value above .40 and can be included in the final instrument, item 19 had a loading value of .412, meaning that it might be more appropriate to either delete it from the instrument or check the wording of the statement. Items 5, 9, 18 and 19 are categorised under the 'evaluating' component. However, items 5 and 9 are very similar and again the wording of these items needed to be checked to make sure that the statements are not repeated.

The MSI is an instrument for collecting data of self-reported game design related metacognitive skills. It assesses students' self-perceived metacognitive skills within the context of game making activities. I conducted confirmatory factor analysis (CFA) in order to demonstrate the strength of a four-factor model underlying the MSI: Planning, conversation, monitoring and evaluation. Not all the observed scores of the MSI regressed on the factors that they were supposed to measure. This does not make the four metacognitive skills components invalid; however, it might suggest that the wordings of the statements used to represent each component may need to be reviewed.

In summary, in this chapter, I investigated the metacognitive skills that children develop when making computer games and methods for measuring these. The data analysis showed that children used metacognitive skills such as planning, monitoring and evaluation to regulate their activities whilst working on their games. Using the findings of this study, I proposed a framework for metacognitive skills with four components: planning, conversation, monitoring and evaluating. I suggested that language as the core of conversation is crucial for triggering metacognitive activities such as planning, monitoring and evaluating. I discussed the development of an MSI self-report instrument for measuring children's metacognitive skills in a game design context. Although the four components proposed in the metacognitive framework were confirmed with the result of MSI, and all 20 items could be retained in the pool as they were loaded above .40, not all of the items regressed on the factors that they were grouped in the beginning. This might suggest that the wordings of the items should be revised and re-tested to ensure the validity and reliability of the MSI instrument for measuring metacognitive skills in game-design context.

This chapter is the final one in which I discuss the findings of my study. In the next chapter, I will draw some conclusions from my research and discuss these in connection to relevant literature.

Chapter 8: Conclusions

In this chapter, I will first summarise the research in the light of the findings and relevant literature. I will then discuss the contributions that this study has made, especially for providing an insight into assessing children's learning in a game design context and measuring metacognition. This is followed by recommendations for teachers, based on the findings. I will also examine the possible limitations of this research and share ideas for future research in relation to children's game making activities in classroom.

8.1 Implications of the key findings

This study found that overlapping link between thinking, learning and metacognition made the analysis of learning process more challenging. For example, when investigating the metacognitive skills that children develop whilst making computer games, the question of how teachers can evaluate, and measure metacognition also arose. Similarly, when it was clear that the conversational exchanges played an important role in metacognitive process, further study was needed to define what constitutes conversational exchanges and how game making activities can facilitate the application of this skill.

Below, I will answer the individual research questions through a synthesis drawn from the study findings.

RQ 1: What is the educational value of children's game making activities in relation to thinking, learning and metacognition?

Research question 1 was addressed in Chapter 4. This chapter presented the findings from participant observations, semi-structured interviews, field conversations, problem solving sheets, diary logs, video recordings of group discussions, interviews and children's completed games. The findings indicated that it is not possible to list the learning benefits of game design under one category as it has links to many different aspects that are part of the learning process. This confirms the notion of MacBlain (2014) who stressed the difficulty in defining learning and the necessity of investigating learning from different aspects (Qvortrup et al. 2016). This was also evident in the literature review which showed that a number of studies explored children's game making activities from different learning aspects, including learning in curriculum subjects (Buckingham and Burn, 2007; Robertson and Good, 2004; Robertson, 2012, 2013; Ke, 2014; Vattel and Riconscente, 2012); computational concepts (Kafai and Burke, 2014; Denner, Werner and Ortiz, 2012); developing transferrable or 21st century skills (Bermingham et al, 2013; Denner and Werner, 2007); and metacognitive skills (Vos, Meijden and Denessen, 2011).

Although this thesis did not attempt to study learning in a specific curriculum subject, students shared comments comparing their learning activities to other curriculum activities such as planning and writing stories in literacy lessons. This shows that, as Robertson and Good (2004) found in their study, the writing elements of game making activity may have an impact on children's language development. It is more difficult to state whether game making activity helped children's learning of mathematical concepts as only one student shared how his experience of game making supported his learning in Mathematics and only four students mentioned using mathematical operations and functions to design their games. However, the study found that students used mathematical operations and expressions, angles and decimals to create their games. Furthermore, there were many opportunities for developing their problem solving and critical thinking skills, which suggests that this might contribute to other learning situations, including when solving problems in Mathematics lessons.

A number of studies suggested that game making can help children develop 21st Century skills such as collaboration, communication, and problem solving (Bermingham et al, 2013; Ching and Kafai, 2008; Denner and Werner, 2007; Jenson and Droumeva., 2016; Pinto and Escudeiro, 2014). This study found that there were many opportunities for children to develop their problem solving, creativity, critical thinking, collaborative working and communication skills whilst working on their games. The way I approached classroom management whereby I allowed children to move around and interact with each other freely may have contributed to this outcome. Similar to findings of Akcaoglu (2014) and Bermingham et al. (2013), this study also identified problem solving as the core element of game making activities. This was especially visible on children's problem-solving sheets where they kept records of their problems and how they solved these. The findings also suggested that children were able to use their creativity by refining and producing ideas, especially related to design of their games and formulating solutions to problems they faced.

The findings of this study indicated that alongside 4C (critical thinking, communication, collaboration, and creativity) of 21st Century Skills, children developed their knowledge and understanding of computational concepts and self-regulation skills through engaging in conversations by self and others. This finding encouraged me to explore the relationship between game making and these two aspects in more detail and the findings for this are synthesised under questions 2 and 3.

RQ 2: How can children develop computational thinking skills whilst making their computer games?

After a thorough analysis of the literature, this study proposed a definition for CT in Chapter 2, which argued that CT constitutes of computational concepts, metacognitive practices and learning behaviours. This definition then was investigated in Chapter 5 using findings from participant observations, semi-structured interviews, informal conversations, problem solving sheets, diary logs, video recordings of group discussions, and children's completed games.

A key issue that emerged during this study was the challenges around measuring learning with respect to these CT elements. Although I have provided excerpts from semi structured interviews, children's diaries, problem solving sheets and examples from my field observations to illustrate the elements of learning that took place, these methods were not used as an assessment tool; rather, it was to point out the learning benefits of game making activities. The thesis has shared a framework for assessing children's learning of CT skills and argued that a multiple means of assessment approach that has been discussed by previous studies (Brennan and Resnick, 2012; Grover, 2015; Werner, Denner and Campe, 2014) should be adopted for gathering more in-depth information about children's learning of CT, especially during pair programming activities. Multiple Evaluation Approach proposed that the CT process should be evaluated from four dimensions; 'computational concepts', 'metacognitive practices', 'learning behaviours' and 'Context' (game design). This was also supported by Hainey, Baxter and Ford (2019) who analysed children's Scratch games from both programming and game design aspects.

This thesis did not approach assessment as a tool for measuring progression, rather as an inquiry for developing "deeper understanding of individuals as learners, not just performers" (Hargreaves, 2005, p. 11). The aim of this approach was to make sense of children's learning processes in a game design context, rather than coming up with conclusions for improving learning. On the other hand, it can be suggested that knowing about children's learning process can inform teachers' planning and practice, and thus, might consequently support them in improving learning.

Hainey, Baxter and Ford (2019, Kafai and Peppler (2011) and Werner et al. (2014) argue that programming concepts can be taught through making games using a programming application. The findings of this study also suggest that the use of Scratch and Alice programming applications provided children with the opportunity to learn about computational concepts as children had to first learn to code in order to design their games. The case studies and overall analysis of children's games showed that, although the level of the competence varied, children were able to learn to use programming constructs including sequences, loops, parallelism, conditionals, operators, variables, events and abstraction constructs. Furthermore, they were able to develop and apply other components of CT, such as metacognitive practices and learning behaviours. The findings from participant observations showed that children used constant testing and evaluation when working on their games, showing that they used metacognitive practices for controlling and regulating their programming activities. There was evidence of working collaboratively, especially when solving problems, perseverance, communication, debugging problems, tinkering with ideas and using creativity, in both participant observations and interview data.

RQ 3: What is the role of conversational exchanges in metacognitive process and children's learning?

After reviewing the literature on metacognition in section 2.2, and conversational exchanges in section 2.2.2, it was evident that talk had an important role in children's learning. Therefore, I decided to investigate this further and I found that children's private, social and inner speech utterances were connected and necessary for their learning, especially when managing mental activities and self-regulating their learning (Johnson, 2004; Winsler and Naglieri, 2003). Some literature highlighted the link between social interactions and self-regulated learning (Tobin, 1998; Vygotsky, 1987; Schunk and Zimmerman, 2011), whilst other publications discussed the role of private speech in internalization of language as thoughts (Johnson, 2014; Vygotsky, 1978) and some explained the purpose of inner speech in controlling thought and behaviour (Ford et al., 2004; Morin, 2005; Zakin, 2007). This highlighted that children used different types of talk (private, social, inner) for different purposes, such as decision making and managing behaviour. I saw these different forms of talk as conversational exchanges, which I defined in section 2.2.2 as a form of inquiry that engages learners in evaluating their thoughts, decisions and actions through conversations and dialogues with an 'invisible other' and other collaborators which are sometimes audible, sometimes visible through gestures. I then investigated how this relates to game making in Chapter 6, using the findings of the literature and data analysis of semi-structured interviews, children's problem-solving sheets, participant observations and video recordings of group discussions.

The study found that the students used different forms of conversation for different purposes. Sometimes they randomly and audibly talked to themselves to explore their ideas and solutions; sometimes they talked with their friends, especially when solving problems. There were times they had some silence conversation with self which was only visible through their actions and gestures. On some occasions they employed a mixture of talking to self and talking to their peers unintentionally. The findings of this study showed that children used conversational exchanges for self-regulating their planning, monitoring and evaluating activities when making computer games. Building on the literature and the data analysis, the thesis identified four different mode of conversational exchanges that were visible whilst children were working on their computer games. These are:

- Spontaneous audible conversation (private speech)
- Unintended collaborative talk (with 'self' and 'others')
- Intentional social discourse (Focused dialogues with others)
- Tacit inner speech (Thought)

An interesting finding of this study was that the children used some or all of the modes of conversational exchanges in different sequential orders, suggesting that the use of different modes of conversation were neither based on a developmental stage nor related to age. It was more about using it where it was needed for appropriate purposes.

It was challenging to evaluate children's conversational exchanges without a set framework. Although there are studies that suggest keeping a record of children's speech utterances using running records during observations and then analysing these using a coding framework (Copeland, 1979; Girbau, 2002; Kraft and Berk, 1998; Rubin and Dyck, 1980), it is difficult to suggest how this would be implemented by a teacher in a classroom environment. First, teachers would need to learn about the purpose of identifying the type of speech that being used in the classroom and then know how this could be used for improving learning. This thesis did not provide a separate tool for analysing children's speech activities; however, the statements about children's conversations were included under the 'metacognitive process' component within the MSI self-report instrument (Meta cognitive Skills Instrument). Although this provides some information about children's reflections on their use of different modes of conversation for learning, it does not show the details about how children develop and apply these in different learning contexts. Furthermore, the instrument does not portray the details of language development of individual children and how they internalise language to form their thoughts.

RQ 4: How can metacognition be measured in computer game design context?

After discussing the literature on metacognition and its role in the classroom in section 2.2, I investigated how game making activities can facilitate the development of metacognitive skills and the methods that can be used to measure these in Chapter 7. Planning, monitoring and evaluation were listed as the main metacognitive skills by many studies (Fisher, 2005; Schraw, Crippen and Hartley, 2006; Whitebread et al., 2009).

Several studies highlighted the relation between game making and metacognitive skills such as planning and self-regulation skills (Bermingham et al., 2013; Games and Kane, 2011; Kafai, 1996; Vos, Meijden, and Denessen, 2011).The findings of data from the participant observations, game design planning sheets, children's journals and problem-solving sheets, semi-structured interviews and group discussions also indicated that, during game design activities, the children used metacognitive skills such as planning, monitoring and evaluation to regulate their activities. Planning was used not only for game plans, but also planning solutions and actions. The children constantly monitored and evaluated their games by identifying and debugging errors and modifying their game designs.

This study argues that, alongside planning, monitoring and evaluation, conversational exchanges as metacognitive talk should also be listed as a metacognitive skill. Some studies described private speech (Berk, 1986b; Manning, 1991; Rohrkemper, 1989), social speech (Vygotsky, 1987; Whitebread et al., 2009) and inner speech (Morin, 2005; Zakin, 2007) as an instrument for planning, monitoring and managing the thinking and learning process. This highlights that these language-based interactions (Conversational exchanges) enable children to manage their mental activities and learning processes.

The study found that the evaluation of the metacognitive skills that children develop during game authoring activities is possible; however, it requires knowledge of both the skills and the methods for investigating the occurrences of these skills. I used observational methods, as suggested by Whitebread et al. (2009), to identify the metacognitive skills that children used. I then created and used an MSI (Metacognitive Skills Instrument) self-report instrument to gain an insight into children's own perceptions of the metacognitive abilities that they develop or apply whilst creating computer games. The reason for blending these methods was the lack of a single medium that can be used for measuring metacognition (Schraw, 2009; Tobias and Everson, 2002). Both these methods were useful for examining the metacognitive skills that were gained and applied by children whilst working on their games. However, without any reference to progress, it might be difficult to integrate into a curriculum where learning is evaluated through tests.

The thesis contends that there is no simple way of measuring metacognition (Schraw, 2009; Tobias and Everson, 2002), especially in classroom context. Although I shared some methods that can be used for assessing metacognitive skills, including a self-report instrument, these can be very time-consuming and difficult to use in different learning scenarios other than game making without some expertise in adapting them to different learning contexts. Many studies developed and used similar tools successfully for measuring metacognition in different domains (Cross and Paris, 1988;

Kramarski and Mevarech, 2003; Sperling et. al, 2002). The analysis of the MSI self-report instrument that has been developed and used for this study showed that the instrument is reliable; however, some of the statements would benefit from further revision. Nonetheless, the MSI, after further revisions, could be used as a method for evaluating a large group of pupils' metacognitive skills in game design domain, alongside other methods in a formative way to inform future planning.

8.2 Implications for teacher education

In the light of results from this study and existing literature, some important points concerning teacher education have come to the forefront. The following recommendations are suggested to improve teacher education, especially in teaching of computing at primary level.

During this study, I focused on the context of children's learning when making computer games and found that there are many learning benefits of children's game making activities. The thesis shared evidence for children's learning of computational concepts, 21st Century skills, metacognitive abilities and learning behaviours. Therefore, it is crucial for teachers to be aware of the various learning possibilities within a game making context in order to plan suitable lessons and adopt appropriate assessment strategies.

According to Jessel (2012), new approaches to learning that are arising from new technologies have an impact on the role of the teacher. He adds, "At another level, the introduction of innovation makes major demands upon teachers' pedagogical, professional and managerial skills (p.28)." The inclusion of Computer Science in the new Computing Curriculum (Department for Education, 2013), requires that teachers can plan, teach and assess computational concepts, especially CT skills. To achieve this, teachers need to have the necessary subject knowledge. They will need to know how to code using wide range of applications and recognise different programming constructs. They then need to be aware of the strategies that will help them to utilize the full potential of learning to code. Therefore, they need to pay attention to pedagogical principles that they should be adopting when teaching children how to code.

The thesis shared a Multiple Evaluation Approach to evaluate children's learning of CT from three aspects: computational concepts, metacognitive practices and learning behaviours. Teachers should be taught about these elements and supported to develop simple tools to evaluate each aspect in their classrooms. They should also receive training to help them to recognise programming constructs in children's work in different learning contexts in order to assess and monitor children's learning of computational concepts. They should be made aware that the successful evaluation of children's learning of CT skills in game making contexts requires them to blend different methods of evaluation, including formative strategies, to gain an insight into children's learning process in game making context.

Another important finding of this thesis was the importance of metacognition in children's learning and the role of language as the main tool for facilitating metacognitive processes. Many researchers have suggested that teachers could model inner speech as a tool within their pedagogy to help students monitor and improve their own performance (Berk and Landau, 1993; Diehl, 2005; Zakin, 2017). Teachers should create conditions that will enable students to use different modes of conversation for self-regulating their learning. Strategies such as group or partner discussions would allow students to explain their reasoning to their friends and visualise different solutions to problems collaboratively. It was evident from the data analysis that computer game making activities offered a fun and interactive learning space for students to use different modes of conversation. Teachers could provide learners with similar tasks that are at an appropriate level for students' needs which would encourage them to use different modes of conversation. This also highlights the importance of the way lessons are executed as during game making sessions I had adopted a very flexible approach to my classroom organisation where I allowed children to manage their learning independently.

This thesis raised questions about the ways children's metacognitive skills could be measured in a classroom environment and concluded that the use of multiple methods provides a better view of children's metacognitive awareness and self-report instruments such as Metacognitive Skills Instrument (MSI) proposed in this study could be used by teachers to evaluate children's metacognitive skills development from four perspectives; planning, conversation, monitoring and evaluating. These aspects relate to children's all learning activities not only game design, therefore MSI could be used as a diagnostic tool for identifying students' strengths and weaknesses. This would help teachers to plan and teach according to the individual needs of the students. The tool will be made available to teachers after another review and pilot study.

It is crucial that teachers are given training to learn about the role of metacognition in learning and the strategies they could use to integrate it into their classroom practices.

8. 3 Contributions to knowledge

To my knowledge, this is the first study that explored thinking, learning and metacognition in game design context in a classroom environment using an ethnographic approach. Learning through game making has been a focus in recent years; however, many of the studies have taken place in afterschool clubs and for a short period, rather than as part of children's lessons in the classroom. Furthermore, the studies were conducted by an external researcher, rather than a class teacher based in the school. This study adds to academic knowledge as it unfolds the thinking and learning process of children and provides an in-depth overview of the elements of learning in a game design context using direct examples from data.

The present study equally contributes to knowledge of teaching and assessing CT by sharing a Multiple Evaluation Model of children's learning of CT skills which can be applied to different learning contexts. Although some studies have discussed the need for multiple means of assessment for CT, and some that mention that the focus should include more than programming constructs, they do not share a clear model for this multiple means of assessment system. Using evidence from both the literature and the data from my study, I have argued for the inclusion of computational concepts, metacognitive practices, learning behaviours and context in this model. This model contributes to both teacher education and classroom practice by providing teachers with the main learning elements that they should focus on when assessing children's learning as this is part of the curriculum in England in 2019.

I believe that this study will contribute to classroom practice further as it unravels the role of conversations in learning. Not only does the study highlight how children use different modes of conversation to manage their planning, monitoring and evaluation activities, but it also indicates how this leads children to self-regulate their learning. I have shared the characteristics of different modes of conversation that children used for managing their learning, which might help teachers to think about ways of modelling these in their classrooms.

After highlighting the challenges around measuring children's metacognitive skills in a game design context using one method, the study presented an MSI self-report instrument for measuring metacognition in the classroom. To my knowledge, this is the first self-report instrument for measuring metacognition specifically designed for children's game making activities. Therefore, the study has the potential to provide a tool for teachers to use for measuring metacognition when implementing computer game design into their lessons.

Finally, the present study also directs attention to multiple aspects of learning when children make their own games using a programming application as part of their computing lessons. I believe that this will encourage further discussions and studies to investigate the learning process that children go through whilst working on their game design, rather than focusing on the codes that they create.

8.4 Limitations of the research

This was a small-scale study for my PhD; therefore, the research cannot fully address the learning process of students in game design environments. The data included in this study was collected from a small group of focus students and it is not possible to generalize the findings without further studies.

I adopted a mixed methods approach for this study where ethnography was used to gain an in-depth insight into children's activities. I was the computing and Mathematics teacher for the focus children that were include in this study and I believe that this helped them to feel more comfortable around me, in their natural learning environment. On the other hand, because I was their teacher they might have said or done things to please me. I knew the children well which was very useful when having a conversation with them and / or during the interviews; however, my experiences with them might had an impact on the way I observed them or interacted with them unknowingly.

Since the empirical research for this study completed many developments have taken place in terms of supporting teachers with the teaching of the new Computing Curriculum. Additionally, since this time, children's interaction with programming applications such Scratch has altered. The students who were part of this study were in Year 6 and this was the first time they used the Scratch programming application. My recent discussions with schools showed that many schools start teaching Scratch from Year 2. Therefore, by the time the students reach Year 6 they would be expert in this language and their experience would be very different. Repeating this study in a classroom where students were exposed to programming activities from very young ages may well produce different result.

8.5 Further research

Further research is required into children's learning and thinking when making computer games, focusing on the role of metacognition and conversation in learning, and ways to evaluate it in the classroom environment. The thesis highlighted the lack of research into children's learning process when making computer games and facilitating the learning of CT skills through game design activities. Therefore, further research is needed with different age groups to gain a better understanding of how learning progresses when children are authoring their own computer games.

The role of conversational exchanges was very visible in computer game design context as part of the metacognitive processes children used to manage their mental activities and self-regulate their learning. Further research about facilitating the use of different modes of conversation in different learning contexts would be beneficial for classroom practice. The thesis focused on the teaching of computational concepts through game making activities during 2013-2014, when the new computing curriculum was just being introduced. Since this period, teacher guidelines have been published by Computing at School (Berry, 2013), a grassroots computer science community. In addition, an assessment system called 'Project Quantum' for assessing children's learning in Scratch environment has been shared; this focuses mainly on assessing children's learning of programming constructs (https://diagnosticquestions.com/quantum). However, these resources do not cover all the aspects of learning that occurs when children create their own computer games using a programming application, so further support or guidelines would be beneficial. Furthermore, as more schools are implementing game design activities for teaching CT skills, longitudinal research is needed into how schools use game design as a tool for teaching CT skills and the learning process that children go through during these activities.

In summary, this thesis has primarily been concerned with exploring children's thinking and learning processes in order to define elements of learning in game design context. The research approached this question from three facets: learning, thinking and metacognition. Under these three aspects, how computer game design activities could facilitate the learning of metacognitive skills, programming concepts and transferable skills (educational value) was examined in depth through the analysis of data that has been collected using both qualitative and quantitative methods. The data analysis process displayed the multi-dimensional structure of the learning process that children go through whilst working on their games. This also highlighted the complex issues around defining and assessing the skills that children developed and/or applied when making computer games.

Appendices

Appendix 1: Example data analysis

20140312-133820.mp4

1

YA [00:00:02] This is the interview with [redacted]

YA [00:00:07] Can you tell me about your game making experiences when using Scratch and Alice.

YA [00:00:12] Which one do you prefer and why?

[00:00:14] Am I like them both the same. Is like. to me game making is doesn't matetr what you program you use,it just matter that what kind of game you make, what kind of content you have for your game.so but The thing with Scratch that is kind of a little bit different than Alice but.

YA [00:00:37] How different do you think?. What is the difference?

I think with Scratch is s more like forbeginners because it's 2D and is what with it is not a lot options, more easier than Alice. COMPARING ALICE & SCRATCH

[00:00:49] You see with Alice, once you've done yeah it you can put extra stuff like duration and its expressions and. ALICE

YA [00:00:55] So Alice is 3D?. Do you think that is important.

[00:01:00] If you want to make a game like a game you want people to see I think it is a bit important.

YA [00:01:06] Let's talk about your thinking process When you make games. how do think. What are the steps that you've followed.

[00:01:14] Firstly like. Where. When i need do like run ball sometimes I do an .... If you told me to make game like just on the spot Firstly I'll try to think if i get something like real kind of thing and change a bit like change it into something different. So I'll do that. Or maybe I can just think of it in my head. If you want one and then then I will go on to try and find out how I want them movement to happen. THINKING IN HEAD

YA [00:01:43] So you will hear that idea in your mind and then go and try..

[00:01:50] Like explore how you can different ways you can make them move and then you find the best way do it then you can put that in your script.

YA [00:01:56] so you explore it and then you kind of get ideas after that?

[00:02:01] You explore it and once found the best way to do it. EXPLORING

[00:02:04] Like the way looks best then you put it in your actual script. Do MAKING DECISIONS

YA [00:02:08] you ever change that or do you keep.

[00:02:10] Yep I change a lot. Oh yeah yeah because I always notice that is will be better like this or I've done this wrong. I need to go back and do it. CHANGING THE PLAN

YA [00:02:21] Do you think learning game design has changed the way you think?

[00:02:29] I think it changed a lot in maths. → IMPACT ON MATHS

(2)

YA [00:02:31] How?

[redacted] [00:02:32] Because the way in Maths is English you there.

[00:02:36] There is no specific answer like you just write or read. There isn't a specific answer but in maths there's always a specific answer for it. For instance if we do two plus two it won't be nothing else but 4 .Like when you make a game. If the script has to be exactly perfect or it wont make that game.

↓ PROBLEM SOLVING

YA [00:02:55] So it's kind of help you to think when you solve problems.

[00:03:00] yeah problems every kind of things .

[00:03:05] What is the most important thing that you think you learned by making games?

[00:03:12] I think My imagination.

YA [00:03:13] How?.

IMAGINATION CREATIVITY?

[00:03:14] Because like it expresses your imagination different points and it tells you you can come up with good things to say.

[00:03:21] Games do. And also I think it boosts your confidence as well because if you like to give it to other people, like show other people and they say if you did they give you negative or good feedback then you do it. Okay.

↓ FEEDBACK & CONFIDINCE

YA [00:03:49] Would you be able to use what you learn in game design in other lessons?

[00:03:59] like skills that you learned and then games. Yes. Problem solving, you said. What else do you think?

YA

[00:04:05] ermm maybe it could help you, I don't really know.

[00:04:12] It is maths..

[00:04:15] It is like. I was thinking about scripting and storyboard and things so we create. would you be ale to use them?

[00:04:23] you would find it easier to make story.

Impact on LITERACY

[00:04:25] Yeah my help you with your story.

YA [00:04:29] When you make game you mentioned thinking in your head at the beginning, so do you talk or ask questions to yourself.

[00:04:34] Yeah I do when. When. I use one before. I like make people, make people see. I say to myself Are you sure it is alright. I go and check that everything seems alright. now even though one little thing I try and change it change. → TALKING TO SELF

YA [00:05:01] Can you give me an example, like, just give me an example that you did communicate to

3

yourself.

[00:05:08] ermm when I was making the rebel fighting game. I wanted to see I thought to myself How do you make your life more interesting more detailed and make it more like a movement, because you told me to make moving,so I thought maybe let me just think of a way to do it like maybe add boys or make them to do extra stuff like, detail basically. - MAKING DECISIONS - THINKING - TALKIN TO SELF

YA [00:05:35] How do you ask yourself. Give me an example. How do you.

[00:05:38] I just say in my mind. I just say I did ask myself. Once I ask myself I try to think.

TALKIN TO SELF

YA [00:05:43] Give me an example.

[00:05:45] I say. ermm What should I do. What should I do fix this life.

[00:05:50] There's something wrong I'd say that in my head and.

YA [00:05:52] What does that do when you ask that to yourself. What does.

[00:05:55] It kind of makes you think better because it making me, it makes when you don't ask yourself you just try to figure out. when you ask yourself sounds a bit weird. But you know like definitely you need like do it.

TALKING TO SELF

YA [00:06:08] I see.

[00:06:08] If..... repeating is better.

YA [00:06:10] ok. Can you list some new vocabulary that you learn when making games.

[00:06:27] Expressions.

COMPUTATIONAL CONCEPTS

[00:06:28] Yeah.

[00:06:36] Opacity. it makes like invisible Yeah.

[00:06:42] Variables. algorithm. Yeah. Yeah.

[00:06:56] Debugging is if there is a problem you go back to check the coding and correct it. Break into pieces and make it work, thats called debugging.

YA [00:07:12] And what did you do when you come across a problem. How did you go about solving it. Can you talk about the steps.

[00:07:20] Firstly I'll try to figure out it myself.

YA [00:07:22] How do you try to do that?

[00:07:24] Like I said I've asked myself, you just think. - TALKIN TO SELF - PROBLEM SOLVING

[00:07:26] You go search through your game, search and look at everything that script was right. And you need to also ask yourself Like.

(4)

[00:07:41] If you need to make a game, you need to have everything right. So you have to make sure.

[00:07:46] But then if I can't do it myself I would have a look out on the Internet.

YA [00:07:51] Do you plan a solution for that problem then?

[00:07:56] I plan in my head. → PLANNING IN HEAD

[00:07:57] You plan in your head and then try if it works.

[00:08:00] I just sometimes I don't ask myself. I try to think like , oh I if I do this maybe it will work.

YA [00:08:06] Have you helped anyone else to solve problem? Can you give me one example.

[00:08:21] One example was, when. When I helped M and Y over there.When they needed to think, they needed to move the guy, you needed to teleport, move to other place to Ancient Egypt.

↓ COLLABORATION

YA [00:08:43] did you enjoy making games?

[00:08:45] Yeah i enjoyed.

YA [00:08:45] what did you enjoyed the most?

[00:08:46] I enjoyed how people when, I enjoyed three things... One hing is when you make the game you just think yourself, wow, i just made a game. that's a good feeling. Another good feelings when people say good stuff about your game and say to you should keep it up.You should definitely don't stop game making.

[00:09:06] Makes you feel confident, doesn't it →

ENJOYMENT
PROUD
CONFIDENCE

[00:09:12] And also I love playing games. I love these things.

YA [00:09:18] Thank you.

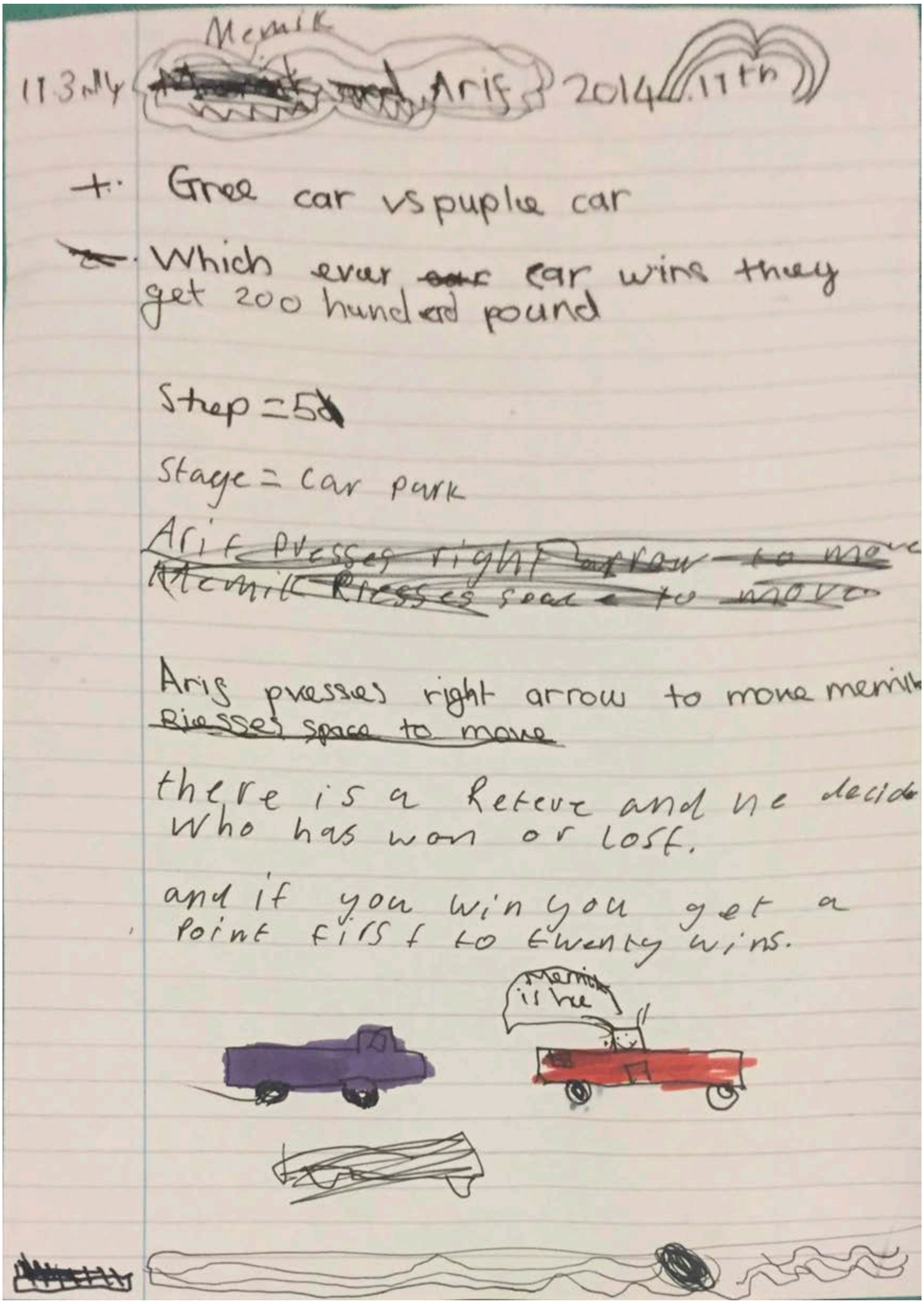
Appendix 2: Example data analysis (Participant observations)

Coding key	
Talking to self: self-remarks, directed at self, visible via audio, directed at an object (e.g. talking to computer)	**Yellow**
Talking to others: asking questions to others, asking for help, answering question, eye/physical contact, expecting response	**Blue**
Inner speech: Silence, pause (then an action such as talking or working on their games), visible through gestures	**Green**
Other: untraceable speech utterances	**Grey**

Participant observation - 2nd Scratch Lesson, Child T.

What! That is ugly trousers, will draw a new one (Looks at a female character in Scratch library). Maybe I can draw my own? Let me see how you do that (Clicks on the Scratch drawing area). Should have black hair, right, or dark brown maybe? (She draws a circle then adds mixture of black and brown hair). Aha, cool (she smiles). It looks similar; oh I forgot the hair clips (she looks at her drawing on her paper then uses black felt tipped pen to over go the lines on the hair clips of the female character on paper). Red pencil please, who has it? (She shouts, then leaves her seat for a few seconds and picks up some coloring pencils from other tables). (She starts colouring the female characters clothes on her planning sheet in red), ba pam ba pam bam pa… (She hums a rhythm while she is working). Shoes, himmm! (She looks at the colouring pencil for a short while then starts colouring the shoes of her character in red too). Looks ok. I know what, I think the hair should have red (She colours the hair below the hair clip in red. Looks at her drawing on the paper, then looks at the screen on her computer, she repeats this a few times, then she starts drawing on her screen). Ah, why is it not working? (She gets cross because the eyes she draws on screen character are not the same size). (Her partner says 'silly, silly, silly' and then adds 'use the circle silly'). (She looks at the screen) Where? (She asks). Oh, silly me (She smiles, finds the circle drawing tool). (She erases her character on screen and then draws it again using the shapes drawing tools. She uses circle for drawing the head and the eyes).

Appendix 5: Children’s own panning sheets



Memik

11.3 July and Arif 2014 .11th

+. Gree car vs puple car

Which ever ~~our~~ car wins they get 200 hundred pound

Step = 5

Stage = car park

~~Arif presses right arrow to move~~

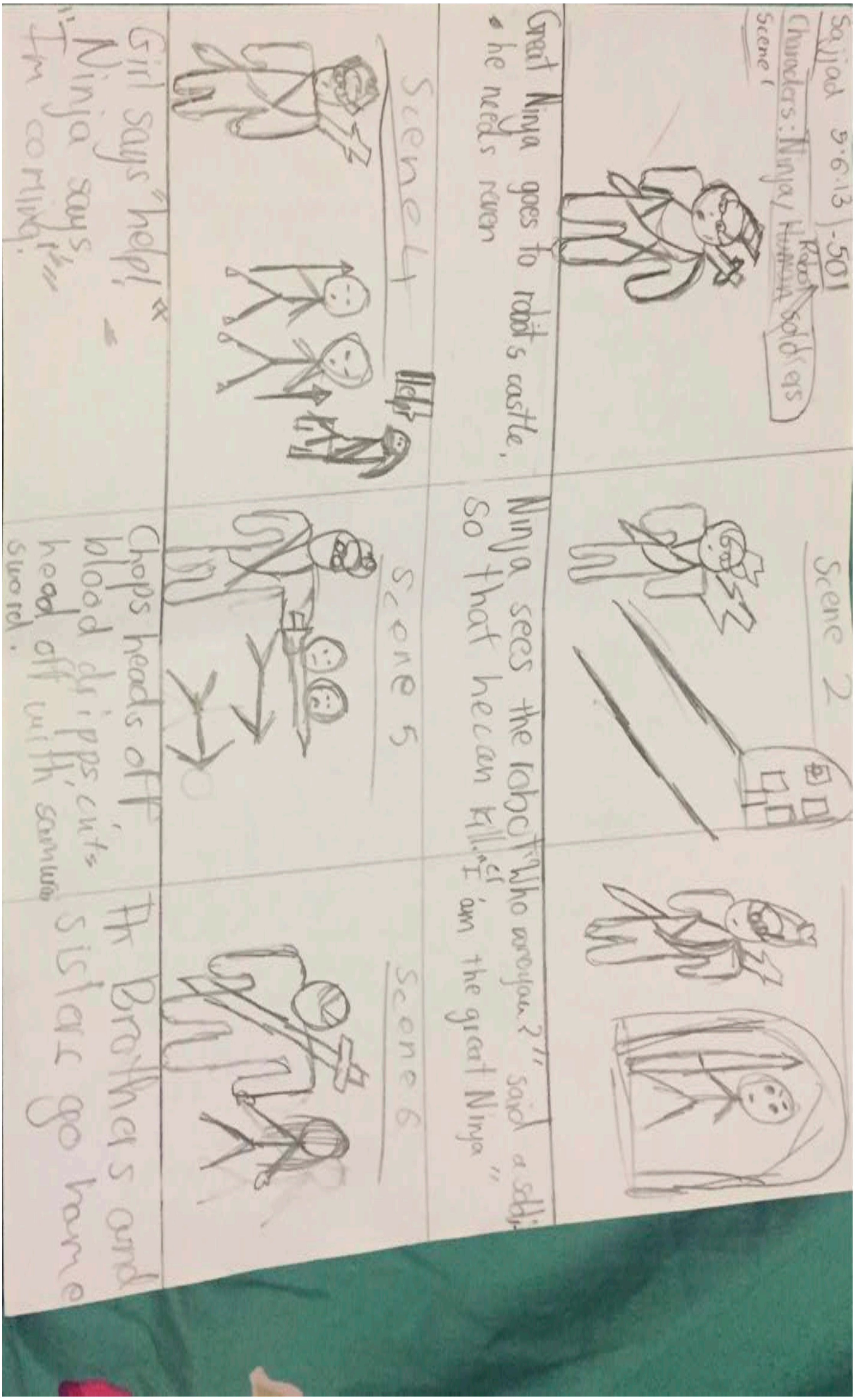
~~Memik presses space to move~~

Aris presses right arrow to move memik presses space to move

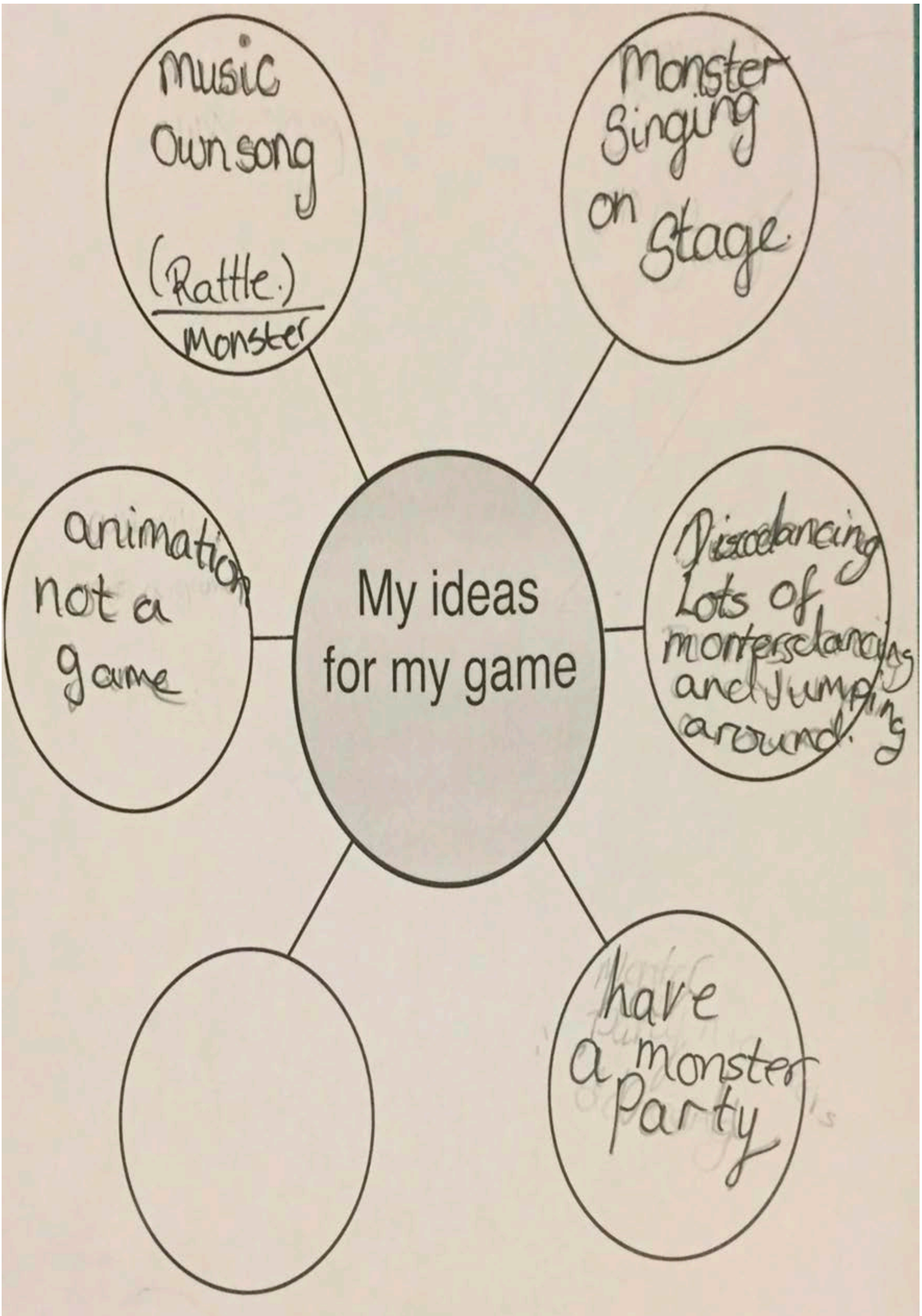
there is a Referee and he decide who has won or lost.

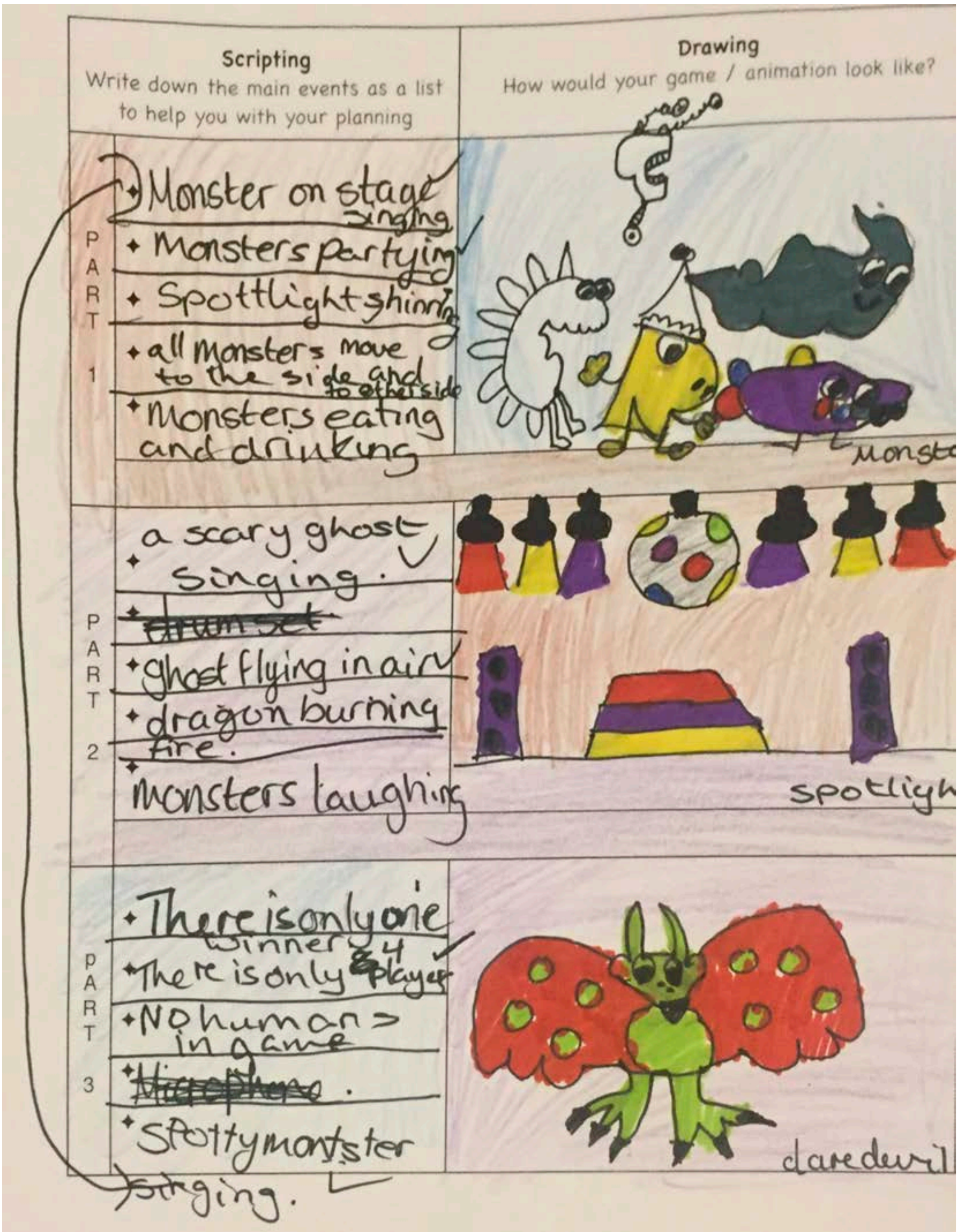
and if you win you get a point first to twenty wins.

Memik is here


Sajjad 5.6.13 -501
Characters: Ninja / Robot soldiers
Scene 1
Great Ninja goes to robot's castle,
he needs raven
Scene 2
Ninja sees the robot "Who are you?" said a soldier
So that he can kill. "I am the great Ninja"
Scene 4
Help
Girl says "help!"
Ninja says "I'm coming."
Scene 5
Chops heads off, blood dripps, cuts head off with samurai sword.
Scene 6
The Brothers and sisters go home

Appendix 6: Planning templates





	Scripting Write down the main events as a list to help you with your planning	Drawing How would your game / animation look like?
PART 1	• Monster on stage singing • Monsters partying • Spottlight shining • all monsters move to the side and to other side • Monsters eating and drinking	monste
PART 2	• a scary ghost singing. • ~~drum set~~ • ghost flying in air • dragon burning fire. • monsters laughing	spotligh
PART 3	• There is only one winner • There is only 4 player • No humans in game • ~~Microphone~~. • Spotty monstster singing.	daredevil

Appendix 7: Problem solving sheet

MY GAME DESIGN LEARNING JOURNAL

My game was about…

a Alien Seafing a space man in Seace

I have learnt to…

use the web gallery for more objects to put in the world

I asked/talked/thought to myself…

I asked my sels that how is it going to the work. ~~and how is it going to questio~~

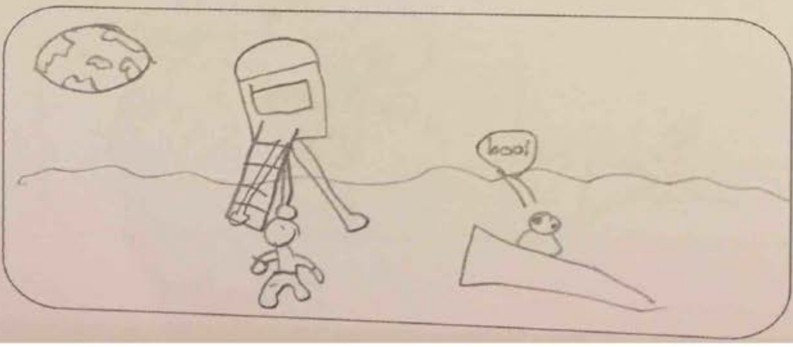
I discussed with my friend about…

How to open the web gallery

My problem and how I solved it:

We did'nt have any problems but are freinds did, they did'nt know how to open the web gallery. Some of them did but they did not have some of the carecters.

My game looked like this:



Appendix 8: Metacognitive Skills Instrument

I am interested in how you think during making computer games. Please read the sentences below carefully and circle the answer that relates to you.

Gender: Male / Female Age:

1= Never 2=Seldom 3=Sometimes 4=Often 5=Always

I start making my game as soon as I open the game design program	1 2 3 4 5
I write down my ideas	1 2 3 4 5
I check if it is similar to anything that I have done before	1 2 3 4 5
I make a plan of what I need to do	1 2 3 4 5
I discuss/share my ideas with others	1 2 3 4 5
I talk/ask questions to myself to make sense of my thoughts	1 2 3 4 5
I design solutions to solve problems using different methods (such as linking up what I know or breaking down the problem)	1 2 3 4 5
I make notes of what works well and doesn't work to develop my game further (such as; loop statements)	1 2 3 4 5
I discuss my work with others during the task	1 2 3 4 5
I make decisions to manage my learning	1 2 3 4 5

I ask myself whether I am on the right track	1 2 3 4 5
I check to see if my plan is working	1 2 3 4 5
I think about other ways of making my game design better	1 2 3 4 5
I look at the work that I don't understand	1 2 3 4 5
I make changes to my planning during the task	1 2 3 4 5
I test my design to see if it works	1 2 3 4 5
I correct my errors	1 2 3 4 5
I ask my friends their opinion of my design	1 2 3 4 5
I share with my friends what I think of their designs	1 2 3 4 5
I think about what I could do better the next time	1 2 3 4 5

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