Examining the Conditions under which Educational Technology Mediates Learning

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Affirmation

I, Frantzeska Kolyda, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

The goal of this study is to explore whether educational technology could have an impact on formal learning and also to identify and discuss the most important factors that could influence and determine the effectiveness of educational technology in a school environment. Assessing the impact of technology on learning is generally complex as it depends on various interconnected factors difficult to isolate and rationalise.

Further to an empirical study that was conducted in a school classroom and the results revealed statistically no significant difference in learning across the different groups, a number of methodological issues and various interconnected factors that could influence the effectiveness of educational technology emerged as well as other important factors that identified through the literature analysis are discussed in this thesis. The focus of this thesis is on a number of key factors: the learning context, the subject area and its consistency with the curriculum orientation, the characteristics of educational technology and learning environments, the students' characteristics and attitudes to learning, student collaboration, the teachers' role and perceptions, economic and political factors, school infrastructure and finally, the methods of assessment and relevant measures of learning.

The main contribution of the thesis is in providing a critical exploration as well as empirical evidence to contribute answers to questions regarding the impact of educational technology on learning, how to best facilitate learning in the classroom with educational technology and also in examining the conditions under which technology could mediate learning. Additional significant contribution includes a set of relevant recommendations that could be useful to everyone involved in formal education such as educators, researchers, policymakers and practitioners.

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Dedicated to my parents

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Chapter 1 : Introduction

Most people nowadays accept the assumption that digital technology plays an important role in formal education. The thesis of this study is that educational technology can support learning in primary schools if it is appropriately designed to support learning and if it is successfully embedded in specific learning activities.

For several years, significant effort has been devoted to the study of computers and technology use in education and whether such technology will replace the school, the classroom or the teacher. A number of studies have been conducted addressing – most of the time – a very specific aspect (such as subject matter, motivation, software development, etc). Nevertheless, the debate continues as it seems that there is not a single study that could provide a clear answer regarding the overall impact of technology on learning and whether there is a specific type of technology which could transform education.

In order to discuss and conclude to this thesis' hypothesis (i.e. that educational technology can support learning in primary schools if it is appropriately designed to support learning and if it is successfully embedded in specific learning activities) it is important to analyse the way educational technology is related to learning, what does this involve and under which conditions. In order to achieve this there is a need to start by reviewing some of the main learning theories (which are discussed in Chapter 2) developed in the last hundred years and their contribution to the use of educational technology for learning.

The research underpinning this study attempts to address the challenges that researchers are faced with while attempting to assess the effectiveness of educational technology in a primary school classroom. The purpose of this study is to explore whether educational technology could have an impact on primary school learning and also to identify and explore the most important factors that can influence learning with technology. The above aim of the study is translated into the following objectives:

a) Investigating to what extent educational technology helps learning in the primary school (and particularly in mathematics).

b) Investigating the most important factors that might influence learning with technology.

c) Providing a set of recommendations on how educational technology can mediate learning at school.

The above leads us to the following research questions.

1.1 Research Questions

This study was undertaken to answer three important questions regarding the integration of technology in the primary school classroom to enhance learning:

1. What is the impact of educational technology on primary school's mathematics learning?

2. What are the factors that could influence and determine the effectiveness of educational technology in the school classroom?

3. How to best facilitate learning in the classroom with educational technology and how to integrate this technology into the school environment effectively?

1.2 Contribution

The main contribution of the thesis is in providing empirical evidence as well as a critical analysis in order to contribute answers to the above research questions as well as in identifying and analysing the main factors that could influence and determine the effectiveness of educational technology in the school classroom. Additional significant contribution includes a set of relevant recommendations that would be useful to teachers, policymakers, practitioners and people involved in primary school learning.

1.3 Technology and learning

How could we consider effective use of digital technology to support learning? One way of doing this is through learning theory and considering why technology is being used in education. Reviewing the key theories of learning, the explanation they offer for the role of technology in learning and what contribution these theories have made to the educational technology use could help us understand how technology is associated with learning.

1.4 Thesis Outline

The thesis is divided into seven chapters:

Chapter 1 provides an introduction to the thesis, presents the Research Questions and this thesis contribution. Chapter 2 involves a review of the key learning theories developed in the last century as well as more contemporary emerging learning theories. Chapter 3 discusses the theoretical approach and method of inquiry.

Chapter 4 describes a school study which compared the effect of two types of educational software in mathematics with a traditional approach on the learning outcome of a group of Key Stage 2 and Year 5 students. The students were exposed to two different types of software that dealt with the same subject matter in mathematics, data handling. A pre-test/post test design was used in order to assess the learning outcome. The results of this study revealed statistically no significant difference in learning across the groups. However the study did highlight a number of methodological issues and various interconnected factors that could influence the effectiveness of educational technology and these factors are discussed in the next chapter.

Chapter 5 concentrates on the identified factors emerged from the school study as well as other important factors identified through the literature analysis and research review. This chapter also considers some of the important but often overlooked challenges that underpin the successful implementation of educational technology in school education.

Chapter 6 discusses the latest developments and emerging technologies which appear to have great potential on learning within a school environment. Chapter 7 summarises the conclusions of this research study and implications. In addition, a set of recommendations is presented. This chapter also discusses the limitations of this research work and suggests possible future directions. The last part of the thesis consists of the Reference list and Appendices.

Citations and references follow the American Psychology Association (APA) style and this is also used in presenting the results of the experimental study at school.

Appendix I consists of the list of publications produced in relation to this work, Appendix II consists of material and information related to the school study (presented and discussed in detail in Chapter 4). For example, screenshots, sample of the pre-tests and post tests used in the experimental study. Appendix III consists of a series of charts and graphs that could offer interesting insights regarding children and their use of technology today.

1.5 Definitions

Before we go on to try and answer our research questions further, we should consider what we mean by the key terms: *Learning* and *Educational Technology* in order that it is clear what is meant, in particular, by these terms in the course of this research work.

The concept of learning according to Mayer (2009) could be defined as follows:

> ***Learning*** *is a change in knowledge attributable to experience. This definition has three parts: (a) learning is a change in the learner; (b) what is changed is the learner's knowledge; and (c) the cause of the change is the learner's experience in a learning environment* (pp. 59-60).

The concept of learning according to Hodkinson and Macleod (2010) could be defined as follows:

> ***Learning*** *is a conceptual and linguistic construction that is widely used in many societies and cultures, but with very different meanings, which are fiercely contested and partly contradictory. Learning does not have a clear physical or reified identity in the world* (p.174).

Based on the above and the rest of the literature the working definition of the term, educational technology, used in this thesis is the following:

> **Educational Technology** refers to a variety of digital technologies (technology-based programs or applications) that could support the learning process and help with the delivery of learning material for educational purposes.

Chapter 2 : Learning Theories

This chapter reviews some of the key learning theories developed over the past hundred years (e.g. behaviourism, cognitive science, socio-cultural theory and constructivism) and their contribution towards the use of technology for learning. The aim is not to provide an exhaustive survey of learning theories but rather a discussion of some of the theories related to the development of educational technology. In addition, it reviews some more contemporary theories (e.g. constructionism, and connectivism) that appear to be more associated with educational technology. It is important to use learning theory to examine why and how technology is used in formal learning.

2.1 Learning theories and technology

2.1.1 Introduction

As defined in Chapter 1, educational technology refers to a variety of digital technologies (technology-based programs or applications) that could support the learning process and help with the delivery of learning material for educational purposes. Therefore in order to fully understand education and technology we need to take in to consideration the important issue of how the use of educational technology can mediate learning (Selwyn, 2011). Digital technologies are currently used at schools either as a means of accessing information (as an information tool) or as a means of supporting learning activities (as a learning tool) (Tondeur et al, 2007). There is a need to analyse the way educational technology is related to learning and what does this involve and in order to be able to do this it is essential to review some of the main learning theories developed in the last hundred years and their contribution to the use of educational technology for learning. Nevertheless, as Harasim (2012) highlights, these learning theories should not be considered as “distinct silos – independent or autonomous of one another” (p. 10).

2.1.2 Behaviourism

According to behaviourism learning occurs when a particular response is elicited from a learner when the latter is placed in a specific stimulus. Classical conditioning as a form of learning in which a conditioned and an unconditioned stimulus become associated could be easily understood if it is taken into consideration how some unpleasant experiences become unreasonably associated with particular situations (e.g. places or people). A very strict and unfriendly teacher might condition students to dislike the particular subject that this teacher teaches. Behaviourism dominated psychology through more than the first half of the twentieth century and led to outcomes such as firstly, programmed textbooks, later, systems of computer-managed instruction and more recently, Integrated Learning Systems (Alessi & Trollip, 2001).

In the 1950s, Skinner introduced his “teaching machines” while claimed that they made the teacher “out of date”. These machines required the learner to complete or answer a question and then receive feedback as to whether the answer was correct. This was based on operant conditioning in which the central point is that behaviour is shaped by its consequences and consequently behaviour is “shaped” by the pattern of reinforcements or rewards in the environment (Boyle, 1997). In the 1960s, the first educational software was designed and it was based on Skinner’s behaviourist theories (Sawyer, 2006). These systems are known as Computer Assisted Instruction (CAI) and such systems are still used today e.g. “drill-and-practice” software. The latter is commonly designed to reinforce basic skills such as spelling words, development of reading vocabulary or typing programs. Contemporary “drill-and-practice” software allows the learner to determine the sequence of instruction or omit particular topics. Other type of software that has been informed by behaviourist principles is “tutorial” software. In this, new concepts are presented and step by step instructions are provided on how the learner should complete specific objectives (Selwyn, 2011). It is therefore quite clear to see that behaviourism continues to underpin the design and development of educational technology for quite long time since the first teaching machines (Selwyn, 2011).

In its most extreme form, behaviourism appears not to involve with internal cognitive processes such as reasoning about the consequences of consistently performing an action (Bartlett et al, 2001). Chomsky (Bartlett et al, 2001) argued that the principles of behaviourism failed to explain complex human behaviour such as language and communication. Similarly, researchers (Alessi & Trollip, 2001) argue that the principles of behaviourism do not predict all learning outcomes. Extreme behaviourism focused on observable stimulus conditions and the behaviours associated with those conditions and as a result, it was difficult to study phenomena such as understanding, reasoning and thinking. Over time, a more “moderate” form of behaviourism replaced this extreme behaviourism. This latter form, although "preserved the scientific rigor of using behaviour as data, it also allowed hypotheses about internal mental states when these became necessary to explain various phenomena" (Bransford, 2000). Recent criticism has focused on the Instructional System Design (ISD) models as they are largely based on behaviourism. Instructional System Design was an approach to the development of instruction, initially in industry and the military where there was a need of developing a great amount of effective instruction that would promote mastery learning (Alessi & Trollip, 2001). Accordingly, its focus was towards the teaching of adults rather than to primary or secondary education. ISD models are considered to ignore important aspects of learning that could not be observed, such as thinking, reflection, memory and motivation. In addition, they emphasise too much on the instructor and instructional materials and at the same time, they do not emphasise enough on the learner (Alessi & Trollip, 2001). However, behavioural principles, such as positive reinforcement and corrective feedback, are appropriate to apply in a number of computer educational environments (Alessi & Trollip, 2001).

Behaviourism emerged from a positivist perspective of knowledge. This perspective meant that teachers tell students *the truth* i.e. the facts and students learned this prescribed knowledge without questioning it and then demonstrate what they have learned (by reproducing this knowledge) in an assessment activity (Starkey, 2012). Nowadays this behaviourist view of knowledge has not disappeared. There are situations where technology used in the past and today focuses on instruction underpinned by behaviourism (Starkey, 2012).

Throughout the 1970s and much of the 1980s, the most prominent form of computer-assisted instruction was drill and practice programs (Jonassen, 1999). Since then, an important number of educational systems have been developed that follow the theoretical approach of drill and practice. This approach was based on the behaviourist theory which focuses on the reinforcement of stimulus-response associations. An example is Suppes' work (Druin & Solomon, 1996) which is linked to this particular style of instruction. This means that learning is accomplished when the subject matter is analysed and broken into concept blocks and each of these blocks contains carefully designed exercises at increasing levels of difficulty. The above approach represents a behaviouristic idea in which the computer plays the role of an individualized teacher who will patiently lead the child at his own pace through a series of carefully designed exercises (Druin & Solomon, 1996), (Metcalf, 2000).

There has been a lot of criticism regarding "drill-and-practice" software and applications designed based on behaviourist theories and in most cases this is justified. For example, according to Kuiper & de Pater-Sneep (2014) such applications lack characteristics associated with the use of educational technology such as interactivity and authenticity. Another argument is that drills do not capitalise on the power of the computer (Alessi & Trollip, 2001) and that they can be easily developed without computers. However, nowadays although pedagogical unpopular, "drill-and-practice" software - when well designed and of high (educational) quality in order to reinforce basic skills such as spelling words, development of reading vocabulary or typing programs - remains useful in this particular type of learning and specific skills (although mainly at the lowest level of learning). As Jonassen (2000) explains, in order to learn complex, higher order skills, it is important for the learners first to be able to perform the lower level *sub-skills* automatically. Using "drill-and-practice" computer applications to master these *sub-skills* enables learners to gain *automacity*. Nevertheless, "drill-and-practice" applications do not facilitate the transfer of those skills to meaningful problems.

2.1.3 Cognitive science

Since behaviourism relies on observable changes in behaviour as an indication of what is taking place inside the learner's mind it is quite limited as an approach/theory to explain in detail how learning takes place and how knowledge is constructed within someone's mind (Selwyn, 2011). On the other hand, the learning theories that have been developed from the field of cognitive science offer a contrasting perspective. Specifically, learning is perceived more in terms of the thought processes that lie behind any observable behaviour and unlike behaviourism, learning is understood as an internal process of mental action (Selwyn, 2011).

Cognitive science, in the late 1950s, allowed a multidisciplinary approach to learning. Its perspective involved a number of disciplines such as anthropology, linguistics, philosophy, psychology (e.g. developmental psychology), computer science, and neuroscience (Bransford, 2000). Cognitive science emphasised the importance of the social and cultural contexts of learning (Bransford, 2000).

Sawyer (2006) highlights that cognitive science through the 1970s and 1980s did not offer enough support to educators as it focused on laboratory methodologies that removed individuals from learning contexts and also it focused on static knowledge (such as facts and procedures) instead of the processes of thinking and knowing. Later on, around 1990, many key concepts from cognitive science became central in the learning sciences, such as representation, expertise, reflection, problem solving and thinking (Sawyer, 2006). According to Selwyn (2011), from the 1960s onwards, cognitive theory was informing the development and design of technology based learning and specifically, it provided the foundation for the development of “Intelligent Tutoring Systems” and “cognitive tutors”. In this case, the intelligent system is designed to respond to a model of what the learner should preferably be doing during the task. “The learner’s performance is then compared with the model and the system is able to “troubleshoot” where the person’s mental actions have deviated from the ideal. On the basis of this comparison, the system is then able to provide “intelligent feedback” to guide the learner in another attempt at a similar task” (Selwyn, 2011, p.71).

Various applications have been produced from the 1960s to nowadays in order to diagnose students understanding of the skills involved in mathematical procedures (as well as scientific), with the system offering a complete diagnostic model of the learner errors which an individual's performance could then be compared against (Selwyn, 2011).

2.1.4 Constructivism

Constructivism in the context of learning comes under the broad heading of cognitive science (Pritchard, 2013). The central figure of constructivism has been Piaget whose theories became the foundation for several generations of developmental psychologists. Piaget noticed that all children go through the same types of sequential discoveries about their world, making the same mistakes and finding the same solutions (Bee, 2002). He embraced the idea that all people possess certain biological characteristics and they all interact with an environment with specific constant features (Boyle, 1997). Piaget explained cognitive development as being driven by an internal need to understand the world (Bartlett et al, 2001). His detailed observations of systematic changes in children's thinking led him to a number of assumptions. The most important of which has been that it is the nature of the human beings to adapt to their environment (Bee, 2002). This active process of adaptation, according to Piaget, consisted of several significant sub-processes or concepts: assimilation (absorbing new experiences or information into existing schemes), accommodation (modifying existing schemes as a result of new experiences or new information absorbed by assimilation) and equilibration (periodic restructuring of schemes in order to bring assimilation and accommodation into balance) (Bee, 2002).

In Piaget's view, constructivism has the meaning of constructing "adapted" representations of reality. "The representation is a product neither of the mind alone nor of "reality" alone but the adapted interaction of the two" (Boyle, 1997, p.81). Piaget's theory is known as the "constructivist" approach because it focuses on the active, constructive nature of human development (Wood, 1997). There is no doubt that developmental and educational psychology has been greatly influenced by Piaget's views even if his ideas have not been supported by recent research. A significant criticism of Piaget's theory is that he fails to take sufficient account of the special nature of social interaction (Woolfolk, 2013).

Constructivism challenges the approach of traditional instructional design and proposes a thorough alternative (Boyle, 1996). The central idea is that knowledge of the world is constructed by the individual. Nowadays, constructivism represents the main paradigm in computer educational environments. There is some evidence (Alessi & Trollip, 2001) which indicates that constructivist methods work better only for learners that have developed well metacognitive skills and that constructivist techniques are time consuming in a great extent. According to this opinion, constructivist techniques are effective for "some types of learning, some situations and some learners, but not all" (Alessi & Trollip, 2001). On the contrary to the above, there is a number of well-known researchers, such as Jonassen and Schank, that embraced the constructivist practice. As Jonassen (2000) explains, a common misconception regarding constructivism suggests, "if learners end up constructing their own individual knowledge representations, then intellectual chaos will result. If all learners have their own set of perceptions and beliefs, how can they share meaning?" (p.12). Jonassen explains that this occurs through social negotiation (Jonassen, 2000). In order to clarify this, he gives the example of a red traffic light that people have socially agreed to its meaning.

Certain well designed computer tutorials and Intelligent Tutoring Systems (ITSs) could guide the learner through the information and emphasise a constructivist approach. Throughout a tutorial, new knowledge could be linked to prior knowledge and at the same time provide the learner with increasing confidence through familiarity with the topic (Alessi & Trollip, 2001) which could also lead towards increased motivation. The applications used during the experimental study discussed in Chapter 4 included a comprehensive range of interactive tutorials. Individual tutoring by expert human tutors is seen as possibly to be more effective than the typical one-to-many classroom instruction. In addition, increasing capabilities of technology provide unique opportunities to incorporate advances in learning sciences into the classroom and to test associated learning principles in order to be able then to adapt them in the best way to the student needs (Koedinger & Corbett, 2006).

As Starkey (2012) explains, what learners (individually and in groups) know and perceive becomes significant consideration when teachers apply constructivist learning theory to their learning practice. The focus is on understanding what and how students are learning and how they can be scaffolded towards a more advanced stage of their learning. So how is it then possible for the learners to create a cognitive structure that is more complex than the one they already possess since they construct their own knowledge (Scardamalia & Bereiter, 2006)? The answer to this question could be found on Vygotsky's ideas who suggested the Zone of Proximal Development (ZPD) where the teacher or someone else who has greater knowledge or skills scaffolds the student through.

2.1.5 Sociocultural theory

Social constructivism provides a significant dimension to constructivism. In social constructivism theory, the focus is placed on interaction between the learner and others (Pritchard, 2013). The main supporters of this branch of constructivism are Vygotsky (1896-1934), a Russian psychologist and Bruner (born in 1915), an American psychologist (Pritchard, 2013).

Vygotsky, who highlighted the fact that cognitive development depends mainly on the people in the child's world, provided a complimentary view of Piaget's theory. Vygotsky believed that the most important factors influencing children's knowledge, ideas and values are developed through interaction with others rather than the child's private explorations as Piaget proposed. As Woolfolk (2001) states "whereas Piaget described the child as a little scientist, constructing an understanding of the world largely alone, Vygotsky suggested that cognitive development depends much more on the people in the child's world". He argues that when adults help children to achieve things that they cannot manage on their own, they promote the growth of knowledge and ability.

One of Vygotsky's contributions to educational theory, in addition to his other achievements, is the Zone of Proximal Development (ZPD) which is referred to as the "gap" between a child and adult. In other words, it is "the distance between the child's actual developmental level and his or her potential level of development under the guidance of more expert adults or in collaboration with more competent peers" (Smith et al, 1998). One of the main aspects of Vygotsky's theory is the fact that children learn from other people who have more knowledge than themselves. He provided an explanation of how children learn with the help of others. What the child is capable of doing on their own and what they can accomplish with someone else's help who has greater knowledge or skills. The above process was later named "scaffolding" by Bruner (Bee, 2002).

Although Vygotsky provided alternatives to most of Piaget's theories his views have many similarities with Piaget's. There are, though, a number of differences concerning language and its influence on thinking. To be more specific, one of the most significant differences between Vygotsky's theories and those of Piaget's is the nature of language and its effect on cognitive development. Piaget believed that language has no formative effects on the structure of thinking. He believed that language is simply a medium, a method of representation through which thought takes place. All thought processes are derived from action and not from speech. Vygotsky put significant emphasis on the role of learning and language in cognitive development. According to Vygotsky, "thinking depends on speech, on the means of thinking, and on the child's socio-cultural experience" (Vygotsky in Rieber & Carton, 1987, p.120).

Bruner focused on the problem of "what people do with information that they receive and how they go beyond discrete information to achieve generalized insights or understandings that give them competence" (Bigge & Shermis, 1998). On the contrary to Vygotsky's and Piaget's theories, Bruner's studies of child development were a result of extensive research into the way adults think and how they solve problems. According to Bruner, between the ages of 2-6 years the child starts developing an “iconic” mode of representation with which the child can use images or spatial schemas to represent objects. At around the age of 7 years children develop the “symbolic” mode of representation. This means that they can use symbolic representation and “go beyond the information given” (Smith et al, 1998). Bruner argues that “any subject can be taught effectively in some intellectually honest form to any child at any stage of development” (Smith et al, 1998). He believes that it is possible even for very young children to understand ideas in an intuitive way so that they can come back later able to understand more complex issues of the same ideas. As an example, it is proven that children can understand by intuition the idea of tragedy when represented in a myth or a story. Later, when they become adults they will be able to understand the same idea in a more abstract way. Bruner emphasises the need of good pedagogy to encourage students to discover principles by themselves (Bartlett et al, 2001). According to Bruner this means that the instructor/teacher and student should engage in an active dialogue, introduce and test hypotheses i.e. good pedagogy involves using “discovery methods rather than the provision of prepackaged materials” (Bartlett et al, 2001, p. 141). The teacher should guide this discovery through structured support (i.e. by posing specific questions or providing appropriate materials) (Bartlett et al, 2001).

Nowadays, further research is taking place regarding the sociocultural theory and the crucial contributions that society makes to individual development. Luckin (2008) introduced the *Zone of Available Assistance (ZAA)* and the *Zone of Proximal Adjustment (ZPA)* in an attempt to clarify the relationship between the Vygotsky’s ZPD and educational technology and this is discussed further in Chapter 5 and particularly in relation to learning context as a crucial factor that plays an important role in examining the impact of educational technology.

2.1.6 Constructionism

Constructionism is an extension of the constructivist approach. It may be said that the most prominent example of technology-based constructivist learning has come from the work of Seymour Papert, one of Piaget’s students. Papert used Piaget’s work as a basis for further research concerning the design of computer-based learning environments. He believes that “the child is in control of the computer” and the latter is used as an ‘Expressive Medium’. Papert adapted the word ‘constructionism’ to refer to “everything that has to do with learning by making, an idea that includes but goes beyond the idea of learning by doing” (Papert & Harel, 1991). Constructionism has to do with the creation of environments for children to play in so that they keep learning new things. Papert was especially interested in helping children make sense of abstract mathematical concepts. As a result, the language Logo was designed which was not just a programming language, according to Papert, but rather a way for children to actively explore certain abstract concepts.

In 1991, Papert's research group at the MIT Media Lab published a collection of papers under the title Constructionism (Papert & Harel, 1991) which described a research project called Instructional Software Design Project as a model for constructionist learning. This project was conducted as part of a larger study (called Project Headlight) in the uses of computers in primary schools which took place in an inner city public school in Boston. According to Papert and Harel (1991), this project proposed changes in the approach to the learning and teaching of Logo and fractions as well as more general thinking and problem-solving skills.

Constructionism is based around the idea that learning takes place through the exploratory building of objects that are themselves then able to do something (i.e. build an object and then manipulate this object in order to do something). Constructionism embraces the idea of encouraging a learner’s conversations with an object (i.e. an artefact), placing digital technologies as tools to learn *with*, rather than learn *from* (Selwyn, 2011). According to Papert, the use of computers for self-directed learning could lead to the construction of “Microworlds” i.e.

learning environments that are created while learners construct things and typically encounter problems that require creative solutions (Selwyn, 2011). Consequently, concepts that were previously considered as abstract could obtain a real meaning and tangible rewards could be experienced for experimenting with such concepts.

In addition, simulations have often been associated with constructivism. A computer simulation (as a digitised approximation of a real situation, task or procedure (Howell & Dunnivant, 1999)) is considered a very popular method for learning as simulations are recognised as more interesting and motivating (learning in the real world) than other methodologies. As Alessi and Trollip distinguish (2001), “an educational simulation can be defined as a model of some phenomenon or activity that users learn through interaction with the simulation” (p. 231). The above definition could include several applications such as microworlds, Virtual and Augmented Reality.

Simulations can make visual abstract concepts or as Boyle (1996) states, they can relate the abstract to the concrete. Acting in a simulated environment gives the learner the ability to visualise a process and explore what it would happen to the system if certain parameters change (Rist & Hewer, 1999). Simulations support vicarious experience in real or imaginary situations (Boyle, 1996). They consist of computer systems that allow the learner to experience. An effective simulation has to be designed in such way that its performance objectives can be met within the constraints that natural methods of learning pose e.g. the fact that people remember a new experience to the extent that it can be linked with old ones in some way (Schank, 1998). Such systems allow learners to manipulate one variable at a time which is usually not possible in real life (Jonassen, 1999). Nevertheless, one of simulation’s challenges is that in order to be effective in promoting learning it requires significant work concerning the design and development of such learning environment. An effective simulation allows the learner every possible choice and provides them respectively with real responses/consequences of their choices. The development of such an environment requires a great amount of pedagogical knowledge (apart from the obvious technical skills) - in order to understand user's behaviour).

As it is discussed in Chapter 5, there is currently a need for further research is on the way simulations, virtual words, collaborative environments and games could be used to engage and motivate students while at the same time assessing complex skills and important competencies and aspects of thinking in different contexts and situations. Nowadays the potential of developing powerful simulations that could be effective in learning seems great. Simulations, depending on how they are designed (in regards to pedagogy) could combine elements for various learning theories or only focusing on a particular theory. Nevertheless, as it is discussed in Chapter 5, there are still not enough examples of innovation (Luckin et al, 2012) in educational simulations and this type of learning appears to be underused and undervalued within the school classroom.

Garcia and Pacheco (2013) developed a simulation, based on a constructivism approach, to support mathematics education in primary school. They conducted an exploratory case study concerning dimensions of mathematics problem-solving using these simulations with 8-9 year old primary school children in Mexico. The type of data collected was data from children's responses to questions and interviews that were designed to explore attitudes towards learning mathematics and assess self-efficacy in this area. The results of this case study (of 60 children) indicated that the integration of such simulations into the conventional classroom courses provided elements to improve learner's motivation, collaboration and discussion based on the learners own exploratory experiences (Garcia & Pacheco, 2013).

2.2 More contemporary approaches

The intention of this thesis is to show that the theories and approaches discussed in this section have a place in understanding of how technology has the potential to enhance learning. It is important to keep in mind that the theories discussed earlier in this chapter were not originally developed in an era where technology had the impact that is currently having nor such a plethora of information existed.

Over the last 20 years, psychologists are trying to understand the influence of the social and cultural environments that are involved in someone's learning and cognitive development (Selwyn, 2011) and more emphasis is now being placed on seeing learning as a very social process. This idea of learning as a collaborative and socially situated process has led to a number of researchers e.g. (Luckin, 2010, Greeno, 2006) nowadays focusing on how educational technology could act as powerful social resources in someone's learning context.

When learners acquire information in a meaningful context and are able to relate it to their prior knowledge and experiences, they could form connections between the new information and their prior knowledge to develop larger and better linked conceptual understanding (Sawyer, 2006). This notion of learning occurring in some particular context and this context consequently affects learning consists of the concept of situated learning.

2.2.1 Connectivism

The learning theories discussed earlier in this chapter and approaches were used in the past in the design of interactive learning environments. However, these learning theories were emerged and developed in an era where technology (and particularly networking technologies) did not have the impact that has nowadays and did not play the role it plays in our lives today (Siemens, 2004 and Harasim, 2012) . We are currently living in the digital age where learners can connect and collaborate with other learners or people beyond their physical environment. Today, the plethora of information and ideas rapidly available to each of us through the Internet is remarkable when compared with access in the past (Starkey, 2012). Siemens (2004) developed a learning theory for the “digital age” that aims to take into consideration “how people, organisations and technology can collaboratively construct knowledge” (Starkey, 2012, p.26). This theory is called c*onnectivism*.

> *“Connectivism is the integration of principles explored by chaos, network, and complexity and self-organization theories. Learning is a process that occurs within nebulous environments of shifting core elements – not entirely under the control of the individual. Learning (defined as actionable knowledge) can reside outside of ourselves (within an organization or a database), is focused on connecting specialized information sets, and the connections that enable us to learn more are more important than our current state of knowing.*
>
> *Connectivism is driven by the understanding that decisions are based on rapidly altering foundations. New information is continually being acquired. The ability to draw distinctions between important and unimportant information is vital. The ability to recognize when new information alters the landscape based on decisions made yesterday is also critical”* (Siemens, 2004, p.4).

A learning theory for the digital age needs to consider learning not as an “event” but as a continuous process within a complex environment. This is because “knowledge is rarely developed in isolation” (Starkey, 2012, p.49) and “knowledge creation occurs through connections, from connecting together ideas, through collaboration, or the mashing of different media, concepts or skills” (Starkey, 2012, p.49). The continual growth of knowledge as new and innovative connections open new interpretations and understandings to create new knowledge plays a central role in this theory (Starkey, 2012).

Connectivism as a learning theory is still being developed and evolved through online debates and discussions. According to Kop and Hill (2008), as nowadays control is shifting from the tutor to a progressively more autonomous learner, connectivism sustains a significant role in the development of new pedagogies.

Siemens (2006) asks how learning changes when knowledge growth becomes overwhelming and technology replaces many basic tasks we have previously performed. “The connections that enable us to learn more are more important than our current state of knowing. Connectivism is driven by the understanding that decisions are based on rapidly altering foundations” (p.30).

Siemens outlines the fundamental principles of connectivism as the following (Siemens, 2004):

- Learning and knowledge rest in diversity of opinions.
- Learning is a process of connecting specialised nodes or information sources.
- Learning may reside in non-human appliances.
- Capacity to know more is more critical than what is currently known
- Nurturing and maintaining connections is needed to facilitate continual learning.
- Ability to see connections between concepts, ideas and fields is an essential skill.
- Currency (up-to-date, accurate knowledge) is the intent of all connectivist learning activities.
- Decision-making is a learning process itself.

Regarding the last principle, Siemens (2004) explains: “Choosing what to learn and the meaning of incoming information is seen through the lens of a shifting reality. While there is a right answer now, it may be wrong in the near future due to alterations in the information climate affecting the decision” (Connectivism section, para. 3).

Connectivism offers a new perspective of how learning takes place in the digital era. It is the application of network principles to define both knowledge and the process of learning. Such networks could be internal (e.g. neural networks) and external (networks in which we communicate) (Dunaway, 2011).

Connectivism as a learning theory is developing from a complexity theoretical perspective of knowledge (Starkey, 2012). Complexity theory is a way of taking into consideration aspects of the physical and social world that acknowledge that events do not take place in isolation and hardly ever through a simple cause-effect relationship. A complex system has all its parts connected (Starkey, 2012).

As Starkey (2012) explains, there are three types of connections (in the 21st century educational system) through which knowledge creation or learning takes place: a) learning relationships, b) connections beyond the learning environment, and c) connections between ideas, concepts, information or data.

One of the challenges that connectivism faces (Kop, 2011) is the need for a learner to be fairly autonomous in order to be able to learn independently and to be encouraged in aggregating, relating, creating and sharing activities. A further challenge is the level of presence (Kop, 2011). Downes (2009 & 2012) claims that individuals could create their own personal learning environment and network to find information, connect with experts or more knowledgeable people of their own choice and become actively engaged in the four activities (aggregating, relating, creating and sharing activities) to advance their learning. For example, in relation to a school environment, although the role of the teacher might be taken by others online how could learners be encouraged to become active, participate in activities or discussions and demonstrate critical thinking? Normally people need communication, collaboration and feedback from others similarly to the classroom learning environment. As Kop (2011) highlights, “the lower the presence of others in the learning environment, supporting and providing scaffolds for learning, the higher the need for particular capabilities in the self-directed learner him or herself to find resources and information, create something with these, and push something out onto the Web for others to engage with and learn from"(p.22).

Furthermore, people in a connectivist environment need the ability to understand the obscurity and complexity of the networks in order to be able to negotiate their structures and therefore they need high level of critical thinking (Kop, 2011).

These challenges may eventually be overcome in the future but in a primary school environment it might take a substantial amount of time and rigorous research in order to deal with such challenges.

Digital age learners need to play an active role in their learning process, understand connections and knowledge creation through such connections. As Starkey (2012, p. 127) highlights: "this requires flexible structures, teaching that is focused on learner progress, and the reframing of schools as community centres of knowledge development within their physical and virtual communities". The way currently primary education is structured it seems very challenging to expect learners to be self-directed and with high level of critical thinking. However, if we consider the need for more flexible structures and new learning environments for the 21st century primary education it seems quite inevitable that in the future students will need to become critical thinkers and creators of knowledge as opposed to simply knowledge consumers (Starkey, 2012).

2.2.2 Online Collaborative Learning Theory

Similarly to Siemens (2006), Harasim (2012) highlights the need for a theory of learning for the 21st century education. She introduces a new theoretical perspective, Online Collaborative Learning (OCL) in order to address the need for "a theory of learning that emphasises knowledge work, knowledge creation and knowledge community" and the fact that "the speed of intellectual change and knowledge construction has increased" (p.83).

According to Harasim (2012):

> *"Online Collaborative Learning (OCL) is a learning theory and practice based on collaborative learning and knowledge-building discourse modelled on knowledge communities. The role of the instructor is as representative of the knowledge community, inducting students into the conceptual framework and terms and their applications in solving problems and creating knowledge and innovation, constructing plans or developing explanations for phenomena"* (pp.178-9).

Through the Internet and digital revolution people nowadays interact with others all over the world and the online communication has transformed the way we learn and the way we create knowledge collaboratively (Harasim, 2012).

> *"Teachers and learners today have the fortunate opportunity to contribute to and participate in shaping this new online environment, and thereby, most importantly, fully engage in their mission of advancing the conversation of humankind"* (pp.173-4).

While Harasim (2012) accepts that OCL theory encourages the learner to be active and engaged, she does not believe that this is sufficient for knowledge construction and learning as the role of the teacher is not taken into account. On the other hand, in the OCL theory, the role of the teacher is very important as the teacher becomes the link to the knowledge community. A key aspect of knowledge creation, according to the OCL theory, is discourse. Collaboration and discourse are crucial aspects in building knowledge and this theory attempts to introduce the learners into the processes of conversation i.e. discourse employed by knowledge communities to construct knowledge and develop ideas (Harasim, 2012).

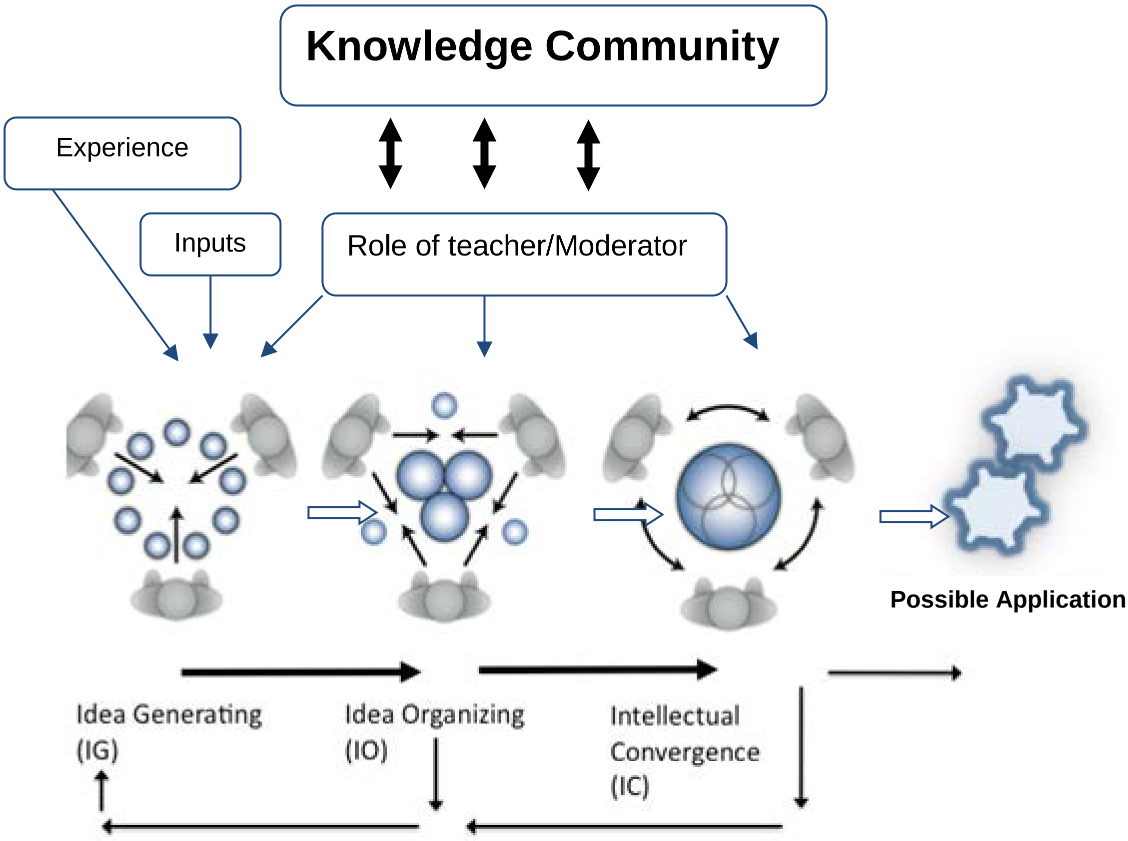

Figure 1: Example of Online Collaborative Learning Processes in a class (adapted from Harasim, 2012, p.95).

Figure 1 illustrates the role of the teacher as facilitator within the pedagogy of group discussion and the progress from separation to intellectual convergence that approximates the knowledge community (Harasim, 2012). According to Harasim (2012), the role of the teacher is crucial in facilitating the learning process and giving learners the resources and types of activities that will help them to construct knowledge collaboratively, using the internet.

2.3 Concluding remarks

The above theories and approaches make assumptions about what is *learning* and highlight how important is to match specific types of learning and learner with specific types of technology. It seems that the dominant theoretical position currently in education combines constructivism with a situative approach.

According to the situative approach (Greeno, 2006), instead of focusing on individual learners the main focus should be on complex social organisations containing learners, teachers, curriculum materials, software tools and the physical environment. Such complex social organisations, Greeno (2006) defines as *'activity systems'*. Asking someone if they have learned a specific topic in mathematics (e.g. numerical multiplication), without considering the kind of activity system in which the learner's 'knowledge' is to be evaluated is in essence meaningless (Greeno, 2006).

> *"Learning that occurs in one kind of activity system can influence what one does in a different kind of system, but explanations in terms of overlapping aspects of activities in practice are much more promising than explanations in terms of transfer of knowledge structures that individuals have acquired"* (p.80).

This situative approach focuses on the importance of the activities that take place in different learning environments not only because of differences in how effectively they teach content knowledge but also due to the fact that participation in practice is an important part of what students learn. Learning environments should provide opportunities for the students to participate in such practices (Greeno, 2006). Therefore, it seems logical how some knowledge – that has been formed in a particular situation (i.e. context) might be difficult to transfer. The theory that learning always occurs in some context and that this context affects significantly learning is the theory of situated learning (Alessi & Trollip, 2001). The significance of this theory is that a well-designed (i.e. meaningful) learning context reinforces/increases transfer to another context.

The notion of context and its significance - on designing digital learning environments for learners at school and as an important factor while trying to assess technology's impact - is discussed further in Chapter 5. Context is an essential part of our psychological development. There is no doubt (Luckin et al, 2005 and Luckin, 2010) that the context in which learning takes place has a significant role in this learning.

Underline themes are emerging as to how learning has changed nowadays, how it could be defined in the digital era and whether there is anything innovative in education. There is currently a shift towards learner-centred approaches as opposed to the previous teacher-centred ones (e.g. Aslan & Reigeluth, 2013, Quintana et al, 2006). Furthermore, researchers are attempting to explore whether the definition of knowledge has changed and how learners could construct knowledge today (Harasim, 2012, Starkey, 2012, Laurillard, 2012, Siemens, 2005).

Learning theories are underpinned by epistemological beliefs and therefore as ideas about knowledge evolve learning theories evolve too (Starkey, 2012). The way knowledge is perceived changes over time and between contexts (Starkey, 2012) and as a result perspectives of knowledge and learning theories will carry on influencing learning in the 21st century and beyond.

The 21st-century digital era signifies the need for a learning theory that focuses on knowledge creation and knowledge community and where the role of the teacher translates into the mediator between the learners and the knowledge community. As Harasim (2012) highlights, "the challenge is how to engage learners in creative work with intrinsic rewards, within the context of the Internet and the Knowledge Age, and how to bring the gap between 21st-century environments and 20th-century pedagogies" (p.84). The 20th-century pedagogies "focused on narrow individualistic tasks with simple sets of rules and clear destinations" (p.83) while the 21st-century age focuses on "creative, conceptual work where there is no clear right or wrong answer, or where there may be many right answers" (pp. 83-84), requiring learners to collaborate in order to indentify or create the best possible option.

The learning context as an Ecology of Resources (Luckin, 2010) is discussed further in Chapter 5 as being one of the most important factors that could mediate learning through technology. Moreover, the subject area, domain of knowledge and resources are also discussed in Chapter 5 as equally important factors as well as the teacher's role that has been identified as crucial in a number of learning theories discussed in this chapter.

Chapter 3 : Theoretical Approach and Method of Inquiry

This chapter discusses the theoretical approach of this research study and presents, discusses and justifies the methodology followed in order to answer the research questions stating in Chapter 1 (i.e. Introduction) and as a result the aim and objectives of this study.

3.1 The research paradigm

As Opie (2004) underlines, it would be misleading to claim that research design could always be straightforward and researchers are able to be totally objective and therefore able to choose the most appropriate methodology for a particular study. In the real world, it is possible that a number of different perspectives and interpretations of social phenomena exist. However, it seems that what influences the selection of a particular methodology are the researcher's paradigm (a way of viewing the world) and their philosophical assumptions (Mertens, 2009, Opie, 2004) about the nature of the world (ontology) and how people can understand it (epistemology). Such specific assumptions seem to be shared by researchers working in a particular field (Maxwell, 2005).

There are two main clusters of paradigms that have influenced educational research (Opie, 2004): a) The scientific, positivist, objective, quantitative paradigm and b) the interpretative, naturalistic, subjective, qualitative paradigm. However, some other researchers (e.g. Cohen et al, 2000, Mertens, 2009) offer a slightly different categorisation. Specifically, Cohen et al (2000) distinguish three approaches: normative, interpretive and critical, while Mertens (2009) identifies: the post-positivism, constructivist, transformative and pragmatic paradigms.

Postpositivism	***Constructivist***	***Transformative***	***Pragmatic***
Experimental Quasi-experimental Correlational Causal comparative Quantitative Randomized control trials	Naturalistic Phenomenological Hermeneutic Symbolic interaction Ethnographic Qualitative Participatory action research	Critical theory Neo-Marxist Feminist theories Critical race theory Freirean Participatory Emancipatory Postcolonial/indigenous Queer theory Disability theories Action research	Mixed methods Mixed models Participatory

Table 1: Labels Commonly Associated With Different Paradigms (Mertens, 2009)

Educational research studies often involve procedures and methods that are associated with more than a single paradigm. The research paradigm, within which a study is situated consists a very important part of the study's conceptual framework. According to Miles et al (2013), a conceptual framework "explains, either graphically or in a narrative form the main things to be studied – the key factors, variables or constructs – and the presumed relationships among them" (p.20). The decision regarding which paradigm should be adopted for this study involved an assessment/comparison of a number of different approaches and consequently their methodological issues (the scientific/positive/quantitative, the interpretive/naturalistic/qualitative and the pragmatic/mixed methods).

Scientific methods are different from other more informal approaches due to their reliance on validated public procedures that have been regulated to produce reliable knowledge (Rudestam et al, 2007). An alternative approach to the scientific/positive/quantitative and interpretive/naturalistic/qualitative paradigms could be pragmatism. For the pragmatists truth is "what works" (Robson, 2002). "Hence the test is whether or not it is feasible to carry out worthwhile studies using qualitative and quantitative approaches side by side" (p.43). Mixed methods research is driven by pragmatism and seeks real answers to real questions that are useful in the real world and has the flexibility in usage that reveals the changing and integrated nature of the world and the phenomenon under study - such as educational technology and learning in this case (Cohen et al, 2011).

This research work started by adapting the scientific method and specifically through designing and conducting an experiment in order to explore (through empirical evidence) the impact of educational technology on primary school learning. The context of this work (as outlined in the Chapter 1/Introduction) has had implications for the choice of research design. The research design, which was determined by the aims of this research, involved the development of a hypothesis from a pre-existing theory and then testing this particular hypothesis in order to examine whether the theory appears to retain an explanatory function. In addition, the choice of the research design was influenced by the need to obtain answers to the research questions within the limitations imposed by ethical and practical issues, time and resources. The particular data collection methods in our school study were chosen due to the limitations of this research work (time and resource constraints). Based on the above analysis, it could be possible another method (e.g. qualitative) to have been also suitable to be used as a supplement. There is no doubt that for a cause to be established there is a need for a control experiment to take place. However, sometimes experiments in classroom research can be very difficult to conduct. As discussed through this thesis and particularly in Chapter 7, during the school study involved in this research a number of reschedules and consequently significant delays and there is significant amount of complexity in regards to scientific work in education, due to the fact that "humans in schools are embedded in complex and changing networks of social interaction" (Berliner, 2002, p.19). As Wragg (2012) argues, "whereas in research in the physical sciences it is easy to keep some elements under the direct and precise control of the investigator and specify what temperature or pressure will be maintained, the same certainties cannot be built into classroom research" (p.104). Some concluding remarks on this issue are also presented in Chapter 7.

3.2 Methodological approach

This research' work methodological approach involves two phases in order to address its aims and objectives:

- Phase One: An experimental study at a primary school
- Phase Two: An investigation of the factors identified during Phase One as well as through analysis of the literature and published research.

3.2.1 Phase One

In Phase One, the analysis focused on examining two existing applications in order to examine their impact on children's learning and attitudes towards a certain subject matter in a school environment at Key Stage 2 and Year 5. The reason of choosing children between the ages of 8-10 years old is explained in the next chapter (i.e. Chapter 4, see section 4.1.3).

The analysis and its findings formed this study's theoretical framework. This framework is then used to investigate the computer applications as educational tools within the classroom.

Once the school study was completed, it became clear that it would be appropriate and valuable to approach this research work not only through control experiments but also through a more pragmatic approach. The complexity of applying technology to education, especially in a school (real) environment indicates that there is a need for research evidence that goes beyond "simply quantitative indicators of 'effects' on isolated outcome measures" (Ross et al, 2010). Although a qualitative approach only, would not provide us with sufficient evidence, there are a number of educational issues (e.g. the complexity of controlling as many variables as possible) which challenge scientifically the experimental method (i.e. quantitative) or even make it appear inappropriate (if it is the only method used).

Future work will follow a mixed-methods approach which quite recently is becoming more and more acceptable in educational research. According to this approach, "instead of methods being important, the problem is most important, and researchers use all approaches to understand the problem" (Creswell, 2003, p.11). Creswell (2003) underlines the importance for focusing on the research problem in social science research and then using "pluralistic approaches" to gain knowledge about the problem.

3.2.1.1 Procedure for answering RQ1

RQ1: What is the impact of educational technology on primary school's learning?

Responding to the question requires a scientific methodology i.e. experimental design, in which students are randomly assigned to different learning environments or, as it is a common approach in education research and studies, quesi-experimental design. This experiment takes place in the natural setting rather than the laboratory. This is a similar type of experiment to the classic "true" experiment in that variables are isolated, controlled and manipulated but the setting is the real world (in our case a school) rather than the artificially constructed world of the laboratory (Cohen et al, 2011).

Kerlinger (cited in Cohen et al, 2011) refers to quasi-experimental designs as "compromise designs", an appropriate description when applied to such educational research where the random selection or random assignment of classrooms and schools is quite impracticable. Although the experimental designs require random assignment of participants to conditions, this is not always possible in educational research. This is the reason that quasi-experimental designs are used as these maintain significantly the rigor of the experimental designs while at the same time allow for the use of intact groups in conditions (Mertens, 2014). There are several forms of quasi-experiments. The one used in this research is a quasi-experimental design: the pre-test-post-test non equivalent group design. This is one of the most commonly used quasi-experimental designs in educational research. Experimental and quasi-experimental designs can provide researchers, educators and policy makers with significant information regarding the relative merits of different approaches (Sawyer, 2006). This is the reason why this form of inquiry was used in the first phase of this research work.

A set of logical procedures must be followed in conducting an experimental investigation. Our investigation follows Cohen et al (2011) ten-step model which involves the following:

Step One:	Identify the purpose of the experiment.
Step Two:	Select the relevant variables.
Step Three:	Specify the level(s) of the intervention (e.g. low, medium high intervention).
Step Four:	Control the experimental conditions and environment.
Step Five:	Select appropriate experimental design.
Step Six & Seven:	Administer the pre-test & Assign the participants to the group(s) or vice versa.
Step Eight:	Conduct the intervention.
Step Nine:	Conduct the post-test.
Step Ten:	Analyse the results.

Table 2: Adapted from Cohen et al (2011) ten-step model for conducting experiments.

This experimental work is presented and discussed in detail in the next chapter (i.e. Chapter 4).

3.2.2 Phase Two

In Phase Two, this research focuses on the procedure towards answering the second research question (see Introduction and below) and consequently, it focuses on a number of factors that could influence and determine the effectiveness of technology in school settings.

3.2.2.1 Procedure for answering RQ2

> RQ2: What are the factors that could influence and determine the effectiveness of educational technology in the school classroom?

Responding to the above question requires a focus on two interrelated aspects, reported in Chapter 4 and Chapter 5 respectively: a) the experimental study's process as well as results and also b) the conditions and factors identified in the light of the study as well as by examining published research and earlier studies.

As mentioned above, experimental and quasi-experimental designs can provide us with significant information regarding the relative merits of different approaches. However, they cannot tell us enough about why and how a teaching method is working i.e. the detailed structure of the classroom activity that results in student learning (Sawyer, 2009). Learning scientists and researchers incorporate a range of methodologies in order to understand better learning processes as they would then be able to improve teaching methods (by constantly revising them) having studied better these classroom processes (Sawyer, 2009). This is why after completing Phase One we proceeded with identifying and analysing the factors identified in the light of the experimental study as well as through examining the relevant published research.

3.2.2.2 Procedure for answering RQ3

> RQ3: How to best facilitate learning in the classroom with educational technology and how to integrate this technology into the school environment effectively?

The procedure for collecting the required information in order to answer this research question involved examining the relevant published research as well as considering the factors identified in view of the experimental study as well as through examining the relevant published research (see Chapter 5) and in addition, by producing a set of relevant recommendations (see Chapter 7: Conclusions).

Chapter 4 : School Study

In a first step, this analysis focused on examining two existing educational applications in order to explore their impact on students' learning and attitudes towards a certain subject matter, mathematics, in a school environment at Key Stage 2 and Year 5. The subjects of this study were children between the ages of 8-10 years and the reason for this is explained further in this chapter. In regards to educational technology research from the age of seven, children attempt to work out more clearly what is happening around them and this ability is very important in regards to evaluation of educational technology (Markopoulos et al, 2008). The key point for educational technology in regards to Piaget's Concrete Operations stage is that "children can classify things and understand the notion of reversibility and conservation" (Markopoulos et al, 2008, p. 9). According to Piaget's developmental stages, during the Concrete Operations stage (ages 7-11) (the third one of the four stages) the child starts to create logical structures that explain their physical experiences. At this stage, abstract problem solving is also possible (Guthrie, 2003). Choosing to study children between the ages of 9-10 years can ensure that the selected children were within the above developmental stage. Researchers have found that children ages 7-10 years old are able to develop ideas from abstract concepts, are self reflective and they are capable enough to discuss what they are thinking (Druin, 1998). The main study (discussed in section 4.1.5) took place after having conducted a pilot study (discussed in section 4.1.4) in order to identify and clear up any ambiguities or experimental anomalies.

The analysis and its findings have formed this research's theoretical framework. This framework is then used to investigate the role of educational technology in the classroom and a number of factors that could influence and determine its effectiveness. The findings of this study support the argument that when technology is used in schools, the software does not by itself convey the subject-area content (Becker & Ravitz, 1999).

> *"To determine all the technology-related factors that promote student performance would be daunting. But experiments do not seek to identify all the factors involved in creating some outcome. Rather, they estimate the marginal impact of a clearly specified individual component from within some more global experience, whether this component is a software package, a general application, or anything else"* (Haertel & Means, 2004, pp. 18-19).

4.1 Experimental design

4.1.1 Description of the research design

This study was an investigation of the effectiveness of educational technology on students' learning. It sought to develop knowledge through the collection of numerical data on educational software effectiveness of a sample of a classroom from Key Stage 5 of a London school. It was designed to see whether educational software had positive effect on achievement in a certain subject area, mathematics, within the National Curriculum (see the first of the Research Questions presented in Chapter 1, section 1.1). It was designed to compare the impact of the use of software or its absence on participants' scores on the post-test across the two time periods.

The research question of the experimental study (which is aligned with the first of the Research Questions presented in Chapter 1, section 1.1) was: Is there a change in participants learning outcome (test scores) across the two time periods (before the treatment and after the treatment)?

At least three variables were involved:

a) Independent variable 1 (IV1): type of software (between subjects variable) with three levels: group 1 (use of CD-ROM), group 2 (use of online application) and group 3 (no use of software).

b) Independent variable 2 (IV2): time (within-subjects variable) with two levels: time 1 (pre-test) and time 2 (post-test).

c) Dependent variable (DV): participants' test scores on the topic measured at each time period.

This analysis aimed to test whether there were main effects for each of the independent variables and whether the interaction between the two variables is significant.

In this case a statistical procedure that takes into account of the variance within the conditions and compares this to the variance between the conditions was needed (Brace et al, 2003). The statistical procedure that was used is Analysis of Variance (ANOVA) as the experimental design involves more than two conditions. As this experiment involves both between and within subjects factors the design employed is a 2x3 mixed ANOVA (or mixed between-within subjects

ANOVA) design. A two way mixed design ANOVA is appropriate for studies which investigate change over a period of time and it can be used where a group of participants serves in a number of different conditions of an experiment (Howitt & Cramer, 2014).

However, there is also a possibility that a variable other than the different types of educational software or the absence of software (independent variable) could affect the achievement-scores (dependent variable); for example, the personality of the child, their learning styles or anxiety. The above could be identified as possible confounding variables and there is a need of finding ways to eliminate as possible their effect.

4.1.2 Ethical considerations

There are particular ethical issues associated with working with children and which have been considered closely in this research and ethical guidelines for educational research such as those published by the British Educational Research Association (BERA, 2011) were followed. Specifically, there was a need of asking for teachers' consent before this study was started. This study takes into consideration a range of issues and questions emerge from conducting research on and with children. There is no doubt that such research involves multidisciplinary and interdisciplinary approaches (Lewis & Lindsay, 2000). While the choice of the particular method is determined by the research question, it is important to consider some key variables such as age, social class, gender and ethnicity of children. In addition, it is clear that examining the impact of computers on children's learning has to be considered with respect to the children-participants in a context. This means that it is important to take into account the children-participants, the research task and the interaction between these two (Lewis & Lindsay, 2000).

There are a number of psychological aspects of methodological issues regarding the way of performing the data collection. In particular, a) the strengths and limitations of the school setting (the school environment although a familiar for the children setting involves a number of limitations such as changes on the timetable, staff or students' absence or unexpected functions-events); b) children's capabilities (it is important to make sure that children's performance would provide an accurate indication of competence and not a possible misinterpretation or underestimation of children due to linguistic, cognitive or memorial skills) and c) effective ways and appropriate form of posing questions to children.

Obtaining informed consent is also a very significant issue. Seeking informed consent in relation to young children involves two stages. First the researcher consults and seeks permission from the adults responsible (in our case teachers and parents) for the prospective participants and second, the researcher approaches the children themselves. The point of the research study needs to be explained, questions would be invited and permission (to proceed) will be sought. This was the procedure followed in our study (Cohen et al, 2011). All the information and details regarding the children who participated in this study and the school are not disclosed in this thesis (or any publication resulted from this study) and remain confidential in order to protect their right to privacy and anonymity.

4.1.3 Description of the sampling strategy

The selection of the sampling strategy that followed was based on its suitability for the purpose of this research, the time scale and constraints on the study, the data collection methods and the chosen methodology (Cohen et al., 2000). In this way, the validity of the research could be served and ensured. The chosen method was probability sample that had a degree of generalizability[1] and less risk of bias than a non-probability sample. The type of probability sample used is cluster sampling which is "a method of reducing large-scale sampling to manageable forms by carrying out random samples at successively lower stages of the

[1] Generalizability concerns with the extent to which the findings of the study are more generally applicable (Robson, 2002).

population" (Leach, 1991). In this case, a classroom of students (Key Stage 2 and Year 5) was selected randomly from a primary school in London.

The subjects of this study were children between the ages of 8-10 years. According to Piaget's developmental stages, during the Concrete Operations stage (ages 7-11) (the third one of the four stages) the child starts to create logical structures that explain their physical experiences. At this stage, abstract problem solving is also possible (Guthrie, 2003). Choosing to study children between the ages of 9-10 years can ensure that the selected children were within the above developmental stage. Researchers have found that children ages 7-10 years old are able to develop ideas from abstract concepts, are self reflective and they are capable enough to discuss what they are thinking (Druin, 1998). In regards to educational technology research from the age of seven, children attempt to work out more clearly what is happening around them and this ability is very important in regards to evaluation of educational technology (Markopoulos et al, 2008) – (see also the introduction in this Chapter).

4.1.4 Pilot Testing

In a small exploratory study of twenty-four children (age between eight and nine years old for this pilot testing), as part of pilot testing the experimental study conducted afterwards, it was attempted to examine the impact of educational applications on children's learning. The pilot testing was important in order to identify and clear up ambiguities or experimental anomalies. The experimental design then was adjusted as necessary in order to become operationally possible and the actual data gathering process (described below – see 4.1.5 - in the main study) to begin. This pilot was conducted for a day (it was not possible at that time to extend the duration of this pilot testing due to the school's timetable) to pilot test the experimental procedure in order to identify possible difficulties/complications in connection with the aspect of this investigation (Cohen et al., 2011). It was also ensured that the questions in the pre/post tests were understandable and unambiguous.

Prior to the pilot study, at least three school visits had taken place in order to obtain all required permissions from the school staff, the Deputy Headmaster and the Information Technology Coordinator and also in order to discuss the study and its purpose. Most importantly, the author of this thesis spent time observing the mathematics class and how this took place without the use of technology. The teacher first gathered the students in the front corner and she asked revision questions about fractions and liquid measures (e.g. litres, ml etc). Then the students went to sit at their desks and they worked through some work sheet exercises until the end of the lesson where all went into the assembly.

The pilot study was conducted in a Key Stage 2 and Year 4 class. This pilot testing had been previously performed at the same school, however, it was not possible to complete and therefore not provide us with useful data due to problems that arose in the school's Information Computer Technology (ICT) laboratory and which was impossible to overcome within that particular day. The main study- described in section 4.1.5 (once this pilot was completed was conducted with the same group of children during their new academic year when there were in Key Stage 2 and Year 5.

At the beginning of the pilot, all students (whole class) took the test (i.e. pre-test) in the classroom. The teacher explained to the classroom that the results of these tests would not affect their mathematics grade. The author of this thesis told the students that the purpose of this study was to help her understand how to design better educational software for use in a classroom. The test consisted of five multiple-choice questions related to perimeter of simple shapes, a topic that had previously discussed and agreed with the teacher. The author of this thesis read the introduction sheet with the instructions aloud and emphasised that in case the students did not know the answer of a question they should circle the "I don't know" answer instead of trying to guess an answer or pick one randomly. This was important in order to assess the learning outcome. After this test, all the students sat in the maths lecture on perimeter with the teacher. This lecture lasted approximately twenty minutes.

The treatments to be used were as follows: a) BBC Maths workshop (a CD-ROM) application and b) Juniors (an online) application. Five students worked with the BBC Maths workshop application, five students with the Juniors application and four without any software application. Initially, it was arranged to test fifteen students, ten of which would be our two experimental groups that would be using the computers in the school's ICT laboratory and the other group of five students would be the control group that would not use any software. However, one computer was out of order so we had been able to use only nine computers. Five students used the Juniors application, four students used the BBC Maths workshop application and five students worked during this session on pen and paper exercises and activities. The teacher remained in the classroom with the children that were working on pen and paper activities while the researcher went to the ICT laboratory with the rest of the students.

In order to increase the likelihood that the groups of students would be equivalent, the students were allocated to one of the three treatments by the Deputy Headmaster and the mathematics teacher who divided the students into three groups making sure that all three groups would include mixed ability students. This thought to be more representative sampling than using a random sampling.

The subject matter for the two treatments and the control group (students that worked on pen and paper activities) was shape, space and measures. The choice of the subject was influenced by its relevance to the National Curriculum for mathematics for England at Key Stage 2. The two treatments used in the study were run on the school computers in the computer laboratory. The students had used the laboratory before so they were familiar with the use of the computers and the environment.

Initially, in the laboratory all the students were excited to use the computers instead of being in the classroom. However as the time was passing by, some of the students that were using the web-site (i.e. Juniors) application were getting impatient seeing their classmates using the BBC Maths workshop application. The reason why this happened seems to be that the latter application involved a game based activity that students had to complete by calculating the perimeter of simple shapes. This activity (as with all sixty-four activities of the BBC Maths workshop application that were mainly following the same format) had a number of levels giving a progression of three levels of difficulty. In comparison, the Juniors application consisted of a comprehensive range of interactive tutorials, the structure of which followed the format of a lesson with an introduction of each topic, guided practice and assessment and a recapitulation of the mathematical concept that had been explored. At the same time, all the students that worked with the Juniors application were very keen on reaching the end of the tutorial in order to be able to access and print out their personalised certificate showing their name, the time and their percentage score on the quiz. During this session, the researcher (i.e. author of this thesis) observed the students and asked them about their overall experience using these applications. The student responses were very positive.

After completing the laboratory session, which took thirty minutes, all fourteen children took the same test that had completed at the beginning in the classroom. The only difference on this test (i.e. post-test) was that the order of the five multiple-choice questions had been altered.

Having done this testing only for one day (due to the very busy timetable of the school) at a local school it was very difficult – as expected- to draw any conclusions on the educational outcome. However, it was a very helpful process and insightful experience in order to go ahead with the main experimental study. In the main study described below, there was a need to use another application (CD-ROM based) in order to accommodate the respective subject matter and topic that was taught in those particular weeks during which the study run. However, it was ensured by the researcher that the features and principles used for both applications i.e. BBC Maths workshop (used in the pilot) and Maths Explorer (used in the main study) were very similar and both aligned with the online application used, Juniors.

4.1.5 Main Study

After completed the pilot testing, the next stage was to proceed with the main study described below.

4.1.5.1 Method

The design of this study was a quasi-experimental design: the pre-test-post-test non equivalent group design. Designs involving matching help to reduce the problem of differences between individuals overshadowing the effects of the particular treatment (Robson, 2002). The strength of a fix design is its ability to transcend individual differences and identify patterns and processes that can be related to social structures and group or organisational characteristics (Robson, 2002). In order to ensure validity, a pilot was conducted to make sure that the experimental design was appropriate and unambiguous and also that it was effectively operationalised the purpose of this research.

The research question addressed in the study (as it was addressed in the pilot study) was (Kolyda & Bouki, 2005):

> RQ: Is there a change in participants learning outcome (test scores) across the two time periods (before and after the treatment)?

The key hypothesis of this study was:

> H0: Educational software cannot improve learning and have no effect on achievement in mathematics within a school classroom.

This was tested against the alternative:

> H1: Educational software can improve learning and have positive effects on achievement in mathematics within a school classroom.

4.1.5.2 Sample

The participation of the school (i.e. the same school in which the pilot study described earlier was conducted) was gained via informed consent. This school provided a classroom (Key Stage 2 and Year 5) in which twenty-two students (age 9-10 years old) were assessed for three weeks at an hour a time, thus each student was seen for three hours in total. Prior to the above three-week period there had been a number of visits to the school in order to check the available facilities, classroom visits during the lesson of mathematics and observations as well as informal meetings with the school's Deputy Headmaster and the Information Technology Coordinator. Furthermore, as described above, a pilot study of twenty-four students (age 8-9 years old) was conducted for a day (it was not possible at that time to extend the duration of this pilot testing due to the school's timetable) to pilot test the experimental procedure in order to identify possible difficulties/complications in connection with the aspect of this investigation (Cohen et al., 2000).

4.1.5.3 Treatments

In this study the students were exposed to two different types of software that dealt with the same subject matter in mathematics. In the first case this study looked at an educational CD-ROM based application called Maths Explorer. This application is designed to cover mathematical topics and practical activities at a level appropriate to the 8-11 age groups. It was based on the content of the National Curriculum for mathematics for England at Key Stage 2. The second approach was using an online application called Juniors which also followed the Curriculum and the National Numeracy Strategy. The Juniors online application consisted of a comprehensive range of interactive tutorials, the structure of which followed the format of a lesson with an introduction of each topic, guided practice and assessment and a recapitulation of the mathematical concept that had been explored.

In order to increase the likelihood that the groups of students would be equivalent, the students were allocated to one of the three treatments by the Deputy Headmaster and the mathematics teacher who divided the students into three groups making sure that all three groups would include mixed ability students. This thought to be more representative sampling than using a random sampling.

The subject matter for the two treatments and the control group (students that worked on pen and paper activities) was data handling. The choice of the subject was influenced by its relevance to the National Curriculum for mathematics for England at Key Stage 2. The two treatments used in the study were run on the school computers in the computer lab. The students had used the lab before so they were familiar with the use of computers. The treatments used were as follows: a) CD-ROM based application: Maths Explorer and b) Online application: Juniors.

4.1.5.4 Choice of software

In this study the students have been exposed to two different types of software that dealt with the same subject area, mathematics: an online application called Juniors and a CD-ROM called Maths Explorer. These two applications were chosen for our research for a number of reasons. Firstly, after searching and reviewing a number of similar applications the difficulty that aroused was to find applications that not only were designed for use in whole class teaching but also it would be possible for both to be used in parallel for the purpose of this testing. It was important to find applications that would cover the exact subject area it has been previously discussed and agreed with the teacher.

The initial objective has been to select applications that support and are aligned to the National Numeracy Strategy framework for teaching mathematics at Key Stage 2 and Year 5. Since our purpose has been to study students using the software at the school environment it has been important that this software would contain material that fit with the National Curriculum in England. After a selective online research the main sites that proved crucial to our choice were:

a) The Department for Education (UK)

b) British Educational Communications and Technology Agency (Becta, 2011) - the government's main agency leading the national drive to ensure the effective and innovative use of technology throughout learning.

c) The Teachers Evaluating Educational Multimedia (TEEM, 2009) - a number of teachers in the UK that write educational software evaluations after having used in the classroom the specific application.

According to the Department of Education (2013), the National Curriculum subjects for Key Stages 1, 2 and 3 are set out in section 84 of the Education Act 2002. It is a requirement that maintained[2] schools follow the locally agreed syllabus approved by their local authority. The National Curriculum applies to students/students of compulsory school age in maintained schools. It is organised on the basis of four key stages.

Key Stage	Ages	Years
1	5-7	1-2
2	7-11	3-6
3	11-14	7-9
4	14-16	10-11

Table 3: The National Curriculum in UK schools

[2] *Maintained schools (UK) are funded by central government via the local authority and do not charge fees to students.*

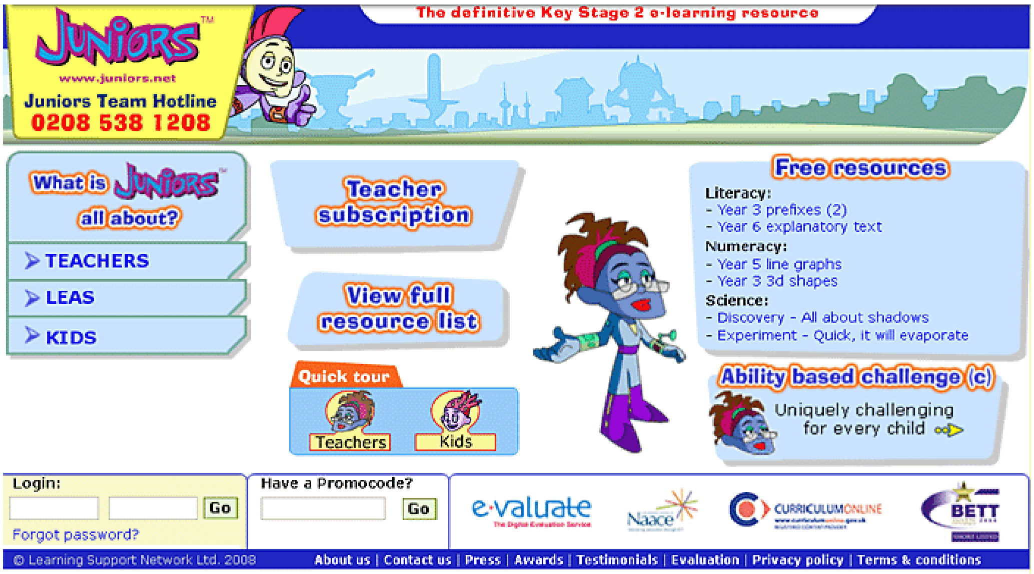

Figure 2: Juniors home page

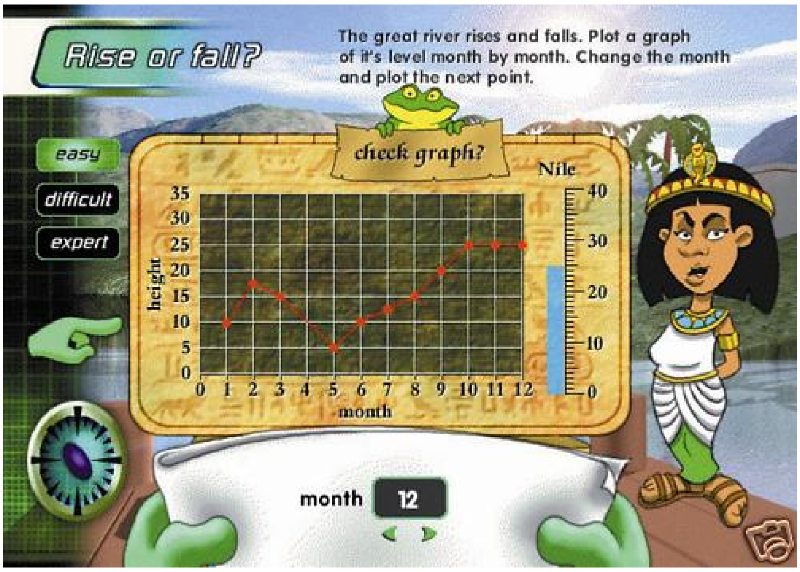

Figure 3: Screen from Maths Explorer application

Maths Explorer (Data Handling) is an application that encourages students to investigate mathematical topics in relation to data handling and is set in the time of the ancient civilisations of the Romans, Incas and Egyptians. It provides full screen slide-shows, mathematical puzzles to solve and interactive investigations in order to reinforce understanding of the concepts covered. Topics include collecting data, sorting charts, measuring of average, distance charts, results and league tables, line graphs, pie charts, scattergrams, timetables, pictograms, probability and chance and probability calculations. There are also materials for teachers to use in the classroom and which can also be printed off.

Maths Explorer application -similarly to the BBC Workshop used during the pilot- involved (among other activities) a game based activity that students had to complete. This activity (as with the other activities of the application that were mainly following the same format) had a number of levels giving a progression of three levels of difficulty, a feature that most students found very interesting and were looking forward to play the game and progress to higher levels of difficulty. Research (Luckin et al, 2012) has shown that games that integrate the knowledge and skills that need to be learnt directly into the structure of the game activity are more effective (as well as more fun for children) than those activities where the game is used as motivation although without connection to the learning material. Juniors followed more the structure and characteristics of a tutorial which as a learning approach is used in order for new material to be taught and to accomplish the first two phases of instruction which are presenting information and guiding the learner. Playful scenarios were used in order to engage students with the learning material, something that the students also found interesting.

Juniors application was available online until very recently and it might be the case that due to the current financial situation in the UK the company that was publishing this application was not able to survive the economic recession.

It was very important to choose the software used in this study in a way that was reflecting the way such educational applications were used at school and being fully aligned with the National Curriculum in England and the National Numeracy Strategy framework for teaching mathematics at Key Stage 2. In order to ensure that this was the case, several face to face meetings and discussions took place with the Head Teacher and Mathematics teachers prior to conducting the study as well as studying the relevant documentation and resources available from the Department of Education.

Furthermore the educational applications used were a representative example of the software used at schools and an example of best practice award winning educational software approved by various educational communities, providers and the British Educational Training and Technology Show (i.e. BETT), the world's leading learning technology annual vent taking place in London every January. In addition, the software used in this study was appropriate for use in the classroom or the school computer lab as opposed to individual study at home.

4.1.5.5 Materials

In order to assess the learning outcome three tests of the same format were constructed to measure students' achievement of the objectives of the specific piece of the mathematics curriculum which was 'data handling'. In particular, each test was relevant to the specific topic (within the data handling subject) covered earlier that day during the experiment.

The students' knowledge of the material was examined at the end of each session in a five multiple-choice questions test related to data handling. All these questions assessed the students' knowledge and understanding of data handling concepts. These tests were constructed after discussion with and consultation from the school's mathematics teacher. In order to ensure validity and reliability of the tests a number of issues were taken into consideration such as that there was no interfering with any school tests or holiday breaks or that the children were not tired or overloaded with school as it usually happens towards the end of the school year. Another issue regarding the reliability of the tests was the amount of guessing of answers by the students (Cohen et al., 2000). This threat to reliability of the tests was addressed by including among the possible answers in the questions the answer "I don't know". In order to construct effectively the multiple choice test items clarity for each item was ensured and that all options were plausible so that guessing of the only possible option would have been avoided (Cohen et al., 2000).

Furthermore, the content of the tests was decided after taking into consideration the following (Cohen et al., 2000):

a) The suitability of the format of each item (question) for the learning objective. In particular, the number of choices in each multiple choice item was five including the “I don’t know” answer and there was only one right answer to each question.

b) The relevance of each item so that the students were able to demonstrate their learning. Each question enabled students to establish their performance of a particular topic within data handling. For example, students had to be able to read and understand certain graphs (i.e. bar charts and line graphs) in order to answer specific questions.

c) The independence of each item. This means that each question did not influence the rest of the questions and successful respond to a question was not dependent on successful respond to another.

d) The sufficient coverage of the learning objective by the items of the test. Given the available time in order to perform this study, the five questions for each test covered most of the material presented earlier to the students through the lecture and also through either the computer applications or the pen and paper activities.

e) The avoidance of the possibility of students making the correct choice through incorrect reasoning and the ensurance that there could only have been a single correct option since a single answer was required.

f) It was ensured that the length of each response item was the same (to avoid an answer from standing out) and that the correct option was positioned differently for each item and options such as “all/none of the above” were avoided.

During the design and construction of the tests that were used it was taken into consideration that all the items of each test should have been equally difficult. In addition, the test items were directly aligned with the National Numeracy Strategy framework for teaching mathematics at Key Stage 2 and Year 5. It was also examined the kind of tasks each item was addressing (e.g. applying known knowledge or integrating diverse areas of knowledge), how motivating and interesting the item was, the sufficiency (regarding the experience of the students) and relevancy of each item. Furthermore, the selection of the type of the test was based on the need of collecting the maximum amount of information regarding students’ achievement in the most economical way. There was also consideration regarding what the outcome of the test would be, which in this case was a tick/circle of multiple-choice items. Attention was given to the presentation (the task was introduced by oral and written instructions), operation (the students would be sitting in the classroom performing a pen and paper test) and response modes of the test (they had to choose one answer from a multiple choice question). The number of the questions was decided after a discussion with the teacher (the initial idea was to have ten questions in the test instead of five, however, due to limited time this was not possible). The score was the total number of correct answers (the maximum score was five).

Finally, there was also consideration regarding the time allowance that was given to each test. Specifically, although the participants were told what the general overall time allowance was for the test (five minutes) there were not imposed time restrictions in such way to put the participants under time pressure. The time allowance was proven at the end to be sufficient.

4.1.5.6 Procedure

At the beginning of each session, all the students took a test in the classroom. This test consisted of five multiple-choice questions related to data handling. The researcher read the introduction sheet with the instructions aloud - so that all participants heard the same script and therefore to ensure reliability (Neuman, 2005) - and emphasised that in case the students did not know the answer of a question they should circle the “I don’t know” answer instead of trying to guess an answer or pick one randomly. This was important in order to assess the learning outcome. After this test, all students sat in the mathematics lecture on data handling with the teacher. The lecture lasted approximately fifteen to twenty minutes. When it finished the teacher remained in the classroom with the students that were working on pen and paper activities while the researcher with another teacher went to the lab with the rest of the students.

Immediately after completing the laboratory session, which took twenty-five minutes approximately, all students took the same test that had completed at the beginning in the classroom. The only difference on this test was that the order of the five multiple-choice questions had been altered in order to eliminate any ‘practice’ effect.

4.1.5.7 Results

A two way mixed ANOVA was conducted to explore the impact of the use of software on students’ achievement. Participants were divided into three groups according the treatment they received: group 1 (use of CD-ROM), group 2 (use online application) and group 3 (no use of software). There was no statistically significant main effect for groups (treatment) [$F(2, 48)=1.75$, $p=0.18$]. There was a statistically significant effect for time [$F(1,48)=23.72$, $p<0.05$]. This suggests that there was a change in achievement scores across the two different time periods (such that mean post-test score was higher than mean pre-test score). The main effect for time was significant, however, this was expected. In addition, the interaction effect was not statistically significant [F(2, 48)=0.31, p=0.74]. This means that there was the same change in scores over time for the three different groups. The major results are shown in Table 4 (and further details could be found in Appendix II).

MEAN TEST SCORES (& SDs) BEFORE & AFTER EACH TREATMENT					
		TREATMENT			
		CD-ROM	ONLINE	PEN & PAPER	Means
TIME	PRETEST (max score: 5)	2.93 (2.09)	1.81 (1.76)	2.25 (2.02)	2.33
	POSTTEST (max score: 5)	3.87 (1.68)	2.88 (1.36)	3.60 (1.60)	3.45
	Means	**3.40**	**2.35**	**2.93**	

Table 4: Mean test scores (& Standard Deviations) before and after each treatment

It was immediately apparent that the null hypothesis (H0) had to be accepted, contrary to expectations the educational software had no effect on achievement in mathematics within a school classroom.

It is important though to highlight the fact that there was no evidence that the use of educational applications had negative impact on children’s learning or attitudes towards computer environments.

4.2 Discussion

This school study highlighted the need to consider the conditions and the factors that could influence learning in the school classroom.

One of the significant limitations during this study was that there was not possible at that time to test the participants for anxiety. However, a future study aims to examine this issue and find ways to eliminate its effect. In particular, in order to be able to take into account the anxiety which children might experience during the study and while they are been asked to take a test in order for the researcher to assess the learning outcome, a State-Trait Anxiety Inventory for Children (STAIC) (Spielberger et al., 1973) would be used. This inventory has been developed for the measurement of anxiety in 9-12 year old children. It contains two separate scales for measuring two definite anxiety concepts: a) state anxiety (A-State) and trait anxiety (A-Trait). The A-State scale consists of twenty statements regarding the way children feel at a particular moment in time, while the A-Trait scale consists of twenty statements indicating the way the children generally feel. This inventory generally requires eight to twelve minutes to complete each scale and less than twenty minutes to complete both. The standard procedure for the STAIC administration is that the researcher reads the directions aloud while each child reads them silently. Although it is important the group of children should not be very large, as it has been reported that in such situation children do not pay enough attention, in groups that are consisted from fifteen to thirty-five children the size did not seem to affect the inventory’s scores (Spielberger et al., 1973).

In addition to the above, another problem that seemed to have occurred was some form of computer anxiety that children might have experienced during the study due to unfamiliarity with the applications in relation with the required task or even with the computer environment in general. To be more specific, there is a need to consider the fact that teachers’ perceptions and use of computers could influence children’s attitudes towards computers and also their experiences of computer use within the classroom. Many teachers appear to use computers in isolation from a meaningful context and they focus on the development of computer awareness instead of integrating the computers as tools into their teaching and learning across the curriculum (Muntaz, 2001). As a result, the educational benefit of such applications could be negatively affected. In this particular case, although the school was using at that time a couple of applications related to mathematics the students were not using them during their mathematics class but only sometimes during their ICT class. Therefore, students lacked important experience of using such applications in order to acquire mathematical thinking and understanding.

In the school study reported earlier, although there was an effort to eliminate possible differences between the instruction types with the use of computer applications and without, beyond those measured by this study’s achievement tests, there is still a need to consider certain aspects. For example, during this study it was not possible at that time to examine further or assess the degree of excitement, enjoyment of learning and motivation when using the applications in comparison with the traditional method. It is important to develop technologies to assess what matters and as Noss (TEL project publication, 2012) highlights, we need to consider how we can design technology that enhances learning and how we can measure that enhancement.

A positive climate in learning within the classroom could be achieved by blending a number of elements together with the integration of the technology and the uniqueness of the teacher in order to create places where students can excel in learning. It is not enough to think about the number and specifications of the technologies available in a school. There is a need for answers in broader questions. For example, how does the use of technology change the learning environment and what factors can influence the effective integration of technology enhanced learning within the school environment? The impact of educational technology is generally difficult to assess as it depends on various interconnected factors difficult to isolate and rationalise. These issues and factors are discussed in the next chapter.

Tamin et al (2011) conducted a second-order meta-analysis and validation study, examining 40 years of research in order to address the question, does computer technology use affect student achievement in formal face-to-face classrooms as compared to classrooms that do not use technology? (p. 4). It was found that:

- *"Computer technology that supports instruction has a marginally but significantly higher average effect size compared to technology applications that provide direct instructions.*

- *The average student in a classroom where technology is used will perform 12 percentile points higher than the average student in the traditional setting that does not use technology to enhance the learning process"* (pp. 16-17).

In relation to the last point above, Tamin et al (2011) noted that we need to interpret these average effects cautiously because of the wide variability that encompasses them and that other factors, not identified previously, may account for this variability. What is particularly interesting in Tamin's et al conclusion is that there is suggestion that one of technology's main advantages may lie in aiding student efforts to achieve rather than functioning as a tool for delivering content. In addition, similar to Tamin's et al view (2011), it seems that currently a shift from technology versus no technology studies to more nuanced studies comparing different conditions, both involving emerging and innovative educational technologies would help the field progress.

Tamin et al (2011) highlight that there are factors such as pedagogy, teacher effectiveness, subject matter, age level, "fidelity of technology implementation" as well as other factors that may influence the effect sizes than the nature of the technology intervention. In this empirical study, presented and discussed in this chapter, certain factors were identified such as the subject matter, learning context and software characteristics. At the same time, after completing this experiment and studying the research literature further, a number of other factors also identified, such as learner's characteristics and attitudes to learning, teacher's role, methods and issues of assessment, technology infrastructure of schools, and learners' collaboration. Of course there is no doubt that other factors (that could influence and determine the effectiveness of educational technology in a school classroom) could be identified however those mentioned above (and in the next chapter) were identified during this research work as of great significance and therefore they are explored further in the next chapter.

Chapter 5 : Factors

This chapter focuses on the identified factors emerged from the school experimental study as well as other significant factors identified through the research review. This chapter also considers some of the important but often overlooked challenges that underpin the successful implementation of educational technology in formal education.

5.1 Introduction

Based on the results of the school study reported in the previous chapter, the hypothesis that the use of computer educational software has positive effects on students' achievement was not supported. Although during the study learning did take place, however, this learning according to the post-test scores appeared to be the same (there was no significant difference) whether students were using a computer or a pen and paper (traditional learning) activity. After completing the experimental study at the school and having analysed the results there was clearly a need to look back and reflect on the overall experience, results, as well as considering a number of limitations.

As Ramage (2002) explains while reviewing the "No significance difference" phenomenon "it is difficult, if not impossible, to apply scientific methods to social science hypothesis. Human cognition has, to date, provided no quantifiable absolutes or baseline from which research can benchmark" (p. 6). As it becomes evident through the course of this research project, it is particularly difficult if not possible to control all external variables that could affect the results of a scientific study in educational research. As Russell (1999) summarises, "we are, after all, working with real students in the real world, not controlled experimental conditions in a laboratory".

Further to the empirical study described in Chapter 4 which was conducted in a school classroom and the results revealed statistically no significant difference in learning across the different groups, a number of methodological issues and various interconnected factors that could influence the effectiveness of educational technology emerged as well as other important factors which are identified through the literature analysis. These are discussed in detail through this chapter. In the study, it became apparent that the null hypothesis had to be accepted, contrary to initial expectations the educational software had no effect on achievement in mathematics within a school classroom. Nevertheless, this study highlighted the need to consider the conditions and the factors that could influence learning in the school classroom (with real learners in real educational settings).

Aligned with previous research (e.g. Selwyn, 2011, Luckin, 2012, Laurillard, 2008, Sawyer, 2006, Berliner, 2002), it was proven very difficult to design and carry out empirical studies that can show with great confidence or certainty that there is a clear cause-and-effect relationship between technology and learning at school. This lack of strong evidence regarding the impact of educational technology on mental and cognitive development and performance remains so far mixed and inconclusive and this leads to the following important issue: whether technology may or may not promote learning depends on the way it is used.

The school study highlighted the need to consider the conditions and factors that could influence learning in the school classroom (Winn, 2006). These issues and factors are discussed in this chapter. The aim is to try and understand when and how educational technology does affect learning. There is no doubt that the relationship between the use of educational technology and the learning environment could not be one of simple cause and effect.

A positive climate for learning within the classroom could be achieved by blending a number of elements together with the integration of the technology and the uniqueness of the teacher in order to create places where students can excel in learning. While a prerequisite, it is not enough to think about the number and specifications of the computers available in a school. There is a need for answers to broader questions. For example, how does the use of technology change the learning environment and what factors can influence the effective integration of technology within the school environment? The impact of educational technology is generally difficult to assess as it depends on various interconnected factors difficult to isolate and rationalise. Some of these factors were identified during the school study while a number of others became obvious while reviewing relevant published research. These factors and issues are discussed below.

5.2 Factors

5.2.1 Learning context

It is crucial that the learning context should be taken into consideration when designing effective educational technology. Many teachers appear to use computers in isolation from a meaningful context and they focus on the development of computer awareness instead of integrating the computers as tools into their teaching and learning across the curriculum (Muntaz, 2001 and Department of Education, 2009). During our school study (Kolyda & Bouki, 2005) – discussed in Chapter 4 - there was an indication that students might experience some form of anxiety due to unfamiliarity with the applications in relation to the required task or even with the computer environment in general. In that particular case, although the school was using at that time a couple of computer applications related to mathematics the students were not using these applications during their mathematics class but only sometimes during their ICT class. Therefore, these students lacked important experience of using such applications in acquiring mathematical thinking and understanding. However, for educational technology to support learning it should be appropriately embedded in specific learning activities (Luckin et al, 2013, Luckin et al, 2012, Moher et al, 2005, Dede et al, 2005).

An interesting example is RoomQuake, a simulation that aimed to enhance salience by situating phenomena such as earthquakes directly in the classroom. This application is presented as an example of a class of simulations that Moher et al (2005) call *Embedded Phenomena*. “Applications in this class embed imaginary dynamic phenomena—scientific or otherwise—into the physical space of classrooms. These phenomena are "made visible" through a (usually small) number of computational affordances scattered around the room, representing visual or instrumented observations of the state of the phenomena, as well as controls (for experimentation). Teachers design instruction that includes student observation and investigation of those phenomena” (Moher et al, 2005, p.1665).

Context is an essential part of our psychological development. There is no doubt (Luckin et al, 2005 and Luckin, 2010) that the context in which learning takes place has a significant role in this learning. Luckin (2010) defines context as "something that belongs to the individual and that it is created through their interactions with the world" (p.i). According to Siemens (2006), "context influences our capacity to convey our thoughts" (p.63) and also "context shapes our actions and our beliefs" (p.106). The learners need to understand the prominence of context, to contextualise. "The context changes so rapidly that we need to continually evaluate what we know and how it applies to what is happening around us" (Siemens, 2006, p.122).

Dey (2001) defines context as "any information that can be used to characterise the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves" (p.5). Luckin et al (2005) explain that "context has both a static and a dynamic dimension in which the nature of the dynamic interactions changes the nature of the static definition" (p.5) which is aligned with the Zone of Proximal Development (ZPD).

It is important to increase our understanding regarding the relationship between learning and context so that we could specify the requirements for the design of learner activity and technology. The nature of context is crucial for someone's development, Luckin (2006) concludes that different contexts will lead to different social interactions and consequently to the development of different mental processes within the individual. Further to her definition (of context) above, Luckin (2010) defines a learning context as "an Ecology of Resources: a set of inter-related things that provide a particular context". Past research has confirmed the importance of exploring the learner's context but has been largely limited to specific environmental locations. Nowadays, the capacity to create learning context is widely available and the challenge is to develop ways in which technology can support learners to effectively create their own learning contexts (Luckin, 2006).

Luckin (2008) argues that we need a framework which helps us design educational experiences that match the available resources to each learner's needs. According to Luckin's Ecology of Resources framework, there are four different types of resources:

- Tools: learning materials
- People: teachers, peers and adults
- Knowledge and Skills: the teachers' expertise
- Environment: the setting in which learning is taking place

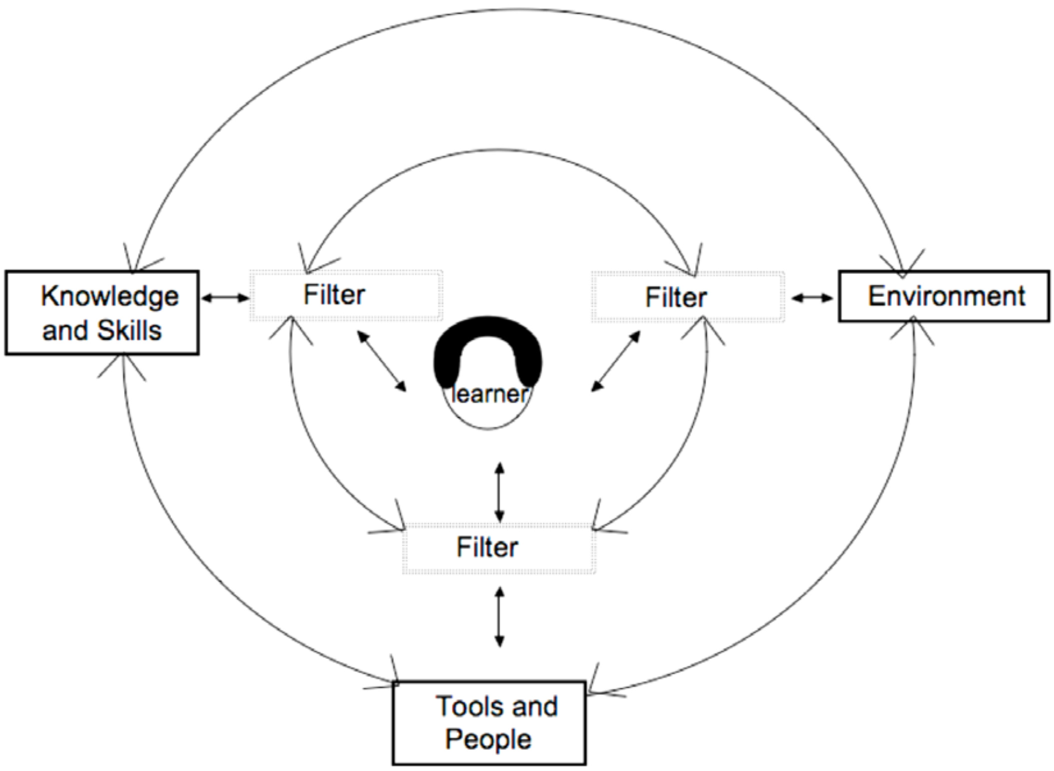

Figure 4: The Ecology of Resources Model (of Context) (Luckin, 2012 and Luckin 2010)

In addition to all the issues discussed above regarding the learning context, it is also significant to consider the overall power of contexts in educational research which makes the need for adapting a qualitative approach necessary in trying to understand school life and particularly assessing learning. Our own empirical study at school has shed some light on the role that numerous various factors and interactions could play in a school classroom. As Berliner (2002) explains, the difficulty of “doing science and implementing scientific findings” in education is due to the fact that “humans in schools are embedded in complex and changing networks of social interaction” (p.19). The complexity of scientific work in education and in this case in assessing the effectiveness of educational technology in a school classroom became apparent.

5.2.2 Subject area and resources

For educational technology to be effective it has to have focus and facilitate students’ engagement with the content and the information in a meaningful way so they can learn without becoming distracted by other activities such as following randomly links and accessing resources aimlessly (Laurillard and Taylor , 1994). According to Laurillard and Taylor (1994), children do not have sophisticated skills regarding the way of handling information. Therefore, they can easily browse or follow a random path through the information instead of maintaining a focused search strategy. Nevertheless, as discussed in Chapter 2, if we consider the perspective that connectivism is offering, it is the application of network principles that defines both learning and knowledge. However, the challenge is the need for a learner to be fairly autonomous in order to be able to learn independently and to be encouraged in aggregating, relating, creating and sharing activities. This is a very interesting area that further research is needed in order to study whether children that are born in this current advanced technological era will be able to acquire such sophisticated skills regarding the way of handling information.

Murray Gell-Mann, the Nobel Prize winner physicist, suggests (sited in Gardner, 2005) that the most important mind in the 21st century is the synthesising mind i.e. the mind that could browse the web, decide what is important, what is worth paying attention to and exploring further, what should be ignored. Given the amount of information that we all come across daily nowadays this seems most important and relevant today than ever before. As discussed in Chapter 2 (and particularly section 2.3.1) today we are living in an area where learners can connect and collaborate with other learners or people beyond their physical environment and the plethora of information and ideas rapidly available to each of us through the Internet is remarkable when compared with access in the past (Starkey, 2012). A synthesising mind - that Murray Gell-Mann suggests (sited in Gardner, 2005) seems an important requirement of the digital age learners.

New technologies can facilitate learning if they are specifically designed for specific kind of activities and domains of knowledge. For example, the design of an application to teach mathematics will be different from the one that teaches history. Each of them should have different organisation and structure of the subject and content (in the same way that traditional instruction for mathematics differs significantly from the one for history).

As Sutherland (2004) emphasises, learning within a subject area involves learning about the discourses, practices and tools related to the specific subject discipline. In a school environment students have the opportunity to participate in alongside their teachers who are more experienced and who can provide support in exploring new subject domains.

> *"Within any learning situation in which Information and Communications Technology (ICT) is to be used, it is important to analyse the interrelationship between the knowledge domain and the proposed use of digital and non digital tools, together with a consideration of the culture and context of learning, the students' previous history of learning and the ways in which the teacher will interact with students throughout the learning process"* (Sutherland, 2004, p.8).

Knowledge is not just a list of unrelated facts but it is connected and organised around important ideas within a discipline and includes information about the appropriate conditions for applying key concepts and procedures (Bransford et al, 2005).

One of George Lucas Educational Foundation[3]'s (in the US) recent projects, the Digital Generation Project (George Lucas Educational Foundation, 2009) - which was part of a digital-media and learning initiative that explored how digital media are changing how young people learn, play, socialise and participate - had focus on supporting four key components of learning:

- active engagement
- participation in groups
- frequent interaction and feedback and
- connection to real-world experts

This project's researchers emphasise that "effective technology integration is achieved when the use of technology is routine and transparent and when technology supports curricular goals" (Edutopia, 2008, para. 2).

Sinclair et al (2010) analysed a range of digital technology implementation projects with focus on mathematics and which have been implemented at a national scale in various parts of the world. The researchers highlighted that although early work with digital technologies mainly focused on individual learners and then maybe classroom – or school-based groups, these large-scale projects that they analysed demanded a much more systemic approach that considered issues such as teacher adoption and curriculum integration. According to Sinclair et al (2010), these projects were very modest in encouraging new content for the mathematics curriculum:

[3] *This foundation aims to help improving the primary school learning process by documenting, disseminating and advocating for innovative and evidence-based strategies that prepare students to excel in their future education and lives*

> *"Perhaps, following extensive arguments for the benefits and opportunities of doing new mathematics with the new technologies, we are now in a period of restraint in which the goal is to support teachers in making the technologies work within the scope of existing school mathematics. As we shall see, the traditional interest in new content for learners seems to have shifted to emphasise new practices for teachers"* (p.69).

It was concluded that these projects were focusing more on *endorsing new practices* than they on *encouraging new content*.

> *"By practices we include a wide variety of normative behaviours that might include ways of structuring interaction in the classroom (lecturing, using individual problem solving, coordinating small-group work), ways of assessing students (homework, quizzes, alternate forms of assessment), and ways of interacting outside the classrooms (developing lessons with colleagues, attending professional development workshops)"*(p.69).

Sinclair et al (2010) noticed a shift in focus towards the teacher's role and participation that was emerging across these projects. Furthermore, it appeared that the majority of these projects were focusing on the use of one *multi-purpose digital technology* (such as dynamic geometry environments and Java applets).

The majority of digital technology implementation projects that have been undertaken at a national scale in different parts of the world are still focusing nowadays on a mandated curriculum. Nevertheless, there are some exceptions where certain projects encourage new content or new variations of curriculum content (Sinclair et al, 2010). For example, by offering different ways of approaching primary school mathematical ideas, they focus on scaffolding learning. For instance, the use of a visual animation could enhance understanding of a difficult mathematical idea, or an abstract mathematical idea.

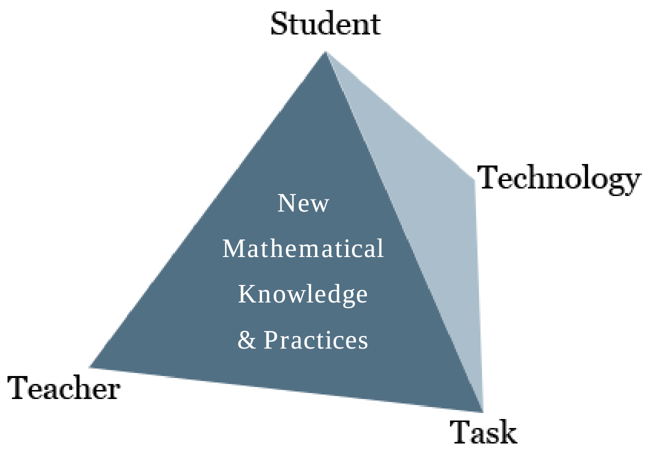

Figure 5: An adaptation of the didactical tetrahedron illustrating how the interactions among student, teacher, task and technology form the space within which new mathematical knowledge and practices may emerge (Hoyles et al, 2010, p.169)

Mathematics - nowadays with the use of educational technology- could be learned through a more dynamic approach for concepts such as functions, geometry etc which was not possible in the past.

The conclusions from this research work embrace the approach that educational technology could influence mathematical learning if it is embedded in activities designed following particular learning objectives as well as if it supports/provides new forms of interaction and open-ended environments that encourage exploratory learning. The latter is discussed within the next section.

5.2.3 The characteristics of educational technology and learning environments

Learning environments have been an important subject of research in the past. We define as learning environment: a) the people in the environment (teachers, learners and others), b) the computers and their role, c) the architecture and layout of the room and the physical objects in it and d) the social and cultural environment (Sawyer, 2006).

In order to understand how a learning environment could facilitate learning there is a need to consider how much support for the learner should come from the environment, for example, from the teacher, peers (i.e. the other learners) or the computer. In addition, it is important to consider what kind of support should be provided by the environment.

Research evidence suggests that for educational computer-based systems to be successful they should have the following characteristics (Wartella et al, 2000, Salomon, 1990): a) interactivity, b) guidance and informative feedback, c) multiple symbol systems, and d) supplanting users' memories by allowing them to engage in higher order thinking.

First of all, interactivity has a crucial role in such systems. The interactive design of an application that allows the user to communicate with the program introduces a unique experience to the user's engagement in a particular activity. This could be easily understood if we consider that someone learns more from participating in a discussion than overhearing the same discussion (Clark, 1994). Interactivity is the defining characteristic of an interactive system (Dix et al, 2003). Consequently, it is important in any stage of this system (e.g. in the order with which the screens appear or the level of access).

Interactivity could include interactions between learners, interactions with the teacher and/or interactions with the subject matter. Evans and Sabry (2003) formulated a three stage interaction model of computer-initiated interactions. According to this model, an interaction involves three sequential actions which are connected: initiation, response and feedback. Each action includes an exchange of information between two agents. The first agent invites input from the second (initiation), the second agent provides that input (response) and consequently (of the response) the first agent passes back information (feedback). "The response must be a direct consequence of the initiation and the feedback must be in direct relation to the response" (p.1149). Evans and Sabry (2003) claim that all types of computer-initiated interactivity could be described in terms of the above model. For instance, a navigation interaction consists of three actions: a) present button or control to learner (computer initiation) b) the learner presses button or uses control (learner response) and c) present new information to learner (computer feedback).

Today, we fail to focus on the significant aspects of interactivity and interaction (De Freitas et al, 2010). We do not notice that interactivity could control the learning process and could be in inverse proportion to the degree of freedom in the learning process. A careful analysis of the meaning of interactivity could lead to a distinction between intentional and unintentional (interactivity). In the intentional interactivity learning is active in order to lead to the results or directions that the educator has previously determined and set. As a result, the amount of freedom the user has is restricted. On the other hand, during the unintentional interactivity there is obviously a greater amount of freedom to the user since the instructional outcomes are not the result of teacher's decisions but this of the user themselves. In this case, the user is an active participant in their own learning.

Nowadays, innovative technology and open-ended environments afford new forms of interaction that offer great opportunities for exploratory learning as well as personalisation. Nevertheless, in the classroom there is a need to obtain a balance between allowing students to express their own ideas and follow their own paths, and at the same time steering them towards the activities and ideas that are concerned with the curriculum material (Noss et al, 2012). A potential solution to this problem could be to equip the teacher with tools that could provide the latter with valuable insights as to how the students progress so that the teacher could still orchestrate the classroom but without becoming intrusive as this would almost certainly lead to the elimination of any exploratory learning opportunities.

Exploratory learning seems to have great potential nowadays through information visualisations, online environments, powerful simulations and Augmented Reality. Nevertheless, there are not enough examples of innovation (Luckin et al, 2012) and this type of learning appears to be underused and undervalued within the school classroom. Possible reasons for this could be the obvious limited amount of time that teachers have to use such environments, the complexity of designing such environments and also, the difficulty of assessing and effectively evaluating what needs to be learned at school through such exploratory environments.

Evans and Gibbons (2006) conducted a study that illustrates the role of interactivity in learning from computer-based systems. Their study concerned two groups of undergraduate students: those who used an interactive version of an educational multimedia system and those who used a non-interactive version. The result was that the group which used the interactive version outperformed the other group. However, Evans and Gibbons have yet to conduct studies in order to establish whether a similar outcome can be obtained for younger learners (aged 8-11) and for non scientific subjects. They also highlight that further research is necessary. There is little doubt, however, that interactivity facilitates child's exploration of the learning environment and as Salomon (1990) underlines, interactivity adds a completely different value to the child's engagement in the activity. In addition, it makes possible the testing of ideas and receiving guidance and informative feedback.

Guidance and feedback is another characteristic of successful educational programs. In contrast to other mediums of learning (e.g. books), a well-designed interactive computer program can provide important guidance and informative feedback (Salomon, 1990). In fact, it could be said that it creates for the child a "Zone of Proximal Development", the distance between the child's actual developmental level and their potential level of development under guidance and help (Smith et al, 1998). However, it is obvious that different kinds or amount of feedback can have different effects on learning. For example, when the students start an interactive activity the amount of guidance and feedback is greater in comparison with what they receive as they move on and complete a number of activities and acquire certain skills.

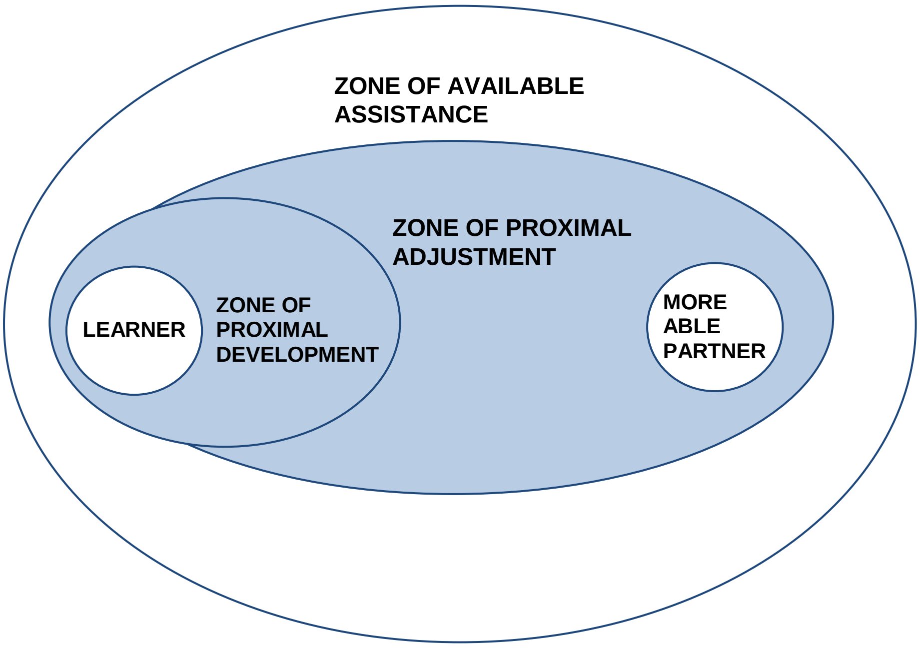

Figure 6: A basic level context model depicting learner and MAP (more able partner) and development of ZPD to the 'Ecology of Resources' elements of ZPA and ZAA (Luckin, 2011).

New and emerging technologies require reconsidering the concept of scaffolding within software. Luckin (2008) introduced the Zone of Available Assistance (ZAA) and the Zone of Proximal Adjustment (ZPA) in an attempt to clarify the relationship between the ZPD and educational technology. Luckin used ZAA to describe the types of resources, both human and artifact, available within a particular context to help a more able partner to offer appropriate help to a less able learner. The ZPA represents a selected subset of the ZAA that are the resources which are the most appropriate form of help for a specific learner at a particular moment in time. However, Luckin argues that the existence of a rich set of resources within the ZAA is not sufficient to ensure the required interactions in order to create a ZPD for the learner.

In addition to the above, another element that a well-designed educational program offers is the use of multiple symbol systems (Salomon, 1990).

> *"Symbol systems are modes of appearance, or sets of elements (words, picture components, etc.), that are interrelated within each system by syntax and are used in specifiable ways in relation to fields of reference. (Words and sentences in a text may represent people, objects, and activities and be structured in a way that forms a story)."* (Kozma, 1991, p. 181).

Computers can coordinate the use of different symbols systems (Kozma, 1991) and therefore, they can offer the various advantages of the co-existence of different kinds of situated learning opportunities (Wartella et al, 2000). Learners use various symbol systems in order to construct mental representations which are depended on the capabilities of the medium used and the nature of the internal mental representations the learner wants to construct (Hokanson & Hooper, 2000).

Furthermore, another characteristic of a successful computer-based educational program is supplanting users' memories which allow users not to rely heavily on their memories while carrying out a task (Salomon, 1990). In this way, the users can get involved in higher-order thinking. This characteristic can be easily understood if we consider a piece of software that creates semantic networks (concept maps) of ideas, dates and events and ways to interrelate them (Salomon, 1990). Such programs can shift the user's focus from remembering the entries to engaging in finding ways to relate them. According to Jonassen (2000), semantic networking enhances comprehension and retention of the ideas studied. Consequently, the learners can reflect on what they know and also on what they do not understand in order to be able to construct a meaningful knowledge framework.

In the experimental study discussed in Chapter 4, the educational interactive applications that were used focused on a specific piece of the mathematics curriculum for Key Stage 2 and Year 5, Data Handling (Department for Education, 2013). The learning objectives of this knowledge base include the ability of the children to describe the occurrence of familiar events using the language of chance or likelihood, answer a set of related questions by collecting, selecting and organising relevant data and draw conclusions, construct frequency tables, pictograms and bar and line graphs to represent the frequencies of events and changes over time and find and interpret the mode of a set of data. The challenge here is how teachers and educational technology could introduce mathematical problems to students in the best possible way.

The applications used in our study (Maths Explorer and Juniors) provided a number of problems which were set in an everyday context that would appeal and interest the students. The ‘step by step’ session of Juniors took the students through the problem in a meaningful way and the animation and audio enabled them to understand the problem in much more engaging and meaningful way than if they were just reading a text book. Within Maths Explorer, the students were transported back in time to the ancient civilisations of the Romans, Incas and Egyptians to investigate maths related to data handling. This application provided a range of mathematical problems for primary school students which were contextually appropriate to students of a particular age and within their mathematical capabilities.

In general, the teacher’s job is to assist the learner in making sense of the presented material and in the integration of this material into a coherent mental representation. The computer-based learning environments/applications should not only present information but also provide guidance for how to process the presented information (i.e. determine where to focus, how to mentally organise it and how to relate it to prior knowledge) (Mayer, 2005).

Research (Mayer, 2009) emphasises that there is a need to develop educational computer environments that will foster meaningful learning and that this could be achieved through active learning. However, we need to consider what we actually mean when we refer to active learning. Is the latter related to the learner’s physical behaviour (e.g. the level of hands-on activity) or to what is going on in the learner’s mind (e.g. the level of integrative cognitive processing). As Mayer (2005) highlights:

> *"Research on learning shows that meaningful learning depends on the learner's cognitive activity during learning rather than on the learner's behavioural activity during learning... My point is that well-designed multimedia instructional messages can promote active cognitive processing in learners, even when learners seem to be behaviourally inactive"* (pp. 14-15).

In successful educational games, difficult concepts could be explored through gaming that motivates and engages students. In addition to this, students' interactions with a game could be logged and then analysed in order to acquire valuable information regarding their learning, for example, what section they found difficult or easy etc. Such data-mining in a school environment could reveal which curriculum areas lead to achieving the required learning outcomes, which as Noss (2012) explains is particular difficult information to collect traditionally.

An educational game, such as Zombie Division (Habgood, 2007) - developed as part of a research project at University of Nottingham - that teaches mathematics to children (8-11 years old) through swordplay with skeletal opponents, does not only teach mathematical skills but at the same time collects such data/performance logs. One of the online applications used in our experimental study (see Chapter 4) had also this option (i.e. to collect data regarding students' performance and logs). However, it was not possible during our school study to explore this further due to technical and time limitations.

Furthermore, educational games or other technology-enhanced learning environments could help learners apply their knowledge in real life. Simulation authoring tools such as SimQuest[4] enable students to explore the physics of motion in a real life context. Immersive virtual environments such as EcoMUVE (2011) teach secondary school students about ecosystems and causal patterns. (Noss et al, 2012). Simulation tools/microworld environments such as ThinkerTools[5] allow primary and secondary school students to run simulations of

[4] *http://www.simquest.nl*
[5] *http://ott.educ.msu.edu/2002pt3/thinkertools.htm*

objects moving and observe the affects of various forces such as impulses, gravity and friction.

In summary, there is a need for better understanding whether and how specific characteristics of a particular type of educational technology could be effective in promoting learning since by expanding our knowledge in this area we create the foundation for further research that could lead to the implementation of systems capable of making a real difference in schooling.“Technology by itself cannot be expected to revolutionise education, but rather should be seen as one of a collection of tools that might spark and facilitate innovative thinking” (Bitter & Pierson, 2004, p.104).

5.2.4 Economic and political factors

There is no doubt that there has been great enthusiasm on the transformative potential of educational technology supported by research or practice-based evidence. On the other hand, often educators go on to only make limited use of technology for a number of reasons, such as technical, professional or personal (Selwyn, 2011). Therefore, there is a need for a greater change regarding governmental, political, institutional arrangements and policies in order for school teachers to be able to have the opportunity to become orchestrators of students’ use of technology in the classroom. It is not enough to generally blame teachers for resisting innovation (Selwyn, 2011). Selwyn (2010) reasons:

> *“If the meaning of educational technology is seen to be inseparable from the conditions under which it is generated and experienced, then the use of digital technologies within educational settings is best understood as being situated within all of the social interests, relationships and restrictions that are associated with the formal and informal provision of education”* (p.70).

Furthermore, looking on the role of educational technology on students' learning at school should not be confused with looking on commercially successful educational technology trends. As Buckingham et al (2001) explain "what counts as a valid educational use of technology is, it would seem, inextricable from what sells" (pp.38-39). Livingstone (2009) shares Buckingham et al (2001) view and calls for "a shift in the entire educational establishment as well as its relation to the home, state and the private sector" (p.88). She offers a very good example to illustrate this point: when once she contributed to an expert discussion on a project that involved the development of a new educational game for children. Instead of the team to focus on what they wanted children to learn from this game, how it would complement what they already knew, what use such knowledge would be to them and whether this was what children themselves wanted to learn, the project team focused on discussion regarding the presentation, branding and promotion! Although Livingstone was reassured, by the team, that these educational issues will be considered at the end as feared the opportunity to do something original, to rethink what might really benefit children, was overlooked (Livingstone, 2009). Furthermore, there is, according to Livingstone (2009), a fundamental lack of clarity over the main purpose of educational technology use and it is essential to decide whether "educationalists expect the internet to enhance the efficient delivery of a pre-defined curriculum" or do they hope that it "enables alternative, student-centred, creative form of knowing?" (p.89). According to this research, both aspects are important however there is a need to be very clear as to how each of the above aspects would be assessed and its impact measured.

5.2.5 Learners' characteristics and attitudes to learning and technology

Numerous researchers (e.g., Noss, 2012, Noss et al, 2012, Druin & Solomon, 1996, Fraser, 1999, Papert & Harel, 1991, Soloway et al, 1994) have emphasised the common idea that computers can create learning environments that would not otherwise be possible without a computer. Hence how can learning be achieved and facilitated by using technology? The key answer to this question is to know the users and their needs. Knowing and analysing what is meaningful to the children and their possible interactions with educational technology is fundamental. We need to study children's preferences, desires and adopt their perspective. Understanding their needs as users and learners means that we can design technology that make the learning object meaningful and provide children with a context in which learning becomes a tangible need (Sedighian & Sedighian, 1996). It is widely known that children want to learn because they have a natural desire to do so (i.e. increase their knowledge and understanding and investigate the world around them) (Ward, 2012) and not because their teacher or parent wants them to learn.

Recent research into learning has concluded that children do not enter school as empty vessels, waiting to be filled. They enter school with half-formed ideas and misconception about how the world works. Learning scientists study how the novices think and their misconceptions and then they design curricula that influence those misconceptions in such way that learners become experts (Sawyer, 2006). There is a large body of comparative research on the effect of individual differences has on learning and a number of researchers (Alessi & Trollip, 2000, Jones & Paolucci 1998, Ford & Chen, 2000) argue that individual differences play a significant role in the success of educational technology.

It is important to understand why and how learners differ because then educational technology could be designed and used in such way that learners could achieve their full potential and guided though the learning process. Intelligence, personality and cognitive styles contribute to variations among individuals. According to Riding and Rayner (1998), cognitive style refers to "an individual's preferred and habitual approach to organising and representing information" (Riding & Rayner, 1998, p. 8). Although within the literature, the term "learning style" has been used in two ways: a) as "cognitive style" and b) as a term to indicate a wide description of rather consistent behaviours in relation with the way people learn, in both ways the term meant to cover "a range of concepts which have emerged from attempts to describe aspects of student learning" (Eysenck, 1994, p. 208). Research into the field of individual differences and learning styles is particularly significant in order to design instructional material through technology. In this way it is possible, if we adapt the instruction, to accommodate learners' differences in styles or preferences (Moallem, 2002) and help them approach their learning in the best possible way. Riding and Rayner (1998), argue that academic performance is related to the development of learning strategy, the learning process and individual differences.

In addition, it is important to study the relation between educational technology and certain processes that learners employ in their learning, i.e., their learning strategies. Mayer (1988) defines learning strategies as "the behaviours of the learners that are intended to influence how the learners process information" (p. 11). Investigating the learning strategies that students are engaged in when learning from and with certain computer applications could be beneficial. It could provide an assessment of the way computer-based learning strategies differ from the strategies used in the traditional learning environment within the school (lectures, tutorials, use of textbooks). Although the use of computer applications in the classroom becomes greater there is still a dearth of research (particularly in primary education) regarding the kind of learning strategies students use when working with technology. The use of certain learning strategies in the course of learning could affect the encoding process and consequently, the learning outcome and performance (Weinstein et al, 1988).

It is important to match specific types of learning and learners with specific types of technology.

Moreover, children's academic use of educational technology and their attitudes towards it can be heavily influenced by the family. For example (Wartella et al, 2000), children who have rarely engaged in using software or the Internet for learning appear to have parents who expect that their children would experience such activities within school. As a result, these parents do not assist with this kind of computing activities. The value of the family learning cultures and practices can influence students' experiences at school and their expectations of learning.

As Hohlfeld et al (2008) highlight, it is important to ensure that all students have right instructional experiences that integrate ICT skills at school and that their families have appropriate access to educational technology resources at home in order to support the educational process of their children.

In order to be able to evaluate the effects of educational technology, socioeconomic status, family status and prior educational history (achievement) are needed to be taken into consideration (Lesgold, 2003). As Lesgold (2003) underlines, innovative ideas and schemes would usually work when tried out in school environments in which students are easy to teach but this would not be the case in schools where students do not have home support for learning, do not have the latest technology at home, are lacking of adequate previous education or even arrive at school hungry.

Furthermore, there is empirical evidence regarding the relation between mood and performance; although the findings are controversial: learners in a positive mood can have reduced cognitive performance but also more flexible thinking while learners in a negative mood can be more systematic and data-oriented regarding information processing but can also have impair cognitive performance (Brand et al, 2007). Brand et al (2007) findings (of experiments with adults) suggested that a negative mood had effects both in terms of transfer of knowledge to new contexts and in terms of learning and performance when knowledge needed first to be acquired and then applied to new situations.

To date, there have only been a few studies examining emotions in relation to perceived classroom environments which are mainly concentrate on anxiety. A study that examined the relationships between students' perception of their mathematics classroom environment and their experiences of enjoyment, anxiety, anger and boredom in mathematics showed that the above emotions are differentially affected by aspects of the classroom environment as perceived by students (Frenzel et al, 2007). The above four emotions were studied because these are the most frequent emotions that occur in the context of learning and achievement. Frenzel et al (2007) believe that teachers are able to influence and shape students' beliefs in the subject domains they teach. Their study focused on mathematics and secondary education but it would be interesting to expand their study in primary education and in a computer-based learning (classroom) environment.

Another significant factor that influences the way learners construct their knowledge is motivation. Schank and Jona (1999) argue that students are not motivated in the classroom because they think that what they learn in school is unlikely to apply to their adult lives. According to Schank and Jona (1999), primary school should be about reading, writing, arithmetic and learning good "work habits", communication and reasoning (Schank & Jona, 1999). Although they highlight the fact that primary school children need to learn by doing (without instruction) or sitting still in a classroom, they also believe that a lot of instruction should be available to children in case they need it.

Schank and Jona (1999) emphasise the need to make the curriculum content aligned with learners' concerns and interests. Tests and grades, according to Schank and Jona (1999), make children fear school and force them to learn what otherwise would not have intended to. As they point out, individual interests are too difficult to match with a fixed curriculum; but would it be a solution to this problem to change completely the role of the school by removing the concept of teaching within a classroom environment and replace it with only social activities, as Schank and Jona (1999) believe? In addition to individual differences, the differences of interest and enjoyment to learn a particular subject due to age need also to be underlined. For example, a child of eight years old might not like mathematics but later on they might change their perception for whatever reason and enjoy studying mathematical concepts. If this child had been encouraged to focus on different subject when they were not keen on mathematics how would have been possible for them to develop a different attitude?

Therefore, it seems that it is currently unavoidable for school not to provide certain core subject areas for all children. However, what school should try to do is finding effective ways to encourage children to learn and motivate them without forcing them or making them to fear school or the teachers and this where educational technology could make a significant difference. According to Barnard and Slater (Bartlett, Burton, et al, 2001) three types of factors affect students' progress: a) teacher's "professional characteristics", b) "teaching skills" and c) "classroom climate". Hence the main concern nowadays should be how educational technology can be integrated effectively in the classroom in order to have a positive effect on students' progress by taking into consideration the above factors.

Adaptive learning environments through the use of educational technology could also play an important role on enhancing the learning process. Adapting content and instruction to particular learner characteristics, needs and abilities is a particular important area of research (e.g. Vandewaetere et al 2011) nowadays especially since the recent advances in technology have created a number of exciting opportunities for personalised learning and instruction. However, as Mavrikis et al (2012) highlight, computational analysis and reasoning in supporting learning with and from exploratory environments will be of little benefit when designing these exploratory environments without subtle understanding of the interaction between the child and the computer and the types of support they need.

5.2.6 Teachers' role and perceptions

Godwin and Sutherland (2004), researching on the ways in which mathematics teachers can use digital tools for enhancing the learning of functions and graphs within a classroom setting, concluded that learning is totally linked to the choice of tools, however it is not possible to determine in advance what students will learn. Godwin and Sutherland argue that teachers need to interact with students "to develop an emergent and collective mathematical community, one in which knowledge construction converges to some acceptable 'common knowledge'" (p.150).

In learning mathematics the teacher plays a crucial role in planning tasks and activities so that the students could focus on and understand specific mathematical concepts. Educational technology could be used in a classroom setting to enhance learning and the development of mathematical knowledge. According to the socio-cultural perspective each student brings their own personal experience of learning to any new learning situation and variation in (student) ideas is moderated by the learning context (Linn, 2006). Such diversity of student experience although might seem a very significant challenge for the teacher, the latter could bring together these differences “to construct a whole which is more than the sum of the parts” (Godwin & Sutherland, 2004, p.132).

> *“It is by mediating the technologies and knowledges of the learning environment and drawing together the diversity of student experience as they appropriate digital and non-digital tools that the teacher can nurture the development of the knowledge collective within a whole-class approach to learning mathematics”* (p.150).

In order students to be effective in their learning, teachers should encourage them to explore different ways/types of learning situations (e.g. lectures versus practical work in a lab). Learning could be achieved through active engagement in which the teacher provides support, resources and encouragement (Rieber, 2005). According to Barnard and Slater (cited in Bartlett et al, 2001), three types of factors affect students’ progress: a) teacher’s “professional characteristics”, b) “teaching skills” and c) “classroom climate”.

Murphy and Beggs (2003) carried out a study in order to compare the use of computers and attitudes towards them in the primary school between teachers and students. The results revealed that teachers and students had different perceptions of the amount of how much computers were used. Besides this, students were more confident than teachers regarding their computer ability and seemed to enjoy using computers more than their teachers. However, the teachers were more enthusiastic about the educational value of computers. Murphy and Beggs (2003) concluded that there are certain issues concerning the way educational technology is used in the primary school and emphasised the need for further research.

In addition to the above, Tincher, and Mills (2002) after analysing the teaching practices of teachers using technology in classrooms, concluded that technology integration in the classroom has a strong association with the quality of teacher interactions with technology and not only with the quantity of such interactions. Antonietti and Giorgetti (2006) underlined the importance of considering teachers' perceptions regarding the role of technology in learning since the effects of technology are influenced by teachers' beliefs. They concluded that although research about teachers' attitudes towards computers provide us with information about teachers' overall reactions towards technological tools, it fails to give us information about teachers' specific ideas about what such tools may bring into the process of learning (Antonietti & Giorgetti, 2006).

Examining whether the teachers' perceptions of educational technology match the students' perceptions would be significant towards a more positive climate within the classroom. There is a need to study and identify factors that are related to teachers' attitudes and beliefs regarding their ability to apply effectively educational technology into the classroom practice.

Specifically in mathematics, there is evidence (Triggs et al, 2003 in Sutherland, 2007) that teachers do not utilise the capabilities of educational technology for learning mathematics as much as the teachers of other subjects. There is a number of different reasons that may justify this. For example, it might be the case that as many computer-based environments for mathematics are quite rich and complex environments, teachers have to dedicate a great amount of time to learn these tools. Further to the above, teachers might experience difficulty in deciding how and where to start using such powerful environments (Sutherland, 2007). Therefore, it is important for teachers to get support in order to start using them with confidence. A supportive environment within a school will encourage teachers to integrate technology in their classroom and to be innovative in its use.

During a case study of a grade six mathematics' classroom, Hardman (2005) observed that the teacher used non-verbal actions (for example, pointing to a child to direct their attention or to select them to answer a question) to manage classroom interaction and regulate students' behaviour. However in the computer laboratory, the teacher became more formal. Language was not a tool to explain mathematical content any more (as it was within the classroom) but a tool to regulate behaviour (i.e. direct students' actions in relation to the computer). Hardman (2005) believes that the need to use the computer as a tool requires that the teacher *rethinks* teaching and learning in the mathematics classroom, leading to contradictions between the use of the computer as a tool for "drill and practice" and its use as a creative tool that could help students to develop an understanding of mathematics. The way with which the teacher would deal with and overcome such contradictions will be significant in the future use of computers at school.

There is evidence (Hermans et al, 2008) that teachers' beliefs are crucial determinants in justifying why teachers adopt computers in the classroom. Among all the other reasons, constructivist teacher beliefs were found to be a sound predictor of classroom use of computers (Hermans et al, 2008). On the contrary, traditional (educational) beliefs of the teachers according to Hermans et al (2008) seem to have a negative impact on the integrated classroom use of computers.

It appears that there is not enough research on the way teachers might learn with educational technology although it makes sense to accept that a teacher who is trained to integrate technology into the curriculum may teach differently than the one who is not trained. Teachers' confidence and skills in using ICT are crucial in trying new/innovative teaching approaches. Researchers (Moseley et al, 1999) discovered that more effective teachers tended to relate to higher levels of (personal) skills in ICT and, as Moseley et al (1999) believe, this fact reflects not only these teachers' understanding of the potential of ICT but also their determination to use it to support their teaching.

A study published by Becta in 2010 (Underwood et al, 2010) reports on findings from online surveys of teacher and learner perceptions of aspects of the learning environment. Teachers were asked how much they thought that ICT had affected the way they taught and in addition, how much impact there had been on the learners. As Figure 13 and 14 (see Appendix III, p.160) shows, the most positive responses (to both questions) were from Early Years teachers and ICT specialists. Among the least positive responses about the effect on teaching were humanities and mathematics teachers who were also least positive about the impact on learners. When teachers were asked about the extent to which their school promoted and supported personalised learning, science and mathematics teachers were the least positive (as shown in Figure 13 (see Appendix III, p.160) The perceived impact of ICT on learners showed variation between different subject specialism with humanities, English and mathematics teachers reported the least impact (Underwood et al, 2010).

In sum, teachers' beliefs and attitudes towards educational technology are crucial factors in integrating the latter within the school environment and therefore, relative training within the teachers' educational programs and further support is needed. Lastly, it is particularly significant to highlight that by developing technology that enhances learning we are trying to give teachers support not to replace them (Noss, 2012).

5.2.7 Methods and issues of assessment

Examining the impact of educational technology requires investigation from a number of different perspectives (e.g. types of assessment, relevant measures of learning) and an understanding of the difficulty of evaluating this impact on learning. Lee (2004, cited in Haertel & Means, 2004) argues that there are a number of questions about evaluating educational technology, among them: a) educational effects should be assessed on what outcomes? Lee recognises that there are some serious problems in using more authentic assessments (e.g. portfolios or performance assessments) to measure change over time such as low reliability. b) How do we measure change over time (and what is changing)? In school education it is quite difficult to assess long-term change (such as learning) due to changes in classroom conditions for example, change of a teacher (which is something very common at least every year). c) How do we analyse change in outcomes? Lee argues that outcomes such as performance assessments, engagement, academic self-concept or aspirations are more complex to measure than the assessment scores (e.g. standardised tests) therefore, there is concern regarding the reliability and validity of other measures (that could be used in order to measure the impact of technology).

Ridgway and McCusker (2004) agree that educational technology raises important questions about "what is worth learning in an ICT-rich environment, what can be taught, given new pedagogic tools and how assessment systems can be designed which put pressure on educational systems to help students achieve these new goals" (pp.7-8). They distinguish between two different types of assessment: summative and formative (Ridgway & McCusker, 2004). The first type is meant to summarise performance and attainment at the end of a course of study (e.g. the GCSE exams in UK) while formative assessment takes place in the middle of a course in order to enhance students' final performance (e.g. teacher's comments and feedback on a draft of an essay, portfolios of work etc). It is important to note that poorly designed assessment systems could "harm" students and societies while one could argue that it appears to be a paradox when traditional (non-technology based) assessment systems are used to measure academic achievement with the use of technology.

In addition to the above, as Jonassen (2000) underlines, the most important reason for assessment and evaluation is to provide learners with feedback that facilitates their comprehension of how much they have learned in order to "better direct their learning" (p. 272). Jonassen embraces the opinion that computers should be used to support meaningful learning and engage students in critical thinking but at the same time he highlights the fact that critical thinking is difficult to assess because, apart from all the other reasons, it is quite complex to define.

It is important that assessment methods are better aligned with our current understanding of how people learn (Technology Enhanced Learning (TEL) project publication, 2012). However, reforming assessment is difficult as it involves changes at various levels of the school system e.g. from changes in the classroom up to changes in government policies. As Cox highlights, (Technology Enhanced Learning (TEL) project publication, 2012) “for the first time, we can assess what really matters, rather than simply what is easy to assess. We need to move beyond ‘snapshots’ of students’ performance towards assessments that track how their learning is developing through time” (p.21).

Assessing the process of learning (i.e. the *how*) as opposed to simply the product/result (i.e. the *what*) is crucial. Being able to assess competencies such as students' ability to a) analyse and solve complex problems, b) synthesise information and c) apply knowledge to new situations. At present, assessment in school is designed to simply indicate if students have learned but it is not sophisticated enough to assess student inquiry learning or students' thinking during learning. Educational technology has the potential to engage students in immersive, meaningful and challenging learning activities that could provide the teachers as well as the students themselves with rich insights into their reasoning and knowledge (Technology Enhanced Learning (TEL) project publication, 2012).

Similarly, too often, there is great concern about the importance of creativity in the curriculum. There have been many attempts to provide a definition of creativity. Fisher (1995, p. 76) attempts to define creativity as:

> *“…a form of intelligence that can be trained and developed like any other mode of thinking. It is not merely a question of playing with things, of randomness or chance, but, at its best, has to do with serious and sustained effort in thinking about any area of learning”* (p. 76).

Nevertheless, how can we assess creativity in educational technology or most importantly, when we assess learning with educational technology do we also have to measure creativity? As Loveless (2002) states, the attempts to find ways to assess creativity have not been straightforward. Fisher (1995) summarises research findings that suggest that creativity is a significant element in the achievement of some children despite their intelligence.

It becomes clear that to assess the impact of educational technology there is a need to determine the purpose of the assessment and to identify the best ways to measure the key (and usually multiple) outcomes. For example, are we measuring the learning outcome, creativity, higher order thinking or any changes in learning attitudes? According to Rutter, "the long term educational benefits stem not from what children are specifically taught but from the effects on children's attitudes to learning, on their self-esteem, and on their task orientation" (cited in Fisher, 1995, p.126).

> *"The same technology that supports learning activities gathers data in the course of learning that can be used for assessment... as students work, the system can capture their inputs and collect evidence of their problem-solving sequences, knowledge and strategy use, as reflected by the information each student selects or inputs, the number of attempts they make, the number of hints and feedback given, and the time allocation across parts of the problem"* (pp. 2-3).

There is a need to consider how we can design technology that enhances learning and how we can measure that enhancement (Technology Enhanced Learning (TEL) project publication, 2012). Further research is required on the way simulations, virtual words, collaborative environments and games could be used to engage and motivate students while at the same time assessing complex skills and important competencies and aspects of thinking in different contexts and situations.

We are still not using the full power and flexibility of technology to design, develop, and validate new assessment tools and processes for formative as well as summative assessment. Nevertheless, interest in formative assessment through technology (i.e. e-assessment) is increasing (Luckin et al, 2012). There is currently a number of examples of projects in e-assessment with the use of mobile or immersive environments as well as collaborative networks (Luckin et al, 2012).

For example, a research project in Sweden (Johansson et al, 2011) focused on kinaesthetic learning (i.e. how we learn and acquire understanding through bodily interactions and through moving into a large space setting). Researchers explored how abstract notions of energy and energy consumption could become something that could be experienced and interacted with in a physical manner using our body and movement. They argued that:

> *"by adapting the interchange needed between the different spaces, it is possible to build activities and learning environments that allow for both a rich experience of small details in the personal space to a joint understanding of concepts in the larger whole, through both system and real world feedback and interaction"* (p.167).

Johansson et al (2011) concluded that there was a promising approach to design for alternative pedagogical practices that supported kinaesthetic learners in their preference to learn by being physically engaged.

Nevertheless, as Luckin et al (2012) highlight, currently the level of research innovation in technology-supported assessment is quite modest with the most innovative work focusing on self-assessment through reflection. Technology-supported assessment could constist of learning activities as well as enabling both learners and teachers to reflect upon those activities and keep track of the learning process and also present the information and learning material in rich and interactive ways. Monitoring learner progress and providing feedback that supports and guides instead of examining and judging learners (i.e. formative assessment) seem to offer greater scope for innovation (Luckin et al, 2012).

Researchers today recommend (Noss et al, 2012) the use of technology to acquire a better understanding of how people learn and consequently help people to learn better.

5.2.8 Technology infrastructure of schools

Impact 2007 (a UK national research project) demonstrated a clear connection between technology resource and usage. Although educational technology physically exists in most schools today, its relation with instructional practices and processes remains limited and often focused on issues of school administration and management instead of learning and teaching issues (Selwyn, 2011). As Selwyn (2011) states, there is a need to consider carefully about "the future shape and forms of the educational landscape in term of its formal and informal elements" (p.160). Educational technology can reconsider the connections between formal and informal learning.

As Sharples et al (2012) argue (in Noss et al, 2012) some of the benefits include:

- Helping students to learn inside as well as outside the school, through activities (enhanced by technology) that start in the classroom and then continue outside school.
- Connecting students with the experts and people with alternative perspective other than their teachers and increasing student's awareness of places outside the classroom and the wider world, strengthening the relevance of classroom learning.
- Collecting data from the real world to take back into the classroom, enabling authentic and original investigations that could lead to developing abstract knowledge (by observation and experimentation in the real world).
- Capturing individual students' interests and learning strategies in an obtrusive manner.
- Making use of communities and social interactions that take place outside school.

As Smith (in Means & Haertel, 2004) highlights,

> *"some educational technology is designed to teach the kinds of reading skills and mathematics procedures that are covered on standardized tests. If a technology infrastructure is used to provide students with extended use of such software, positive effects on scores on tests of reading and computation skills is a plausible expectation. The issue becomes much more complex when a teacher, school, or district is considering implementing a technology-supported innovation with a different kind of learning goal. Even if the program involves reading or mathematics, it may not call upon or teach the same kinds of skills or knowledge as the standardized tests used in a state's accountability system"* (pp. 42-43).

5.2.9 Collaboration

Technology is offering new ways for individuals to communicate and share information as well as constructing new kinds of knowledge. Such technologies can reconnect formal and informal learning. Outside formal learning (i.e. school environment) students empowered by personal devices and technology (Noss et al, 2012). They communicate and they collaborate through social networking which enables to develop powerful skills. However, within school there are still limits as to how students could engage with such digital activities. Collaborative learning is more and more important for students and educational technology supports such experience in a powerful way unlike previously, when the research community investigated whether educational technology in the classroom would isolate students! Today, not only technology can encourage students to work together but most importantly it can encourage them to learn about things that would be difficult to learn alone (Noss et al, 2012).

As we saw in Chapter 2, through the Internet and digital revolution people nowadays interact with others all over the world and the online communication has transformed the way we learn and the way we create knowledge collaboratively (Harasim, 2012). In the primary school classroom, collaboration is a significant factor towards positive learning outcomes. Technology can create networks within and outside the classroom as well as make use of communities and social interactions outside the school. As Luckin et al (2012) highlight, although there is currently a significant number of research innovations on this type of learning, i.e. learning with others, such ideas have not filtered through to classrooms.

5.3 Concluding remarks

There is no doubt that measuring the learning outcome and the real educational impact of educational technology is particularly complex. In this chapter we have reflected on a number of different factors that could influence and determine the effectiveness of educational technology. The conclusion that can be drawn is the importance of considering further all the above issues before designing such educational systems. It is essential to develop new evaluation tools that could be used in classroom settings in order to trace and understand fully how and when learning is taking place. As Muffoletto (2001) highlights “educational technology is not about devices, machines, computers, or other artefacts, but rather it is about systems and processes leading to a desired outcome” (p.2).

Chapter 6 : Learning at School in the Digital Age

Students need to learn at school the new things that matter in the 21st century and we need to find new ways to teach and assess them. New technologies such as Augmented Reality, Cloud-computing, large Multi-touch Surfaces and Learning Analytics could offer great opportunities for learning (as well as teaching). This chapter discusses some of the latest developments and emerging technologies which appear to have great potential on learning within the school environment.

6.1 Knowledge creation in the digital age

In the digital age the growth of accessible knowledge is exceptional. Starkey (2012) believes that although students will continue to need to learn subject based concepts (for example, regarding mathematics: trigonometry, numbers, fractions, etc or regarding science: atomic structure, force, circulatory system, etc), skills and methodologies, they will also be making the connections between and across subjects and as a result create knowledge (Starkey, 2012).

A practical example could be addressing a mathematical principle such as long multiplication. Having been first taught in class long multiplication students could then work in small groups producing video footage of the teacher demonstrating how the mathematical principle work and then the students themselves create a commentary that describes what is happening (Barber & Cooper, 2012). Once this is done it could be then uploaded to an online resource such as Teacher Tube (this is a media sharing website such as YouTube but for educational purposes). The groups could then watch the videos in class and critique them (for example, identify the most effective elements, etc) with a final goal to decide on a single video or podcast. Such activity combines video and sound through which students could demonstrate their understanding of a process, while using (and perfecting) an appropriate mathematical vocabulary. Such in class activities through the use of digital/online technologies (use of podcasting, publishing resources online, digital story telling etc) could support students' development as producers of knowledge.

Further research is needed in order to explore how such technologies could help stimulate student's creative potential and how it could support collaborative work among students in order to form learning communities (Barber & Cooper, 2012). "This is not simply a question of producing materials, the mechanical process of editing and publishing a photograph for example, but how these kinds of activity can aid in the development of understanding in the attainment of curriculum objectives" (p.62). This type of knowledge creation could be powerful within (and beyond) the classroom context.

6.2 New and emerging technologies

The potential of technology in learning becomes clear when we consider the possibilities of the new and emerging technologies such as tablet computers, mobile devices and ubiquitous computing.

Researchers at Brown and California universities (Howison et al, 2011) developed an embodied-interaction instructional design, the Mathematical Imagery Trainer (MIT), in order to help young students develop grounded understanding of proportional equivalence (e.g., 2/3 = 4/6). MIT has taken advantage of the low-cost availability of hand-motion tracking (e.g. Nintendo Wii remote) and it involves an application of cognitive-science findings that mathematical concepts are grounded in mental simulation of dynamic imagery that is acquired through perceiving, planning and performing actions with the body. The early results from this research study concluded that remote manipulation appears to be an opportunity for the mind to reflect on what the body could already do. “Embodied interactions can drive both the realisation and resolution of cognitive conflicts between users’ implicit assumptions and their own observable enactment; and with careful guidance, these experiences can be recast in terms of emerging mathematical principles” (p.1996).

Interestingly, this research concluded that an educator should also be present as they could play a critical role in the learning process with the MIT application. The researchers are currently working on how to scale up the MIT design to full-classroom use.

6.2.1 Learning analytics

Learning analytics refer to “the interpretation of a wide range of data produced by and gathered on behalf of students in order to assess academic progress, predict future performance, and spot potential issues" (Hoover, 2012, p.57). Learning analytics technologies that gather data about learning have a great potential for improving assessment, providing appropriate and individual feedback and learning activities in suitable level of difficulty.

Research in mathematics education (Noyes, 2012) highlights that there is a need to improve student-centred teaching (apart from an increase in the quantity and quality of student-centred learning) and research shows that there is association between student-centred teaching and enjoyment of learning mathematics. Acquiring awareness of what a learner understands is crucial in the learning process and emerging analytics could offer a great insight in this in order to tailor and provide appropriate level of support. There are currently examples of using automated feedback to support the writing skills of students at university education such as a) by providing comparisons with other students' work and b) by the use of automated marking systems such as AssignSim (Naudé et al, 2010). Nevertheless, there is an urgent need to design and study such tools and their potential for younger learners at school (Luckin et al, 2012).

Learning analytics and data captured through various digital tools could support self-assessment through reflection and formative assessment. Accurate and detailed information and analysis of learners' current understanding and performance could lead to provide more appropriate learning activities, feedback as well as enhancing learners own understanding and awareness of their learning. Nevertheless, further work is needed in supporting formative assessment and self-guided learning through technology (Luckin et al, 2012). Learning analytics could also transform "the quality of learning, teaching and assessment by exploiting the responsive and adaptive capabilities of advanced digital technologies to achieve a better match with learners' needs, dispositions and identities" i.e. enhance personalisation, an important issue towards enhancing learning (Technology Enhanced Learning (TEL) project, 2012, para. 1).

6.2.2 Augmented Reality and Global Positioning Systems

Advances in mobile technologies offer opportunities for learning outside the traditional classroom. Using Global Positioning System (GPS) and mobile technologies as well as Augmented Reality (AR) educational games could be designed or provide the tools and platform for the students or teachers to use such technologies in order to develop their own games (e.g. location–based games with their application programming interface (API)). There is currently growing evidence that technologies such as Augmented Reality can support learning through overlaying the real world with digital information (Luckin et al, 2012).

AR technologies can enable learners to engage in authentic exploration and help them to manipulate virtual materials from a variety of perspectives. For example, an AR 3D dynamic geometry system which aims at facilitating mathematics and geometry education, not only could provide learners with a real world setting to work collaboratively but also it could demonstrate virtual 3D objects for learners to operate, measure and manipulate while trying to understand spatial relationships (Wu et al, 2013). Subjects such as mathematics require visualisation of abstract concepts and therefore AR technologies offer unique opportunities for detailed visualisations. However, there is no doubt that AR technologies themselves are not important for educational research. What is important is the way these technologies support and afford meaningful learning (Wu et al, 2013) and how their use could be associated with different instructional/learning approaches in order to achieve the particular learning objectives.

As (Wu et al, 2013) explains, research on AR educational applications is still in an early stage and further and more in depth research is needed in order to understand their effectiveness in learning. Currently, a number of AR studies are focusing on initial implementation of AR tools, development and usability and these studies tend to be relatively simple, small in sample size and short term so any conclusions tend to be quite preliminary and limited.

AR has unique affordances that can influence/determine the learning experience. In particular, (Santos et al, 2013) review of the literature concluded that there are three inherent affordances of AR to educational settings: a) Real World Annotation (which may reduce significantly cognitive load), b) Contextual Visualisation and c) Vision-Haptic Exploration (which enables embodied interactions and therefore provides more natural ways of acquiring information and construct knowledge). These affordances could be understood further if we consider them in relation to the situative approach to learning and knowledge creation discussed in Chapter 2.

At the same time, there is however, concern as to whether the novelty of the AR technologies are the reason on increased student engagement and this is something that the researchers will be looking at in the future, i.e. whether such innovative technologies could sustain engagement beyond the one offered by the novelty of the technologies themselves. Furthermore, some teachers are also worried about being able to manage the technologies and devices involved when orchestrating the field trip outside a particular research study (i.e. in everyday, real life) and how could they possibly deal with any technical issues. This is clearly a very important factor in the effectiveness of educational technology which was considered during our school study as well as a factor that is continuously coming up in the research literature. Research studies usually involve a team of researchers, educators, technicians and technical experts so this is a very important issue to consider when assessing the educational impact of any such technologies. Particularly, given the fact that in real life, the teacher will not even be able to take advantage of the technical support that might be available within their school since such projects and technologies are designed to be used outdoors, during school fieldtrips.

6.2.3 Cloud-computing technology

Often students in the classroom do not feel the need to learn the respective curriculum topic/material as they could not usually see the relevance in real life. However they could enhance their knowledge and acquire deeper understanding when they apply their learning across different locations, representations and activities (Luckin et al, 2012). Nevertheless, such application (and transfer) of learning across different settings and contexts such as school and home (formal and informal learning) could be difficult. This is where technology can help not simply by making such transfer possible but most importantly by making it meaningful, enjoyable and successful. Cloud-computing technology could support such learning in various ways; for example, by providing a suite of learning environments/tools (e.g. educational projects, games, applications, tools etc).

The National Institute of Standards and Technology[6] (NIST) offers the following definition (Mell & Grance, 2011):

> *"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models"* (p.2).

Cloud computing offers an opportunity to improve primary education with services tailored to teachers' needs in individual classrooms. Cloud computing refers to a) the applications delivered as services over the Internet and b) the hardware and software systems in the data centres that provide these services (Armbrust et al, 2010). Some of the advantages of cloud computing in primary education are the following (Stein et al, 2012): a) Diversity of software choices (*flexibility of choosing diverse software applications*). b) Availability of Internet

[6] *This is a US Federal government agency responsible for developing technology standards and guidelines.*

connectivity outside schools (*access to learning tools from anywhere at any time*). c) Affordability of class time delivery (in class/school education requires specific time periods during which software must be available with minimal delay. Using a cloud designed specifically for educational needs, block allocations could make it possible for the teachers to register their class and make pre-loaded software remotely available immediately). d) It is usually the case that schools do not have sophisticated technical support due to lack of funding or resources. Cloud computing removes such constraints since applications could be uploaded on a cloud server which removes any barriers about performance issues, software conflicts or multiple installations on the school computers (Stein et al, 2012). Of course, future research is needed into Cloud-computing technology (as a means of delivery) at school and the impact that this could have towards greater advancements in pedagogical effectiveness (Stein et al, 2012).

Cloud-computing technology could enhance flexibility through “enabling the provision of education and skills to be deployed in more open, variable, and accessible ways, so that learning opportunities are available in a more seamless environment that can link classroom, home, workplace, and community” (Technology Enhanced Learning (TEL) project, 2012, Flexibility section, para. 1) and productivity through “achieving higher quality and more effective learning in affordable and acceptable way” (Technology Enhanced Learning (TEL) project, 2012, About Productivity section, para. 1)

While studying the research literature, it becomes clear that there is a need for educational research in relation to cloud-computing. Considering the pedagogical aspects would be a very important future research direction as although this particular area of cloud-computing appears to have been the research focus in relation to technical requirements, specifications and infrastructure, there is currently very limited research on the pedagogical aspects especially regarding schools and primary education. Cloud-computing could offer a plethora of educational resources to students. However, how the latter could be really benefitted by this and how they could comprehend and decide what constitutes of higher significance resources and what not. As discussed in Chapter 2, if we consider the perspective that connectivism is offering, it is the application of network principles that defines both learning and knowledge. Connectivism might be one of the emerging learning theories that could embrace the affordances of the *cloud* as a learning platform. Nevertheless, as discussed in Chapter 5, the challenge is the need for a learner to be fairly autonomous in order to be able to learn independently and to be encouraged in aggregating, relating, creating and sharing activities. This is a very interesting area where further research is needed in order to study whether children that are born in this current advanced technological era will be able to acquire such sophisticated skills regarding the way of handling information and resources in various platforms such as cloud-computing technologies.

6.2.4 Artificial Intelligence

VanLehn (2011), reviewing experiments that compared the effectiveness of human tutoring, computer tutoring, and no tutoring, observes that when human tutors cause larger learning gains than computer tutors, it is due to the fact that humans are better at scaffolding students and giving feedback that encourages students to engage in interactive and constructive behaviours as they self-repair and construct their knowledge. However, VanLehn (2011) concludes that it is important to remember that no classroom teacher has been replaced by an Intelligent Tutoring System (ITS), but classroom instruction is often replaced by human tutoring (e.g. in home schooling) and that ITS should be used to replace homework and maybe other activities but not to replace a whole classroom experience.

Such systems could facilitate inclusion through “improving the reach of education and lifelong learning to groups and individuals who are not best served by mainstream methods” and personalisation through “transforming the quality of learning, teaching and assessment by exploiting the responsive and adaptive capabilities of advanced digital technologies to achieve a better match with learners' needs, dispositions and identities" (Technology Enhanced Learning (TEL) project, 2012, para. 3). Inclusion and personalisation are important issues in enhancing learning.

One of the important factors that was identified and discussed in Chapter 5 was the characteristics of the educational technology and specifically, the interaction. Emerging technologies provide new forms of interaction that could create new opportunities for exploratory learning (Mavrikis et al, 2012). Researchers emphasise the need to provide student-adaptive support, a very important pedagogical aspect particular within the classroom environment, in order for exploratory learning environments to be integrated into the complex environment of a classroom. Intelligent systems are still difficult to design and implement. Nevertheless, as Mavrikis et al (2012) underline, computational analysis and reasoning in supporting learning with and from exploratory environments will be of little benefit when designing these exploratory environments without subtle understanding of the interaction between the student and the computer and the types of support they need and this currently an area where researchers are looking at, for example the MiGen project (an intelligent, computer-based support system for 11-14 year old students learning algebra that recognises a central role for the teacher unlike other intelligent systems which only focus on the students).

Noss (2012) highlights the fact that very few applications used Artificial Intelligence (AI) for supporting exploration but AI has been mainly used for intelligent tutoring. This is due to the complexity of using AI for exploration and designing systems to support learners' exploration.

6.2.5 Multi-touch Surfaces into the school classroom

Multi-touch devices, such as large multi-touch tables and multiplayer games on the Wii or Kinect offer exciting new opportunities for learning and entertainment. Multi-touch technology offers unique ways for interaction between learners and collaboration in the classroom and the potential of this technology is currently being explored by researchers (Higgins et al, 2011, Mercier & Higgins, 2013, Yuill & Rogers, 2012, Harris et al, 2009). Research on collaborative learning using multi-touch tables is still quite new and in early stages. Such technology makes possible to have a surface which can detect multiple touches (from one or more users). Therefore, it offers opportunities for interaction with multiple points of control between users (i.e. learners) unlike the single point of control (that standard/common desktop or laptop computers with mouse and keyboard offer) which requires negotiation over control of the device (Higgins et al, 2011, Mercier & Higgins, 2013).

Higgins et al (2011) propose a working definition for an interactive tabletop as "a computer system that allows direct physical interaction with its non-vertical display surface" (p. 518). Based on this definition, the key elements of an interactive tabletop are: a) display surface, b) direct interaction and c) computer system. Further to the above definition, Higgins et al (2011) introduce a typology of design features (see Figure 7 below) as a way of distinguishing between the capabilities of the range of multi-touch tables that are emerging. This typology provides an analysis based on the features of these systems in order to identify distinguishing characteristics and significant features which may be related to their pedagogic capability.

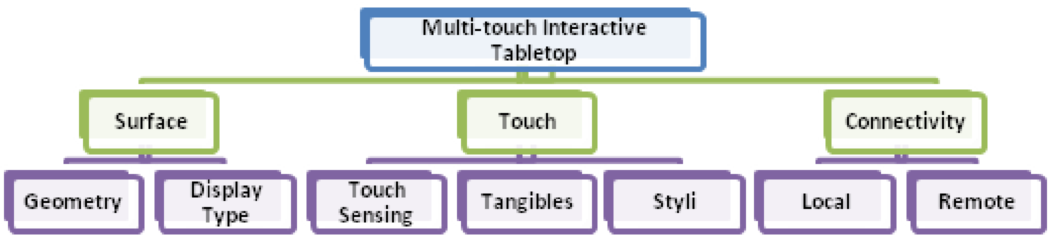

Figure 7: A typology of design features (adapted from Higgins et al, 2011, p.530)

Higgins et al (2011) argue that although features related to the surface determine in general the parameters for physical collaboration among learners around the surface, it is also the very particular way that learners interact with the technology that influences the way they interact with each other. Moreover, it is the way that the content is accessed and shared on a tabletop and between tabletops that influenced the pedagogical opportunities in a multi-touch classroom (Higgins et al, 2011).

SynergyNet is a Technology Enhanced Learning (TEL) research project led by Durham University (Hatch et al, 2011) that explores the benefits of such technologies and new forms of interaction and how large networked multi-touch tables could influence students' learning as well as identifying ways to support the teacher in "orchestrating learning" with innovative ways of interaction (Noss et al, 2012). The SynergyNet project developed a classroom environment with networked multi-touch tables. Preliminary findings indicate that using these tables encourages the young learners to have discussions that are more task-focused and increases their joint attention (Noss et al, 2012).

NumberNet (Mercier & Higgins, 2013) is a tool designed to promote collaboration in a mathematics classroom within and between groups (of learners). It uses a network of large networked multi-touch tables in a classroom environment. It builds on the common individual classroom activity called "Explode-A-Number" - in which children are given a number and asked to produce as many calculations as they possibly can that form that number – to create a three-stage collaborative activity that promotes flexibility with numbers, operators and calculations (Higgins et al, 2011, Mercier & Higgins, 2013). The pilot results from 32 primary school children indicated significant benefits in the number of calculations that children produced in relation to pre test and post test.

The results from a quasi-experimental study (Mercier & Higgins, 2013) of 86 students (44 using NumberNet, 42 using a paper-based comparison activity) indicated that all students increased in fluency after completing relevant activities (that aimed to support the development of flexibility and fluency in mathematics), while students who used NumberNet also increased in flexibility. Video analysis of the groups that used the NumberNet tool indicated that the opportunity to collaborate and learn from other groups' mathematical expressions may have supported this increase in flexibility.

Of course we need to consider that there were certain limitations to the above study of NumberNet. For example, the brevity of the study and the relatively short time between intervention and post-test, the use of research staff rather than the students' own teachers to conduct the intervention and the lab-classroom environment of the NumberNet activity (Mercier & Higgins, 2013).

Interactive educational tabletops offer new affordances for collaborative learning in the classroom. Combined with other technologies (e.g. mobile devices, learning analytics, or perhaps ideally with intelligent systems) could provide the teacher with better control and awareness about the classroom performance.

Teacher's role in the classroom could be enhanced (Martinez et al, 2012) using an orchestration tool such as a multi-platform application which could be displayed on devices, such as a desktop or laptop computer but perhaps most appropriately on another tabletop or a mobile device such as a tablet.

Dillenbourg and Evans (2011) argue that almost any educational software can be run on tabletops but if we focus on the deep differences between desktops/laptops and tabletops, the latter implicitly convey a "pedagogical flavour" that can be understood if we consider the following points regarding tabletops:

1. Tabletops are designed for *co-location*.
2. Tabletops are designed for *multiple users*.
3. Tabletops are designed for *hands-on activities*.
4. Tables are designed for *multiple modes of communication*.

"Desk(top)s are personal, table(top)s are social, and (digital) whiteboards are public" (Dillenbourg & Evans, 2011, p.501).

Dillenbourg and Evans (2011) attempted to analyse the relation between interactive tabletops technology and teaching and learning processes and highlighted 33 points that need to be considered. They presented these points in a taxonomy that has four levels i.e. *circles of interactions*: a) individual user-system interaction, b) teamwork, c) classroom orchestration and d) socio-cultural contexts. Dillenbourg and Evans (2011) argue that tabletops require a deep dialogue between Human Computer Interaction (HCI) and learning sciences and emphasised that we should not expect great learning outcomes from tabletops simply because they are more "natural" than desktop computers but in order to understand the potential of tabletops for education we should thoroughly analyse (circle by circle) their affordances. "Technologies do not offer intrinsic pedagogical effects rather, they have designed affordances" (p. 493).

6.3 Eight learning themes

Nesta commissioned two UK research institutes (a) the London Knowledge Lab, Institute of Education and b) the Learning Sciences Research Institute, University of Nottingham) to analyse how technology has been used in the UK education systems and lessons from around the world. This report (Luckin et al, 2012), identified the following eight approaches to learning (i.e. learning themes) that are proven to be effective and provided the taxonomy in the above research in order to organise and analyse learning/digital technologies and practices: a) Learning from Experts, b) Learning with Others, c) Learning through Making, d) Learning through Exploring, e) Learning through Inquiry, f) Learning through Practising, g) Learning from Assessment and h) Learning in and across Settings. Nesta's review identified 210 innovations which showed the potential for technology to support one or more of the above approaches to learning.

It is highlighted that the starting point should be identifying the type of learning and then asking whether digital technologies are making this particular type of learning more effective. There is a need for design research (this is also one of the conclusions of this thesis, discussed in Chapter 7) in order to understand better the tools that shape learning and in particular mathematics and with regard to each other, understand how individuals and communities can shape the evolving technology (Hoyles & Noss, 2009).

6.4 A conceptualisation of mathematical categories

Knowledge in mathematics and science appear to share characteristics that may not probably apply in other disciplines. For example, such knowledge is rigorously articulated; it has gained a high degree of consensus and there are detailed representational formalisms to represent such knowledge. Knowledge in history, art or literacy is likely to be different and consequently, these latter forms of knowledge may be learned in fundamentally different ways than the former (Sawyer, 2006).

Although in learning to read children, once they have acquired basic principles and skills, they use those skills in the service of other activities and although their skills could still be polished they do not need additional explanations and demonstrations of reading by others (National Research Council, 2001). Similarly, students develop certain basic concepts and practices in mathematics but a new or unfamiliar topic in mathematics normally cannot be fully understood without some assistance from a text or a teacher. Although reading uses a core set of representations (and therefore after a certain point requires little explicit instruction), mathematics have several types and levels of representation which build on one another as the mathematical ideas become more abstract (National Research Council, 2001).

Moreover, the main difficulty with learning algebra is a) learning to make generalisations and b) understanding the rules of transformation of algebraic expressions (i.e. developing algebraic ways of thinking) (Noss et al, 2012). So what does it mean to learn mathematics successfully i.e. obtain mathematical proficiency?

According to Kilpatrick & Swafford (National Research Council, 2002) this consists of five strands which are all interdependent and interconnected:

1. ***Conceptual understanding***: comprehension of mathematical concepts, operations, and relations

2. ***Procedural fluency***: skill in carrying out procedures flexibly, accurately, efficiently, and appropriately

3. ***Strategic competence***: ability to formulate, represent, and solve mathematical problems

4. ***Adaptive reasoning***: capacity for logical thought, reflection, explanation, and justification

5. ***Productive disposition***: habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

Understanding mathematics means understanding the world, the ability to reason mathematically and having a sense of enjoyment and curiosity about the subject in which learners are able to move fluently and confidently between representations of mathematical ideas as well as applying this knowledge to science and other subjects (Department for Education, 2014).

It is well known that mathematics is the science of patterns. The source of the power of mathematics consists of identifying, analysing and predicting patterns whether it is a number sequence, the structure of shapes or the climate change (Noss, 2012). However, identifying such patterns in some cases are not sufficient for mathematicians – they need to be able to generalise i.e. to express the pattern that it is true for all cases (Noss, 2012). Generalisation in mathematics (e.g. algebra) is very difficult to learn and teach and this is where educational technology could make this possible, for example through intelligent microworlds (such as the MiGen project – see also section 6.2.4).

Furthermore, technology can "relieve the computational burden and free working memory for higher-level thinking so that there can be sharper focus on an important idea" (National Research Council, 2001, p. 437). According to Kilpatrick & Swafford (National Research Council, 2001) empirical evidence has shown that even the use of calculators can enhance conceptual understanding, enhanced ability to choose the correct operation and enhanced skills in estimation and mental arithmetic without losing fundamental computational skills. As an instructional tool, technology should be used in such way that facilitates the development of all strands of learners' mathematical proficiency mentioned above.

The National Curriculum for mathematics in England (Department for Education, 2014) aims to ensure that all primary school children:

- *Become fluent in the fundamentals of mathematics, including through varied and frequent practice with increasingly complex problems over time, so that pupils develop conceptual understanding and the ability to recall and apply knowledge rapidly and accurately.*
- *Reason mathematically by following a line of enquiry, conjecturing relationships and generalisations, and developing an argument, justification or proof using mathematical language.*
- *Can solve problems by applying their mathematics to a variety of routine and non-routine problems with increasing sophistication, including breaking down problems into a series of simpler steps and persevering in seeking solutions.*

Our intention as educators and researchers should be to help school children excel on the above aims through the use of technology and technology enhanced learning while becoming independent learners, confident in their abilities and responsible for their sources of knowledge (Laurillard, 2012).

A popular subject of educational research over the last twelve years has been the one of “threshold concepts” and “troublesome knowledge”. According to Meyer and Land (2003), a threshold concept “can be considered as akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress”. Furthermore, troublesome knowledge is “knowledge that is conceptually difficult, counter-intuitive or ‘alien’” (p.1). An interesting and promising future direction of educational research could be how educational technology may help with the teaching and learning of “threshold concepts” and “troublesome knowledge”.

An important characteristic of a threshold concept is that it is likely to be transformative. This means that once understood by the learner, its “potential effect on student learning and behaviour is to occasion a significant shift in perception of a subject, or part thereof” (Meyer & Land, 2003, p.4). There are a number such examples in the discipline of mathematics.

In particular, the access to mathematical knowledge and ideas is greatly related to the representational infrastructures in which knowledge is conveyed. Thus, educational technology may offer new representational infrastructures which could enhance the learnability of particular mathematical ideas and consequently, educational technology may enable learners to become engaged in mathematical topics that were considered in the past as too advanced for their level (Sacristan et al in Hoyles and Lagrange, 2010).

Chapter 7 : Conclusions

This chapter discusses the main conclusions of this work and presents a set of recommendations that could facilitate learning in the classroom with educational technology and may promote the effective integration of this technology into the school environment. These recommendations, which were formulated during this research work, could be relevant to educators, researchers, policymakers and practitioners. The chapter concludes with the limitations of this thesis and future work.

7.1 Conclusions

There is no doubt that measuring the learning outcome and the real educational impact of educational technology is particularly complex. This thesis reflected on a number of different factors that could influence and determine the effectiveness of educational technology. A conclusion that can be drawn is the importance of considering further all the above issues before designing such learning systems. Furthermore, it is essential to develop new evaluation tools that could be used in classroom settings in order to trace and understand fully how and when learning is taking place. Technology has benefits to the learning process which are not directly measured by specific learning outcomes (Dusick, 1998). Certain conditions, such as sufficient access to technology, adequate teacher preparation and support, effective curriculum and relevant assessment as well as specific types of technologies to support specific types of learning must be met for such educational environments to be successful.

The question is not anymore whether to use educational technology or not; rather how to effectively design such technologies that could enhance learning and how to implement these technologies that maximise their benefits. "The success of the use of any technology as an educational tool depends upon the extent to which it is integrated into a pedagogically grounded framework" (Luckin et al, 2004, p.2).

One issue that became apparent in the course of this study is the need for innovation and innovative use of technology in the school classroom that could really transform the learning environment. The majority of educational technology currently used at school is quite conservative and new technologies are simply integrated into existing practices instead of becoming the catalyst of change and improvement.

If we consider for example the use of the internet within the school settings this could be a great tool for authentic learning if used for instance in order to critically analyse and choose resources in a particular topic or communicate with experts around the world. Particularly, in regards to the latter, what is important to highlight here is the need for supporting and encouraging dialogue among learners or between teachers and learners not simply expect students to passively “copy and paste” information found online. A major issue in this case is the way this approach will be implemented in the classroom.

Regarding the above opportunity for dialogue between teachers and learners, another important condition is the use of carefully designed and developed pedagogical material which requires the collaboration of several experts in different fields (e.g. domain experts, developers) with the teachers and learners as well as appropriate internet connection speed and obviously, a further requirement would be that all the students have access to the relevant devices used (Luckin et al, 2012).

Approaches that encourage learning with others could be very powerful. For example, as discussed in Chapter 6, NumberNet (Mercier & Higgins, 2013) is a tool designed to promote collaboration in a mathematics classroom and uses a network of large connected multi-touch tables in a classroom environment. In addition, another approach that encourages collaboration could be a multi-user game with focus on problem solving or an online authoring where learners could collaborate on writing stories, solving problems etc.

Furthermore, the applications used in the experimental study (see Chapter 4) consisted of a comprehensive range of interactive tutorials. Tutorials are an important approach to learning as they are traditionally used in order new information to be taught and to accomplish the first two phases of instruction which are: presenting information and guiding the learner (Alessi & Trollip, 2001). Like traditional tools, tutorials mainly use a narrative method, a sequential presentation of information. They are considered effective when large amount of information has to be taught to learners. However, although they are useful for factual materials they are not as effective for teaching complex processes. Tutorials can present the logical procedure and the specific steps the learner has to follow. Nevertheless, they cannot actively engage the latter in the performance of these tasks (Howell & Dunnivant, 1999). In particular, simulations are considered more appropriate tools than tutorials in order to engage the learner in higher order thinking skills (i.e. problem solving). Tutorials have influenced a lot the development of computer applications for learning (e.g. Intelligent Tutoring Systems) (Luckin et al, 2012). Nevertheless, nowadays, researchers are calling for more innovative approaches to learning.

On the other hand, for several years great effort has been devoted to the study of technology used to support practice. Drill and practice exercises are considered as supporting activities that provide practice rather than a complete methodology. The main advantage of drill and practice programs is "automaticity" (Jonassen, 1999). Conversely, as Jonassen (1999) highlights, such programs do not facilitate the transfer of skills to meaningful problems.

There has been a lot of criticism regarding drills and particularly the computer based ones. The main argument is that drills do not capitalise on the power of the computer (Alessi & Trollip, 2001) and that they can be easily developed without computers. On the other hand, other educators believe that computers provide the possibilities for designing more effective drills with essential feedback that could lead to learning opportunities. For example, feedback to incorrect answers that provides the learner with insight into the error in rationale behind the wrong answer or positive guidance to the correct reasoning behind the correct answer (Howell & Dunnivant, 1999). There is a need to clarify that drills are not designed to teach new concepts but to reinforce previous knowledge and skills. Therefore, they are not effective for initial training or detailed instruction (Howell & Dunnivant, 1999). Besides, drills are in nature highly repetitive hence if they are poorly designed they can easily lead to situations where the learner loses interest. Regardless of the fact that nowadays learning by practicing is not considered at the forefront of learning theory, practice has been long associated with learning and learning by practising for examinations has clearly influenced substantially education policy and practice (Luckin et al, 2012).

While it is true to say that the use of technology to support practice is not usually regarded as innovative, there are currently some promising developments using games or multimodal environments that they provide students with challenging problems and with constructive feedback in order for the learners to develop new insights (Luckin et al, 2012). For example, the Zombie Division game (Habgood, 2007) is designed to help children 8-11 years old to practise their multiplication and division. Educational games, such as this, that integrate the knowledge and skills to be learnt directly into the structure of the game activity are both more effective than those where the game is used as motivation but without connection to the learning content and more fun for children to play (Luckin et al, 2012). As Mayers highlights (2009), well designed multimedia instructional messages could support active cognitive processing in students even in a situation where they appear to be *behaviourally* inactive. Furthermore, assuming that meaningful learning is based on active cognitive processing in the learner, then it is essential to design learning episodes that facilitate appropriate cognitive processing (Mayers, 2009).

The present study adds to a growing body of studies (e.g. Noss et al, 2012 & Luckin et al, 2012) which have shown that there is not a single type of technology that is “best” for learning. Individually or in combination, different technologies can be used to support different forms of learning. The learning theories discussed in Chapter 2 highlight how important it is to do this, i.e. matching specific types of learning and learners with specific types of technology. As Selwyn (2011) points out, there is no one-size fits-all solution for applying technology to learning. Technology in education should not be offered as “*a solution in search of a problem*” (Selwyn, 2011) a view that Laurillard (2008) also embraces. We, as educators, should use technology to solve a specific problem (e.g. ask what the technology can do for us), not finding the problem that the technology is a solution for (i.e. rather than asking what we can use the technology for).

The experimental study revealed that although the educational software used had no effect on achievement in mathematics within a school classroom, there is a need to consider the conditions and factors that could influence learning in school settings. One of the more significant findings to emerge from this study is that assessing the impact of technology use in education is a complex topic with many factors (see Chapter 5) and variables involved: social, cultural, economic and political. Aligned with previous research (Selwyn, 2010 & Tamin et al, 2011) it has been proven very difficult to design and carry out empirical studies that can show with great certainty that there is a clear cause-and-effect relationship between technology and learning at school. This lack of strong evidence regarding the impact of educational technology on mental and cognitive development and performance remains so far mixed and inconclusive and this leads to the following important issues/conclusions:

- We should not judge educational technology on such outcomes/impact and such perspective might be incorrect.
- A more appropriate question to consider could be: how can technology support learning that would not otherwise take place?
- Also, how effective educational technology is in helping learners and teachers achieve the appropriate instructional/learning goals in the school classroom?

This study confirms previous findings (Ross et al, 2010) that educational technology involves a variety of modalities/configurations, tools and learning strategies and therefore measuring its effectiveness is particularly complex.

Furthermore it is important to develop technologies to assess what matters, rather than what is easy to assess (Noss et al, 2012). Flexibility, enhancing teacher's productivity (with new tools) and inclusion (new technologies could now bring learning to anyone, anywhere, anytime) are also crucial.

It is important to employ tools to help children as learners make sense of the information overload. There is a need for educators and researchers to reconsider the nature of knowing by "changing the ways in which information is presented and understood, challenging our prior knowledge and helping us to seek out new directions and associations" (Noss et al, 2012, p.46).

This thesis provides a critical analysis and an empirical study, discusses its outcomes and factors identified during the empirical study as well as through published research. In addition, it provides a set of recommendations that could be relevant to educators, researchers, policymakers and practitioners. As Noss et al (2012, p.2) state “education at all levels needs technology that is designed for learning and teaching, not the leftovers of systems designed for quite other purposes”. The work of this thesis is a small contribution towards realising this vision. Research should guide the production of educational technology that foster learning and transfer of learning i.e. empower students to apply what they have learned at school to real-life problems or situations.

7.2 Recommendations

This thesis defends the idea that educational technology can support learning in primary school if it is appropriately designed to support learning and if it is successfully embedded in specific learning activities. There is no technology that has an impact on learning on its own. This depends on how it used. In order to address this further we provide a set of recommendations below, formulated during the course of this research that could facilitate learning in the classroom with educational technology and may promote the effective integration of this technology into the school environment. These recommendations could be relevant to educators, researchers, policymakers and practitioners.

7.2.1 Empowering learners to apply and use mathematics in real-life problems and to make connections across the different areas of the curriculum subjects

What makes the current technologies interesting is the access and distribution capability they can offer and their use as a tool for understanding as opposed to an interactive form of a book (Laurillard, 2008). Students need to learn at school the new things that matter in the 21st century and we need to find new ways to teach and assess them. New technologies (like tablets, mobile computers and powerful visualisations) have the potential to turn the *unlearnable* ideas into learnable and we should find new ways to represent such ideas. For example, a European research project, WebLabs, developed in order to help learners (11-14 years old) access and explore advanced mathematical ideas through digital technological environments. In particular, explore infinity-related ideas by providing them with an alternative formalism i.e. computational setting that would use to construct, think and discuss ideas about infinite sequences, series and the cardinality of infinite (Sacristan et al in Hoyles and Lagrange, 2010). As discussed in Chapter 6, the access to mathematical knowledge and ideas is greatly related to the representational infrastructures in which knowledge is conveyed and educational technology may offer new representational infrastructures which could enhance the learnability of particular mathematical ideas and consequently, educational technology may enable learners to become engaged in mathematical topics that were considered in the past as too advanced for their level (Sacristan et al in Hoyles and Lagrange, 2010).

A number of researchers (Noss et al, 2012) are focusing on the power of personalisation and the use of Artificial Intelligence to personalise teaching and learning (as discussed in Chapter 6). In the near future, computers would be able to know enough about us to offer us personalised learning, adapted to our strengths and styles and can learn from us about how best to help us learn. Researchers should try and understand how students use digital technology outside the classroom in order to overcome any divide between these two different settings. As Noss et al (2012) emphasise, “what people learn in formal education has to be as powerful and engaging as they do at home”. We should also aim to study further learning through technology of what matters (i.e. what counts as learning) in the 21st century.

The Royal Society last year published a report (Furber, 2012) that analysed the current state of Computing education in UK schools and set out a way forward for improving on the present situation. The President of the Royal Society, Paul Nurse, stated in that report's foreground that we need "to ensure that the next generation of young people in this country can be creators of technology – not just consumers of it" (p.3). It is time that we use the capacity of the current technology to finally meet the needs and requirements of education. As Noss et al (2012) highlight - and other researchers e.g. Laurillard (2008) embrace - for a long time until now "learning has been subsisting on the crumbs of technologies designed for other purposes" (p.2). The importance and complexity of this issue is too great to be ignored. The power and uniqueness of current technology could be understood if we use it in order to teach school children ideas and topics that are currently difficult to understand or even *unlearnable* because of the way they are represented.

In order to empower learners to apply and use mathematics in real-life problems and to make connections across the different areas of the curriculum subjects, teachers have a very important role to play. As discussed in Chapter 5, students bring their own personal experience of learning to any new learning situation and variation in (student) ideas is moderated by the learning context (Linn, 2006), according to the socio-cultural perspective. The teacher could bring together these different personal experiences "to construct a whole which is more than the sum of the parts" (Godwin & Sutherland, 2004, p.132) and encourage learners to explore different ways/types of learning situations (e.g. lectures versus practical work in a lab). Learning could be achieved through active engagement in which the teacher provides support, resources and encouragement (Rieber, 2005).

Equally, the school's role is also important. As seen in Chapter 5, currently, educational technology' relation with instructional practices and processes often remains limited and focused on issues of school administration and management instead of learning and teaching issues (Selwyn, 2011). It is important that schools facilitate the connection of students with the experts and people with alternative perspective other than their teachers and increasing student's awareness of places outside the school and the wider world, strengthening the relevance of classroom learning and helping students to learn inside as well as outside the school, through technology enhanced activities that start in the classroom and then continue outside school. Local education authorities could also play an important role towards make this possible for their schools.

At a national level, it is important that research and other relevant bodies provide support, resources, sufficient educational research funding, encourage communication and collaboration between projects such as TEL (2012) and respective partners and educators throughout the UK. It is important to disseminate research findings as widely as possible and also to explore opportunities for possible links to research taking place in the same areas in different countries and continents. Developing links with researchers, educators and learners in other countries could not only lead to fruitful discussions and exchange of ideas but also it could lead to share best practice.

7.2.2 Empowering teachers to become orchestrators of students' use of technology in the classroom

Teachers should be confident enough of the significant role they have in introducing learning opportunities through educational technology which students may otherwise not have the chance to experience. As discussed in Chapter 5, teachers' confidence and skills in using technology are crucial in trying innovative teaching approaches. They should support and scaffold students' learning through technology. In order for teachers to be able to achieve the above in the current stressful and increased workload, they need to be supported and relevant provision to be in place. Continuing professional development is needed and this offers a great opportunity for schools and industry to work together towards continuously updating the technical skills of teachers who they will then be able to explore the full potential of the educational technology available in their classroom and school. Teachers should be encouraged to share among themselves and colleagues best practices as well as have the time to use and familiarise themselves with educational tools that not only could then use in class but most importantly they could be inspired to use these tools in innovative ways, improvise and discover.

Difficulties arise, however, when an attempt is made to apply professional development to teachers that only focuses on technical competences without pedagogical reasoning (Loveless, 2011). Continuing professional development (of teachers) needs to foster effective pedagogy together with competence in the appropriate use of technology in order for this technology to support and shape learning.

There is no doubt that there has been a great enthusiasm on the transformative potential of educational technology supported by specific research or practice-based evidence. At the same time, somehow educators go on to only make inconsistent use of technology for a number of reasons, such as technical, professional or personal (Selwyn, 2011). Therefore, there is an urgent need to a greater change regarding governmental, political, institutional arrangements and policies in order for school teachers to be able to have the opportunity to become orchestrators of students' use of technology in the classroom. It is not enough to be repeatedly given a number of justifications of the lack of impact such as lack of funding, resourcing, bureaucracy or generally blame teachers for resisting innovation (Selwyn, 2011).

The use of educational technology requires a different teaching approach and in particular, the teacher may become a facilitator or mediator and who in addition to guiding learners through their learning activities, they intervene in order to promote learning (Sacristan et al in Hoyles and Lagrange, 2010).

In order to empower teachers to become orchestrators of students' use of technology in the classroom schools and local authorities have a very important role to play. As discussed in Chapter 5, there is a need to a greater change regarding governmental, political, institutional arrangements and policies in order for school teachers to be able to have the opportunity to become orchestrators of students' use of technology in the classroom.

Teachers should be encouraged to seek continuing professional development and to work in a supportive school environment that encourages teachers to integrate technology in their classroom and to be innovative in its use. Expecting or demanding teachers to use technology without any such support or professional development will not lead to positive outcomes or successful classroom learning environments. University programs for teachers and teachers' education should be also continuously reviewed in order to remain aligned with best practices and informed by the latest educational research.

7.2.3 Matching specific types of learning and learners with specific types of technology

As we saw in Chapter 2 and Chapter 5 it is important to match specific types of learning and learners with specific types of technology. In the empirical study discussed in Chapter 4 the applications used consisted of a comprehensive range of interactive tutorials, the structure of which followed the format of a lesson with an introduction of each topic (could be considered as *Learning through Exploring*), guided practice (*Learning through Practising)* and assessment and a recapitulation of the mathematical concept that had been explored. The assessment was provided in the form of interactive activities and quizzes. Auditory learners could respond to the audio/voiceover while kinaesthetic learners could enjoy direct manipulation such as dragging icons and clicking buttons. Visual learners could enjoy visual animations and illustrations. This experience of course would have been more enhanced, particularly for kinaesthetic learners if there they could interact through gestures. As Mayer (2009) highlights, different people learn in different ways and therefore it is recommended to present information in various formats. New and emerging technologies provide great opportunities in achieving this (e.g. Augmented Reality or embodiment and ubiquitous computing, gesture or tactile interfaces etc). However, the focus should always be on the learning activity and not the technology (Luckin et al, 2012).

There is some evidence (Alessi & Trollip, 2001) that indicates a constructivist approach may work better for learners that have developed well metacognitive skills, as discussed in Chapter 2. In this case, some types of simulations and open-ended learning environments might not be appropriate for learners that might not have developed sufficiently these skills.

Similarly, as discussed in Chapter 2, learners in a connectivist environment need to be able to understand the obscurity and complexity of the networks in order to be able to negotiate their structures and therefore they need high level of critical thinking (Kop, 2011). Computer learning environments that follow this (connectivist) approach may therefore be more appropriate for self-directed learners.

As discussed in Chapter 6 (see 6.3 section), Luckin et al (2012) identify eight approaches to learning (i.e. learning themes): a) Learning from Experts, b) Learning with Others, c) Learning through Making, d) Learning through Exploring, e) Learning through Inquiry, f) Learning through Practising, g) Learning from Assessment and h) Learning in and across Settings. Each of these themes includes a variety of learning activities and there could be links between these different activities within and between the above themes (Luckin et al, 2012).

Interactive educational tabletops offer new affordances for collaborative learning in the classroom. Combined with other technologies (e.g. data captured through various tools, mobile devices, learning analytics, or perhaps ideally with intelligent systems) could provide the teacher with better control and awareness about the classroom performance and consequently with opportunities for formative assessment. Although *Learning from Assessment* appears to be the least popular learning activity as currently there is not a great amount of technical innovation in this area, it appears that educational technology has potential to support formative assessment (Luckin et al, 2012), a very important aspect of learning. As it is highlighted in Chapter 6, the starting point should be identifying the type of learning and then asking whether digital technologies are making this particular type of learning more effective (Luckin et al, 2012).

New technologies can facilitate learning if they are specifically designed for specific kind of activities and domains of knowledge (Kolyda & Bouki, 2006). As Sutherland (2004) emphasises, learning within a subject area involves learning about the discourses, practices and tools related to the specific subject discipline. In a school environment students have the opportunity to participate in alongside their teachers who are more experienced and who can provide support in exploring new subject domains.

Knowledge in mathematics and science appear to share characteristics that may not probably apply in other disciplines. For example, such knowledge is rigorously articulated; it has gained a high degree of consensus and there are detailed representational formalisms to represent such knowledge. Knowledge in history, art or literacy is likely to be different and consequently, these latter forms of knowledge may be learned in fundamentally different ways than the former (Sawyer, 2006).

Knowledge is not just a list of unrelated facts but it is connected and organised around important ideas within a discipline and includes information about the appropriate conditions for applying key concepts and procedures (Bransford et al, 2005). Nowadays, it appears to be great promise and potential for effective education when we consider the possibilities of the new and emerging technologies such as tablet computers, mobile devices, ubiquitous computing and innovative interfaces. Of course there is no doubt that an innovative interface itself will not improve learning but if it is used effectively can enhance and support it.

Educational technology might never realise its full potential if it is merely an add-on to the existing instructionist classroom. Educational researchers, teachers and schools need to work together in order to build carefully designed entire learning environments and particularly technology-enhanced learning environments (not just simply stand-alone computer applications as it has been the case in the past.

In summary, there is a need for better understanding whether and how specific characteristics of a particular type of educational technology could be effective in promoting learning since by expanding our knowledge in this area we create the foundation for further research that could lead to the implementation of systems capable of making a real difference in schooling.

7.2.4 Measuring and assessing what REALLY matters

It is important to develop technologies to assess what matters to learners, rather than what is easy to assess (Noss et al, 2012). Flexibility, enhancing teacher's productivity (with new tools) and inclusion (new technologies could now bring learning to anyone, anywhere, anytime) are also crucial. We need to study how we can design technology that enhances learning and how we can measure that enhancement. We should employ tools to help students as learners make sense of the information overload.

Researching learning at school using the scientific approach is particularly hard (as it became evident during our school study and discussed in Chapter 3 and Chapter 4) as all those involved in schools are embedded in complex and changing networks of social interaction (Berliner, 2002). Children as well as adults involved in those networks have somehow the power to affect each other in various ways and contexts (a new teacher, a new child in the classroom, an illness, problems at home etc) that cannot be controlled. Consequently, these could then affect any experimental school settings since there is a limited degree to which results can be generalised to the wider populations (such as other schools, classrooms etc) i.e. the external validity is low. In order to be able to conduct educational technology research at a school environment it is important to aim towards achieving balance between rigor and relevance or in other words, balance between internal and external validity. How do we analyse change in outcomes? Outcomes such as performance assessments, engagement, academic self-concept or aspirations are much more complex to measure than the assessment scores (Lee, cited in Haertel & Means, 2004).Therefore, there is concern regarding the reliability and validity of other measures (that could be used in order to measure the impact of technology).

As discussed in Chapter 5, although sometimes a school or a local authority in principle appears to encourage the use of educational technology in the classroom, the issue becomes much more complicated when a teacher, school, or district is considering implementing a technology-supported innovation with a different type of learning goal rather than the one of standardised tests (Smith, in Means & Haertel, 2004)**.** Being able to measure and assess what really matters for 21st century and authentic learning requires adapting a more flexible and innovative assessment approach. Is it still important to use the same format of standardised tests? The following section elaborates further on this issue.

7.2.5 Creating Knowledge in the digital age

In the 21st century, both constructivism and connectivism are important in developing knowledge at school (Starkey, 2012). Within the framework of constructivist learning theory students learn to be users (i.e. consumers) of knowledge while through the connectivist learning theory students create knowledge though connections and analysis (Starkey, 2012).

In the digital age, the growth of accessible knowledge is exceptional. Starkey (2012) believes that although students will continue to need to learn subject based concepts (for example, regarding mathematics: trigonometry, numbers, fractions, etc or regarding science: atomic structure, force, circulatory system, etc), skills and methodologies, they will also be making the connections between and across subjects and as a result create knowledge (Starkey, 2012). However, as Harasim (2012) highlights:

> *"Without theoretical or pedagogical frameworks however, there is a high risk of teachers importing or reproducing the content and employing didactic teaching approaches at the expense of encouraging learners to construct knowledge and create their own content. The intent of open content may be excellent, but the implementation requires careful consideration"* (p.172).

School teachers, academics and other members of the computing community (in the UK) looked at how to address growing concerns that the design and delivery of the computing curricula in schools is discouraging students from studying the subject further. This is due to the fact that students are not inspired by what they are taught which is usually basic digital literacy skills, for example, how to use a word-processor or a database. Moreover, the majority of students nowadays own and use advanced and powerful devices (such a smart phones, tablets, etc) in their daily life outside school and therefore going to school to be taught very basic digital literacy skills could completely discourage them. In the relevant report it was highlighted that: "We want our children to understand and play an active role in the digital world that surrounds them, not to be passive consumers of opaque and mysterious technology" (Furber, 2012, p.29). If the above aim is to be fulfilled, education at all levels needs purpose-built technology which will provide learners with the best possible tools to learn and to understand. "Without it, our schools will languish, locked in an analogue mind-set while the rest of society goes digital" (Noss et al, 2012).

Furthermore, in relation to numeracy, according to an independent review of the Primary Curriculum (UK) that was published in 2009 (Department of Education, 2009) there is:

> *"Lack of opportunities to apply and use mathematics, which leads to children not understanding what to do when faced with real-life*

> *mathematical problems even though they know how to 'do sums', is a common concern in Ofsted findings and is reflected in the Williams Mathematics Review: 'The content of the mathematics curriculum in most of the schools surveyed was age-appropriate. However, the majority of students had too few opportunities to use and apply mathematics, to make connections across the different areas of the subject, to extend their reasoning or to use ICT. Higher-attaining students were not always challenged enough in lessons. Links with other subjects were insufficient'"* (p. 68).

This is where educational technology can help by providing opportunities to apply and use mathematics in real-life problems and everyday contexts, to make connections across the different areas of the subject. For example, technology could help students interpreting a wide range of mathematical data (e.g. in graphs, diagrams, spreadsheets) in order to recognise patterns and trends. Nowadays the opportunities for powerful data visualisations are great. It could also help learners applying logic and reasoning in order to predict, plan and test ideas and options. Mathematics in school has often been perceived as hard, too abstract and complex to grasp and understand. Educational technology has the potential to control or simplify such complexity through powerful visualisation, manipulation and modelling that could facilitate understanding as well as offer imaginary worlds where learners could try out ideas (Hoyles & Langrange, 2010) – as was also discussed in Chapter 6.

According to Livingstone (2009), we are currently witnessing a reconfiguration of pre-existing learning activities and opportunities for the majority of children. There are some very limited genuinely new learning opportunities focusing on possibilities of child-oriented digital creativity and on collaborative communication with those who share like-minded interest and expertise. If we succeed in embedding such learning opportunities within the school and curriculum the benefit for all students will be substantial.

7.3 Limitations of the thesis and future work

Our investigation into the relationship between educational technology and student achievement provided considerable evidence that the factors involved turned out to be more complex than was first realised. Future work will aim to investigate this complex relationship by using a larger sample, longitudinal studies and multilevel modelling. Multilevel modelling is a statistical method that “recognises that it is uncommon to be able to assign students in schools randomly to control and experimental groups, or indeed to conduct an experiment that requires an intervention with one group while maintain a control group” (Keeves,1997 as cited in Cohen et al, 2011, p.695).

In addition, any future school study will involve a team of researchers, something that was not possible in this research work as it is quite difficult to conduct such an experimental study as a sole research investigator.

A standard learning sciences research project involves at least a year (or more) in the classroom in advance to researching and designing new educational technology applications and a year (or more) afterwards for data analysis from data gathered from the classroom. As Sawyer (2006) explains, this is a complex, difficult and expensive work and almost impossible for a researcher to do alone. In most cases, such research is conducted by collaborative team of people. Future study of the topic will consider such issues.

To researchers contemplating of conducting such school studies, it is recommended to have other researchers assisting them if possible and most importantly have a well-known institution or organisation (academic, research or industrial) supporting the initial attempt to establish a professional or research relationship in such extent that the study ideally could take place as soon as possible without crucial delays and rescheduling that could happen in a school environment due to unforeseen factors such as quality inspections etc. During the school study involved in this research a number of reschedules and consequently significant delays led to having to postpone the study for over a year. A further consequence of such delay was that the learning materials that it was initially planned to be used in the study (both for treatment and control groups) had to change in order to be aligned with what the students learned during that particular time period (when the study took place) based on the school curriculum. All these aspects had to be considered in order to ensure the validity of this empirical study and all these issues were addressed solely by this thesis' author.

While many areas of this thesis are quite comprehensive there are nevertheless areas that could be enhanced further in the future. For example, future work will aim to study and evaluate emerging technologies (like multi-touch screens, tablet computers, gestural interfaces etc) but most importantly, it will aim to study learning through technology of what matters (i.e. what counts as learning) in the 21st century.

When this research began, there was very little in the research literature about formal learning through powerful mobile devices, personal devices that used touch or gesture as a way to interact, as well as educational technologies that used advanced Artificial Intelligence, Augmented Reality or embodiment and ubiquitous computing. The technology itself has also evolved during this research study and latest innovative technologies call for further research. During the completion of this thesis, a number of research projects that focusing on this area have been taking place and researchers have been increasingly recognising that educational technology will not improve learning on its own.

Future research needs to combine a range of methodologies in order to better understand how educational technology could influence the learning processes.

In recent years there has been a significant debate (Rieber, 2005; Berliner, 2002), regarding the standards of scientific research in education and whether the results from educational technology research could be generalised in real school settings.

> *"Generalisation of the results from educational multimedia research to the 'real world' of learning and performing in schools and the workplace should be viewed with considerable caution. Researchers*

> *have just begun to seriously study educational multimedia, so the time is ripe to question not only the results so far, but also the methods we have used"* (Berliner, 2002, p.551).

One way to deal with the complexity of scientific work in education, due to the fact that "humans in schools are embedded in complex and changing networks of social interaction" (Berliner, 2002, p.19), is to use a practical research methodology such as design-based research - in addition to the scientific methodology (i.e. experimental design) used in our study. This methodology evolved near the beginning of the 21st century (Anderson & Shattuck, 2012) and was designed "by and for educators that seeks to increase the impact, transfer, and translation of education research into improved practice. In addition, it stresses the need for theory building and the development of design principles that guide, inform, and improve both practice and research in educational contexts" (p.16).

This (hybrid) methodology has been labelled with several different terms such as a) design-based research, b) development research, c) design experiments and d) educational design research (Reeves et al, 2011). This methodology could offer us a) a new way to address problems with other methodologies and b) a direct link between research and practice and consequently make educational research much more meaningful (Reeves et al, 2011). It allows technologies to be embedded in a complex and integrated school curriculum (Sawyer, 2006). In addition, it seems to be particularly attractive in primary education contexts and with technological interventions such as what this research study aimed to explore. Nevertheless, further work is required in order to obtain evidence in support of this. We need to embrace complexity and adopt a range of longitudinal research and mixed methods approach (see also relevant discussion in Chapter 3).

Lastly, at the same time we should keep in mind, what Selwyn (2011) emphasises: "the implementation of technology in educational settings is the result of human actions, decision-making, expectations and institutions – not simply the result of the relentless march of educational progress" (p.60).

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Appendix I: Publications

Conference full papers

1. **Kolyda, F.** & Bouki, V. (2013, June). School Essentials for 21st Century Learning: Connect, Collaborate, Create, Contextualise. *Proceedings of Information Society (i-Society), 2013 International Conference*. (In press). IEEE.

2. **Kolyda, F.** & Bouki, V. (2013, June). 21st Century Learning: Exploring the Classroom Experience. In T. Amiel & B. Wilson (Eds.), *Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2013 (EdMedia 2013)*. (In press). AACE.

3. **Kolyda, F.** (2013). Towards Simplifying Learning Systems. Manuscript submitted for publication [In *Proceedings of the 31st ACM International Conference on Design of Communication (SIGDOC '13)*. ACM].

4. **Kolyda, F.** & Bouki, V. (2006). E-Learning within the Classroom: Examining the Complexity before Measuring the Impact. In T. Reeves & S. Yamashita (Eds.), *Proceedings of World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education 2006* (pp. 2114-2121). Chesapeake, VA: AACE.

5. **Kolyda, F.** & Bouki, V. (2005). The Effectiveness of Educational Technology on Children's Learning in a School Environment. In C. Crawford et al. (Eds.), *Proceedings of Society for Information Technology and Teacher Education International Conference 2005* (pp. 898-905). Chesapeake, VA: AACE.

6. **Kolyda, F.** & Bouki, V. (2004). The Effectiveness of Educational CD-ROMs and Web-based Applications in the Classroom. *Proceedings of the 2004 WSEAS International Conference on Engineering Education*, WSEAS.

Journal articles

1. **Kolyda, F.** & Bouki, V. (in press). Exploring What Formal Learning Involves in the Digital Era. *International Journal for e-Learning Security (IJeLS)*, [ISSN 2046-4568].

2. **Kolyda, F.** & Bouki, V. (2004). The Effectiveness of Educational CD-ROMs and Web-based Applications in the Classroom. *WSEAS Transactions on Information Science and Applications*, Vol. 1, Issue. 6, (pp. 1730-1733), [ISSN 1790-0832].

Appendix II

School study results (see also Table 4, p.54)

	Activity	Mean	Standard Deviation	N
Pre-test Score	CD-ROM	2.93	2.086	15
	Online	1.81	1.759	16
	Pen & Paper	2.25	2.023	20
	TOTAL	2.31	1.975	51
Post-test Score	CD-ROM	3.87	1.685	15
	Online	2.88	1.360	16
	Pen & Paper	3.60	1.603	20
	TOTAL	3.45	1.579	51

Table 5: Mean test scores and Standard Deviations before and after each treatment

TOTAL SCORES -2WAY-MIXED ANOVA

General Linear Model

Within-Subjects Factors

Measure: MEASURE_1

TIME	Dependent Variable
1	PRETEST
2	POSTTEST

Between-Subjects Factors

		Value Label	N
activity	1	cd	15
	2	web	16
	3	pen&paper	20

Descriptive Statistics

	activity	Mean	Std. Deviation	N
pretest score	cd	2.93	2.086	15
	web	1.81	1.759	16
	pen&paper	2.25	2.023	20
	Total	2.31	1.975	51
post-test score	cd	3.87	1.685	15
	web	2.88	1.360	16
	pen&paper	3.60	1.603	20
	Total	3.45	1.579	51

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.
TIME	Pillai's Trace	.331	23.723[b]	1.000	48.000	.000
	Wilks' Lambda	.669	23.723[b]	1.000	48.000	.000
	Hotelling's Trace	.494	23.723[b]	1.000	48.000	.000
	Roy's Largest Root	.494	23.723[b]	1.000	48.000	.000
TIME * GROUP	Pillai's Trace	.013	.307[b]	2.000	48.000	.737
	Wilks' Lambda	.987	.307[b]	2.000	48.000	.737
	Hotelling's Trace	.013	.307[b]	2.000	48.000	.737
	Roy's Largest Root	.013	.307[b]	2.000	48.000	.737

Page 1

Multivariate Tests[c]

Effect		Partial Eta Squared	Noncent. Parameter	Observed Power[a]
TIME	Pillai's Trace	.331	23.723	.998
	Wilks' Lambda	.331	23.723	.998
	Hotelling's Trace	.331	23.723	.998
	Roy's Largest Root	.331	23.723	.998
TIME * GROUP	Pillai's Trace	.013	.614	.096
	Wilks' Lambda	.013	.614	.096
	Hotelling's Trace	.013	.614	.096
	Roy's Largest Root	.013	.614	.096

a. Computed using alpha = .05

b. Exact statistic

c.
Design: Intercept+GROUP
Within Subjects Design: TIME

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Mauchly's W	Approx. Chi-Square	df	Sig.
TIME	1.000	.000	0	.

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

Mauchly's Test of Sphericity[b]

Measure: MEASURE_1

Within Subjects Effect	Epsilon[a]		
	Greenhouse -Geisser	Huynh-Feldt	Lower-bound
TIME	1.000	1.000	1.000

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

a. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

b.
Design: Intercept+GROUP
Within Subjects Design: TIME

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
TIME	Sphericity Assumed	31.241	1	31.241	23.723	.000
	Greenhouse-Geisser	31.241	1.000	31.241	23.723	.000
	Huynh-Feldt	31.241	1.000	31.241	23.723	.000
	Lower-bound	31.241	1.000	31.241	23.723	.000
TIME * GROUP	Sphericity Assumed	.809	2	.405	.307	.737
	Greenhouse-Geisser	.809	2.000	.405	.307	.737
	Huynh-Feldt	.809	2.000	.405	.307	.737
	Lower-bound	.809	2.000	.405	.307	.737
Error(TIME)	Sphericity Assumed	63.210	48	1.317		
	Greenhouse-Geisser	63.210	48.000	1.317		
	Huynh-Feldt	63.210	48.000	1.317		
	Lower-bound	63.210	48.000	1.317		

Tests of Within-Subjects Effects

Measure: MEASURE_1

Source		Partial Eta Squared	Noncent. Parameter	Observed Power[a]
TIME	Sphericity Assumed	.331	23.723	.998
	Greenhouse-Geisser	.331	23.723	.998
	Huynh-Feldt	.331	23.723	.998
	Lower-bound	.331	23.723	.998
TIME * GROUP	Sphericity Assumed	.013	.614	.096
	Greenhouse-Geisser	.013	.614	.096
	Huynh-Feldt	.013	.614	.096
	Lower-bound	.013	.614	.096
Error(TIME)	Sphericity Assumed			
	Greenhouse-Geisser			
	Huynh-Feldt			
	Lower-bound			

a. Computed using alpha = .05

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	TIME	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
TIME	Linear	31.241	1	31.241	23.723	.000	.331
TIME * GROUP	Linear	.809	2	.405	.307	.737	.013
Error(TIME)	Linear	63.210	48	1.317			

Page 4

Tests of Within-Subjects Contrasts

Measure: MEASURE_1

Source	TIME	Noncent. Parameter	Observed Power[a]
TIME	Linear	23.723	.998
TIME * GROUP	Linear	.614	.096
Error(TIME)	Linear		

a. Computed using alpha = .05

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	838.853	1	838.853	169.043	.000	.779
GROUP	17.394	2	8.697	1.753	.184	.068
Error	238.194	48	4.962			

Tests of Between-Subjects Effects

Measure: MEASURE_1
Transformed Variable: Average

Source	Noncent. Parameter	Observed Power[a]
Intercept	169.043	1.000
GROUP	3.505	.349
Error		

a. Computed using alpha = .05

Profile Plots

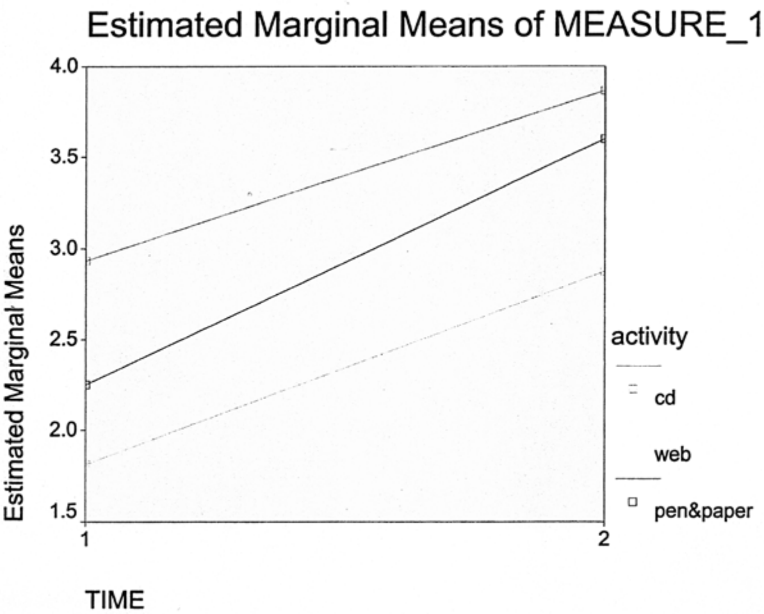


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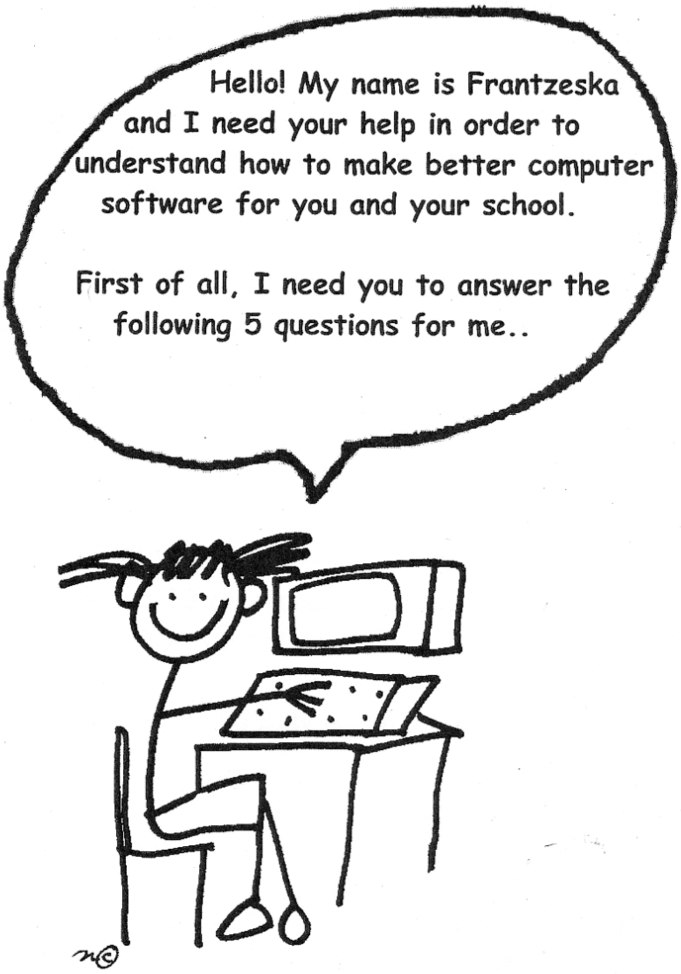
Figure 8: Screens from Juniors application

Sample Pre-test and Post-test

(From study discussed in Chapter 4)



First Name: ....

Last Name: ....

Please answer ALL the questions.

If you don't know the answer to any of the questions, please DO NOT guess the answer.
Simply circle the "I don't know" answer.

1). At the beach club there are 2 boys for every 3 girls.
There are 15 girls.

How many boys are there?

A. 2
B. 3
C. 10
D. None
E. I don't know

2). Billy caught 20 creatures in his fishing net.
1 in every 5 was a crab.

How many crabs did Billy catch?

A. 1
B. 2
C. 4
D. 20
E. I don't know

3). 1 in every 10 ice creams sold at the café is vanilla flavour.
If 50 ice creams sold at the café, how many are vanilla?

A. 1
B. 2
C. 5
D. 10
E. I don't know

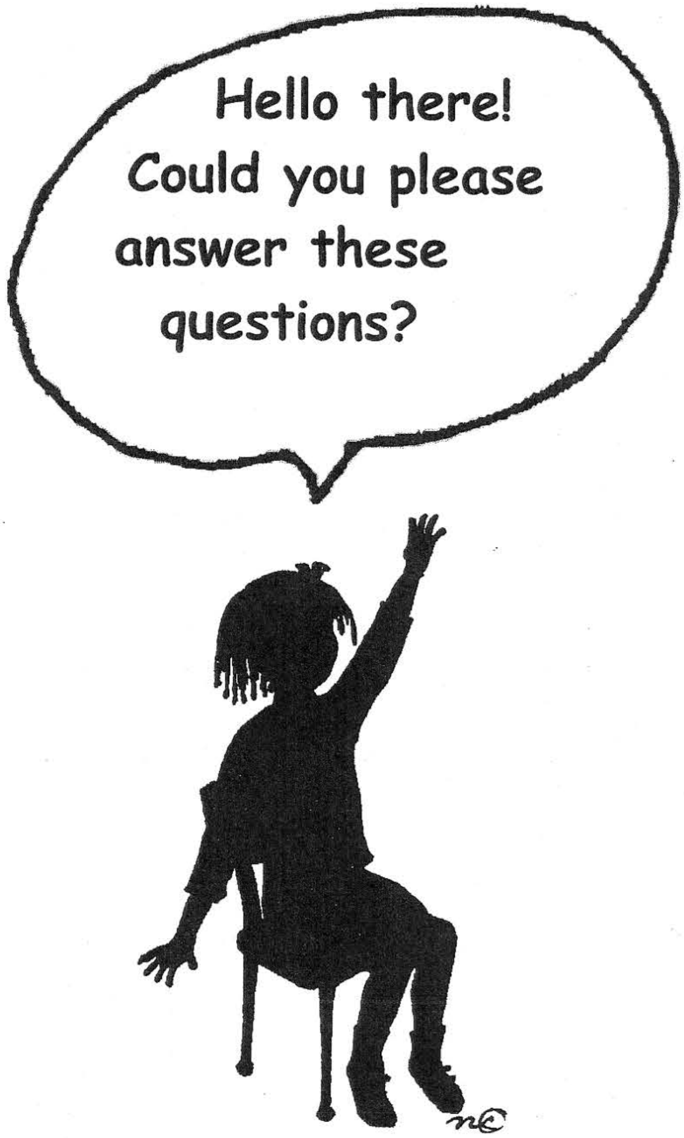
4). On his fishing trip, Captain Cuttlefish catches 60 herring and 15 mackerel. What ratio of the fish are mackerel?

A. 1 in every 3
B. 2 in every 3
C. 1 in every 5
D. 1 in every 4
E. I don't know

5). 1 in every 3 is same as:

A. 2 in every 4
B. 2 in every 6
C. 2 in every 7
D. 2 in every 8
E. I don't know

THANK YOU!

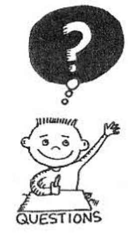


First Name: ....

Last Name: ....

Please answer ALL the questions.

If you don't know the answer to any of the questions,
please DO NOT guess the answer.
Simply circle the "I don't know" answer.



If you have any questions, ask me.

1). 1 in every 3 is same as:

A. 2 in every 4
B. 2 in every 6
C. 2 in every 7
D. 2 in every 8
E. I don't know

2). 1 in every 10 ice creams sold at the café is vanilla flavour.
If 50 ice creams sold at the café, how many are vanilla?

A. 1
B. 2
C. 5
D. 10
E. I don't know

3). At the beach club there are 2 boys for every 3 girls.
There are 15 girls.

How many boys are there?

A. 2
B. 3
C. 10
D. None
E. I don't know

4). Billy caught 20 creatures in his fishing net.
1 in every 5 was a crab.

How many crabs did Billy catch?

A. 1
B. 2
C. 4
D. 20
E. I don't know

5). On his fishing trip, Captain Cuttlefish catches 60 herring and 15 mackerel.
What ratio of the fish are mackerel?

A. 1 in every 3
B. 2 in every 3
C. 1 in every 5
D. 1 in every 4
E. I don't know

THANK YOU!

Appendix III

It would be interesting to look at some recent demographics on children's use of media in the UK presented in Table 5 below:

Children's Use of Media in the UK	[Source: Ofcom, 2011]
Hours spent online at home	*Children aged 8-11 use the Internet for an estimated 8.4 hours in a typical week.*
Social networking activity	*One third (34%) of 8-12s have a profile on sites that require users to register as being 13 or over, up from 25% in 2009. Looking specifically at 10-12 year old Internet users, 47% have such a profile, a rise from 35% in 2009.*
Watching audio-visual content online	*Around one in five (19%) 8-11s who use the internet at home has watched/downloaded TV programmes or films. Two in five 12-15s (38%) have watched/ downloaded TV programmes. Half of all children aged 8-15 who use the Internet at home visit sites like YouTube, with the likelihood of visiting increasing with the age of the child, accounting for just over one third of 8-11s (37%) and two thirds of 12-15s (66%).*
Children's access to, and use of, media (DE households)*	*Children in DE households are less likely than UK children as a whole to have access to the internet, digital television, games consoles and DVRs at home. With lower levels of Internet access in the home, children in DE households are more likely than others to only use the Internet at school (14% vs. 9%).*
* *DE households* can be defined as those households where the chief income earner is either a semi-skilled or unskilled manual worker, including those serving apprenticeships or those on the lowest levels of subsistence including all those dependent upon the state long term, casual workers and those without a regular income.	

Table 6: Children's Use of Media in the UK [Source: Ofcom, 2011]

The next pages provide some further details regarding the ways in which children are accessing the Internet and the number of devices via which they are doing so.

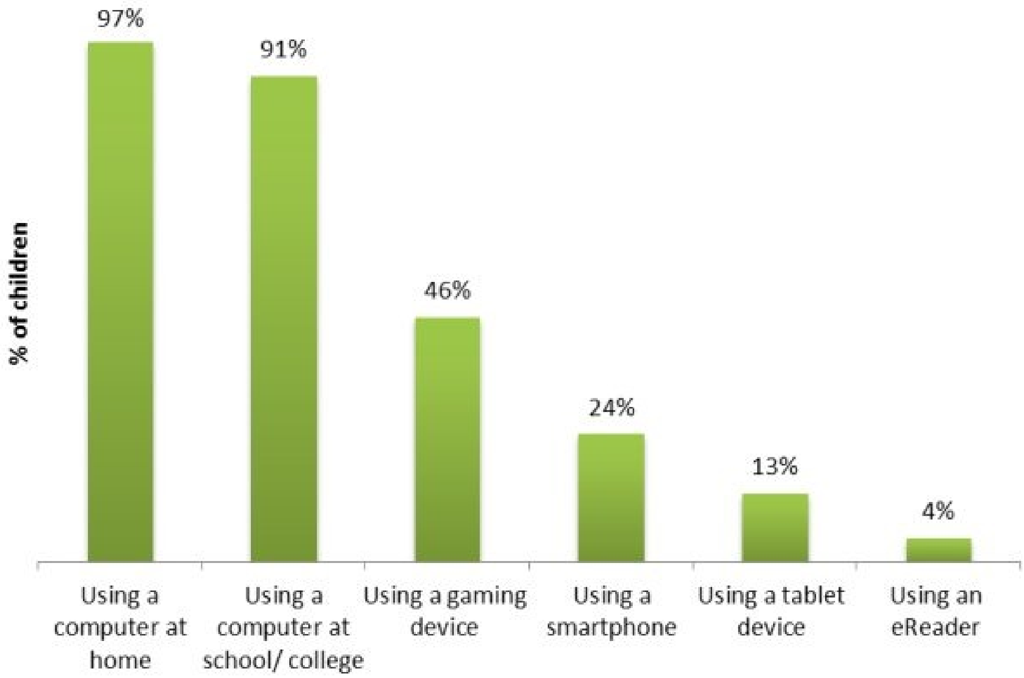


Figure 9: Ways in which children have accessed the Internet, July 2011 - Base: 1,041 Internet users aged 7-12 [Source: CINT/Mintel]

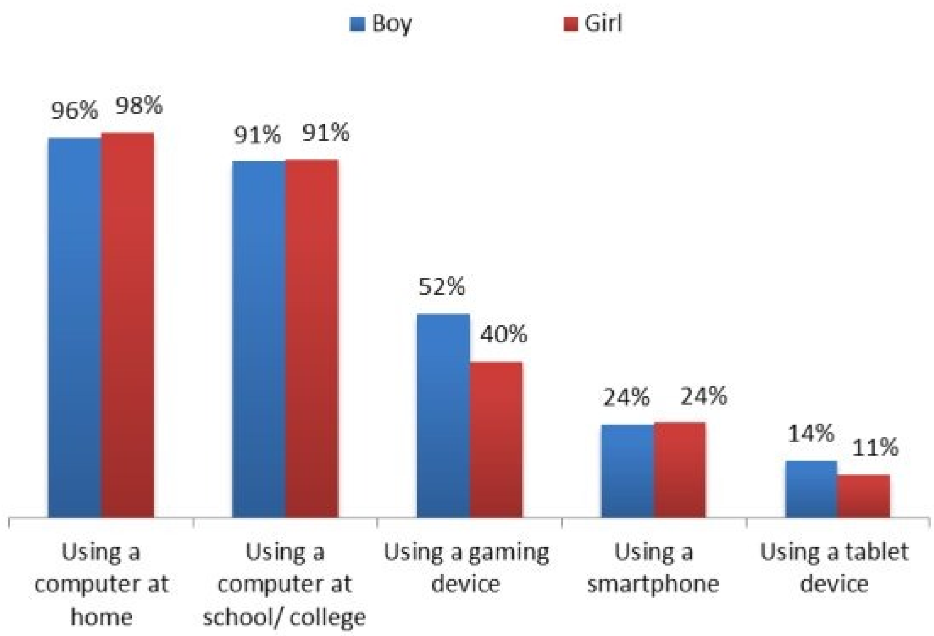


Figure 10: Ways in which children have accessed the Internet, by gender, July 2011 - Base: 1,041 Internet users aged 7-12 [Source: CINT/Mintel]

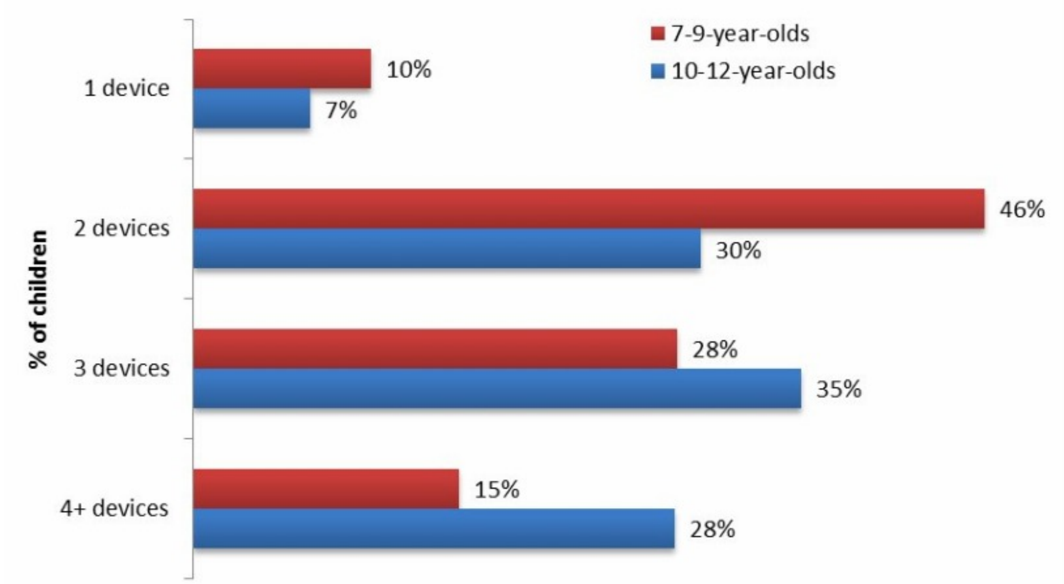


Figure 11: Number of devices via which children have accessed the Internet, by age, July 2011 - Base: 1,041 Internet users aged 7-12 [Source: CINT/Mintel]

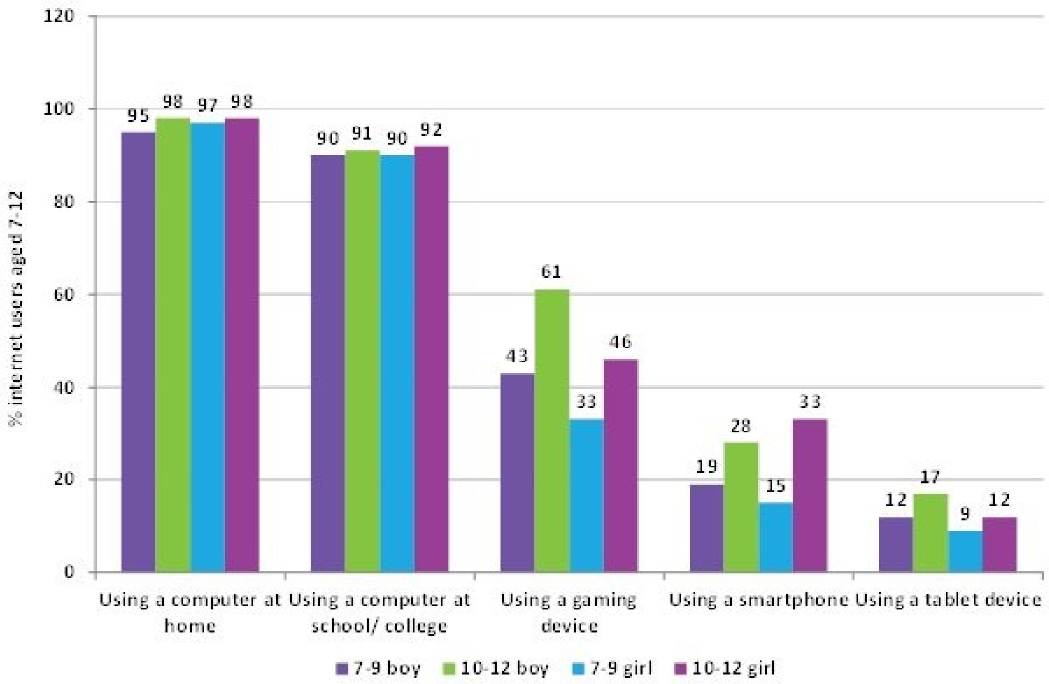
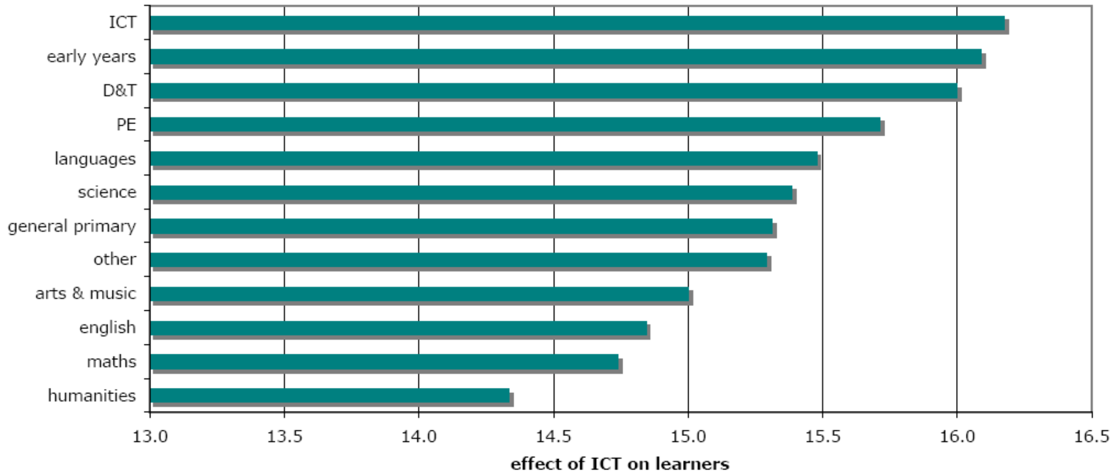


Figure 12: Ways in which children have accessed the Internet in the last 12 months, by age and gender, July 2011 Base: 1,041 Internet users aged 7-12 [Source: CINT/Mintel]



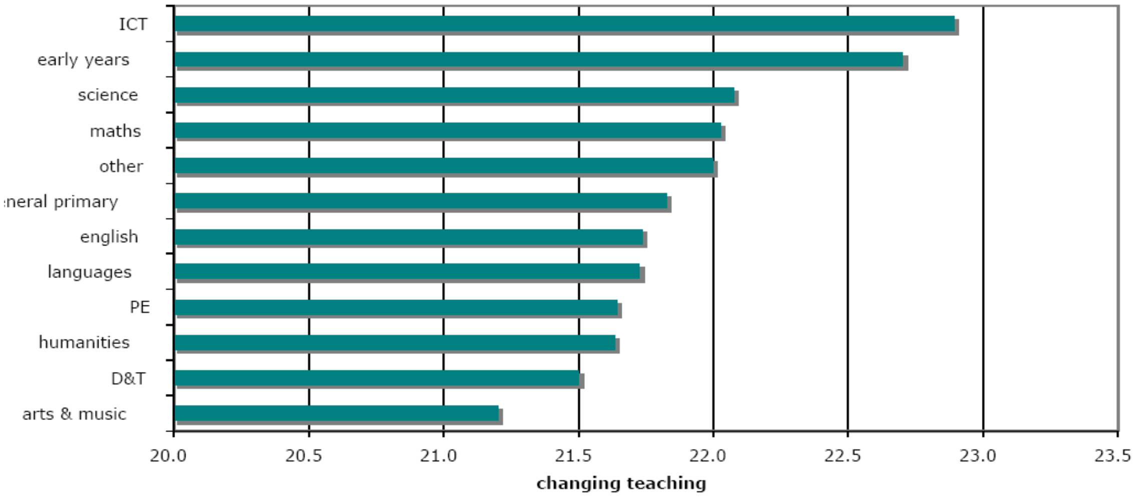


Figure 13: Teachers' responses on the impact of ICT (Becta 2010 report)

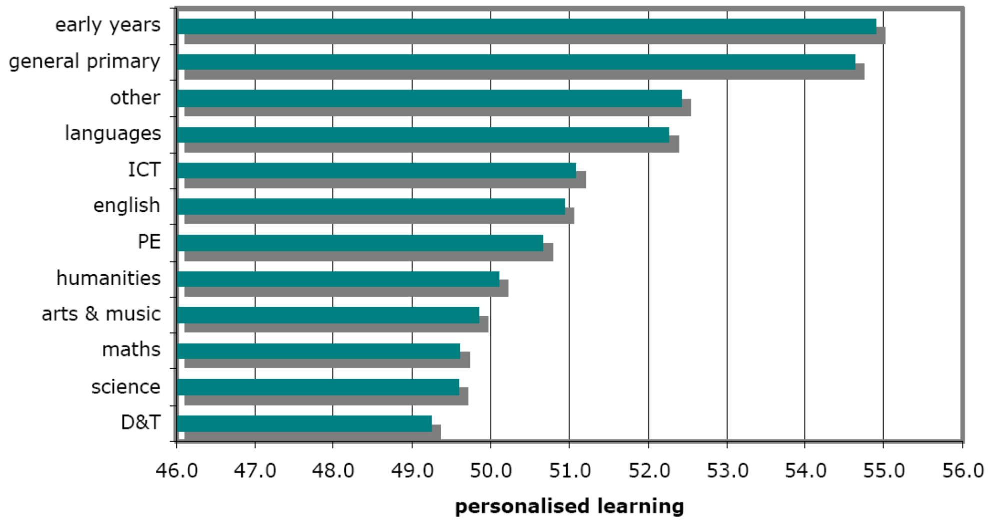


Figure 14: Teachers' responses on personalised learning (Becta 2010 report)