SUPPORTING THE LEARNING OF COMPUTER PROGRAMMING IN AN EARLY YEARS EDUCATION

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A thesis submitted in partial fulfilment of the requirements of Liverpool John Moores University for the degree of Doctor of Philosophy

May 2017

Abstract

The deployment of technology across the globe towards creating efficient learning environments is growing rapidly. In the United Kingdom, for example, the government is investing an enormous amount of money in primary school early years programming lessons. The ideology behind this push is to strengthen the link between the younger generation and the technological growth that will continue to have an ever-increasing impact on their lives and to fuel the pace of innovation. One of the core themes of this area is that of computer programming, which has now become a mandatory subject in early years' education. As a result of this change, many challenges are being faced by teachers and pupils; for example, teachers require more training and young students need appropriate tools that suit their level of learning. Therefore, this research aimed to help facilitate the process of teaching and learning programming for the young generation via the provision of a suitable technologically educational programming system whereby they can develop their programming skills. This proposed system has some pedagogical characteristics that distinguish it from other programming tutoring systems. The proposed system is based on assessment-driven learning whereby pupils are provided with suitable programming learning that fits their appropriate learning levels. Another characteristic of this proposed system is that pupils are learning programming through a deep learning approach, e.g. thinking and analysing how to solve the problem, not like other existing tools which have attempted only to achieve lower learning outcomes, e.g. remembering a concept and then answering multiple-choice questions. Two experimental studies were conducted on pupils from two UK primary schools to evaluate the effectiveness of our proposed system, and the results indicated that pupils found the proposed system helped them to learn programming, as well as they made good progress and they enjoyed what they were learning. Consequently, it can be interpreted from the research findings that an automated teaching and learning programming system that supports the right pedagogical aspects, e.g. assessment-driven learning with the inclusion of game-based learning, would make the learning process more successful and enjoyable for pupils in early years of education.

Acknowledgements

Firstly, I thank God for everything. Then, I would like to express my sincere thanks to my supervisors: Dr Dhiya Al-Jumeily, Dr Abir Hussain and Dr David Lamb for their continuous support of my PhD study, for their motivation, encouragement, and immense knowledge. Their guidance aided me whilst researching and writing this thesis. I would also like to thank all my colleagues at the School of Computing and Mathematical Sciences. I am also indebted to the academic, technician and research staff (both past and present) from the School of Computing and Mathematical Sciences at Liverpool John Moores University for their support throughout this research. Finally, my sincere appreciations go to my grandmother, my parents, my wife, my children and my brothers and sisters, for supporting me emotionally throughout writing this thesis and my life in general.

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Contents

List of Figures

List of Tables

List of Abbreviations

AFL – Assessment for Learning

CS – Curriculum Sequencing

EL – Electronic Learning

GBL – Game-Based Learning

ICT – Information Communication Technology

IT – Information Technology

PSS – Problem-Solving Support

TEL – Technology Enhanced learning

TS – Tutoring System

UK – United Kingdom

CHAPTER 1
INTRODUCTION

1.1 Research Motivation

With the UK government deciding to make 2014/15 the year of ‘Teaching Children Programming’ at the primary school level [1] [2], including recent changes in the information communications technology (ICT) curriculum (e.g. the subject name was changed from ICT to computing [3]), teaching and learning programming became vital for children in UK primary schools.

Furthermore, some researchers from various disciplines, including computer science, psychology, and education, started directing their scientific research to how children can learn and understand programming at this early age [4] [5]. At the same time, both teachers and pupils are facing several challenges in early years education. To clarify this further, teachers require further support and training in how to deliver programming concepts to their pupils in the classrooms. Pupils have an initial lack of understanding of what programming is and what the basic programming constructs are, Sequence, Selection and Iteration. Teaching a large number of novice programmers concepts associated with programming is a challenging process [6] and particularly so with large class sizes and demands on staff; weak students, in particular, may not have the opportunity to get the individual attention required [7]. Consequently, pupils will no doubt need some support from a programming tutoring system that can make the process of learning programming easier as well as encourage them to continue to learn programming. The older ICT courses at secondary and further education levels steered students away from ‘programming’ as it was optional in the curriculum, as well as being termed a so-called ‘hard subject'. Teachers at these levels now have to retrain for an ‘unfamiliar subject’, and also need further support in developing their confidence to teach this technical subject [8]. In addition, existing teaching and learning programming tutoring systems are still lacking and missing some important pedagogical challenges [9] [10].

This research, therefore, focuses on investigation of the challenges associated with those existing tutoring systems as well as programming and its teaching, with the aim of supporting both the teacher and the learner with a suitable system that can aid learners to easily and enjoyably learn programming as well as keep teachers involved in the learning process, such as monitoring their pupils' progress in learning programming using the proposed system.

Truthfully, learning programming in early years education is a challenging process for learners. However, there are many benefits that can be acquired by them. To illustrate this more, we are now living in a world that is controlled by different software, which has been developed by different techniques and different programming environments. More specifically, our telephonic conversations are transmitted over software-controlled networks, and the life of the next generation will be even more online and digital.

Consequently, the promotion of teaching and learning programming in schools is essential for the learning process, as it will teach pupils a new way to think about the things around them and how they work. It will also help them tackle large problems in a sequence of smaller problems, for instance, by breaking those large problems into smaller, more controllable ones, i.e. using the engineering concept of divide and conquer. Teaching pupils programming would enable them to develop a self-defence skill [11], which could protect them from the dangerously connected world with which they are interacting, such as some of the existing content (e.g. photos or textual information) on the web can easily be modified at any time (as this web-based content is created by a programming language), and not all of the information available on the web is accurate and safe.

According to Pesce [11], supporting children to learn programming at an early stage can also be advantageous for their future life. Children who started school in 2015 will graduate around 2030. By then, connectivity, programmability, and interactivity will be ubiquitous [11]. Consequently, teaching these children programming at an early stage would enable them to operate effectively in that world. Teaching pupils programming will lead them to think about various activities around them and help them to understand more and more about the things they will use in their daily life. For further illustration, some examples can be given here from children's daily routines. An electric toothbrush operates for two minutes to ensure that we brush our teeth for the right amount of time, and this is a good example to let children think about how this device works [12]. Another example would be that an oven heats up until it reaches the right temperature; and there are many examples from the wider world that can illustrate programming concepts, e.g. iteration [3].

As pupils can obtain several benefits from learning programming, their teachers can obtain benefits too from teaching programming in the classrooms. Teaching programming in early years education provides an opportunity for school teachers to develop their expertise in computing and to learn programming if they never had the chance earlier. This could also help teachers to make better use of technology and start thinking a bit differently, such as by looking at problems in the same way as a computer scientist [3].

This research was also inspired by including the idea of game-based learning, whereby learners can actively be engaged in learning and enjoy practising programming, such as learning programming through playing a game; similarly, letting children discover the consequences of different activities and to make mistakes in a risk-free situation. By looking at the traditional learning environment, it can be seen learners are not given enough opportunity to repeatedly practise thought processes and programming.

This has motivated the researcher of this study to include this challenge in the proposed programming system that enables learners to continue practising programming until they master the desired learning outcomes. In the proposed system, learners learn programming through the idea of assessment for learning, whereby they are provided with suitable learning materials. This research is also designed to involve learners in learning programming actively, allowing them to learn programming through problem solving as well as rewarding them for their good performance (consideration of different learning theories in relation to how children learn – further information about these theories can be found in Chapter four of this thesis), and this resulted in making them understand and master programming concepts.

1.2 Aims of this Research

Computer programming has now become a mandatory subject in primary schools, as the United Kingdom has mandated this subject into the national curriculum. This introduction has resulted in many challenges that have affected schools, teachers, parents, and pupils. The challenges include teachers requiring further training to teach their pupils programming, as well as needing some appropriate programming tutoring systems that could ease the process of teaching and learning programming for their pupils. Additionally, programming tutoring systems are important technological developments in education. However, while it is undeniable that these systems serve a critical and useful role, particularly with funding pressures on education delivery, they do suffer from several shortcomings surrounding pedagogical rigour and student-centred learning. Therefore, this research provides a solution to address these identified limitations. The stated aims of this research along with its objectives are therefore as follows:

- Specification and Identification of the challenges associated with teaching and learning programming.
- Integration of the pedagogy of 'assessment for learning' into a programming tutoring system.
- Incorporation of the approach of game-based learning in the proposed system, thereby entertaining and engaging pupils via learning programming through playing a game as well as making the learning process more enjoyable for them.
- Facilitation of a personalised learning environment thereby considering the principle of individual differences among pupils and accordingly producing suitable programming materials for a range of levels.

- Cooperation in the development process of the proposed system with other researchers and developers through the use of an agile software development model.

- Testing the proposed system with pupils from two UK primary schools, and analysing the outcomes of their performance in learning programming, which is one of the objectives of this research.

- Comparison of learning programming through the proposed system with two other different methods of learning programming, the traditional method and Scratch as another objective related to this research.

Further to the above-defined points, this research also aims to answer the following questions, which were posed by the idea of teaching children programming in early years education as well as the development of the proposed system for supporting pupils to learn programming successfully:

1. What are the impacts of the proposed system on pupils' programming performance and enjoyment in learning programming from the proposed system?

2. To what extent do UK teachers agree that teaching pupils programming in early years education would be a helpful step and could positively affect their pupils' learning?

1.3 Contribution to Current Research

The research in this thesis is related to the field of technology enhanced learning (TEL) in supporting young students to learn computer programming effectively in early years education. The contribution of this research has been driven by certain pedagogical challenges [13] [5] which were identified through a wide literature review that the researcher conducted of previous studies relevant to this PhD study. The details of those challenges and how this research contributes in addressing them are discussed in this section.

The principle of individual differences among pupils was one of the pedagogical challenges that had not been addressed in previous studies. This is because the idea of assessment for learning was missing from existing programming tutoring systems, as well as there is no consideration of pupils' different learning levels, which led to the recognition of a need for a personalised learning environment.

However, the proposed system incorporates consideration of the fact that different pupils have different learning levels, such that some of them need to begin learning from the basic level while others need to learn at a higher level, and all need learning material suitable to their current level. With regard to how the proposed system has tackled this pedagogical challenge, three learning levels were created: basic level, intermediate level, and advanced level. A list of different learning materials is provided for each level. As the pedagogy of assessment for learning is embedded into the proposed system, the proposed system can recognise the right level for each pupil by testing them before learning, during learning and after learning. According to a pupil's performance or progression, he or she will be automatically upgraded to the next learning level and work with more complex problems. Moreover, the number of attempts made by pupils in solving a problem is automatically calculated by the proposed system and stored in their models, which can also be viewed later on by the teacher. For illustration, there is a difference between a pupil who solves the problem at the first attempt and one who solves it at the second or third attempt. According to the findings of this thesis, the proposed system (assessment-driven learning) was found an appropriate system for pupils to learn programming as it considered their different learning levels and this assisted them in making progress in learning.

Another pedagogical challenge that had not been looked at in the literature review is linking the performance of pupils with a high-level desired learning outcome where pupils are learning programming through the approach of deep learning, e.g. thinking about and analysing how to solve the problem [14]. In addition, this proposed system differs from existing programming tutoring systems that only focus on lower learning outcomes related to a surface-learning approach, e.g. remembering a definition or answering a multiple-choice question [15] [16]. This proposed system has been designed to go beyond lower learning outcomes in promoting pupils' analytical skills and letting them think about, analyse and differentiate between programming concepts in solving a problem, as programming cannot be learnt well by memorising concepts. In relation to how the proposed system has addressed this particular pedagogical challenge, some examples can be provided in this section. The system checks if a pupil has achieved and applied the right programming concept in solving a problem correctly or not (the first considered learning outcome is: can a pupil apply the programming concept that they were taught by the proposed system? This is related to the Apply Category). This proposed system can also detect if a pupil is able to differentiate between the concept of Iteration and that of Sequence when he/she is trying to solve a problem (the second learning outcome is: can a pupil distinguish between the programming concepts that they learnt through the proposed system? This is related to the Analyse Category). The system can also identify whether a pupil is able to solve a problem with an optimal solution, such as using Iteration instead of sequencing (can a pupil decide whether it is better to use an Iteration or something else in the given problem? This is related to the Evaluate Category). These high-level learning outcomes are linked with the three learning levels that had been created; furthermore, each learning level in the proposed system is assigned a high-level desired learning outcome that pupils needed to achieve. For example, the basic-level materials were related to the apply learning outcome, which means if a pupil was able to apply the concept of Iteration correctly, he/she would be able to move to the next level (intermediate) and aim to achieve the next high-level learning outcome (Analyse Category), and so on and so forth. By the end, it was expected that pupils would be able to achieve all three desired high-level learning outcomes.

As this particular obstacle (linking the performance of pupils with a high-level desired learning outcome) is considered in the proposed system, teachers can also identify how their pupils are performing in learning programming and what they have achieved by looking at the high-level desired learning outcomes.

A further issue taken into consideration is that of learners' engagement in learning such a difficult and practical subject as 'programming' while they are still young. Current studies have shown that there is a lack of learner engagement in learning computer programming, such as large numbers of learners had discontinued programming courses as they found it a very difficult subject and could not engage with it [17] [18].

With respect to tackling this challenge, the researcher of this study conducted some investigations into diverse areas, comprising theories about how children learn (more information about these learning theories is provided in Chapter two of this thesis) and game-based learning (further information is also included in Chapter four of this thesis). At the completion of this investigation, it was planned to select the behaviourism and constructivism learning theories whereby learners can gain information and learn programming from the proposed system. As a result of considering the behaviourism learning theory in relation to the proposed system, it was decided that learners would learn programming and receive a reward (collecting stars) when they are performing well, such as solving a problem with the use of a programming concept (iteration) correctly along the way and avoiding 'deaths' (for instance solving a problem wrongly).

With reference to the constructivism learning theory, which is the second learning theory considered in the proposed system, the learning materials are in the form of problem solving and enabling learners to learn programming by solving a programming task. The inclusion of this learning theory resulted in learners being actively involved in the learning process and finding the learning part enjoyable.

These two learning theories were integrated with game-based learning, as they were aimed to support learners to be more focused on learning and achieving the learning part. This is because the proposed system is designed to be a more serious system (not only for playing a game or enjoyment) for supporting pupils to learn programming in early years education, whereas the inclusion of gaming was only for the purpose of increasing the engagement part and letting learners have fun when learning programming using the proposed system. According to the results of the two experimental studies conducted with pupils from two UK primary schools (detailed information is provided in Chapter six of this thesis), pupils successfully learnt programming through the proposed system, as well as they enjoyed what they are learning. Hence, a combination of both of the described learning theories with game-based learning resulted in addressing the issue of lack of engagement while learning programming.

1.4 Overview of the Thesis

The remainder of this thesis is organised as follows.

Chapter two is designed to review and discuss various topics related to the area of teaching children programming in early years education. It is also intended to identify the challenges that are associated with existing systems for teaching and learning programming.

Chapter three is concerned with the area of learning styles and discusses the limitations that exist in learning styles and their educational programming applications.

Chapter four provides a detailed illustration of game-based learning for teaching children programming in early years education. It includes a detailed explanation of our proposed framework with a comparison between it and the Scratch programming system. Clarification of game-based learning approaches and how they were involved in the development of the proposed system is also included in this chapter. A discussion of the importance of game-based learning in early years education is provided as well as a thorough explanation of the chosen software development model (Agile) for the development of the proposed system. A thorough explanation of requirements gathering process, design process, implementation process and testing of the proposed system was included in this chapter.

Chapter five provides a description of the methodology of this research. This is followed by an overview of the pilot study which was carried out on pupils from two UK primary schools. An explanation of the dependent and independent variables in this research is also presented in this chapter.

Chapter six provides detailed information of the statistical results of the two empirical studies which were implemented on a total of 93 learners from two UK primary schools: 41 in the initial experimentation based in Manchester (who used the proposed system to learn programming) and 52 in the other experiment (who were distributed into three sets: Experimental, Traditional, and Scratch) based in Liverpool, and they learnt through one of three different learning techniques. Further details about the reasons for carrying out these two empirical studies on different pupils based in different schools are provided in this chapter, along with a comparison among all the learners who participated in the two empirical studies, and a discussion of the entire results.

Chapter seven provides an overview of the concluded study, restating what the research intended to achieve. A summary of the thesis outcomes emphasising the significance of this research's contribution is provided in this chapter. Finally, some ideas for future work are presented.

CHAPTER 2

TEACHING AND LEARNING PROGRAMMING IN EARLY YEARS EDUCATION

2.1 Introduction

This chapter is intended to review and illustrate the progress of different topics that are considered to be of relevance to this research. In this chapter, the concept of teaching school children programming at an early age will be studied. This will be followed by an overview of the educational challenges that are associated with some existing applications. Pedagogical concepts are also covered in this chapter.

2.2 Learning Theories in Early Years Education

This section is intended to include a discussion of relevant theories which underpin the research study. There are several theories available to describe how pupils learn [19] [20]. Learning can be explained as a way of obtaining new or existing information. However, it is not as simple as this, which is why there are several models or theories about the same process of learning. These theories include behaviourism, constructivism and others [19] [20].

Behaviourism can be described as a learning theory that depends on the response to stimuli [21]. This theory is simply related to how to shape the learner’s behaviour. To illustrate this particular theory, the use of positive reinforcement (rewards) could help pupils to learn more from their teachers in the classroom [21]. It could also increase the possibility that the right behaviour would reoccur, whereas the use of negative reinforcement (punishment) when an undesired behaviour is performed could decrease the possibility of the wrong behaviour reoccurring [21].

When teaching children programming, this particular theory (Behaviourism) can be incorporated into a technological programming tool by rewarding children for performing well when learning programming, while not giving them rewards when they have not made any achievements. More importantly, this theory was implemented in the proposed programming tutoring system, and it worked effectively for children as it was mixed with the idea of “game-based learning” as well as keeping them motivated and focused on the learning. More information about the proposed system and game-based learning is provided in Chapter four of this thesis.

Constructivism can be explained as one of the learning theories where a learner is learning concepts by doing, and this theory would benefit children in the learning process [22]. Children learn more and enjoy learning when they are actively involved in the learning part. Learning works best when it focuses on thinking and understanding not memorising. This approach could help learners to develop their problem-solving skills [22].

When teaching children programming, this theory can be included by making the learning into a form of problem solving and letting children learn programming concepts through solving a problem. In the proposed system, children were learning programming concepts such as iteration by having to use their analytical skills to solve a problem.

2.2.1 Description of Programming in Early Years Education

The purpose of this section is to introduce relevant terminology and give definitions to explain how terms are being used in the context of this research. There are several definitions for the concept of programming. One of these definitions considers programming as a form of problem solving. This involves knowing where the problem is (locating the problem), analysing the problem, designing the solution, writing the actual code and then testing the solution [23]. There are various levels of a programming language [24]. There is a machine language that is known as a low-level programming language [24]. There are also high-level programming languages, which include C, Java, C++ and Visual Basic, and these high-level languages are converted into a low-level programming language. In addition, there are some other programming languages, “script languages", which are interpreted by another application. For example, JavaScript is used in web browsers in order to interpret a program [24]. With regard to the topic of this research, the focus will be on a programming language that can be used with primary school-level pupils, to support them to learn computer programming interactively and with enjoyment (learning programming through playing a game). This is an important subject, since the UK government decided to make 2014 the year of programming for children in primary schools [2], and children today are born digitally native and use technological tools such as smart phones and smart tablets before they even learn to talk [2]. With this new change in the computing subject and generally in how children learn about life, there is the need for both pupils and teachers to be well prepared in order to take on this new challenge. Teachers will require some support and training in how to deliver programming concepts to their young students. Pupils will also need some help from their teachers in the classroom as well as a tool that can support their learning process both at home and in the classroom.

2.2.2 The Importance of Programming in Early Years Education

This section is designed to provide supporting evidence for the issue which this research is addressing. Learning programming can be difficult for students at different levels of learning – for example, whether they are university students or primary school pupils. To clarify this point, novice programmers who are, for instance, at the college stage could face some challenges, including lack of knowledge of the basics of programming including iteration, if statements, etc. Another challenge could be that novice programmers have not been practically taught how to program in their previous studies, for example, at primary school [25]. Consequently, educationalists and parents need to pay attention to these issues and work together to find an optimal solution. One of the possible solutions would be to start teaching programming at primary school level and encourage pupils to learn programming at an early age, rather than leaving them until they reach university level. However, when teaching children programming, it is important to consider their capabilities (every child is different). Some children can read and write years ahead of the average for their age group, so learning programming could be easier for them than for others. Consequently, it is important to consider the idea of assessment-driven learning in the development of a technological programming tool aimed to help children to learn programming.

There are some existing programming tools for teaching children programming such as Scratch [26], which is a graphical programming tool aimed to help in the learning of programming skills. However, these tools still have some pedagogical challenges. One of these challenges is that the idea of assessment for learning is not considered. The idea of cooperative learning between teachers and students is missing from these available tools. Therefore, the aims of this research are to tackle some of these issues and develop an automated tutoring system for teaching pupils programming with the inclusion of game-based learning to keep children's attention focused on learning. Additionally, the planned system was designed for children aged 8 to 11. One of the reasons for targeting pupils at this early age is to simplify the process of learning to program for them as early as possible. For instance, nowadays children have technology on their hands from an early age. According to Bates [27], children are capable of using tablets and mobiles at a young age, with 70% of children becoming proficient in the use of mobiles and tablets by primary school age. By the age of nine, a child has sent over 100 texts and 85 emails [27].

Another aim of the research is to enable children to understand the fundamental aspects of programming. In the planned system, pupils can gain access to the learning environment via various options. One of the given choices is to access learning materials through some smart devices. Another choice is to learn through the web with some interactive applications. Using this proposed learning system in a primary school means that the children can acquire many benefits. One of the main benefits would be that they will be able to think logically, solve problems and gain many important skills (developing their computational thinking). Additionally, a coding skill is similar to a writing skill, where children can write down their thoughts, draw diagrams and organise their ideas and so on [28].

2.2.3 Some Educational Programming Tools for Pupils

Within the content of this section, there is a description of related research in the field and illustration of how this undertaken research improves and addresses a gap in work in the field. Educational programming languages/tools are designed as learning tools for children; it should be noted that they are not used to develop real-world work applications. Although there are some existing tools for teaching children how to program [29] [26] [30], there are still some pedagogical challenges in regard to these existing applications. Table 2.1 shows some of the existing tools that teach children the concept of programming.

Table 2.1: Existing Programming Teaching Tools for Children

System	Overview	Date	Shortcoming
Logo	It is an educational tool that was used to teach learners programming concepts related to Lisp.	1967	The idea of assessment for learning is missing from those tools. There is no consideration of the learners' pre-knowledge of programming. Monitoring the progress of learners is also missing from these programming tools.
RoboMind	It is an instructive programming environment that would allow children to learn some of the programming concepts.	2005	
Scratch	It is a graphical programming tool that can be used by pupils to make animated stories, games and so on.	2006	

"Logo" is the first example of an educational programming tool. It was used to teach the programming concepts related to Lisp [26].

“RoboMind” is another educational programming environment. It enables novices to learn the basics of computer science. This programming environment offers a simple scripting language (a set of rules) and the movement of the robot can be controlled (forward-backward) [30].

“Scratch” is another learning programming tool that can be used by children to create interactive stories, games, animation and share their designs with one another [26].

These educational programming tools are useful to teach children the concepts of programming. However, they require further improvements, for example, the idea of assessment for learning is not included. It is important that any good educational programming system considers how to monitor the children’s progress, as this will help these learners to know their programming levels or progress while they are learning (assessment-driven learning). Hence, this research focuses on the important pedagogical limitations in the earlier systems in order to create a new, improved tutoring system. With cooperation from colleagues, this research developed an educational programming tutoring system for children to learn the fundamental aspects of programming, and tested this system in a UK primary school as well as comparing it to an existing programming system, “Scratch”. Detailed information about these two programming systems can be found in Chapter four, whilst the results of this comparison can be seen in Chapter six of this thesis.

2.2.4 Tutoring Systems in Education

This section illustrates relevant terminology and provides historical discussion to explain the concept of tutoring systems and how it is being used in education as well as identifying some of their challenges which related to the same domain of this research (Programming domain). There are numerous definitions for the term Tutoring System (TS). The most basic description is that it is computer software designed for use in education and to support learners in the learning process [31]. Nwana suggests that a TS is a computer program that can improve the performance of teachers in the classroom, with regard to factors such as how they teach, and how to enhance teaching for specific students [32]. Researchers have argued that a Tutoring System can be considered adaptive if its design satisfies one of the following: Curriculum Sequencing (CS), Solution Analysis (SA), and Problem-Solving Support (PSS) [32] [33]. Curriculum Sequencing (CS) means providing the student with the most suitable, individually planned sequence of topics to learn [33]. Solution Analysis (SA) involves an automated check of the student's solution and provides feedback on the work while updating his/her model. Problem-Solving Support (PSS) gives the student help at each step when he/she is working on exercises or solving problems.

Recent work has begun to look at some of the aspects of TSs, such as how the learning plan can be structured and adapted based on the student's need. However, such existing work, while it focuses on adaptive learning, does not identify the architecture or method for continual adaptation of a student's learning experience (Assessment for learning). More specifically, in the domain of teaching and learning programming, there is no programming-centric adaptive learning support system with curriculum sequencing, solution analysis or even fully integrated problem-solving support. Therefore, it is important for interested educational researchers to focus on some of these issues. This could be, for instance, by conducting further investigations on a learning support system, centred on an adaptive learning approach – to support higher education students to learn more about programming and reduce some of their learning difficulties, as they have not had the chance to learn programming during their early schooling. Some TS applications have been developed to supplement "expert system knowledge", and used to provide or support companies in traditional expert-system fields such as medicine and engineering. Several such example systems are shown in Table 2.2.

Table 2.2: TS System Comparison Feature Matrix

System	Notes	Date	CS	ISA	PSS
Algebrain	Maths system guides students through equation solution process.	1999	No	No	Yes
COMET	Clinical reasoning automated tutorial system.	2007	No	Yes	Yes
ZOSMAT	Maths tutoring system, dynamic content delivery based on limited student model.	2009	Yes	No	No

“Algebrain” [34] is the first system considered, and it is one of the older systems described in this section. It increases the classroom learner experience by providing an environment for experimentation with algebraic equations. Beyond simply solving equations, the software guides the student through the process of solving the equation, providing hints and descriptions for each step of the solution, along with immediate feedback on the steps taken [34]. However, this system does not consider the concept of assessment for learning. Moreover, Brusilovsky [20] reported that the developers of “Algebrain” had not implemented their system as they were required to include some additional development tools [33].

“COMET” [35] is designed to help medical students develop and practise clinical reasoning skills. It is used by student-tutor groups and provides guided tutorial sessions working through clinical hypotheses. It identifies students who perform well in certain scenarios and those likely to do so in future scenarios. Required learning outcomes are identified when students are incapable of forming correct steps in a hypothesis based on a presented scenario. However, there are some drawbacks to this system. Some of these are as follows: this system does not measure the prior knowledge of the learner, and "COMET" has no language processing capabilities (e.g. no chatting between users).

“ZOSMAT” [36] is a mathematics tutoring system that aims to help students learn some aspects of maths. The “ZOSMAT” architecture contains modules including a Student Model, Question Bank, and other components. At a high level, the Student Model records student-specific information [36]. This educational application can be a helpful tool for motivating learners to learn the subject of mathematics. However, it has some shortcomings, such as it is not sophisticated enough to improve student learning efficiency (no clarification for the students about how much progress they have made in achieving the learning objective/learning outcomes). Additionally, there is an issue with the assessment.

Given the above, it can be seen that there is a real demand for a proper educational system in the education sector, in both higher education and primary education, which can, for instance, consider the concept of assessment for learning and aim to help in improving the learner’s progress.

2.3 Teaching, Learning & Assessment

The two sub-sections (2.3.1 & 2.3.2) are intended to focus on the pedagogical requirements of a software system that can personalise the learning process to each student’s needs.

2.3.1 Taxonomy of Education

Bloom's taxonomy [37] features in pedagogical science as a classification of educational goals that can help teachers and lecturers in structuring their approach to learning. This can be reflected in the classroom, such as how to prepare and deliver lectures to students; how to structure and write exam questions; how to assess students; and how to encourage students to increase their attainment levels. Furthermore, Bloom has divided the educational goals into three domains: Cognitive, Affective and Psychomotor [37] [38]. In 2001, Krathwohl et al. [38] revised Bloom’s taxonomy and made some changes in the cognitive domain (Table 2.3). They updated the six levels in the taxonomy based on feedback from teaching practitioners and their interactions with students, from lowest to highest, as Remembering, Understanding, Applying, Analysing, Evaluating and Creating [38]. Thompson et al. [28] also developed Bloom’s taxonomy, citing the difficulties in applying the levels of cognition to software engineering and programming; in their work, the categories were explained using examples specific to programming [39].

Table 2.3: Bloom’s Categories and their Uses in Teaching Programming

Bloom’s Categories	**Software Engineering Derivative**
Remember	Can the student remember the syntax of e.g. an iteration?
Understand	Can the student explain the operation of e.g. an iteration?
Apply	Can the student implement e.g. iteration?
Analyse	Can the student differentiate between iteration and sequencing?
Evaluate	Can the student decide whether it is better to use sequencing or iteration in the given question?
Create	Can the student make novel software?

Applying Bloom’s categories within a technological framework could tremendously benefit both students and instructors [15]. To illustrate this, using “Clickers” [16] technology (student response systems that are small, hand-held keypads, which allow students to provide an immediate response) in the classroom would lead to increase student performance and engagement in learning [16]. It would also enable instructors to see automatically the students' answers and observe whether they have understood the given outcome or not [16]. Cosgrove et al. [30] found that non-majors biology students performed better on the following types of question: knowledge; comprehension; and application/analysis, and retained knowledge from clicker-based exam questions. However, biology students found that the clicker tool is not a helpful assessment method [16]. Nevertheless, a clicker tool is good 'on-the-fly' assessment technology, but it can only consider multiple-choice questions, and students can easily guess the answers to these [40]. Consequently, this educational issue needs to be taken into consideration and a better technological tool needs to be designed that can support other types of question apart from multiple-choice ones. The proposed system aimed to solve this challenge by including various types of question, which enabled pupils to learn programming by doing, and to assess them in an appropriate way instead of using a multiple-choice assessment. Furthermore, it was intended to make the planned system an automated tool that could be used for teaching, learning and assessment to support pupils in learning programming. Additionally, this proposed system differed from the existing systems by including assessment for learning (AfL) during the learning process. Previous studies have mentioned that including assessment for high-level categories of Bloom's taxonomy or any other recommended educational taxonomies within an educational tool would be a significant challenge [15] [16]. This could be because high-level learning outcomes (Analyse-Evaluate-Create) cannot be properly measured by multiple-choice questions, unlike lower-level learning outcomes [16]. Consequently, there is a real demand for an educational tool that assesses those high-level learning outcomes, or at least some of them.

2.3.2 Assessment and Feedback

Assessment is an activity that teachers can use to evaluate the performance of their students, and indeed, that students can use to evaluate their own performance. However, it is important to establish, before setting or performing an assessment, the purpose of the assessment. This is because there are several types of assessment and teachers need to choose the one that is most suitable for their students and the learning outcomes being evaluated [41]. In this section, several assessment types considered particularly relevant to this work will be described: formative, summative, diagnostic, and finally continuous assessment. Formative assessment is a positive form as it will help both teachers and students to see the shortcomings in submitted work, enabling teachers to provide helpful feedback so that students can focus on their weak areas to make real progress in their study. At the same time, it will help teachers to measure the performance of a particular student cohort [42] [43]. On the other hand, a summative assessment is normally carried out at the end of a course and provides a quantitative measure of performance (such as a grade or mark) [42]. Diagnostic assessment is performed at the start of a learning plan, and it is mainly used to identify the learner's current understanding and attainment levels, and, in some cases, identify a student's learning difficulties [41]. Continuous assessment may occur several times while a student is studying; it provides an on-going measure of student performance and can be used to direct or guide future learning [44].

Teachers could find it a challenging process to assess large numbers of students in the classroom [45]. However, this could be solved by developing an automated assessment tool, although many issues would need to be addressed and solved. For example, as students have diverse capabilities in understanding and answering dissimilar types of questions, therefore, it is difficult to build a system that assesses each individual's various abilities, and this is because high-level learning outcomes (Analyse-Evaluate-Create) cannot be simply measured by multiple-choice questions, unlike lower-level learning outcomes [15] [16]. According to Christopher et al. [46], automated assessments would not be able to deal with more complex questions, for example, assessment of high-level learning outcomes, as they are not as flexible as the human brain. Automated essay scoring is another type of automated assessment; it is computerised software designed to assign a grade for the given essay. Furthermore, this automated technology could reduce teachers' effort in marking their students' work [47]. However, previous studies have mentioned several drawbacks about this automated tool; for instance, it does not provide individualised feedback for a learner, and it only provides a simple grade based on mathematical models built on organisational, syntactic, and mechanical aspects of writing [48].

Further details about the assessment and its forms and how they were included in the proposed system can be found in Chapter four of this thesis.

2.4 Summary of the Chapter

Teaching programming to pupils in primary education has both costs and benefits. One of the benefits would be providing these young learners with a better understanding of the fundamental aspects of programming before they reach college/university level. The costs would include additional training for primary school teachers in how to deliver the aspects of programming in a way that suits young students, as well as they would need support from a technological tool that engages the students while they are learning programming. Consequently, this chapter has discussed issues surrounding educational programming tools and studied some of the pedagogical issues to help determine failings and incompleteness in current technological teaching and learning tools for learners. It has also provided a detailed discussion of the importance of teaching pupils programming during their early schooling.

CHAPTER 3
LEARNING STYLES IN PROGRAMMING EDUCATION

3.1 Introduction

This chapter discusses the challenges of educational applications which are used in the teaching and learning programming domain. A detailed overview of the importance of considering learning styles in education. A variety of learning style applications used for teaching programming are also presented here, and their strengths and weaknesses in teaching and learning are highlighted.

3.2 Learning Styles

This section is intended to provide a detailed discussion of a relevant concept (learning styles) which support this research. Rutherfoord et al. [49] defined learning styles as the characteristic ways in which learners learn, understand and obtain information. Some researchers define a learning style as an approach for learning a concept. This is because each learner has a different preferred approach to understanding or learning things. Some learners prefer to – and perform better – when learning visually, while others may prefer to learn aurally [50] [49]. Considering the learning styles of all students in the traditional classroom can be a challenging issue for teachers, who have only a limited time to prepare their materials and deliver their classes, lectures and tutorials [51]. Established pedagogical theory specifies several learning style models [52], including Kolb's Experiential Learning Theory [50], the VARK Model [50][53], Felder-Silverman Learning/Teaching Style Model [50] and the Dunn and Dunn Learning Style Model [50]. Moreover, each of these models has different descriptions for the learning styles [52]. The following subsection discusses the VARK model in more detail.

3.2.1 The VARK Learning Style Model

The acronym VARK stands for Visual (V), Aural (A), Read/Write (R), and Kinaesthetic (K). Learning style has been defined in this model as a learner's preferred ways of remembering, understanding, and reasoning about knowledge [50]. The VARK model has been used for advising teachers how to identify the preferred learning styles of their students [54][55]. Significantly, this model has a supporting validated questionnaire [56] that allows a reasonably quick (self) assessment of learning style preference. This can be done by filling in the online questionnaire, which then links to the website or allows calculation of the VARK learning style. VARK defines four learning methods [50][53][54], as follows:

- Visual: one of the original basic learning methods. In this particular type, a learner learns best by seeing, for example, flowcharts, diagrams, maps and so on [50].
- Aural: another significant learning method in traditional classroom education. Here, a learner prefers to learn best through listening to lectures, discussion, tapes, etc. [50].
- Read/Write: These learners prefer self-directed learning – e.g. reading textbooks, reports, or web pages and then summarising or writing down what they have understood or learned [50].
- Kinesthetic: This is another primary learning method in the classroom. kinesthetic learners do best through experience: undertaking experiments, carrying out case studies, practical sessions, etc. [50]. More importantly, this particular type of learning styles has been fully considered in the requirements for the proposed system of this research. Consequently, learning by doing is one main characteristic of the proposed system. The next section discusses some existing applications of learning-style-sensitive software.

3.2.2 Learning Styles and Educational Applications/Systems

This sub-section describes related research in the educational field and identifies the challenges faced by applications in this field. There are several adaptive educational hypermedia systems that, as part of their adaptive process, consider the learning styles of the learners. However, they still have some limitations [54]. Some of these applications (Table 3.2) and their limitations are as follows.

(a) iWeaver Learning Style Application

This is an adaptive tutoring system used to teach Java programming language [57]. Wolf [57] reported that the aim of developing this system was to accommodate individual learning styles in an adaptive e-learning environment. The learning process inside this system is described in the following steps. First, when a learner logs into the system, the system will request him/her to answer 118 questions from the Building Excellence Survey. Once the survey is completed, the learner is given an explanation of his/her suitable learning style with some recommendations on the media representation of the first content module. After that, the learner can study the first module in his/her preferred learning style or another style. Once the learner finishes studying, s/he is given automated feedback by the system [57]. However, this system is missing some of the important aspects of teaching and learning; for example, there is no pre-assessment of the learner's programming level. Watson et al. [51] note that the iWeaver system also fails to express any pedagogical meaning beyond a very simplistic representation of the relationships between curriculum elements [51].

(b) Protus Learning Style Application

Protus is an adaptive, web-based programming tutoring system that is also used for teaching Java programming language [58]. Learner profiles are created with some basic information, and then the learner's preferred learning style is ascertained via a set of questions. This information is stored in the profile and used to select the appropriate lesson customisation for the specific learning style [58]. However, this system does not provide any significant functionality towards adapting the curriculum regarding the learner's ability; there is no assessment-driven learning, nor any initial diagnostic assessment. In order to create a truly adaptive system, the learner's current – and developing ability – must be tested.

(c) AEHS-LS Learning Style Application

AEHS-LS, or adaptive e-Learning system based on learning styles, was developed for use when teaching the JavaScript language [54]. The author states that it was designed to assess the consequences of adapting educational materials individualised to the student's learning style. As with the Protus system, learners create an associated profile during the registration process. Again, the learners are responsible for selecting their appropriate learning style. AEHS-LS prompts users to select their learning style if known, and, if not, prompts them with the Fleming VARK questionnaire. Once the learning style is either determined or selected, lessons are then delivered according to the selected style. Appropriate style-specific resources are generated for each concept by a subject expert and then simply selected by the software at the delivery time. Analysis of the resulting system showed that AEHS-LS-engaged students outperformed the control group students [54]. However, student feedback suggested that the auditory learners experienced difficulty, although this is not attributed to the system's approach. It is suggested that this is due to audio delivery in a language other than the participants' native language [54]. The AEHS-LS study does not investigate this further.

The research into developing these systems has clearly conducted valuable investigations into harnessing technology as a mechanism for adapting curriculum delivery according to a learner's preferred style. Equally, the systems appear to demonstrate, in limited evaluations, that correctly exploiting a learning style does improve assessment performance. However, it is clear that the systems do not fully address either the pedagogical or technical concerns regarding learning-style-adaptive learning support systems. For example, they have not considered what learners need to be taught, as there is no diagnostic assessment for them. Another shortcoming is that the differences among learners have not been addressed.

The following section further investigates the interaction between learning styles and technology.

Table 3.1: Educational Applications Based on Learning Styles

System	Overview	Date	Shortcomings
iWeaver	A system used to teach Java programming language with the consideration of students' learning styles.	2002	They do not consider the idea of assessment-driven learning. They do not consider the differences among learners.
Protus	An educational system aimed at teaching students programming (Java) based on their specified learning styles.	2011	
AEHS-LS	This e-Learning system is used to teach a scripting language.	2011	

3.3 Technology & Learning Styles

This section discusses the interactions between technology and learning styles. The first subsection looks at how pedagogical research and practice in learning style mapping and application can be applied to existing technological approaches. The second subsection examines the potential for technological impact to augment existing pedagogical practice. The final subsection discusses criticism of learning styles – both in the classroom and in e-learning environments.

3.3.1 The Impact of Learning Style on Technology

Learning styles have several potential areas of impact in existing technology. One such impact is the utilisation of data about learning styles to improve the quality of e-learning systems' adaptation models. E-learning systems should ideally track a learner's progress, and optimise it to take advantage of that learner's strengths and help them to overcome their weaknesses. There is evidence from a recent study [54] that suggests students who engage with a system that incorporates a learning style track-and-response mechanism outperform those who study outside the system. Seventy percent of students who used the Protus system to learn Java found this adaptive system successfully guided them to the appropriate materials with useful explanations [58]. Another potential impact of including learning styles in learning software is that this helps to personalise the learning experience – and, importantly, increases engagement. Several of the educational technology systems were designed to suit a variety of learning styles [58][57][59]. The vast majority of students engaged in these systems found e-learning systems were more enjoyable than the traditional learning system in the classroom [59]. One significant advantage in this regard is that a well-designed software system can make these identifications and selections with little computation cost; this contrasts with the effort a teacher has to make to correctly identify and respond to all of the learners and their differing learning styles in a large classroom [51].

3.3.2 The Impact of Technology on Learning Style

Just as good pedagogical practice can feed into the design of tomorrow's e-learning systems, technology can continue to feed back into teaching practice. To illuminate this, lecturers already engage their students more thoroughly through the use of additional multimedia content [59]. Additionally, technology provides a means to reach a wider range of students [60]. However, e-learning offers a significant advantage regarding the potential for increasing teaching and learning output, letting subject experts focus on material creation, and automating much of the repetitive tasks. Deferring time-consuming tasks to a software system allow greater one-on-one teaching and learning time, which has been a challenging prospect in the traditional classroom [60]. Technology can help to rapidly assess many learners' learning styles. For example, "iWeaver" determines the learning style of its users by asking them over 100 multiple-choice questions, with the system automatically providing the content in their preferred learning styles. However, technological tools do not yet suit all the learning style types. This is because teaching materials are not always adaptable to all types of learning style; for example, some topics do not lend themselves to all the VARK styles. Equally, certain kinaesthetic learning tasks are ill-suited to an electronic or virtual environment. An example of this is the tablet PC, which is a teaching tool used in engineering courses. Kinaesthetic learners evaluated this tool as un-engaging, while visual learners found it an enjoyable classroom addition and had a greater preference for it [59].

3.3.3 Criticism of Learning Styles

It is intended on this section to give an overview of the current context in which this research is situated by referring to learning styles debates. According to previous studies, there is a big debate about introducing learning styles into an adaptive e-learning hypermedia system. Yasir Eltigani [54] found that including learning styles in an e-learning hypermedia system helped to improve students' achievement and performance [54]. Conversely, Brown et al. [61] reported that there is no evidence to support the idea that matching learning styles to learners improve learning effectiveness [61]. Elvira Popescu [62] criticised the learning styles approach for several reasons. One complaint is that there is a large number of learning style models, with no unanimously accepted approach [62]. Additionally, the length of the assessment questionnaires was considered to discourage participants. Popescu suggested that learning-style questionnaires should be revised for use in web-based learning systems, as they ignore technology-related preferences [62].

Another significant issue is that of teaching workload, particularly for those tutors tasked with creating their materials. Designing several sets of very similar material, each tuned to a particular learning style, is likely to be very time-consuming, requiring a considerable increase in effort. Another issue would be that some subjects are naturally unsuited to being taught through a particular style. As an example, it would be very difficult to engage auditory learners if mathematics or programming subjects were taught in a heavily verbose manner. Furthermore, developing materials for auditory learners may create other challenges, as a student's language may differ from the delivery language. Yasir Eltigani [54] noted that his auditory learners who natively spoke Arabic found that listening to English spoken by a non-native was difficult [54].

It is clear that the above-discussed issues should be contemplated before considering learning styles in the development of systems used to support the learning process. Therefore, because of the contradictory views around learning styles, their pedagogical validity and the challenges in incorporating them into technology, it has been decided to exclude a detailed study of learning styles from the proposed work. However, this provides ample scope for extension of the work beyond the PhD study.

3.4 Summary of the Chapter

Modern education benefits from developments in educational systems and widespread high-speed Internet access. An adaptive, educational tool is increasingly gaining ground as a pedagogical delivery method, yet there is still far to go regarding refining the quality of materials, student performance and engagement monitoring. This chapter has discussed learning style applications, and has examined several surrounding pedagogical issues to help determine failings in current learning-styles-based adaptive systems.

CHAPTER 4
GAME-BASED LEARNING: A CASE STUDY

4.1 Introduction

This chapter provides in-depth explanations of game-based learning, for teaching young children programming at an early age. The chapter also includes a detailed overview of the proposed framework with a comparison between this framework and one of the existing systems (Scratch). Game-based learning approaches and how they have been used for developing the proposed system are also presented in this chapter. The importance of game-based learning in primary school children is also discussed here, along with a detailed description of the concept of the software development life cycle highlighting the software development model (Agile) chosen for developing the proposed system. A detailed description of requirements gathering process, design process, implementation process and testing of the proposed system was provided in this chapter.

4.2 Online Games

There is a more extensive range of online games than many people expect. They include casual games, advergames, and serious games [63] [64]. Each is designed with a different intention. To illustrate this, a casual game is purely built for entertainment purposes whereas advergames are designed to be marketing advertisements and promote a product to the public [63]. More importantly and of main relevance to this research are serious games. This is because serious games are developed for a primary purpose other than pure amusement [65]. Such purposes include education, healthcare, emergency management, defence and other various serious aspects. Researchers [65] [17] have described serious games as computer games that are designed for learners to learn something and have fun whilst doing so. Michael et al. [66] discussed the difference between serious games and other forms of online games, and they reported that serious games are more focused on learning and training than anything else, e.g. entertainment. Additionally, serious games differ from other online games by their mission, as they focus on precise, purposeful learning outcomes to accomplish serious, measurable, continued enhancements in the performance of learners or players [63]. According to Derryberry [63], McDonald's uses serious games to train store employees in, for instance, customer service, store operations and employee supervision.

The use of serious games has many benefits for learners. Retention increases when using computer games compared to other traditional teaching methods [67]. They provide learners with the opportunity to experience a situation that is impossible to meet in the real world for reasons like safety, time, cost, and so on [68]. Serious games can be used in several aspects of life including military, safety, education, etc.; however, in this research, the focus was on the education aspect of the serious game, which can be called "Game-Based Learning" [69]. More specifically, this research is related to simplifying the process of teaching and learning programming for pupils in early years education. This is because the education sector is still suffering from many issues. Muratet et al. [17] reported that all over the world students are becoming less interested in computer science. As a result of this, the number of enrolled computer science students is shrinking, and they are no longer interested in continuing with this particular specialisation [17] [18]. Consequently, it is important to consider the idea of game-based learning as a possible solution to some of these significant issues. The details of game-based learning are discussed in the next section.

4.3 Game-Based Learning

A review of the game-based learning literature shows that there are a number of approaches to develop a game-based learning application [70] [71] that encourages gamers to enhance, for instance, their learning skills. The first one would be programmers (while taking some pedagogical instructions from educational researchers) making a professional educational game for learners to learn by playing. The next one would be students making a simple game where they take on the role of game creators in developing the simple game and learning about the content [70] [71]. Further illustration about each of those stated approaches, detailing which approach has been adopted for developing the proposed system, is provided in the subsequent subsections.

4.3.1 Learning Programming by Game Making

The concept of game construction or learning through game making, where students learn mathematics by using a programming tool called Logo, was introduced by Papert [72]. There is another programming tool called Scratch [71], the inspiration for which came from Logo. According to Maloney et al. [73] (p.1), Scratch is a “visual programming environment that allows users to learn computer programming while working on personally meaningful projects such as animated stories and games”. Mitchel et al. [29], offered another description of Scratch, as a tool that enables children to create their own interactive stories, animations, games, music, etc., which they can then share with others. It is mainly designed to help pupils to learn programming via the idea of game making. Furthermore, Scratch is a gamification application which children are introduced to its environment by firstly knowing the three S’s which they will need to make scratch work [74]. These are a stage (which is used for featuring the results), sprite (which is an object can be created by the user or chosen from the scratch library) and Scripts (which have blocks of commands). The block commands have several categories that children need to experiment them but the category that most related to the programming concepts which they will need to use to understand the programming concepts would be a control category which has a conditional if-else statement, repeat and so on. In relation to the concept of sequencing on this particular gamification application, children can learn this programming concept by for example drawing different shapes, and then they show a route that visits all the drawn shapes [75]. With this example, children will require to draw the line from start to finish, write correct instructions, which get the sprite to the end. This example can help them to understand the concept of sequencing. Regarding the iteration programming concept, children can be introduced to the repeat block as a way to repetitively make scripts shorter [71]. It can also be seen in Figure 4.1 an example which illustrates how iteration concepts can be performed and learned from scratch.

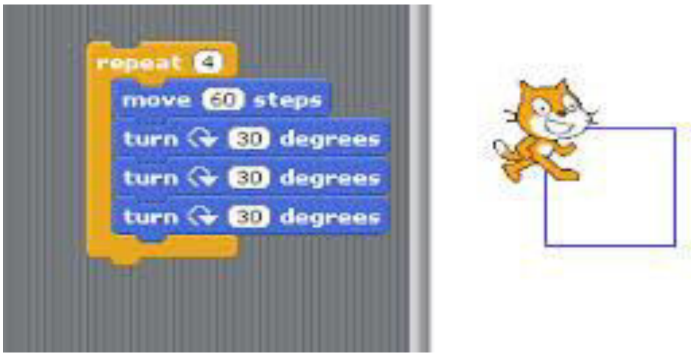

Figure 4.1: A Repeat Block for Iteration

With respect to the programming concept of selection [29], children would be introduced to the block of If () Then (Figure 4.2) which is a control block. The block is going to check its Boolean condition and then accordingly; it will act (if it is true, the blocks held inside it is going to run whereas, if it is false, the code inside the block is going to be disregarded).

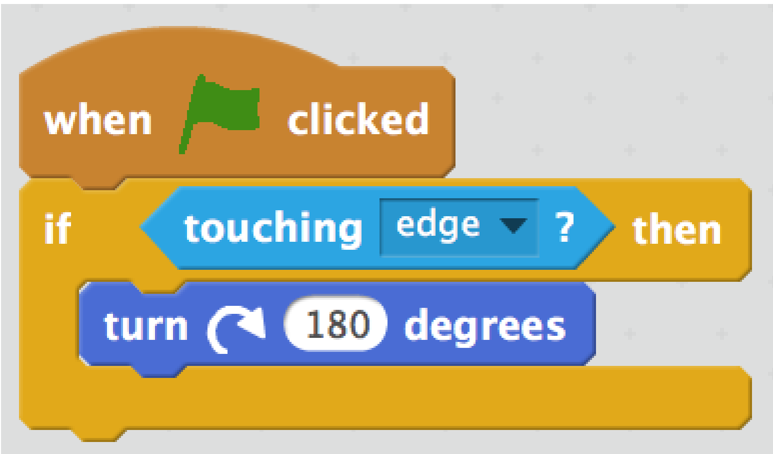

Figure 4.2: IF Then Block for Selection

Although Scratch's scripts (as shown in Figure 4.3) have some programming features [76] for children to use, such as "Motion Blocks", which deal with movement of sprites, "Looks Blocks", which are related to the appearance of the spirits and stage, and "Control Blocks", which run the flow of the project, for instance, using the iteration function and so on, there are some drawbacks that need to be considered particularly when a system is designed for children. Consequently, it is important for children to be automatically assessed and receive appropriate feedback when they use those aspects; however, Scratch has not yet included this pedagogical idea, “assessment for learning”. Scratch only enables pupils to make their own games and share them publicly, which could be unsuitable for shy children, as they might not want their friends to see their weaknesses or enable them to negatively comment on the games they have created.

According to a research study conducted by Malan et al. [74], it was found that some of their participating students felt the Scratch programming system was unsuitable for their level of learning. Furthermore, when using Scratch, it can be easy for young learners to misunderstand an important concept of programming as the learning process is not well structured; for example, understanding of individual differences among learners is missing as well as learners are not informed about what they have achieved in different stages from the learning outcomes. Muratet et al. [17] criticised the Scratch programming system and reported that it cannot be considered as a serious game, as the ability to play a part is missing. This study aimed to make a fully detailed comparison between the Scratch programming system and a proposed system for teaching pupils programming. It was decided to choose the investigated system, Scratch, from a list of other existing educational programming tools such as “Lightbots” [77], “Kodu” [78] and other children’s programming systems. Table 4.1 lists some of those educational tools for supporting children to learn programming.

Briefly, these educational programming tools work as follows: Lightbots is a visual programming game. Children learn programming concepts by arranging signs on the screen to guide a small robot to walk, jump, and turn until the goal is reached [77]. Kodu is a visual programming language where learners can build a basic game by using visual elements through a game controller [78]. However, although those tools are helpful for children to use, there are some important pedagogical concepts missing. For example, the idea of assessment for learning is not included, as there is no consideration of the learners’ pre-knowledge, and their performance is not monitored.

Table 4.1: Existing Programming Teaching Tools for Children

System	Overview	Date	Shortcomings
Scratch	It is a graphical programming tool that can be used by pupils to make animated stories, games and so on [29].	2006	The idea of assessment for learning is missing from those tools. There is no consideration of the learners' pre-knowledge of programming. Monitoring the progress of learners is also missing from these programming tools.
Lightbots	It is a visual programming tool used for teaching children the basics of programming. Children learn through guiding a small robot to light up tiles to solve problems [77].	2008	
Kodu	It is an educational programming tool for supporting children to learn programming through using visual elements to build a simple game [78].	2009	

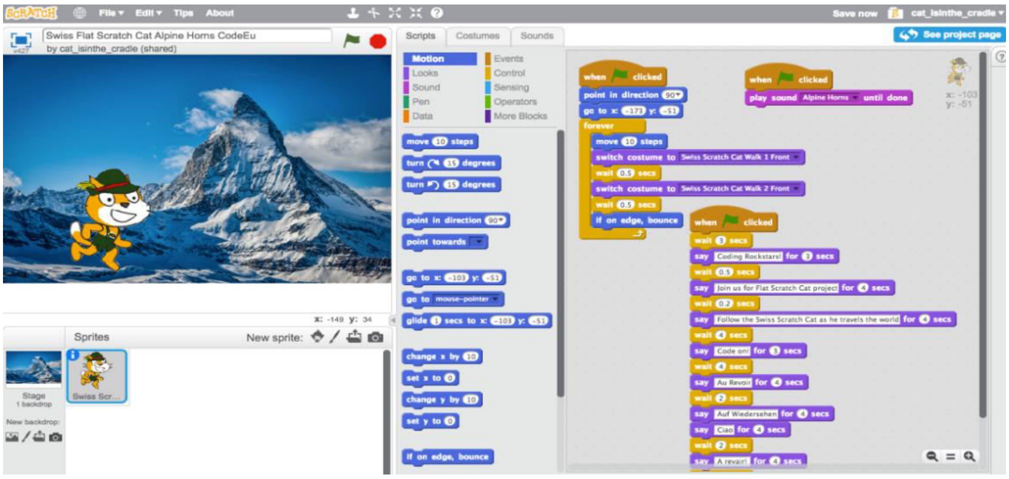

Figure 4.3: A Screenshot of the Scratch Environment

4.3.2 Learning Programming by Playing a Game

The impact of technology in education has created a major increase in students understanding their subject area effectively. Vos et al. [79] have shown that, when learners are playing a game, they are immersed in personal learning experiences, which could be less accessible in regular educational environments. Furthermore, embedding the method of playing into a learning process offers many benefits that could be acquired by learners. To illustrate this more, when playing a game, many activities are carried out; for instance, learners would reflect on their actions as well as being able to draw conclusions, and these advantages are not available in other learning environments such as traditional educational environments. It also can be observed that playing games is becoming an essential activity in the daily life of children. Consequently, it is important for game designers to consider and include the concept of deep learning (more information about “Deep Learning” can be found in the next section, 4.4.2) before they plan and design their games for children. With regard to the proposed system, the concept of deep learning was considered in the system’s requirements as the researcher was working closely with a primary school teacher during the requirement-gathering phase of this research; more information regarding this collection process is provided in section 4.8. To illustrate how deep learning has been included: by using the proposed system, pupils were confronted with problems they had to overcome if they intended to achieve their goals. The proposed system was used by pupils to learn the fundamental aspects of programming, such as iteration, in a playful environment, which developed their problem-solving skills. The details of these learning activities can be found in section 4.13 of this chapter.

4.4 Effects of Gaming on Children

4.4.1 Children's Motivation

The use of computer games by children is nowadays becoming widespread, and it can be seen that children are using some of their time to play computer games as they find this an essential part of their daily lives [80]. According to Vos et al. [79], economically, the games manufacturing industry is one of the biggest businesses around the globe [79]. By studying the gaming concept from relevant literature, children's motivation often appeared as a key element in learning. Kirriemuir et al. [81] reported that a learner's motivation can possibly be increased with the use of computer games. This is because computer games prompt curiosity and awareness, as learning materials are presented in an interactive mode which keeps the learner in control.

Additionally, some experimental studies [82] [83] [84] have been conducted by studying the relationship between computer games and learners' motivation, and their results have indicated that computer games have the potential to increase learners' motivation. To illustrate this, an experimental study was carried out by Carova et al. [84], focusing on the effects of learning mathematics in a meaningful context (gaming) on students' motivation, and their results showed that learners' motivation and performance increased significantly.

Another empirical study was conducted by Tuzun et al. [85], which related to learning geography through the use of a game-based system, and they found that learners who had used this system proved that their level of motivation was significantly higher than those who had learnt geography traditionally.

More importantly, the system proposed in this research has been experimentally tested in a UK primary school, and the results have indicated that pupils who used it for learning programming outperformed those who learnt traditionally; additionally, this proposed system enhanced their motivation towards learning about programming. Consequently, educational games could support learners to increase their motivation to learn more than the traditional approach used in the classroom.

4.4.2 Deep Learning Approach and Attainment

Researchers have described the concept of deep learning [79] (p.128) as "involving the critical analysis of new ideas, linking them to already known concepts and principles, and leads to understanding and long-term retention of concepts so that they can be used for problem solving in unfamiliar contexts".

According to Gee [86], game-based learning may be suitable for the development of deep learning processes in children where they learn through trial and error to solve problems. A deep learning process is a learning approach that differs from the surface learning approach, and Marton et al. [87] differentiated between these two approaches to learning. Other researchers, including Craik et al. [88] and Tulving et al. [89], have reported that information learnt through the deep learning approach will be better recalled than information gained through the second approach, surface learning.

Further studies [90] [91] have shown that the deep approach to learning is related to higher-quality learning outcomes. In the proposed system, the focus was on the assessment of a high-level learning outcome; for instance, can a pupil apply the concept of iteration in solving such a problem? In contrast, the surface approach can only be used for lower learning outcomes, such as a simple assessment of multiple-choice questions. Another weakness of surface level learning is that it is used only for the purpose of memorising concepts, such as what the teacher said about such a concept in the classroom [87], whereas the deep learning approach is frequently preferred by learners as it enables them to look beyond the material that was given to them and helps to develop their thinking [92].

With regard to the proposed system, the deep learning approach was included in the learning process where learners were learning programming concepts such as iteration through thinking and learning by doing in how to solve a problem with the use of iteration programming concepts, not simply memorising and answering multiple-choice questions (surface learning).

It can be confirmed that mixing deep learning with game-based learning is a suitable approach for children to learn programming effectively. This is because learners were positively affected by learning through the use of the proposed system as well as it led to them engaging with learning programming concepts.

Consequently, based on the positive results that have been found in this research (more information about the research findings can be seen in Chapter six), the researcher would confirm that this deep learning approach could reduce some of the complexities and difficulties of learning programming for young students, particularly when it is mixed with game-based learning.

4.5 The Importance of Game-Based Learning in Early Years Education

Education games are games designed to help beginners to acquire new knowledge and skills through the process of adopting an enjoyable platform of playing but in an actual context, and at the same time learning new concepts [93]. The proposed system adopts this educational game methodology to help teach young students how to program and improve their problem-solving skills, for instance, iteration and other programming concepts. Section 4.6 of this chapter explains how this was achieved. Recently, game-based learning tools have been implemented in the UK national school curriculum. This approach is encouraged by the UK government to start teaching young children how to program at an early age in an enjoyable learning environment. The reason behind this innovative approach to learning by playing is because well-designed educational game tools will motivate learners to learn more and develop their programming awareness [94]. Games that have problem-solving case studies can spark learners' creativities [95] as well as provide them with an opportunity to practically apply their acquired skills or experiment, make mistakes and receive feedback in a risk-free environment [96].

4.6 Game-Based Learning Tool Design for a Primary School

Game-based learning is an innovative practice which works to engage pupils in learning, for instance, programming concepts. However, designing an appropriate game-based learning tool for young students is challenging. This is because, in order to develop good game-based learning tools for young children in schools, certain factors need to be considered by both the designers of the tools and the teachers who will be using the tools for teaching [97]. These factors include the age of the pupils and their pre-knowledge (familiarity), and then the learning material within the game would have to be tailored accordingly [98]. Moreover, with regard to this undertaken research, it was aimed to design a fitting game-based learning tool that would provide suitable material to learners (players) at different levels of learning (such as low and high level), and to make the learning process more enjoyable and helpful. In relation to the design approach (learning programming through playing a game) of the educational game (game-based learning) which were used by children in a primary school level, the details can be explained as follows: The first one is understanding the players (pupils) in depth e.g. who will be the players of the designed game, what their ages, what their preferences and what their pre-knowledge (in this scenario it will be pupils in a primary school). Additionally, taking into consideration the entertaining element which considered in the educational game design as it needs to be fun and engage pupils to interact with the learning activities. Also, the educational game was designed to be multimodal content for example text, graphics and etc. The designed game has some learning activities that would challenge pupils during playing and spark their creativities. Furthermore, the inclusion of the pedagogy was included in the game design as it was designed according to the programming lessons identified on the UK national computing curriculums of primary schools and combined with learning theories in order to ensure the desired learning outcomes (pupils are able to apply programming concepts and differentiate between them) were expected to be achieved from playing the educational game. Moreover, this game was designed to support pupils to have self-learning and reflection whereby they learned programming from the game by playing, reading the learning instructions and see their own performance. The form of the learning materials in the game was also designed in a series of problem-solving activities which support pupils to solve problems with the use of programming concepts and stimulate their minds. Furthermore, in the design game, the involvement of the teacher was considered whereby the teacher can see the performance of his/her pupils e.g. who had managed to complete the learning activities and who had not and then support them accordingly.

4.7 Software Development Life Cycle

Software development life cycle (SDLC) models can also be termed as a software development process [99]. SDLC models describe stages of the software cycle and the order in which these stages should be executed [100]. Within each stage of the software development cycle, there are some required deliverables for the next stage of software development [100]. To illustrate this, the requirement stage is translated into the design and then coding is carried out according to the design. After those stated stages, there will be a testing stage, which is the verification of the deliverable of the development stage against the requirements of the software. Thus, this example has simply explained the stages of the software development process or life cycle model. There are several SDLC models that have been developed as technology advances [99] [100]. One of the oldest is the "Waterfall Model" [101]. There is also the "Agile Software Development Model", and some other models [99]. The next subsections describe these models in depth, and provide an explanation of which of them has been chosen for developing the proposed system.

4.7.1 Waterfall Model

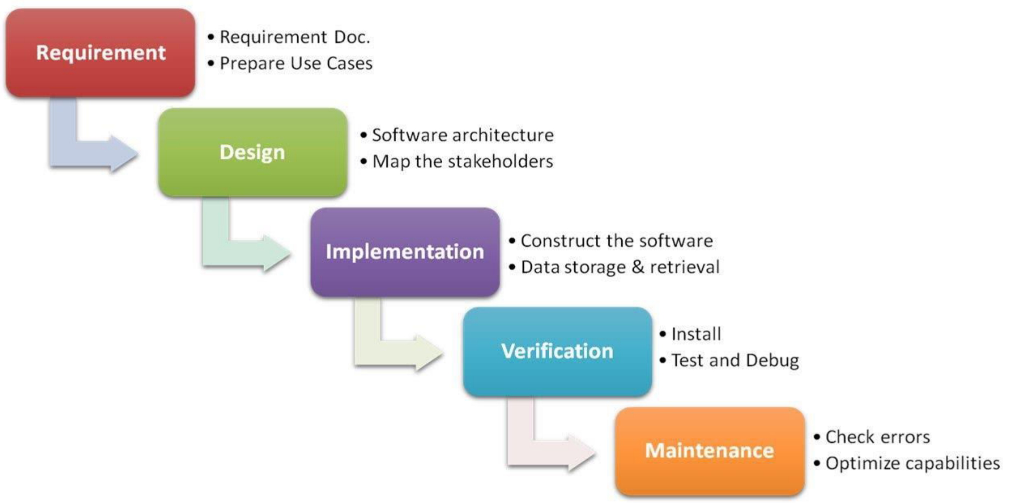

Figure 4.4: Waterfall Model

A waterfall model [101] was the first methodology looked at, and It was felt that the waterfall has a strong structure and would be able to keep the progress in line with the project. However, after some discussion, it was agreed that this particular methodology is unsuitable for developing the proposed system as it would slow down the development. Also, it is not flexible when the requirements need modifying once the system has been built [102]. Consequently, it was decided to look at a different SDLC model where the development of the proposed system can be speeded up.

4.7.2 Agile Software Development Model

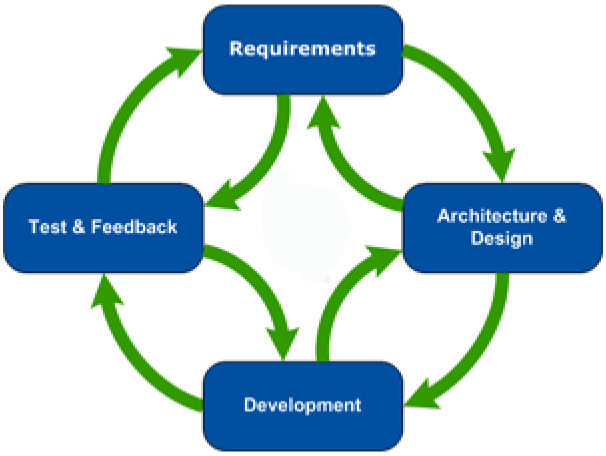

Figure 4.5: Agile Model

An agile software development model is an iterative development model, and it helps a development team in responding to unpredictability or altered situations, for instance, changes in the requirements of a system [103].

With the use of agile software development, products are rapidly delivered to the customers [104]. Not only that, the agile method enables the customers to ask for changes in the requirements any time during the software development, and it ensures that the deliverable product is appropriately improved through the development process by enabling more care and focus to be given to the customers' satisfaction, whereas other traditional approaches cannot do that as they are less flexible [104]. Additionally, the use of agile software development gives the development team the ability to continuously align the developed product according to the needs of the customers [104]. Each iteration of an agile software development model is named a "sprint", and each sprint takes a couple of weeks [105]. It includes gathering a set of requirements, system designs, implementation, and testing. At the end of each sprint is an "end-of-sprint" check-up, this is where the software development team can meet with the customer and discuss the developed system's progress to date, and receive feedback on the development [105]. Due to the big advantages of this model, including the flexibility to adjust to changing requirements, it was decided to choose it for the development of the proposed system. The details of the software development process of the proposed system are described in depth in the next sections.

4.8 Specification Requirements

This research was done for the purpose of supporting the teaching and learning computer programming in early years education. As school teachers and pupils are those who had benefitted from the development of this system, specification requirements of the proposed system (which comprised of “Web Administration” that aides teachers to check the progress of the children learning, and “Game Application” that support pupils to learn programming through playing a game) were created based on teachers’ needs and wants. With regard to how the requirements of the proposed system process were gathered, the researcher used the interview method whereby meeting the school's teachers face to face. In the interviews, there was an open discussion of the subject of computer programming in an early years education such as a discussion of the challenges that faced by teachers in the classrooms when they were teaching their pupils programming as well as a discussion of some possible solutions to addressing their challenges to ease the process of teaching and learning programming. The interviews that the researcher had with school teachers can be summarised in the next subsections:

- Teachers need a system that supports their pupils to learn programming in an enjoyable environment (learning while playing a game).
- Teachers also require a system that enables them to keep monitoring the progress of their pupils. Accordingly, requirements of the proposed system were created, and they are shown as follows:

4.8.1 Teacher Requirements

- The teacher must be able to log in and register to the system (Web Administration).
- The teacher must be able to view progress details for each pupil.

- Teacher must be able to add, remove and edit pupil accounts.

4.8.2 Pupil Requirements

- The pupil must be able to login to the system and get access to the game application.

- Pupils must be able to see their progress.

4.8.3 Proposed System Requirements

The entire specification requirements of the proposed system including the requirements of its both users: teacher and pupil are contained within the next table.

Table 4.2: Proposed System Requirements Specification

Number of Requirement	Requirement Description
1	The proposed system needs to have a record that categories the teachers, and pupils.
2	Each teacher and pupil require having their own account with unique Usernames and Passwords.
3	The proposed system needs to log the pupil's progress and send this information to the database where the teachers can keep informed of the progress.
4	The teachers need to be able to view and track pupil progress.
5	The pupil needs to have the ability to access the learning

	activities, complete these activities and view results of their achievements.
6	The Teacher needs to be able to make accounts for a new pupil.
7	The proposed system needs to be cross-platform among a web browser, tablet, and mobile phone.
8	The proposed system needs to offer levels of increasing difficulty (Basic, Intermediate, and Advanced).

4.9 Design of the Proposed System

4.9.1 Use Case Diagram of the Proposed System

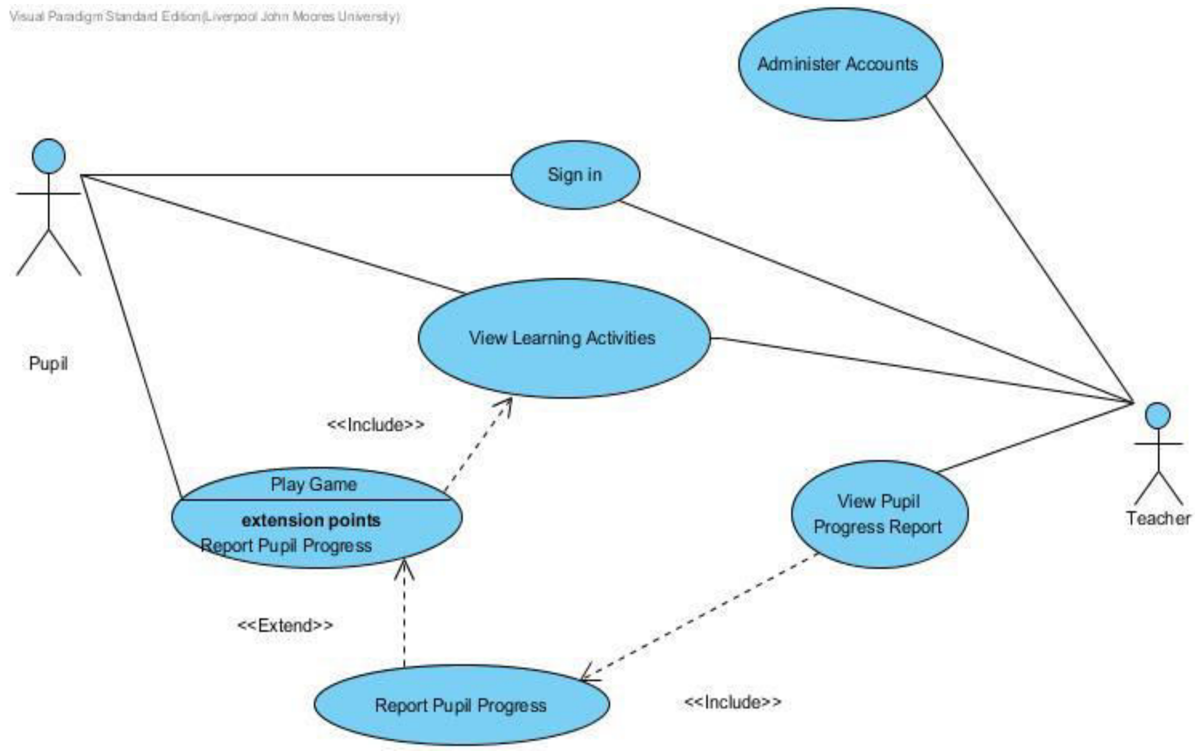

Figure 4.6: Use Case Diagram of Interaction between Pupil &Teacher and Proposed System

USE CASE1: Play Game

Explanation: This use case illustrates that a pupil access a particular level, interact and complete.

USE CASE2: Report Pupil Progress

Explanation: When the level is accomplished by a pupil, the progress of this pupil is calculated per level.

USE CASE3: View Learning Activities

Explanation:

This use case" View Learning Activities" can be viewed by both teacher and pupil. With regard to a pupil, this use case shows the activities where the pupils would interact and play a level. For teachers, they can view activities, view their pupil's allocated levels as well as they can see their progress.

USE CASE4: View Pupil Progress Reports

Explanation: Teachers have the ability to view the progress of pupils and look at their completed activities and their results.

USE CASE5: Sign In

Explanation: This use case is used by both teacher and pupil for the authentication to the system.

USE CASE6: Administer Accounts

Explanation: Teachers have the ability to set up students' accounts and manage their accounts.

4.9.2 Class Diagram of the Proposed System

Figure 4.7 shows the class diagram of the proposed system which consisted of a number of classes (rectangle icons) that are connected by lines with each other via a relationship (a verb) for example a teacher makes a learning activity so, by looking at this example it can be seen the relationship between the teacher class (noun) and the learning activity (noun) is the verb makes. In addition, this UML diagram illustrates the structure of a system by showing the system's classes e.g. pupil class, their attributes e.g. surname, and the relationships among them.

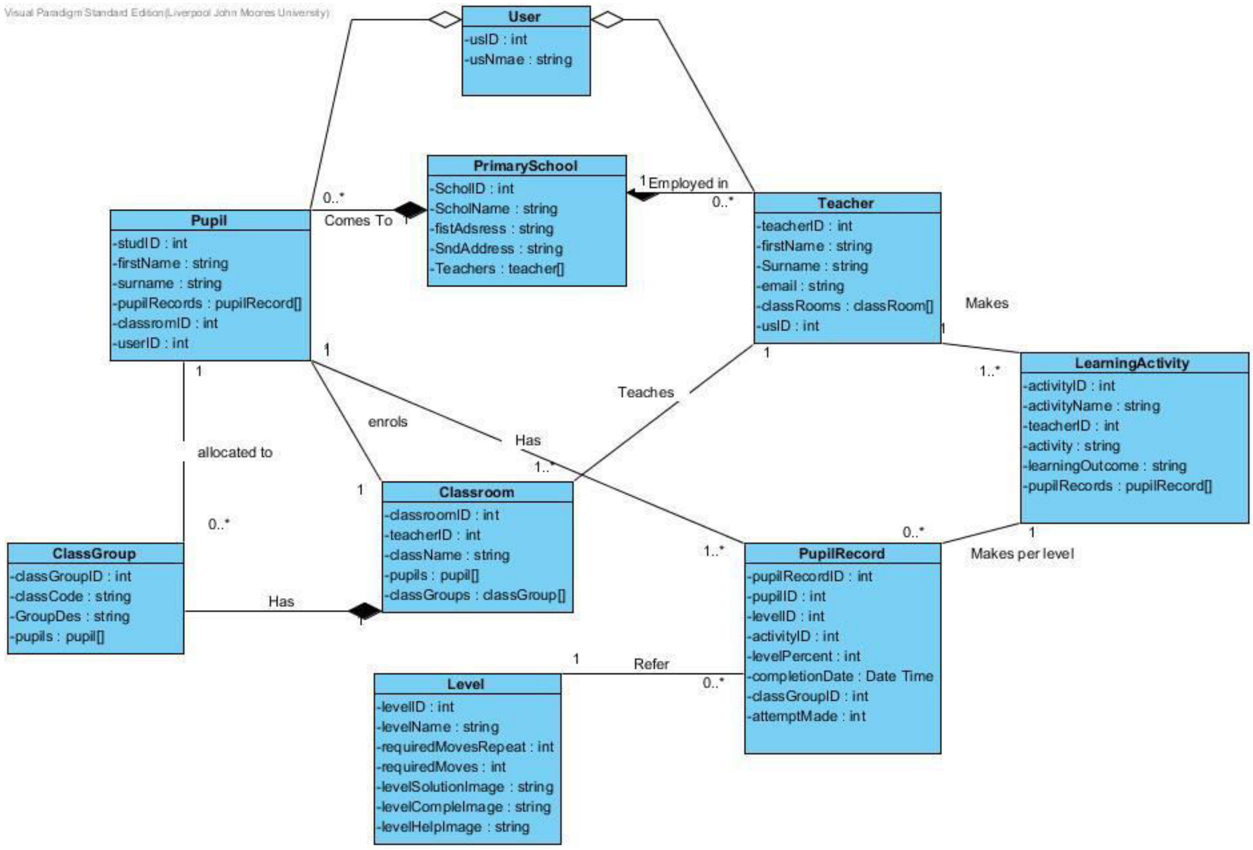

Figure 4.7: A Class Diagram of the Proposed System

4.9.3 Activity Diagram of the Proposed System

An activity diagram is designed to give a clear picture of a list of activities happen during an operation or a process. For example, the following subsection (a) presents an activity diagram of a pupil activities during the learning process from the proposed system whereas the next activity diagram in section (b) shows other activities related to teachers when they use the proposed system.

a) A Pupil’s Activity in the Proposed System

Figure 4.8 describes a sequence of activities happened during the interaction between a pupil and the proposed system. Those activities include the following:

- Pupils Login to the proposed system (through their provided unique username and password by their teacher).
- Pupils are given instructions on how to use this system.
- Pupils are provided programming exercises to see their learning levels.
- The system identifies the right learning level of a pupil.
- The system provides a suitable programming lesson to the right level of a pupil.
- Pupils practice the provided programming lesson.
- The system Checks the progress of the pupils after learning each programming lesson.
- Pupils are provided appropriate feedback.
- System logs pupil's progress and sends this information to the Database.
- If a pupil achieved the expected learning outcomes (learned programming lessons including sequence, selection, and iteration), they could successfully log out as they completed what required.
- If a pupil did not achieve the expected learning outcomes (not learned programming lessons including sequence, selection, and iteration), they would need to take further learning suitable to their programming levels.

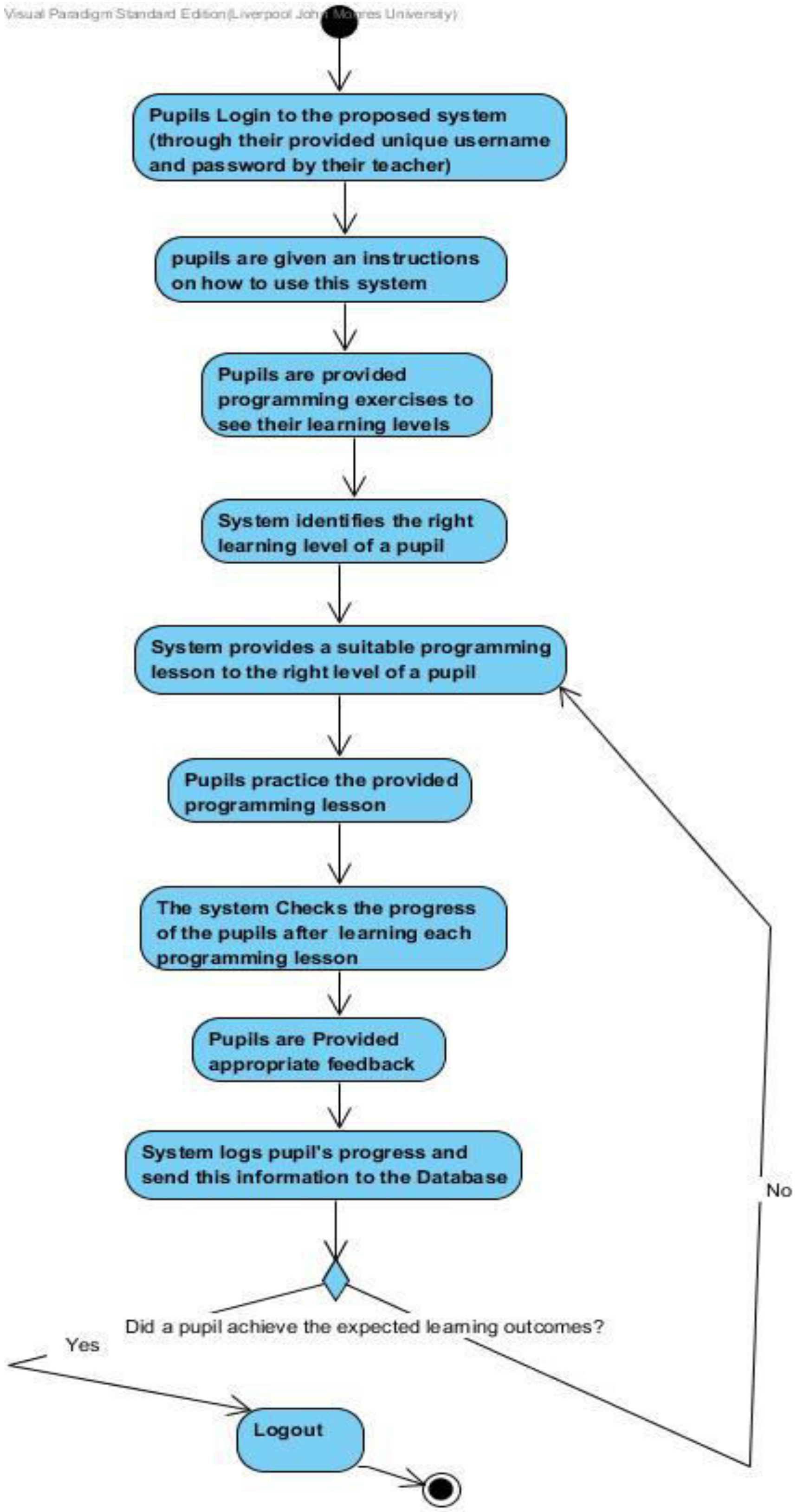

Figure 4.8: A Pupil Activity Diagram

b) A Teacher's Activity in the proposed system

Figure 4.9 shows a sequence of activities happened during the interaction between a teacher and the proposed system. Those activities contain the following:

- A teacher registers and logs into the Proposed System.
- A teacher manages and makes new accounts for his/her pupils.
- Access a pupil profile.
- View a pupil progress.
- Logout.

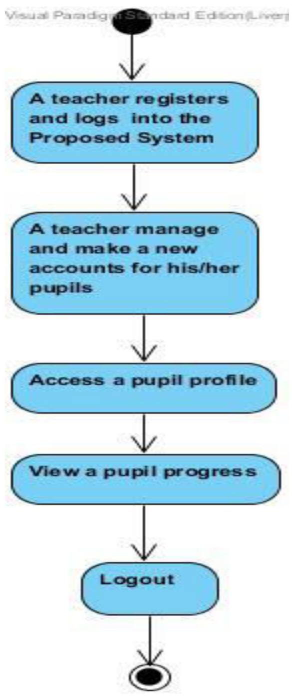

Figure 4.9: A teacher Activity Diagram

4.9.4 Deployment Diagram of Proposed System

Figure 4.10 shows the physical tools and how they were deployed on the system hardware as well as how those tools connect to one another. It can be seen that this figure consists of four nodes, the first node is related to the tools (A desktop computer, tablet and mobile phone) that a client (pupil or teacher) can use to get access to the proposed system. There is another node which was called web server (Windows 2008 server with IIS 7) that is used to host and run the developed application and responds to the client requests. The other two nodes are related to the application and database server (DB Server). In relation to the application node, it has two components: the first one is a web administration which is developed in MVC .NET 4.5 framework by asp.net and the other component is a game application which is developed in Phaser framework by the use of JavaScript. With regard to the node of DB Server (Microsoft SQL Server 2008), it is used for storing all the information of proposed system's components e.g. information about pupils, their learning progress, and learning activities in the game.

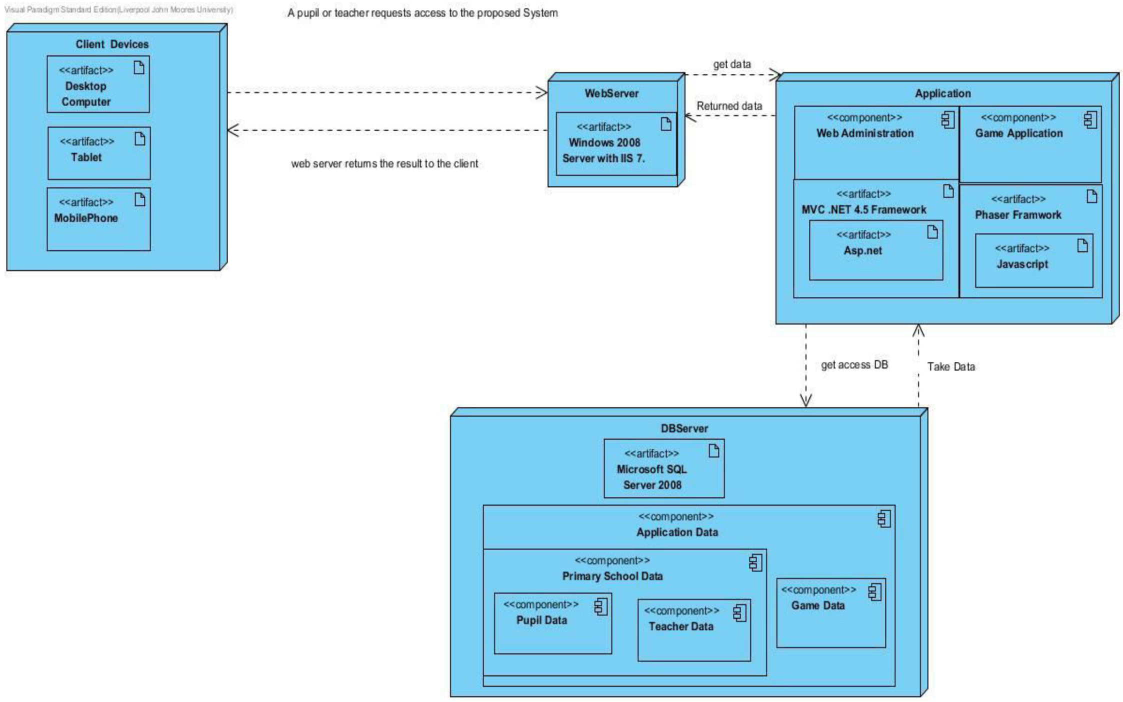

Figure 4.10: A Deployment Diagram of the Proposed System

4.10 Proposed System Development

4.10.1 Language & Frameworks

The language used for developing the game application on the proposed system was javascript, using the Phaser framework which is a fast, free and fun open source framework and it is also well documented and has an active forum if any problems were encountered. Phonegap was also used to host the game on any tablet device, and it is a free open source framework that supports the development of mobile apps. In relation to the implementation of the web administration of the proposed system, ASP.net was used which is an open source server-side web application framework. With regard to the database, SQL server was used in the development for storing all pupils' information e.g. completed levels and other details. (SQL server is provided by the university). After the completion of the development of the proposed system, the final form of it looks as presented in the below figures.

4.10.2 A Form of Visualisation of the Proposed System

The screenshot in Figure 4.11 is one of the learning activities from the proposed system which is related to the iteration concept. A learner is going to learn an iteration concept, which in this example is a repeater button to increase the number of required times to get the key. The proposed system can distinguish between a learner who has used the iteration approach to solving this problem and one who has used the sequencing approach. In addition to this, the system will also calculate the number of times that the repeater button has been increased or decreased and store this action in the student model; this will indicate whether this learner has understood the iteration concept and has thus met the desired learning outcome or needs various further examples.

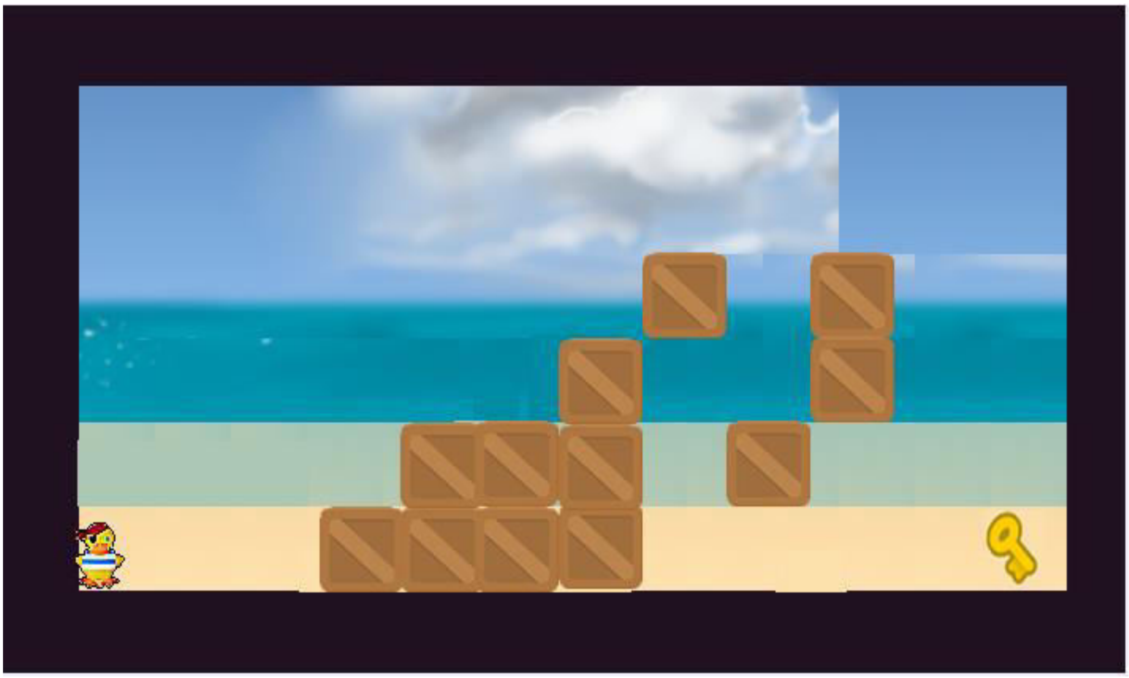

Figure 4.11: An Example of Learning a Programming from the Proposed System

As this pedagogical system is specifically designed for primary school children, teacher involvement was one of the considered requirements. For example, this system enables teachers to obtain access to the proposed system to involve in the learning process and see how their pupils are performing in programming. In Figure 4.12, it can be seen that the proposed system provides teachers the facility to create a new account for their pupils, edit and see the progress details of their pupils.

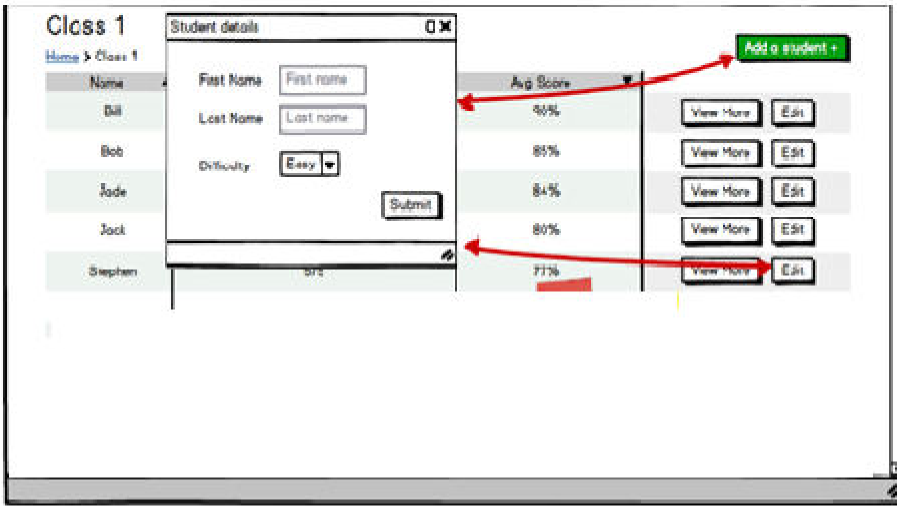

Figure 4.12: A screenshot of Teacher's Supervision Page on the Proposed System

4.11 Proposed System Testing

With regard to testing the proposed system, the following details illustrate this process in depth:- A testing plan was created which included a description of the proposed system environment (a place where it was tested and used which was in primary school children) as well as who was selected to test the developed system (school children). In addition, considering the available hardware or resources in the selected school as this will depend on its funding. Furthermore, specifying what requirements were planned to be tested at this school. More importantly on this section would be how this developed system was tested, it was tested through a number of testing levels.

Those test levels include component (unit) testing, integration testing, system testing and acceptance testing. In relation to the component testing level, the proposed system consists of a set of components, and each component was developed and tested to ensure that the code written for it meets its specification and working as expected. Regarding the integration testing, on this level, the task was to put all the components together to create the system.

The purpose of this particular test level was to expose defects in the interactions between integrated components. More importantly, an integration strategy was planned before the integration testing. The used strategy was top-down integration (starting with components which call other components). On this testing level, the interactions of each component were tested. With regard to system testing level, it was intended at this level to focus on the behaviour (black box testing) of the whole system and assess the system's compliance with its specified requirements.

The two following tables (Table 4.3 and Table 4.4) contained test cases and described the details of expected results and actual results related to the functionalities of the developed system.

Table 4.3: A Set of Test cases of Web Administration Functionality

Test Case Data (Inputs)	Expected Result	Actual Result
A user enters the right username and password into the login screen (username=teacher1 Password=progr12).	A user should Log into the Web administration (login as a teacher).	A user logs into the Web administration successfully.
A user enters incorrect username and password into the login screen.	A user should see an error message for invalid login.	An error message shows for invalid login.
A user only fills the username in the login page and submit without putting a password.	A user should see an error message requiring both fields to be completed.	An error message is shown.
A user adds a class, type a class name, password and clicks done.	A new class should be added to the database.	A class is successfully added.
A user adds a class, type a class name, no password and clicks done.	A class should not be made, and an error message shows the A user did not complete all needed fields.	A class is not created, An An error message is shown.
A user adds a pupil to the class; A user fills in all the fields.	A pupil should be added to the correct class.	A pupil is added to the correct class.
A user removes a pupil; A user selects the remove pupil button.	A pupil should be removed from the class.	A pupil is removed.

A user monitors the progress of pupil.	A correct screen of pupil's progress should be presented.	Show the progress of pupil at each learning level.

Table 4.4: A Set of Test cases of Game Application Functionality

Test Case Data(Input)	Expected Result	Actual Result
A user enters the right username and password into the login screen (pupils' accounts are created by their teachers) (username=pupil1 Password=proge12).	A user should Log into the Game Application (login as a pupil).	A user logs into the Game Application successfully.
A user enters incorrect username and password into the login screen.	A user should see an error message for invalid login.	An error message shows for invalid login.
A user clicks on left button.	The character should be moved to the left.	Moving to the left.
A user clicks on right button.	The character should be moved to the right.	Moving to the right.
A user clicks on up button.	The character should be moved up.	Moving up.
A user clicks on down button.	The character should be moved down.	Moving down.
A user clicks on the help button.	The presented screen should show the user guide.	A user guide information is shown.
A user clicks on exit button.	The shown screen of user guide should be removed.	The user guide screen will be hidden.
A user click is repeating button (The user can increase (via + sign) the repeating times or decrease it (via- sign)).	The user should add how many times (number) he/she wants to move right or left.	The movement will be made according to specified times in the repeating button.
A user clicks on go button.	The character should be moved to the direction is programmed for.	Move with the command direction.

A user clicks complete tasks.	A page with assigned tasks (learning levels) should be shown.	The learning levels are available.
A user starts to play the level.	The game level should start.	A user can complete the assigned level.
A user wants to see his or her progress.	A screen should show the completed learning activities and the assessment.	It shows the completed learning activities and how many stars they got.

Once the system testing is completed, it was the time to move to the next testing level (acceptance).The intention was to provide the end users with confidence that the proposed system is going to function according to their expectations. Acceptance testing has a number of forms including alpha and beta testing, contract and regulation acceptance testing and others. Alpha and beta testing were chosen here as they were more relevant to the requirements of this research study than other forms. Alpha testing which means the testing process will take place at the developer's site before releasing to external customers. Pupils from a Manchester primary school were invited to visit Liverpool John Moores University (LJMU) where this Ph.D. research and the development of this proposed system were taking place and results had indicated that pupils found the proposed system a useful programming system and enjoyed learning from it (further details of this school visit and results can be found in chapter six of this thesis). Once Alpha testing was completed, it was the time to take the proposed system outside and test it externally at the school site (beta testing). The proposed system was tested on pupils from a Liverpool primary school, and results indicated the proposed system was successful for supporting pupils to learn programming. More detailed information about the results of those two different experiments was also provided in chapter six of this thesis.

4.12 The Syllabus for the Teaching Sessions

With the UK government deciding to make 2014/15 the year of 'Teaching Children Programming' at the primary school level, the UK introduced significant changes to the national curriculum in how Computing is taught.

This change is focused on introducing the children to programming and computational thinking. With regard to the considered programme for the teaching sessions in the conducted experiment of this research, the programme of teaching was based on the UK national curriculum and particularly focusing on pupils who are in the key satge2 (Year3 and Year4). By looking at Table 4.5, it can be seen that there are three fundamental programming constructs including “Sequence,” “Selection” and “Iteration” were covered in the teaching sessions. Those three programming constructs are formed an essential part of the contents of the UK computing national curriculum. In addition, once these central programming constructs are learned well by children, they would obtain many benefits in fluidity thinking (e.g. think in a more out of the box way), processing and communicating their thoughts in a structured and logical way. These skills would lead children to become innovative in the future. In relation to the place of teaching sessions, it was conducted on one of the Liverpool primary schools (A detailed of the school information is provided in one of the next comments as there is a question related to it) and the ICT school teacher had arranged this school visit for the researcher as well as prepare his pupils for the teaching sessions. A series of lessons (syllabus for the teaching sessions) covered during the school visit can be found in the following table (Table 4.5)

Table 4.5: An Outline of Year 3/4 Syllabus for the Teaching Sessions

Subject	Lesson	Concept	Outcome
Computing	1	Sequence	• I can use sequence in programs.
	2	Iteration	• I can use both sequence and iteration in programs. • I can differentiate between the use of sequence and the use of

			iteration when solving a problem.
	3	Selection	• I can use sequence, iteration, and selection in programs. • I can solve problems by dividing them into smaller parts.

4.13 Programming Constructs Used in Teaching

4.13.1 Sequence

Within this research, pupils had been taught the fundamental programming constructs in computer programming which they are a sequence, selection, and Iteration or Repetition.

With regard to the first one sequence (it can be defined as instructions are executed one after another), pupils were learning this particular programming construct through a problem-solving approach. By looking at Figure 4.13, it can be seen that a learner is required to carry out a number of steps to reach the desired goal and obtain the key. In addition, the number of attempts made by the learner in solving this problem is calculated by the proposed system and considered in the learner model. The correct steps for solving the given problem in Figure 4.13 are as follows:

- First, the learner needs to turn right (step 1).
- Then, he/she is required to go up twice (step 2, 3).
- First, the learner needs to turn right (step 4).
- Then, he/she is required to go down (step 5).

- This is followed by turning right (step 6) to arrive at the destination or the desired goal.

Figure 4.13: An Example of a Sequence Lesson in the Proposed System

As the levels of pupils develop, they will be provided harder problems to think of and solve (moved to a next level). On the next lesson, there will be another programming construct pupils will be learned and solved by the use of a different programming construct than the one used above in Figure 4.13.

4.13.2 Iteration

“Iteration programming construct” which can simply be described as the act of repeating a process. The Iteration levels follow the same idea as before however the pupil is currently being assessed on if he/she can use the repeat option on solving a problem in Figure 4.14. The proposed system can distinguish between a learner who has used the Iteration approach to solving this problem and one who has used the sequencing approach.

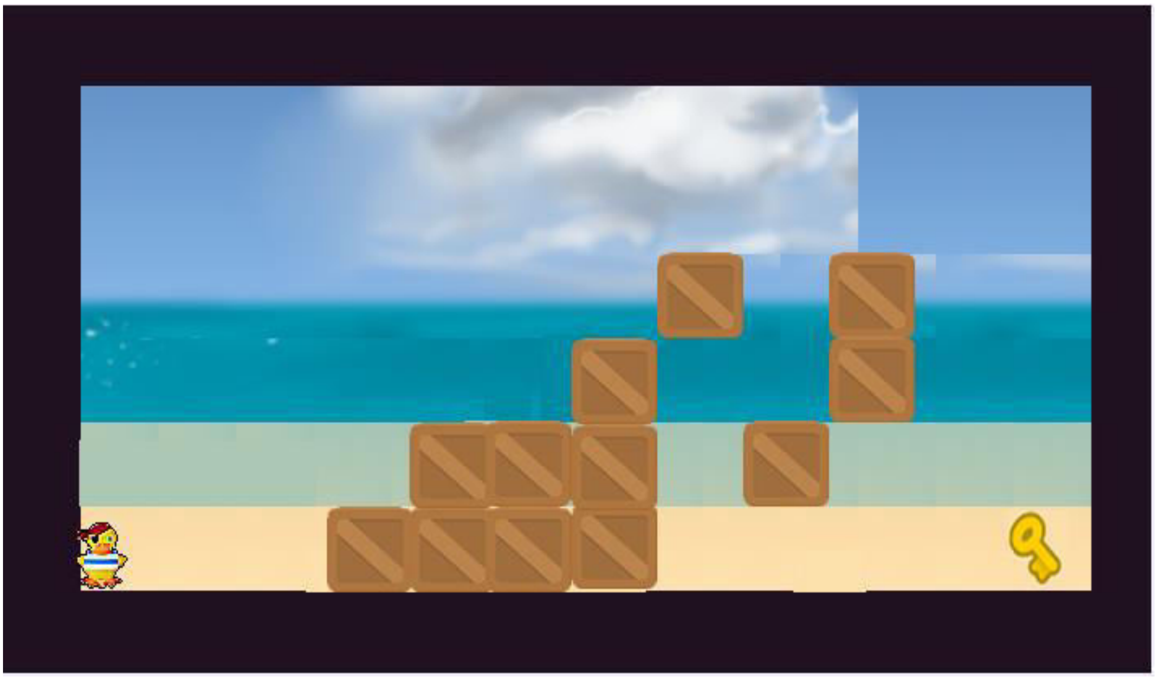

Figure 4.14: An Example of an Iteration lesson in the Proposed System

4.13.3 Selection

A further lesson pupils were taught was “Selection programming construct” which would be simply defined as a decision. With the selection programming concept, pupils are introduced to problems such as broken paths where they have to apply the right solution using the choices presented. For example, in figure 4.15, a pupil is instructed to click “What IF” button, then, they will see an uncompleted statement which will require from him/her to fill in the gaps by dragging the most suitable words. To solve this problem correctly, a pupil is required to look at the game below and see which an object is relevant to the given question. Ideally, the solution would be “IF Ladder Broken use Hammer.”

Figure 4.15: An Example of Selection Lesson from the Proposed System

4.14 The Framework of the Proposed System

This system is designed to teach children the fundamental aspects of programming, such as iteration, through playing a game, and in a way that suits their learning level. The main inspiration for the proposed system is the Assessment for Learning (AfL) initiative, comprising diagnostic and continual assessment. This defines a structured learning approach based on a student's prior knowledge, followed by learning informed by that student's assessment performance. This methodology is applied in the proposed system, such that curriculum sequencing and material generation is fully integrated into an adaptive, student-centric learning tool. In addition, the proposed system was based on the behaviourism and constructivism learning theories which were previously explained in depth in Chapter two of this thesis. In relation to the first learning theory included in the proposed system, "behaviourism", learners who used the proposed system and performed well in learning programming, received rewards, as reinforcing correct actions was one of the teaching requirements considered in the proposed system. The second learning theory considered in the proposed system was "constructivism": learners who learnt programming from the proposed system were learning by thinking and doing in solving problems, not simply memorising information, and, according to the findings of this research, those considered learning theories kept learners actively involved in the learning process of the proposed system and they enjoyed it, as they were rewarded for their positive performance.

More important is the interaction between a learner and the proposed system or learning process, which is shown in Figure 4.16. When first-time learners enter this proposed system, they need to sign up to it by completing a registration form (each learner was given a username and password by the researcher). Once a learner registers, a learner profile will be created to store all their information and it will be saved in the Student Knowledge model. After that, the system will assess the learner's prior knowledge of the subject via Diagnostic Assessment (which is providing a learner with a list of different programming activities to test his/her current programming ability via the use of sequencing and iteration concepts) in order to establish the learner's entry-level ability.

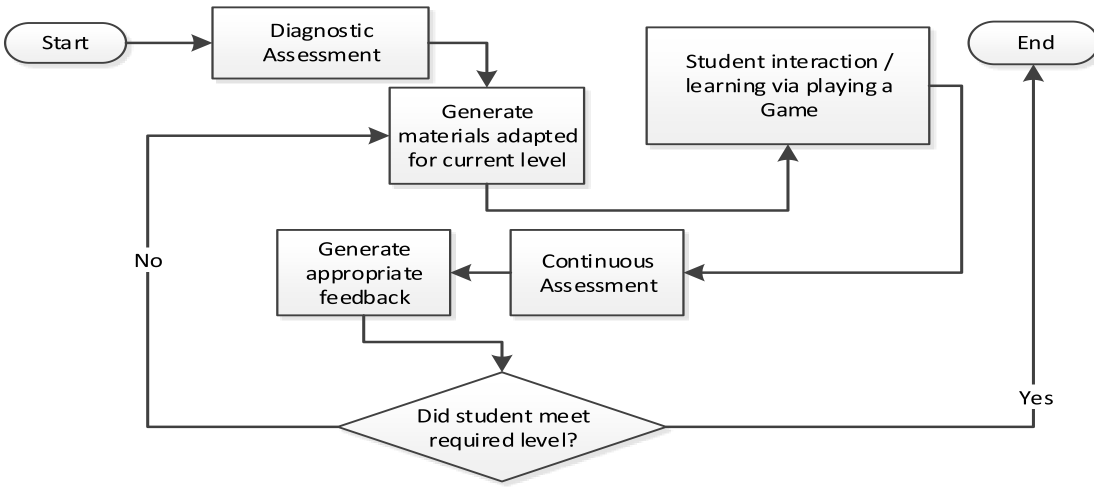

Figure 4.16: Learner-Followed Process in Proposed System

Once the initial assessment is completed, the system will generate appropriate material for the learner in the form of playing a game (suitable for entry level); for example, if a learner was unable to achieve the first learning outcome – which is being able to apply the concept of sequencing to solving a simple problem – at the first attempt, this learner is considered to be at a beginner level and so on and so forth. Then, the student continues to be engaged through informative "Continuous Assessment", providing appropriate feedback and adapting the learning materials accordingly, which simply means such a student is given more exercises suitable to his/her needs or level of learning until he/she has achieved the specified learning outcome. It is expected that learning completed in this way will be an enjoyable experience through which pupils can learn the fundamental aspects of programming, such as iteration and sequencing, as well as how to practically apply these two programming concepts to solving a simple or complex problem. Once again, this proposed system consisted of a series of levels that the learner was required to complete, collecting stars (e.g. solving a given problem correctly) along the way and avoiding "death" (e.g. solving a given problem incorrectly). For each level, the learner was timed, and the stars and deaths were stored and can be viewed by the teacher. With regard to the discussion of scalability of the proposed system, it can be explained as follows. The proposed system was designed to be used in a primary school environment for teaching and learning programming, so, the system can be used by as many pupils as the school have, not only that, the system had the capability to accept as many teachers to be added from a school. Furthermore, it had the capability to involve teachers to monitor the performance of their pupils when they were learning programming and see what learning activities had been completed or not completed. It can also offer a level of increasing difficulty. The proposed system can also be run on different platforms as it was designed to be a cross-platform system.

4.14.1 The Assessment of Pupil Work with the Feedback

In terms of the assessment of pupils in the proposed system, they were getting assessed through three different learning levels (Figure 4.17).

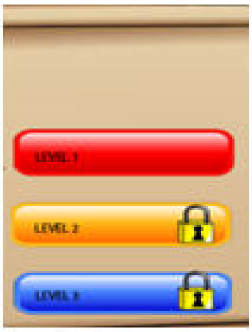

Figure 4.17: Learning Levels on the Proposed System

Each level has both a learning outcome (needs to be achieved) and a learning activity (each activity gets slightly harder which require the children to take time to think of and evaluate the best route for solving a problem on each activity- by looking at the learning activity in Figure 4.18, it can be seen it is less challenging than the another learning activity in Figure 4.19 as the learning activity in Figure 4.19 has more blocks or items in a pupil way which he/she requires to move up and move down) that a pupil needs to complete. More importantly, by looking at Figure 4.17, it can be noticed there is a lock on level2 and level3. The purpose of this lock is to structure the learning for pupils which means they will not be allowed to go the next level and learn an additional programming construct until they successfully complete the current learning level which they were working on. Once pupils understand the current programming concept on this particular level, this will then allow the next level to unlock, and the pupil can get on with next learning activities which will be in a different programming construct.

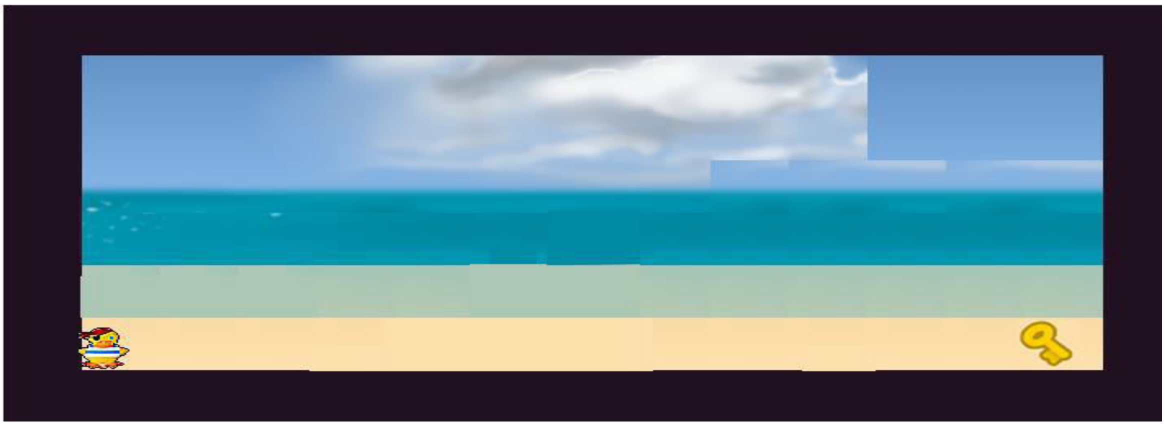

Figure 4.18: A simple learning activity from the Proposed System

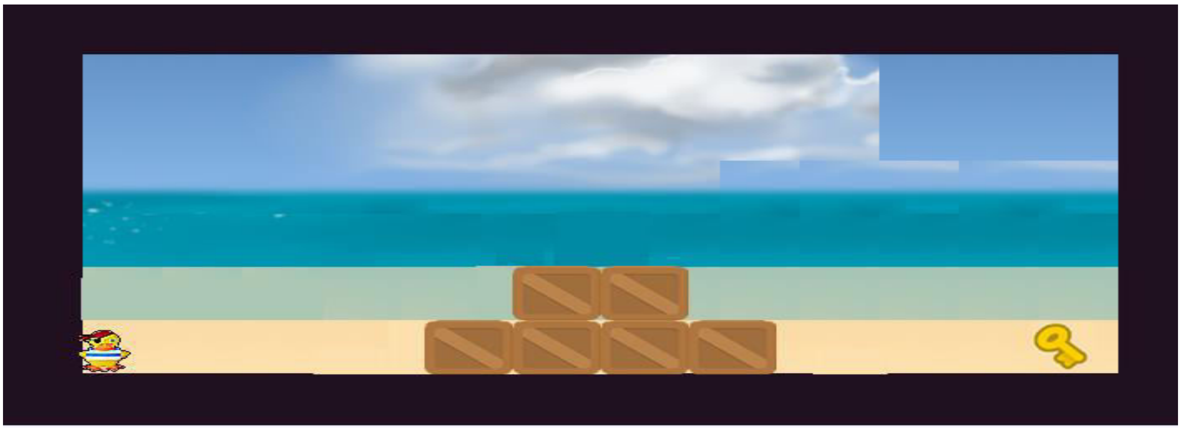

Figure 4.19: A harder Learning Activity compared to the one above from the Proposed System

With regard to the details of each level, they can be explained as follows: The first level is about sequence programming construct which is classed as "Basic" (further details of the lesson on this level were provided in section 4.13.1). With a completion of this level, a pupil was expected to use the programming concept on solving a problem.

The second level is about iteration programming construct which was classed to be "intermediate," pupils will also have here learning activities to complete and a learning outcome expected to be achieved.

The last level was about selection programming construct where pupils need to complete the learning activities related to this level and aimed to achieve the expected learning outcome (More details about of the lessons of those two levels were included in sections 4.13.2 and 4.13.3).

With regard to how the proposed system assess and checks if a pupil was doing a learning level correct or not, the proposed system looks at the number of movements made by the pupils (submitted to the database) when they were solving a problem and then compare it with the right movement on the model answer (stored in the database) and then provide feedback accordingly. By looking at Figure 4.20, it can be noticed feedback was provided to a pupil who had completed a learning activity from the proposed system. The feedback includes congratulations for the achievement to the pupil along with the correct sequence confirming the correct way to complete this activity as well as there was also the code underneath that is related the commands identified. This shown code in Figure 4.20 enables a pupil to see what they were doing is a set of instruction programmed not only playing a game, and this would lead to educate them to get the idea of how the code works.

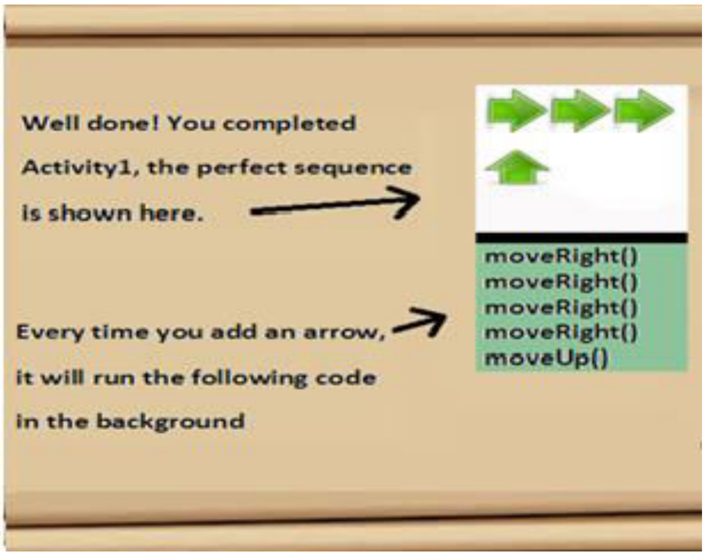

Figure 4.20: An example of Feedback from the Proposed System

4.14.2 Supervision of Pupils through the Proposed System

As this pedagogical system is specifically designed for primary school children, teacher involvement was one of the considered requirements. For example, this system enables teachers to obtain access to the system through having a number of privileges. One of the main privileges is to view the progress of their pupils by simply clicking on their names (or click on “All options” to view the progress of the entire class) and see how they are performing in programming, as shown in Figure 4.21. Also, the teacher can click to ‘view more’ button for a particular student. To illustrate this further, the pop-up window in this Figure provides further details on the achievement of this particular student e.g. learning activities completed. In addition, teachers can access this educational system through their preferred access methods, such as a tablet, web browser and so on.

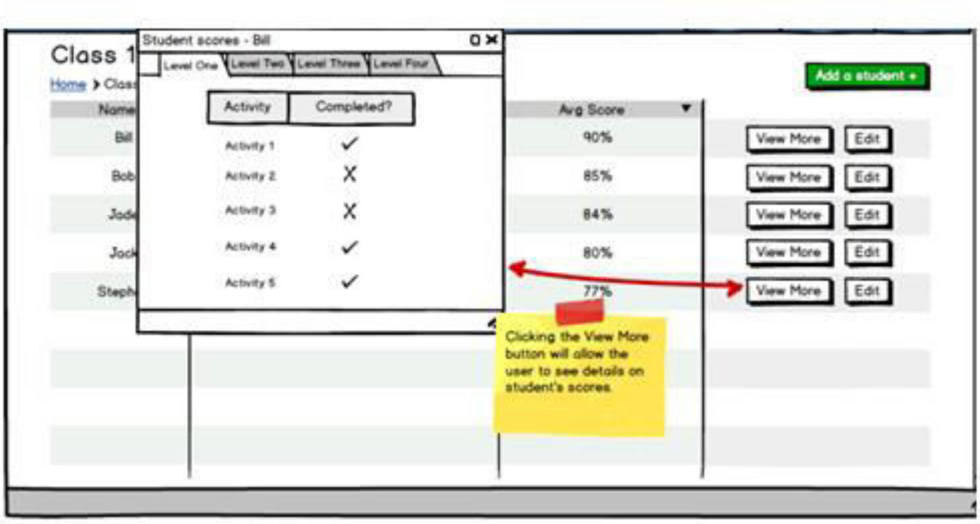

Figure 4.21: A Screen Shot of Progress Assessment for Teacher

4.15 Summary of the Chapter

Game-based learning and its implications for the proposed research have been discussed throughout this chapter. Furthermore, a detailed overview of the proposed framework with a comparison between this framework and one of the existing programming systems (Scratch). The chapter has also provided an illustration of the software development process including requirements gathering process, design process, implementation process and testing of the proposed system that have been carried out for constructing the proposed system as well as detailing the suitability and success of the selected model, “Agile software development,” in the construction of the proposed system among other different software development models.

CHAPTER 5
EXPERIMENT DESIGN

5.1 Introduction

This chapter provides an in-depth discussion of the research methodology, the pilot study conducted on pupils from two different UK primary schools and the survey of UK teachers. Furthermore, the chapter contains details relating to the design of the experiment. The research methods, as well as the analysis of relevant variables of the proposed questionnaires, will also be discussed in this chapter.

5.2 Research Methodologies

The following subsections detail the research methods chosen by the researcher for this study.

5.2.1 Quantitative Research Methodology

According to Bryman [106], a quantitative research approach is a process that can be applied to the natural sciences, where there is a specific interest in the positivist approach to phenomena [106]. Muijs [107] has described quantitative research as an explanation of phenomena through gathering numerical information which is examined using mathematically-based methods [107]. Furthermore, quantitative research is a widely used research method in many different fields, including psychology, economics, human development, and other diverse fields [108] [109]. It can be simply defined as asking participants (those who are willing to discuss their opinions by answering a research survey) specific and narrow questions in order to obtain a sample of numerical data, for instance, statistics, percentages and so on. Additionally, this quantitative approach offers several advantages for researchers undertaking scientific studies [107]. One of these benefits is that it allows them to involve a greater number of subjects, and this enhances the generalisation of their research results. It also offers them the ability to summarise vast sources of information as well as helping to ensure the accuracy of their research results.

More importantly, the researcher of this study aimed to use this quantitative approach, among other approaches, for data collection and analysis. This was in order to evaluate the performance of the proposed system that was created for supporting pupils to learn programming effectively in a primary school. This research employs a questionnaire, which was distributed to both teachers and students who were involved in experiments relating to using the proposed system, as a quantitative approach is useful in analysing statistical data from a questionnaire. However, although a quantitative approach is an advantageous method to use, it sometimes might not provide researchers with enough details about their research findings. Consequently, the researcher of this study also planned to use a qualitative method as well in order to record participants' attitudes, feelings and behaviours in greater detail (which will be discussed in depth in the following section) for evaluating the performance of the proposed system.

5.2.2 Qualitative Research Methodology

According to Denzin and Lincoln [110] (p.14), a qualitative approach differs from a quantitative one as the qualitative approach implies: "an emphasis on processes and meanings that are not experimentally analysed, measured, in terms of amount, quantity, intensity, or frequency." [110]. In addition, Noor [111] (p.1602) reported that "there are cases, where researchers are interested in insight, discovery, and interpretation, rather than hypothesis testing." [111]. With regard to this research, interviewing, as a qualitative technique, was selected to collect data from a number of primary school teachers from the UK, in order to understand their motivations and feelings by enabling them to talk openly about their opinions on the concept of teaching children programming during early years schooling.

This method enabled the researcher to conduct further investigations and gather more information from the participants, such as why teaching children programming in primary school is helpful. In addition, another purpose for choosing this research approach was to gain an understanding of further details from the participants on the idea of learning programming in early years education, for instance, how they found learning programming through the proposed system and why they liked it.

To conclude the research methodology section: a combination of both qualitative and quantitative approaches was used in this research. According to Johnson et al. [112], the use of mixed methods (quantitative and qualitative) brings many advantages in finding out answers to research questions. This is because a mixture of both quantitative and qualitative methods provides variation in data collection. This, in fact, leads to greater validity; in addition, a combination of both methods provides a better understanding of a research issue than only using one single research approach [112] [113].

5.3 Variables (Independent & Dependent)

In every experiment, there are certain variables that need to be well studied by the researcher in order to investigate and measure whether an independent variable has an effect on the dependent variable or not. More details about the two types of variable can be found in the next subsections.

5.3.1 Dependent Variable (Effects-Outputs)

This particular variable can be defined as what will be measured or what things the researcher thinks will be affected during the experiment. For example, in this research, the researcher wanted to measure pupils' programming performance before and after using the proposed system. Therefore, their performance could be one of the main dependent variables in this study. This particular dependent variable, "pupil's performance", was measured as follows: firstly, a number of independent variables (detailed in section 5.3.2) were used as input to the dependent variables. After that, those dependent variables were measured against independent ones. For example, the performance and enjoyment rate of pupils who have been taught traditionally differs from those who have learnt through the proposed system. In order to measure this situation, certain dependent variables need to be observed, including the performance and enjoyment rate, as well as noting that there are also two different learning methods – "independent variables" – the traditional method and the proposed system method. After carrying out the required classification of those different variables, IBM SPSS statistical software can be used to analyse the relevant data from them.

5.3.2 Independent Variable (Causes-Inputs)

Independent variables can be described as the things that will affect the dependent variables which were previously discussed. In this research, independent variables are the two ways of teaching pupils programming. The first way will be using the proposed system, and the second one will be via the traditional classroom. Further illustration about what has been mentioned in the earlier section and this particular section is provided here with an example that clarifies the relationship between dependent variables and independent variables: the effect of the proposed Programming Tutoring system on pupils' programming performance. From this given example, it can be seen there are two different underlined variables that will be detailed here. The first one is the independent variable, and the second is the dependent variable. This research aimed to measure the Dependent Variable or performance of pupils before and after using the proposed system and then see if there were any noticeable significant changes among this experiment's participants. Furthermore, the researcher has measured the performance of pupils who have a different independent variable (taught by the traditional method) and subsequently analysed the given results, which are detailed in the research findings chapter of this thesis.

5.4 Obtaining Ethical Approval for the Proposed Research

The ethical approval task was planned within the early stages of this proposed research and was completed before commencing any activity with the research participants. It was obligatory as this research required participation from teachers and pupils in early years education. The required ethical approval form was completed and submitted along with planned questionnaire questions and some other related documents to LJMU's ethical committee. The committee officially approved the researcher's request and sent the researcher official notification of this. Further details of the ethical approval can be found in Appendix 1 "Ethical Approval".

5.5 The UK Teacher Survey

The aim of this investigation was to study and analyse teachers' reactions to the decision to teach children programming in early years education (as is becoming compulsory in the UK), their preparations to tackle the challenges of teaching programming to young pupils, and how the proposed system could solve some of these challenges and support their pupils to learn programming better. With regard to the details of the selected questions in Table 5.1, they were designed to obtain teachers' thoughts more specifically on the idea of teaching their pupils programming, such as checking if they are happy for their pupils to learn programming at a young age, as well as to what extent those teachers would agree that teaching their pupils programming during early years education would be beneficial, and whether learning programming would equip their pupils with the problem-solving skills that would help them to learn how to tackle an issue. Participants gave their responses to each item on a five-point Likert scale ranging from 1 (Strongly Disagree), 2 (Disagree), 3 (Don't know), 4 (Agree) to 5 (Strongly Agree) to measure respondent reaction.

Participants were reassured that their answers would be kept confidential by the researcher. A sample of the survey can be seen in Table 5.1 while the full details can be found in Appendix 2 "UK Teachers Survey".

Table 5.1: A Sample of the UK Teachers Survey

	Strongly disagree	**Disagree**	**Don't know**	**Agree**	**Strongly agree**
Teaching children programming is one of the ways to develop their problem-solving skills and innovative thinking.	1	2	3	4	5
I like my pupils to learn about programming and how the technology works in their primary schooling.	1	2	3	4	5

An assessment-driven learning tool would reduce some of my workloads when I am teaching my pupils programming.	1	2	3	4	5

5.5.1 Descriptive Statistics of the Teachers' Responses (Scale Data)

This section provides an in-depth description of the statistical data relating to teachers' thoughts on the concept of teaching young students programming, and how technology could be beneficial to their pupils in developing their problem-solving skills as well as a tool to aid teachers in the classroom. According to the statistical results in Table 5.2, it can be seen that a number of items were made for the participating teachers. Those items were distributed in the experiment stage of this research to 30 teachers from UK primary schools, and the details of those created items and participants' responses to this survey are discussed in detail as follows.

In this particular study, 23 teachers out of the 30 informed the researcher about their views on the concept of teaching pupils programming in the UK and how programming could be a useful subject for pupils regarding developing their computational thinking and helping them in problem solving. With regard to the contents of the survey completed by the participants, there were five items. The first one was about the possible benefit that children could acquire when they had the opportunity of being taught programming in early years education, such as the development of their problem-solving skills. This was followed by the second item, which concerned how pleased teachers are to teach their pupils about programming and how the technology works. The third item was about teaching pupils programming at an early stage; this could reduce some future learning challenges when they, for instance, specialise in computing, as they have received a good foundation whilst at primary school. After that, there were two additional items, which were testing the need for assessment-driven learning technology in classrooms to be used by teachers as well as how this technology could be advantageous for teachers by, for instance, reducing some of their workloads.

Table 5.2: Descriptive Statistics of the Items Considered by UK Teachers

Items	Number of teachers	Mean
Teaching children programming is one of the ways to develop their problem-solving skills and innovative thinking levels.	23	4.74
I like my pupils to learn about programming and how the technology works in their primary schooling.	23	4.57
Teaching programming in early schooling would decrease some of the challenges of learning programming for your pupil when he/she may specialise in computer science in the future (e.g. college).	23	4.26
I need an assessment-driven learning tool to teach my pupils programming in the school or at home.	23	4.39
An assessment-driven learning tool would reduce some of my workloads when I am teaching my pupils programming.	23	4.30

5.6 Pilot Study

This experiment (external experiment) took place in a Liverpool preparatory school named “Belvedere Preparatory School” which is an independent preparatory school (funded by fees paid by parents), and it delivers an independent education for pupils of a diverse ethnic, social and religious mix [114]. The age range of pupils 3-11 and the total number of pupils in this school is 110 pupils. According to the Ofsted inspection report [114] on this school, the overall quality of education is good which means it is effective in delivering outcomes which provide well for all its pupils' requirements.

The experiment was carried out in 2015 after the completion of the development of the proposed system. In this experimental study, 52 pupils participated, and they were divided into three groups with the help of the ICT school teacher. The first group was the experimental group, pupils who had used the proposed system for learning programming through playing a game (a mixture of Year 3 pupils and Year 4 pupils, as they still have not experienced programming in the school, whereas Year 5 and Year 6 pupils have started to learn programming via Scratch). The second group was the traditional group, pupils who have learned via attending a traditional classroom to learn programming (a mixture of Year 3 pupils and Year 4 pupils). The last group was those who have learned programming via making a game using the Scratch tool (Year 6 pupils). More importantly, the only group had some prior experience in programming from those discussed above three groups is Scratch groups while others did not. There was also another experiment (Internal Experiment), which took place at Liverpool John Moores University (LJMU), with 41 pupils from a Manchester primary school named "Whitefield Community Primary School" which is a primary community school. This type of school is supported by a local education authority called "Bury" [115]. The support includes the funds for the school, the school's staff employment and so on. The age range of pupils is 3–11 and the total number of pupils in this school are 167 pupils. In this primary school, the percentage of pupils from minority ethnic sets is high, as they speak English as an added language. Based on the Ofsted inspection report [115], the overall effectiveness of this school is good. More details about the results and purposes of the two experiments conducted on pupils from the two different primary schools are provided in depth in Chapter six of this thesis.

5.6.1 Pre-Run Student Survey

This survey was designed for the purpose of seeking some information about the background of the participants in this study. This would include both the experimental group and the non-experimental group. The researcher wanted to find out their level of interest in the use of technology and how the technology works, as well as to test their interest and motivation relating to computing and programming. The survey contained a number of items. The first one was about the students interest in the use of the Internet and looking for information, whereas the second item related to them playing computer games, such as after finishing their school homework: do they like to use their free time to play computer games or not? The next item aimed to assess their interest in understanding how the technology works and learning about computational thinking. The third item aimed to discover their familiarity with an existing programming tutoring system, such as what it is and what they like and dislike about it; it also wanted to find out whether they preferred to learn to program from a technological tool or not. Participants gave their responses to each item on a five-point Likert scale ranging from 1 (Strongly Disagree), 2 (Disagree), 3 (Don't know), 4 (Agree) to 5 (Strongly Agree) to measure respondent reaction. A sample of this particular survey can be found in Table 5.3, while the full details can be found in Appendix 3 "Pre-Run Student Survey".

Table 5.3: A Sample of the Pre-Run Student Survey

	Strongly disagree	**Disagree**	**Don't know**	**Agree**	**Strongly agree**
I like to use the Internet.	1	2	3	4	5
I spend my free time in playing computer games when I finish my school homework.	1	2	3	4	5
I am happy to learn programming in my early schooling.	1	2	3	4	5

5.6.2 Learning through Practice

With the cooperation of the school teacher, the subjects were divided into two equal groups. The groups were balanced such that the average ability of the students in each group was similar, according to their performance at school. These two groups were “the experimental group” and “the traditional group”. The subjects in the experimental group were given a demonstration of the proposed system, which aimed to show them in how to use it, whilst the researcher used the known traditional teaching and learning method to explain the fundamental aspects of programming, for instance, iteration, to the traditional group.

5.6.3 Test

This test was for both traditional and experimental groups. The subjects were given an evaluative test, which covered what they had previously learnt in the training sessions. The details of both groups’ achievements are discussed in depth in the research findings chapter (Chapter six). After the completion of this test, pupils from both groups were asked to fill in a questionnaire, which will be detailed in the next subsection.

5.6.4 Post-Run Student Survey

This survey was intended for the purpose of gathering the responses after the learning process from the experimental group, who have used the proposed system in learning programming, and the traditional group, who have learnt programming with a classroom teacher. Some of the survey questions were designed with the intention of measuring subjects’ feedback and satisfaction in using the proposed technology compared to the traditional way of learning. The survey contained a number of items. The first one was designed to measure their enjoyment of the specific learning method (traditional or proposed system). The second related to how they found their specific learning method and how they viewed their progress now compared to before the learning process. The next item asked if they had found the specific learning method interesting. Furthermore, there were two other items that were intended to measure if they would like to continue using their specific learning method for learning more about programming, as well as looking at whether this method was a suitable way for them to learn continuously about programming. Participants gave their responses to each item on a five-point Likert scale ranging from 1 (Strongly Disagree), 2 (Disagree), 3 (Don't know), 4 (Agree) to 5 (Strongly Agree) to measure respondent reaction. A sample of this particular survey can be found in Table 5.4. The details of the subjects' results from this survey can be found in the research findings chapter of this thesis. A sample of this post-run student survey can be found in Table 5.4 below, while the full details can be found in Appendix 4 "Post Run Student Survey".

Table 5.4: A Sample of the Post-Run Student Survey

	Strongly disagree	**Disagree**	**Don't know**	**Agree**	**Strongly agree**
I have enjoyed learning programming.	1	2	3	4	5
The used learning method has increased my progress in coding.	1	2	3	4	5
The used learning method is interesting.	1	2	3	4	5

5.7 Summary of the Chapter

This chapter has described in depth the design of the conducted experiment, which includes a pilot study that was carried out with pupils from two UK primary schools. Furthermore, the chapter has discussed the research methods used for gathering the responses of both teachers and pupils from the UK. More importantly, the measurement of the research variables within this study and how the researcher conducted the required analysis have been detailed in this chapter. Ultimately, although learning programming is a challenging process for children, statistical findings based on teachers' responses have shown that teaching children programming in early years education is beneficial for them and would develop their problem-solving skills and innovative thinking when supporting them with a programming tutoring system (Proposed System) that considers their learning levels (Assessment-driven learning) and learning interest (Game-based learning).

CHAPTER 6
RESEARCH FINDINGS

6.1 Introduction

This chapter discusses in depth the statistically significant results of the two experimental studies of this research work, which were conducted on pupils from two different UK primary schools. A total of 93 pupils were involved in those two research experiments: 41 in the first experiment (learnt programming through the proposed system) and 52 in the second experiment). As the researcher wanted to compare the proposed system with two other learning methods (Traditional method and Scratch), participants involved in the second experiment were divided into three groups with the help of the ICT school teacher, who is aware of their pre-knowledge in programming. The first group was the experimental group, which comprised those who had used the proposed system for learning programming via the learning by playing method (learning by playing a game); they were a mixture of Year 3 and Year 4 pupils. The second group was the traditional group, which was made up of those who had learnt programming by attending a traditional classroom (learning through lecturing); they were a mixture of both Year 3 and Year 4 pupils. The last group was those who have learnt programming via the making a game method (learning through the use of the Scratch tool); they were all Year 6 pupils. A detailed discussion of the three groups with the results of their chosen learning approach can also be found in this chapter.

6.2 Testing of the Proposed System on Pupils from the Two Primary Schools

As the development process of the proposed system was designed to be entirely based on the agile software development model (described in depth in Chapter four of this thesis), the experiment phase (Testing) of the proposed system was iteratively done, which means that this proposed system was tested twice during the development process on pupils from a UK primary school and, after the completion of the development of the proposed system, on different pupils from a different primary school. Testing this proposed system a number of times on different pupils, at different times and in different places enabled the researcher to observe the pupils' performance via the use of the proposed system, provide feedback on their learning experience, and consider any shortcomings faced before completing the development of the proposed system and conducting the final experiment. More importantly, performing this experiment a number of times with different pupils in different schools has given this PhD scientific research more accuracy and consistency in the statistical results of this conducted experiment, which are described in more detail in this chapter. More information about the two types of experiment is detailed in the following subsections.

6.2.1 Initial and Rapid Experiment on Pupils (Manchester Primary School)

As this initial experiment was carried out during the development of the proposed system, primary school teachers and 41 pupils from a Manchester primary school were invited by the supervisory team of this research project to visit Liverpool John Moores University (LJMU) where this PhD research and development of this proposed system were taking place. This visit was arranged for the purpose of testing the efficacy of the current development of this proposed system in teaching these pupils programming. Upon their arrival, the participants were warmly welcomed and fully informed about the purpose and other details of this experiment, such as how to use the proposed system. Then, they started using the proposed system to learn computer programming. After that, an evaluative sheet was distributed for them to complete and inform the researcher about their learning experience and how they experienced learning programming through the proposed system. More importantly, the researcher was observing the pupils when they were using the proposed system, for example, their interaction with the system, as well as studying their views about the proposed system after the completion of this experiment. According to the results shown in Figure 6.1, it can be noticed that 31 of the pupils enjoyed learning programming through playing the game in the proposed system whereas nine of them did not enjoy it, as they wanted to see different colours, photos and characters (this comment was considered before commencing on the next main experiment). Furthermore, in the second item “Learning through playing this game in the proposed system has helped me to learn something about programming," it can be seen that 40 of the pupils indicated that this proposed system helped them to learn something about programming. With regard to whether the proposed system was interesting and considered the various levels of the pupils who participated, it was noted that 36 of them found it interesting and suitable for their learning levels in programming.

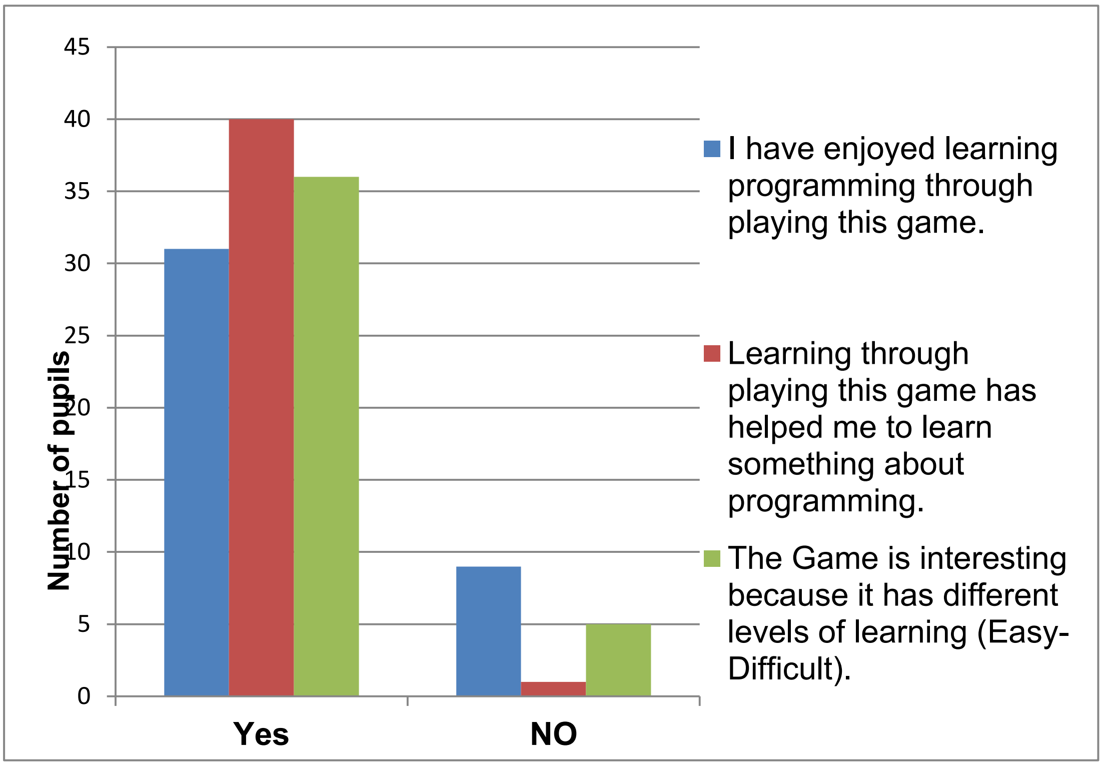

Figure 6.1: Initial Experiment Results for the 41 Pupils from the 1st Primary School

The researcher also managed to obtain the opinions of the primary school teachers (four teachers) who attended this initial experiment of the proposed system with the 41 pupils. All of those teachers felt that the proposed system was fun for their pupils (for example, on the day of this initial experiment some of their pupils did not want to go for the lunch offered by LJMU as they wanted to continue using the proposed system to learn programming, which made their teachers and the researcher smile), and that they would allow their pupils to use the proposed system again.

Some advantages were found after completion of this initial experiment. The pupils confirmed that they had successfully learnt programming through the proposed system, and that the system had considered their learning levels. This experiment assured the researcher that all of the specified requirements of this proposed system (described in Chapter four of this thesis) had successfully been met and that the system was ready to be externally used in a different school. Detailed information about the external experiment which was conducted outside LJMU is described in the next subsection.

6.2.2 The Final and Main Experiment on Pupils (Liverpool Primary School)

This main experiment was performed after the completion of the development of the proposed system. It took place in a Liverpool primary school and 52 pupils participated in this experimental study. Those participants were divided into three groups with the help of the ICT school teacher. The first group was the “Experimental Group”, which comprised those who have used the proposed system for learning programming through playing a game (a mixture of Year 3 pupils and Year 4 pupils, as they still have not experienced programming at the school). The second group was the “Traditional Group”, which comprised those who have learnt programming via attending a traditional classroom (a mixture of Year 3 pupils and Year 4 pupils). The last group was those who have learnt programming via making a game (“Scratch Group”) with the use of the Scratch tool (Year 6 pupils). In this main experiment, many activities were carried out with the participants, such as a pre-run student survey, post-run student survey and others. Consequently, the researcher visited this primary school several times to successfully complete this final experiment. The details of the results of this main experiment with all of the various groups who have been involved in this experimental study are illustrated in depth in the succeeding sections, followed by a detailed discussion of the statistical results of all pupils who have been involved in this experimental work from both Manchester and Liverpool primary schools.

6.3 Experimental Group Results for the Final Experiment

The characteristics of the experimental group (e.g. the number of participating pupils, which year they are in, and other characteristics or variables) involved in this final main experiment (in a Liverpool primary school) with the use of the proposed system to learn programming are statistically described in the following subsections (IBM SPSS statistical software was used by the researcher for the statistical analysis of this experimental research).

6.3.1 Descriptive Statistics for the Categorical Variables

In this subsection, the focus is mainly on the categorical variables of the questionnaires completed by the experimental group. Thus, frequencies are used here as a method to obtain the statistics of the categorical variables, which are described in Table 6.1. Table 6.1 also shows the total number of pupils in both Year 3 and Year 4. Additionally, it shows that these 18 pupils have used the proposed system as a programming learning method.

Table 6.1: The Statistics for the Three Categorical Variables

No. of pupils	Method of learning (proposed system)	No. of pupils who attended the test
18	18	18

From the output shown in Table 6.2, it is presented that seven pupils from the Y3 group have used the proposed system (38.9%) and 11 pupils from the Y4 group have also learnt through the proposed system (61.1%). This gives a total of 18 pupils who have been nominated as an experimental group in this experimental study.

Table 6.2: The Number of Pupils in Each Year who have used the Proposed System

Year	No. of pupils	Percent
Year 3	7	38.9
Year 4	11	61.1
Total	18	100.0

By observing Table 6.3, it can be noticed that a large number of the experimental group have achieved a high score on the given test after learning programming from the proposed system (12 pupils out of 18), whereas four of the pupils achieved a medium score and a small number of this particular group achieved a pass (two pupils out of 18).

Table 6.3: Experimental Group Results

Grade	No. of pupils	Percent
Pass	2	11.1
Medium score	4	22.2
High score	12	66.7
Total	18	100.0

The percentage of the experimental group's achievements is provided in Figure 6.2. This indicates that a large number of pupils achieved a high score (66.7%), whereas a small percentage of pupils achieved a lower or pass score (11.1%).

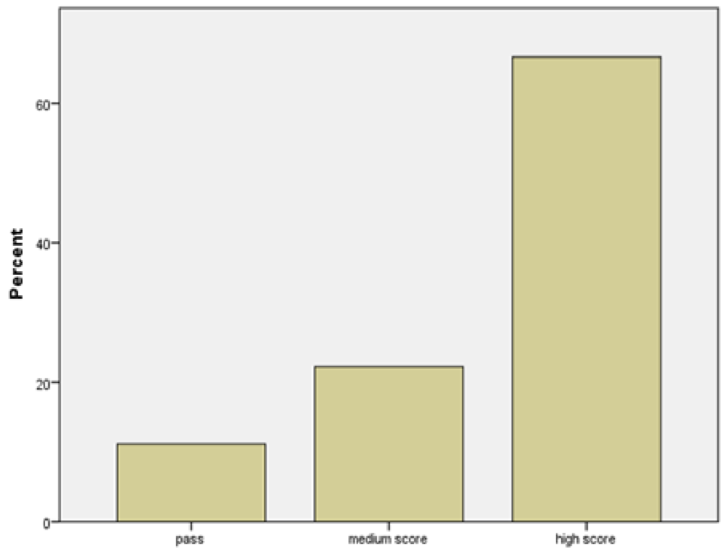

Figure 6.2: Experimental Group's Achievement

6.3.2 Descriptive Statistics for the Continuous Variables (Scale Data)

Table 6.4 provides statistical information for the experimental group including 10 items that were responded to by this group during the experiment stage of this research. The first five items were answered by the experimental group before using the proposed system. Those items are the following:

1) I like to use the Internet.
2) I spend my free time in playing computer games when I finish my school homework.
3) I am happy to learn programming in my early schooling.
4) I like to learn about how technology works.
5) I need a technological tool to help me better in programming.

According to the results described in Table 6.4, it can be noticed that Items 1 and 3 received the highest responses from the experimental group, as the mean of Item 1 is 4.33, from a range of 1 to 5, and the mean of Item 3 is 4.22, also from a range of 1 to 5. This shows that the experimental group strongly agreed with those two statements, "I like to use the Internet" and "I am happy to learn programming in my early schooling".

After learning programming through the proposed system, the experimental group responded to the rest of the items listed in Table 6.4 (items 6-10). Those items were as follows:

6) I have enjoyed learning programming.

7) The used learning method has increased my progress in programming.

8) I would like to recommend my friends to use the same method for learning programming.

9) I would like to continue learning programming from recently developed programming tutoring systems such as Proposed System.

10) The used learning method for learning programming is interesting because it considers my level of learning.

From the output shown in Table 6.4, the results could indicate that learning programming through the proposed system (learning programming via playing a game) helped the experimental group to enjoy learning programming (the mean is 4.67), increase their progress in programming (the mean is 4.39), recommend their friends to use this proposed system (the mean is 4.22) and also to continue learning programming electronically (the mean is 4.28). The experimental group also found this proposed system (which is based on assessment-driven learning) suitable for their levels of learning (the mean is 4.39).

Table 6.4: A Statistical Description the Experimental Group's Responses to the 10 Items

Items	No. of Pupils	Minimum	Maximum	Mean	Std. Deviation
I like to use the Internet.	18	1	5	4.33	1.029
I spend my free time in playing computer games when I finish my school homework.	18	1	5	3.89	1.183
I am happy to learn programming in my early schooling.	18	1	5	4.22	1.003
I like to learn about how technology works.	18	1	5	3.94	1.110
I need a technological tool to help me better in programming.	18	1	5	3.22	1.353
I have enjoyed learning programming.	18	1	5	4.67	.594
The used learning method has increased my progress in programming.	18	1	5	4.39	.979
I would like to recommend my friends to use the same method for learning programming.	18	1	5	4.22	1.003
I would like to continue learning programming from recently developed programming tutoring systems such as Proposed System.	18	1	5	4.28	1.127
The used learning method for learning programming is interesting because it considers my level of learning.	18	1	5	4.39	.979

6.3.3 Measurement of Pupils' Programming Progress (Proposed System)

As the researcher was interested to see if there is a statistical difference between pupils in Year 3 and Year 4 when learning programming through the proposed system, the means of the dependent variables (continuous variables) were measured for the group of pupils in Year 3 and the other group of pupils in Year 4. This statistical measurement or examination was performed with the use of a T-test statistical technique. According to Pallant

[116], the description of a T-test would be: a statistical examination of the two groups' means. This statistical technique is used for comparing the mean scores on some variables in order to detect whether there are statistically significant differences between those means or not [116].

Table 6.5 shows the mean of the variable "The used learning method has increased my progress in programming" for pupils from both Year 3 and Year 4, and this statistical data is compared in Table 6.6.

Table 6.5: Experimental Group Programming Progress in Year 3 & Year 4

Dependent Variable	Year	No. of pupils	Mean	Std. Deviation
The used learning method has increased my progress in programming	Year 3	7	5.00	.000
	Year 4	11	4.00	1.095

Table 6.6: Experimental Group Achievement—t-test at 0.05 Level of Significance

Dependent Variable	Levene's test for equality of variances		T-test for Equality of Means						
								95% confidence interval of the differences	
The used learning method has increased my progress in programming	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	2.333	.146	2.388	16	.030	1.000	.419	.112	1.888
Equal variances not assumed			3.028	10.00	.013	1.000	.330	.264	1.736

An independent sample T-test was employed, which is a technique used to statistically compare the means of programming progress scores for Year 3 and Year 4 pupils who have learnt programming through the proposed system. From the generated results in Table 6.6, it can be seen that there is a statistically significant difference in the programming progress between the two years, as shown in the Sig. (2-tailed) column; the significance result was .030, which is less than 0.05 (the result of the level of significance or P value).

6.4 Comparison of Experimental and Traditional Groups

As this research aimed to see how both learning programming via the proposed system and learning programming traditionally could affect the learning progress of pupils in Year 3 and Year 4, a detailed statistical comparison was made, as can be found in the following subsection. Table 6.7 shows the two learning methods that have been used. Seventeen pupils had used the traditional method whereas 18 had learnt through the proposed system.

Table 6.7: The Learning Method and Number of Pupils

Learning method (Independent Variable)	No. of pupils	Percent
traditional	17	48.6
proposed system	18	51.4
Total	35	100.0

Statistical data in Table 6.8 shows the number of pupils who learnt both traditionally and through the proposed system in Year 3 (14 pupils) and Year 4 (21 pupils).

Table 6.8: The Number of Pupils in Year 3 and Year 4 (Proposed System & Traditional System)

Year	No. of pupils	Percent
Year 3	14	40.0
Year 4	21	60.0
Total	35	100.0

Figure 6.3 shows that the percentage of participants in the traditional method was 48.6 whereas the percentage of others who learnt via the proposed system was 51.4.

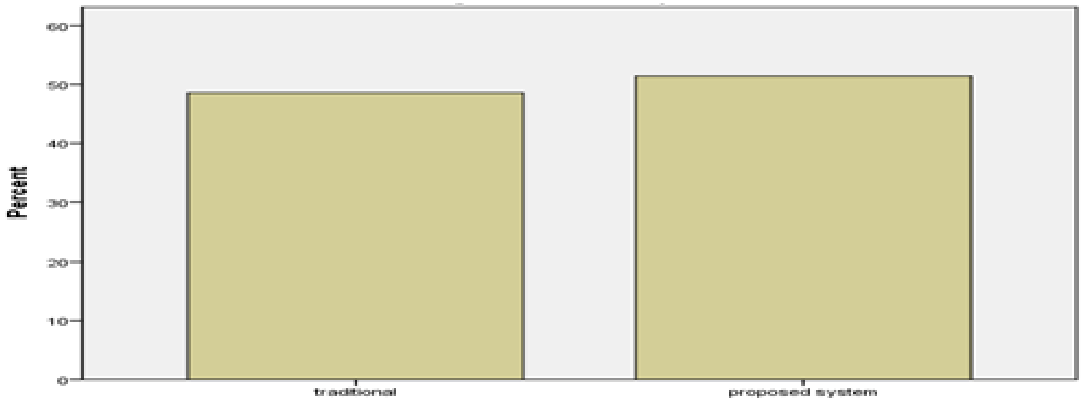

Figure 6.3: Comparison of Learning Methods (Traditional System & Proposed System)

Statistical data in Figure 6.4 shows the percentage of pupils who learnt both traditionally and through the proposed system in Year 3 (40%) and Year 4 (60%).

Figure 6.4: The Percentage of Year 3 and Year 4 Pupils who learnt via both Methods

6.4.1 Measurement of Pupils' Performance (Proposed &Traditional Ways)

Table 6.9 shows the two learning methods used by both groups (Proposed system and Traditional system) with an illustration of the mean of the variable "The used learning method has increased my progress in programming", and this statistical data is compared in Table 6.10.

Table 6.9: Some Statistics about a Learning Method Variable for both Groups

Dependent Variable	Learning method (Independent Variable)	No. of pupils	Mean	Std. Deviation
The used learning method has increased my progress in programming	traditional	17	3.65	.996
	proposed system	18	4.39	.979

An independent sample was used here as a method to statistically compare the means of programming progress for both groups, those who learnt traditionally and those who learnt via the proposed system. By looking at the statistics in Table 6.10, it can be noticed that there is a statistically significant difference in the programming progress of the two groups and this is according to the significance result, which is .033, as well as it is less than 0.05 (the result of the level of significance or P value).

Table 6.10: Experimental Group & Traditional Group Achievement—t-test at 0.05 Level of Significance

Dependent Variable	**Levene's test for equality of variances**		**T-test for Equality of Means**						
								95% confidence interval of the differences	
The used learning method has increased my progress in programming	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	.166	.686	-2.222	33	.033	-.742	.334	-1.421	-.063
Equal variances not assumed			-2.221	32.80	.033	-.742	.334	-1.422	-.062

6.4.2 Measurement of Enjoyment Rate

Table 6.11 shows the mean of the variable "I have enjoyed learning programming" for the two different learning methods and this statistical data is compared in Table 6.12.

Table 6.11: Some Statistics about the Enjoyment Variable of both Groups

Dependent Variable	Learning-method (Independent Variable)	No. of pupils	Mean	Std. Deviation
I have enjoyed learning programming	traditional	17	3.35	1.057
	proposed system	18	4.67	.594

An independent-samples t-test was used to statistically compare the means of enjoyment scores for both groups. From the generated results in Table 6.12, it can be seen that there is a statistically significant difference in the enjoyment variable between the two groups and this is according to the significance result, which is .000, as well as it is less than 0.05 (the result of the level of significance or P value).

Table 6.12: Experimental Group & Traditional Group Enjoyment—t-test at 0.05 Level of Significance

Dependent Variable	Levene's test for equality of variances		T-test for Equality of Means						
								95% confidence interval of the differences	
I have enjoyed learning programming	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	10.473	.003	-4.566	33	.000	-1.314	.288	-1.899	-.728
Equal variances not assumed			-4.497	24.884	.000	-1.314	.292	-1.916	-.712

6.4.3 Comparison of Test Result Means

Table 6.13 indicates the means of the "test result" variable for the two different learning methods and this statistical data is compared in Table 6.14.

Table 6.13: Some Statistics for the Test Result Variable of both groups

Dependent Variable	Learning method (Independent Variable)	No. of pupils	Mean	Std. Deviation
test result	traditional	17	1.65	.862
	proposed system	18	2.56	.705

An independent-samples t-test has been used as a procedure to statistically compare the means of the test result for both the experimental and traditional groups. From the generated results in Table 6.14, it can be seen that there is a statistically significant difference in the test result variables between the two groups. This is because it is shown that the significance result is .002 and it is less than 0.05 (the result of the level of significance or P value).

Table 6.14: Experimental Group & Traditional Group Test Result—t-test at 0.05 Level of Significance

Dependent Variable	**Levene's test for equality of variances**		**T-test for Equality of Means**						
								95% confidence interval of the differences	
test result	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1.975	.169	-3.423	33	.002	-.908	.265	-1.449	-.368
Equal variances not assumed			-3.403	30.968	.002	-.908	.267	-1.453	-.364

6.5 Comparison of Experimental and Scratch Groups

A detailed statistical comparison between learning through the proposed system and Scratch (which is another programming tool for children, details of which were provided in Chapter four, section 4.5.2) can be found in the following subsections.

6.5.1 Experiment Analysis of the Two Groups

By looking at Table 6.15, it can be seen that two groups have been involved in this experimental study. The first group comprised pupils who have used the proposed system for learning programming: seven pupils from Year 3 and 11 from Year 4. The second group comprised pupils who have used Scratch for learning programming: 17 pupils from Year 6.

Table 6.15: The Frequency of Pupils in Each Year and in Each Group

Participating Groups	Year	No. of pupils	Percent
Proposed System Group	Year 3	7	20.0
	Year 4	11	31.4
Scratch Group	Year 6	17	48.6
Total		35	100.0

Table 6.16 shows the frequency of pupils in the two different learning methods, the proposed system and Scratch.

Table 6.16: The Number of Pupils in Each Learning Method

Learning method (Independent Variable)	No. of pupils	Percent
proposed system	18	51.4
Scratch	17	48.6
Total	35	100.0

By looking at Figure 6.5, it can be noticed that 18 pupils from years 3 and 4 learnt programming through the proposed system and 17 pupils from Year 6 learnt programming through Scratch.

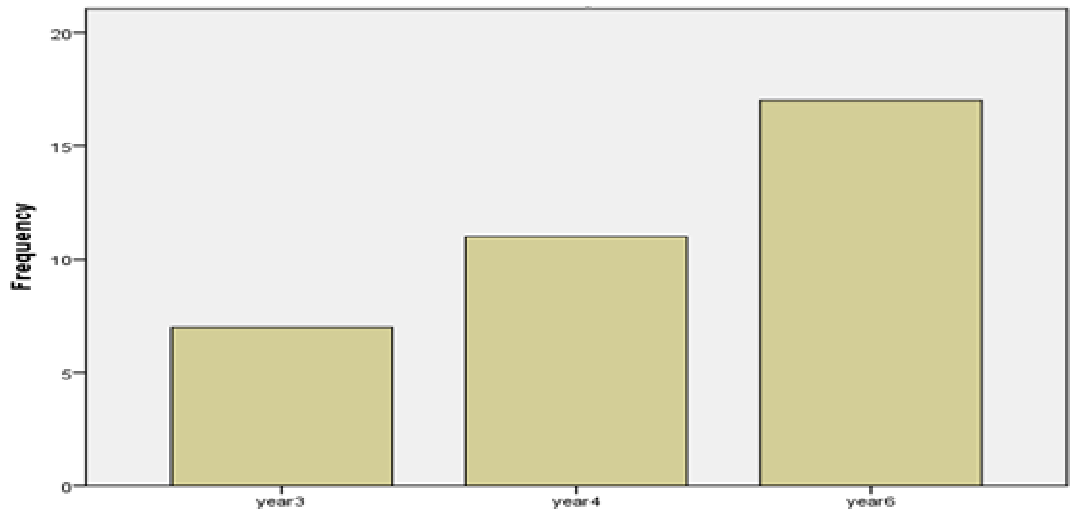

Figure 6.5: The Frequency of Year 3, Year 4, and Year 6 Pupils in both Groups

Figure 6.6 shows that there are two learning methods, the Scratch method, which is for teaching programming through making a game, and the proposed system method, which is for teaching programming through playing a game. The figure shows that the frequency of those who were in the proposed system method was 18, whereas the frequency of those who learnt via the other method was 17.

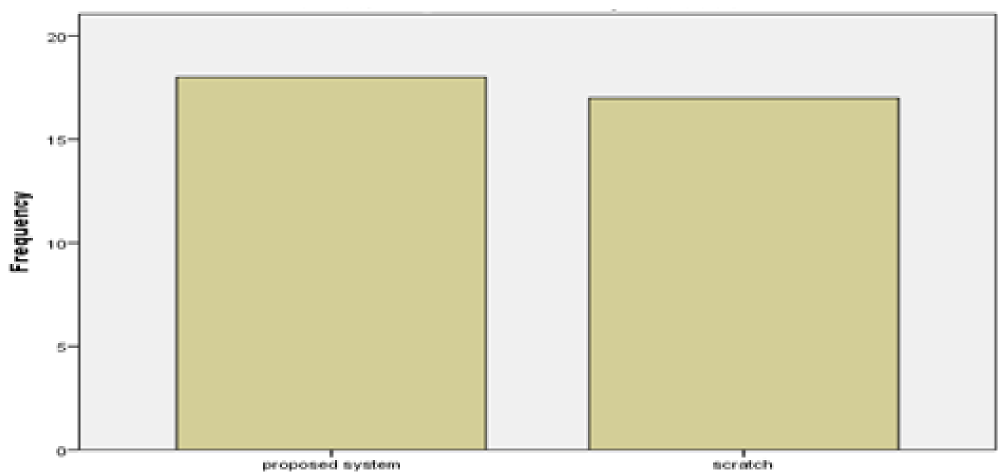

Figure 6.6: The Frequency of Pupils in both the Proposed System and Scratch

6.5.2 Measurement of Programming Progress (Scratch and Proposed System)

Table 6.17 displays the mean of the variable “Using learning method has increased my progress in programming” for the group who used the proposed system for learning programming and the other group, who used the Scratch system, and this statistical data is compared and explained in Table 6.18.

Table 6.17: Some Statistics about the Programming Progress Variable of both Groups

Dependent Variable	Learning method (Independent Variable)	No. of pupils	Mean	Std. Deviation
The used learning method has increased my progress in programming	scratch	17	3.41	.712
	proposed system	18	4.39	.979

An independent sample was used here as a method to statistically compare the mean of programming progress of both groups. By looking at the statistical data shown in Table 6.18, it can be noticed that there is a statistically significant difference in the programming progress of the two groups, as shown in the significance result, which is .002, as well as it is less than 0.05 (the result of the level of significance or P value).

Table 6.18: Experimental Group & Scratch Group Programming Progress—t-test at 0.05 Level of Significance

Dependent Variable	Levene's test for equality of variances		T-test for Equality of Means						
								95% confidence interval of the differences	
The used learning method has increased my progress in Programming	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	.096	.759	-3.360	33	.002	-.977	.291	-1.569	-.386
Equal variances not assumed			-3.391	31.044	.002	-.977	.288	-1.565	-.389

6.5.3 Measurement of Significance in Enjoyment Rate in both Methods

Table 6.19 illustrates the mean of the variable "I have enjoyed learning programming" for the two different learning methods, and this statistical data is compared in Table 6.20.

Table 6.19: Some Statistics about the Enjoyment Variable of both Groups

Dependent Variable	Learning method (Independent Variable)	No. of pupils	Mean	Std. Deviation
I have enjoyed learning programming	Scratch	17	3.71	.772
	proposed system	18	4.67	.594

An independent sample was used here as a method to statistically compare the means of enjoyment for both groups including. By looking at the statistical data in Table 6.20, it can be noticed there is a statistically significant difference in the enjoyment; as shown in the Sig. (2-tailed) column, the significance result is .000, which is less than 0.05 (the result of the level of significance or P value).

Table 6.20: Experimental Group & Scratch Group Enjoyment—t-test at 0.05 Level of Significance

Dependent Variable	Levene's test for equality of variances		T-test for Equality of Means						
								95% confidence interval of the differences	
I have enjoyed learning programming	F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Equal variances assumed	1.063	.310	-4.141	33	.000	-.961	.232	-1.433	-.489
Equal variances not assumed			-4.110	30.059	.000	-.961	.234	-1.438	-.483

6.6 Clarification of the Rationale for Statistical Data Analysis and Justification of Sample Size

The rationale for statistical data analysis process chosen on this research can be explained through the following steps: firstly, it was decided what the research question is (e.g. what are the impacts of the proposed system on pupils' programming performance and enjoyment in learning programming from the proposed system?). Then, which groups were planned to study (within this research, it was interested in pupils from a primary school e.g. Year3 and Year4), how those should be divided (in this research, pupils in Year3 and Year4 were equally divided into two groups (experimental group who used the proposed system to learn programming and traditional group who learnt programming traditionally and both groups did not have prior experience in programming whereas Year6 pupils were only the group who had prior experience in programming through the use of Scratch), which variables need to be focused on (e.g. pupil's performance, enjoyment rate and so on) and what are the best ways to classify and measure them. With regard to the statistical measurement or examination on this research, it was performed with the use of a T-test statistical technique which would be described as a statistical examination of the two groups' means. This statistical technique was used for comparing the mean scores on some variables in order to detect whether there are statistically significant differences between those means or not. More importantly, what the reason (rationale) is for using these statistics, the answer is find out and measure the impact of the use of the proposed system on pupils performance on learning programming and make comparisons between pupils who used the standard approach to learning programming and pupils who used the developed system and then draw conclusions based on sample results. In relation to the justification of the sample size, the sample was from two different UK primary schools participated in the experiments of this research. A total of 93 pupils were involved in this study which considered to be sufficient. According to Brown and Saunders [117], there is no precise way to calculate the best size for a sample. The rule of thumb is that you require a sample of at least 30 respondents for most statistical tests. In addition, the researcher of this study also used his common sense as well as his supervisory team advice to estimate the suitable sample size for this research.

6.7 Discussion of the Overall Results

According to the statistical data of the game-based learning approaches such as learning programming through playing a game with use of the proposed system which have been statistically discussed in the previous sections, the results indicate that pupils who used the proposed system – including those who participated in the first experiment (from a Manchester primary school) and in the final experiment (from a Liverpool primary school) – to learn programming through playing a game found learning programming to be enjoyable and fun, and it increased their interest in continuing to learn programming. Furthermore, it can be seen that pupils (from both primary schools) who used the proposed system to learn programming found it suitable, as they were assessed by the proposed system and then accordingly they were provided with suitable material for their learning level. Additionally, a large number of pupils who used the proposed system to learn programming found their progress in programming had improved and that this system helped them to continuously learn about programming. Another approach to teaching and learning programming was analysed and compared in this chapter with the previously discussed approach of game-based learning, which is a traditional method of teaching or learning programming from a traditional classroom teacher. Results have shown that pupils who learnt programming traditionally found programming a boring and difficult process, and this had severely affected their motivation and acceptance of programming in the school.Additionally, the Scratch programming tool for children (which supports one of the game-based learning approaches for teaching children programming through making a game) was studied in depth and compared with the significant results of the proposed system, which is inspired by the concept of teaching children programming via playing a game. Results have indicated that using Scratch is another enjoyable approach for teaching pupils programming. However, according to the statistical results of this research, it was observed that, for some pupils, learning programming through Scratch was challenging and made learning programming a little difficult for them, as assessment-driven learning is missing from this tool. Therefore, it can be summarised from the statistical data that learning programming through playing a game via the proposed system was the most suitable approach for children in early years schooling, especially those who need to be encouraged to start learning programming.

6.8 Summary of the Chapter

The statistical results of the two experiments for teaching UK children programming in early years education have been broadly discussed in this chapter. This chapter has also compared the results of learning programming through the proposed system with the two other different learning approaches, the traditional method and the Scratch programming system, for supporting children to learn programming effectively. More importantly, statistical results of this chapter have indicated that learning programming through playing a game using the proposed system is a more suitable approach than the other discussed approaches for introducing children to programming.

CHAPTER 7
CONCLUSIONS AND FUTURE WORK

7.1 Introduction

This chapter reaffirms the thesis statement, discusses the issues on teaching and learning programming in early years education, and reaches a final judgement. In addition, this chapter summarises the thesis and highlights its contributions to this particular research field. Finally, some ideas for future work are presented.

7.2 Thesis Summary

Chapter one introduced the main themes of the thesis and described the inspiration for this chosen research. It highlighted the main aims in conducting this research work. Then, the main contribution of this research to the current research was presented.

Chapter two is concerned with the area of teaching and learning programming in early years education. The challenges that are associated with existing work in the domain of teaching pupils programming were highlighted with some examples to support the discussion.

Chapter three presented a survey of research into the educational applications proposed for use in supporting teaching and learning programming. A detailed investigation of learning-styles and their weaknesses was also provided.

Chapter four provided in-depth explanations of game-based learning for teaching pupils programming in early years education. This was followed by a detailed overview of the proposed framework with a comparison between this framework and one of the existing systems (Scratch). Game-based learning approaches and how they have been used for developing the proposed system were clarified in this chapter. The importance of game-based learning for primary school children was also discussed, along with a detailed description of the concept of the software development life cycle highlighting the software development model (Agile) used for developing the proposed system. A description of proposed system development process: requirements gathering, design, implementation, and testing was in depth provided in this chapter.

Chapter five presented a detailed discussion of the chosen research methodology, the survey of UK teachers and the pilot study conducted on pupils from Liverpool and Manchester primary schools. This chapter showed the design of the experiment as well as the analysis of relevant variables from the questionnaires.

Chapter six provided a detailed discussion of the statistically significant results of the two experimental studies, which were conducted on a total of 93 pupils from two different UK primary schools: 41 in the first experiment from a school in Manchester, UK (who learnt programming through the proposed system) and 52 in the second experiment (who were divided into three groups: Experimental, Traditional, and Scratch and they learnt through three specified different learning methods) from a school in Liverpool, UK. The chapter also provided further information about the purposes of conducting these two experimental studies on different pupils from different places, as well as a comparison between all of the involved participants in those two experiments and a discussion of the overall results.

This final chapter provides an overview of the concluded research, restating what the thesis aimed to accomplish. The chapter also summarises the thesis findings, highlighting the significance of the contribution to this PhD research. Lastly, some ideas for future work are indicated.

7.3 Conclusion

7.3.1 A Restatement of What the Thesis Aimed to Achieve

As teaching and learning programming is becoming compulsory in early years education in the UK, there are many challenges that need to be well researched and solved by researchers from different disciplines such as computer science, psychology and others. With regard to this research, the researcher aimed to achieve the outcomes that were set out as part of the project plan. They include investigation of the challenges that are associated with existing tutoring systems that have been used for teaching and learning programming, and supporting primary school teachers with a technological system that can ease the process of teaching and learn programming for their pupils. Furthermore, this research was intended to promote computational thinking by teaching pupils problem solving and how to tackle large problems by dividing them into a sequence of smaller problems. Pupils' engagement with the learning process was one of the challenges taken into consideration in this research. To illustrate this more, the idea of game-based learning was included in this research, where pupils can learn programming through playing a game, and the research experiments showed that pupils who used the proposed system found the learning process more enjoyable compared to the traditional approach. Consideration of individual differences among pupils was included in the requirements of the proposed system through applying the idea of assessment for learning.

7.3.2 Summary of Thesis Findings

When studying the literature for this research, several challenges were identified for both primary school teachers and their pupils. Those challenges include: primary school teachers require further training on how to teach and deliver programming concepts to their young learners in a way that fits their pupils' learning needs; pupils will also need support from an existing programming tutoring system that can simplify the process of learning programming by considering their levels of learning before learning, during learning and after learning. In consequence, this research practically investigated these challenges further as the researcher visited a primary school in the UK a number of times and met with school teachers and their pupils. As a result of this investigation, the researcher proposed a solution, which was the inclusion of the concept of assessment for learning into the development of an automated programming tutoring system. More importantly, this tutoring programming system was tested with 93 pupils from two different primary schools based in the UK, and the results of the experimental work are described here as part of the thesis findings. With regard to the depth of the findings of this thesis, some results were drawn from pupils' participation, and other results were taken from primary school teachers' involvement.

In relation to the pupils' results, the first experiment was carried out during the development of the proposed system and the results of this initial experiment indicated that this proposed system was working correctly according to the designed requirements of this system. The pupils' results in this experiment also indicated that this proposed system was built according to their learning needs (assessment-driven learning) and that the system helped them to learn programming, as well as they enjoyed learning programming when using it.

Then, they were asked to give their views on how they had found learning programming through the proposed system (their suggestions were taken into consideration in the development of the proposed system before conducting the next experiment at a different primary school).

The next experimental study focused on comparing this proposed system with two other learning methods (Traditional method and Scratch). The pupils who participated in this final experiment were divided into three groups. Each group used one of the three different learning methods; for example, the first group used the proposed system for learning programming through playing a game, whereas the second group learnt using the traditional method.

The purpose of providing those various learning methods to each group was to measure some variables including the progress of each group in programming and the enjoyment rate of each group, and to statistically compare those variables between all three groups. More importantly, the results have indicated that the group that used the proposed system as a learning method performed better in programming (as the learning materials were suitable for their learning levels), and also found learning programming more enjoyable compared to the other groups who learnt via different learning methods. From this, it can be proved that teaching and learning programming through playing a game with the inclusion of assessment for learning is one of the best approaches for introducing pupils to programming.

Regarding the results for the UK teachers, they completed a questionnaire. The aim of this designed questionnaire was to obtain their thoughts on the concept of teaching young students programming and how technology could be beneficial to their pupils in developing their problem-solving skills as well as an aid for teachers to use in the classroom. The results indicated that teachers were happy for their pupils to learn programming in early years education. The teachers agreed that it was important to have an assessment-driven learning tool for teaching their pupils programming as it offers a number of advantages, such as learning materials will be provided according to their pupils' needs or levels.

7.3.3 The Significance of the Contribution of this Research

The exploration in this thesis was based on how to suitably and successfully teach pupils programming in early years education through an automated system. The contribution of this research was driven by certain factors. To highlight some of these factors or issues, the researcher conducted broad research on the previous studies relevant to this PhD research, and it was seen that several pedagogical obstacles needed to be addressed by this undertaken research [13] [5], and other obstacles need to be addressed by future researchers (those are discussed in the following section). One of these obstacles was the principle of individual differences among learners, which had not been tackled in previous studies; it means that different pupils have different learning levels. Some of them need to start from the basic level whereas others require being moved beyond the basic level to learn something suitable to their level. This research has considered this obstacle by creating three different learning levels, basic level, intermediate level, and advanced level. Each of these three levels has a list of different problems, so students who are assigned by the proposed system to be basic learners (this system can identify the correct level for a learner by testing him/her before learning takes place) will need to complete all the given problems successfully at the basic level. Then, they will be allowed to move beyond that level and work with more complex problems. In addition, the number of attempts made by pupils for solving a problem is automatically calculated by the proposed system and stored in their models, which can also be viewed later on by the teacher. For example, there is a difference between a pupil who solves the problem at the first attempt and one who solves it at the second or third attempt.

Another difficulty that had not been looked at by previous researchers was linking the performance of the learners with a high-level desired learning outcome where pupils are learning programming through the approach of deep learning, e.g. thinking and analysing how to solve the problem [14] (existing work has attempted only to achieve work related to lower learning outcomes which are related to a surface learning approach, e.g. remembering a concept [15] [16]).

Accordingly, this research has considered this additionally discussed issue and worked out how to tackle it for the purpose of easing the process of teaching and learning programming for pupils in early years education, enabling teachers to be aware of how their pupils are doing and what they have achieved from the high-level desired learning outcomes, as well as providing pupils with the opportunity to learn programming practically. To further illustrate this point of linking the performance of learners with a high-level desired learning outcome, an example can be given here that shows how the proposed system is tackling this challenge. This proposed system checks if a pupil has achieved and applied the right programming concept to solving a problem correctly or not (the first considered learning outcome is: can a pupil apply the programming concept that they were taught by the proposed system? This is related to the Apply Category). Furthermore, this proposed system can detect if a pupil was able to differentiate between the concept of iteration and that of sequencing when he/she is trying to solve a problem (the second learning outcome is: can a pupil distinguish between the programming concepts that they learnt through the proposed system?. This is related to the Analyse Category). The system can also see whether a pupil was able to solve a problem with an optimal solution such as using iteration instead of sequencing (can a pupil decide whether it is better to use Iteration or something else in the given problem? This is related to the Evaluate Category).

The stated high-level learning outcomes were linked with the above-discussed three learning levels, e.g. the basic-level materials were related to the apply learning outcome, which means if a pupil was able to apply the concept of iteration correctly, he/she would be able to move to the next level (intermediate) and aim to achieve the next high-level learning outcome (Analyse Category), and so on and so forth. By the end, it was expected that pupils would be able to achieve all three desired high-level learning outcomes.

A further challenge looked at it in this research was the matter of student engagement in learning a hard and practical subject like programming when they are still in their early years of education [4]; in other words, how to keep these young students engaged while they are learning at the same time. Existing researchers have reported that they found that students lacked engagement to learn programming, e.g. large numbers of students had discontinued programming courses due to the difficulty of the subject [17] [18].

Consequently, this research conducted several investigations into different areas, including theories about how children learn and game-based learning. As a consequence of this investigation, the researcher decided to choose the behaviourism and constructivism learning theories (which were described in depth in Chapter two of this thesis) as a means for pupils to obtain information and learn programming from the proposed system. Thus, with the inclusion of behaviourism learning theory on the proposed system, children were learning programming and being rewarded for good performance in solving problems, collecting stars (e.g. solving a problem correctly) along the way and avoiding deaths (e.g. solving a problem incorrectly). In relation to the second considered learning theory, constructivism, the learning materials in the proposed system were designed in the form of problem solving and letting children learn programming through solving a problem, and this resulted in the children being actively involved in the learning process and enjoying learning.

These two described learning theories were integrated with game-based learning where the theories focused on achieving the learning part (letting children obtain information and be more focused on learning), whilst the gaming was only for the purpose of increasing the engagement part and letting children have fun when obtaining information or learning programming from the proposed system. The two experimental studies of this research have confirmed that pupils who used the proposed system successfully achieved both goals: the main goal, "learning programming", and the secondary goal, "engagement with the proposed system and having fun".

Consequently, a combination of both learning theories with game-based learning led to solving the challenge of lack of engagement when learning programming.

From what has been discussed in this section, the main achievements of this work could be summarised as follows:

- Embedding the pedagogical concept of assessment for learning into the proposed system. This enables learners to be assessed before learning, during learning and after learning. This achievement made the learning process in the proposed system more organised and suitable for learners than other existing learning methods, e.g. a traditional learning method. According to the findings of the experimental group in Chapter six of this thesis, those who used the proposed system confirmed that they found it suitable for their learning levels and this helped them to make progress in learning programming.

- Combining the performance of pupils with high-level desired learning outcomes (consideration of deep learning) was achieved in the proposed system. As earlier illustrated in Chapter five of this thesis, this proposed system was based on a deep learning approach. This proposed system differs from an existing tutoring system that only focuses on lower learning outcomes related to a surface learning approach, e.g. remembering a definition or answering a multiple-choice question. This proposed system was designed to go beyond lower learning outcomes in prompting pupils' analytical skills and letting them think about, analyse and differentiate between programming concepts in solving a problem, as learning programming cannot be learnt well by memorising concepts.

- This proposed system was designed to be a more serious system, and so focused on learning not only as used for enjoyment (playing a game). Theories about how children learn, such as behaviourism learning theory, were included in this proposed system as a means or a way of learning programming to enable learners to obtain information, which resulted in encouraging and motivating pupils to learn from the proposed system as they were receiving rewards (collecting stars) when they were performing well, e.g. learning programming concepts by solving problems correctly. Additionally, behaviourism and constructivism learning theories were designed in an enjoyable environment to increase the pupils' engagement, where learners learn programming by playing a game (interactive condition). According to the statistical results of Chapter six, pupils who used the proposed system found learning through it helped them to like programming and continue to learn programming whereas, looking at some existing work, researchers have shown that it is challenging to engage learners in continuing to learn programming.

7.3.4 Further Work

Nowadays, commerce, facilities, knowledge, amusement and so on are all in one way or another controlled by software that has been developed by a programming language. The United Kingdom is waking up to the need for children to start being taught at an early age about how the progressively digitalised world in which they are living is created. In September 2014, computer programming was made part of the UK's national curriculum for pupils in early years education. With this decision came several challenges for UK primary schools, including the school teachers and pupils.

In consequence of these obstacles, which greatly affect the people who are involved in early years education, some significant contributions have been made within this research and successfully tested on pupils from two different UK primary schools. This section suggests supplementary work that could be carried out by a future interested researcher to further contribute to the facilitation of the process of teaching and learning programming in early years education, and to try to overcome as many of the challenges as possible that have been caused by the decision to teach programming in early years education. The more research that can be done to tackle the challenges of learning programming in primary schools, the better the level of education and services that can be offered to the children of today, who will be expected to build the future of tomorrow with their innovative thinking and become creators of technology instead of consumers of technology.

This PhD research has successfully contributed to overcoming some challenges that occur in primary schools and has promoted the significant pedagogical concept of assessment-driven learning in a playful environment, as well as linking the performance of learners to the high-level desired learning outcomes. As a result of this successful work, it was found that pupils who learnt programming through the proposed system found learning enjoyable and made good progress in programming. However, it cannot be denied that an education sector, in particular, a primary school, would still require further development and work from future researchers. The following suggested research ideas for further work were inferred from various research areas: educational crowdsourcing for teaching and learning programming, learning styles and game-based learning.

The area of educational crowdsourcing is one recent area, and some of its challenges were discussed in depth in one of the researcher's published papers [2]. Consequently, it is recommended that anyone interested in continuing working on the same track as this research should consider the many techniques and details that might be quite helpful, which include the following:

- Further investigation and research on the integration of crowdsourcing methods [118] [119], e.g. crowd wisdom and crowd voting, into an automated teaching and learning programming system specifically in early years education which can be remotely supervised by primary school teachers and parents from their preferred location (Home - School). This is because, by the inclusion of crowd wisdom into technology, pupils would be supported to aggregate data in the form of problem solutions and sharing workings between them, and it would also allow them to assess the quality of their submitted shared works with the use of crowd voting. In addition, their school teacher can intervene when required, e.g. to correct misconception among pupils. (This future task can support and develop the pedagogy of peer learning among children in early years education and also develop their abilities to socialise, thus benefiting those who struggle to make friends at school.)

- Another future work and perhaps the one most related to educational crowdsourcing is altruistic participation or community reward [118] [120]. Participants join the crowd for the reward of participating and exchange of information. This is perhaps a more obvious draw when it comes to rewarding novice students – they will benefit from the good-quality information in the form of solution assistance and guided discussion. However, beyond the collegiate-like effect of gifted and talented students feeling personal satisfaction in helping less able students, it is not immediately obvious as to how these high-ability students can be attracted to participate. As such, investigation and experimentation should be conducted by a future study on the value of other reward systems for able-student crowd participation.

Another area that was looked at in this research was the learning styles area and its inclusion into the development of technology for teaching and learning programming. This area has been the subject of a lot of critical discussion among researchers who have directed their scientific research towards this area. Consequently, it would be interesting for a future researcher to carry out the following:

- Further analytical discussion and evaluation of all of those contradictory views [61] [62] [54] (which were described in Chapter three of this thesis) in this particular area and then development of a tutoring programming system that can automatically specify a learner's preferred learning style (e.g. monitor pupils' actions like which page they are browsing more and testing them with different learning styles, without asking them to fill in such long online questionnaires), taking into account all of the discussed contradictory views in order to provide the right material for each learner's preferred learning style (visual learners, aural learners and so on) and learning level.

A further area investigated within this research was game-based learning and its association with some of the pedagogical concepts such as assessment for learning and some other theories related to children's learning, like the behaviourism learning theory. As this PhD research specifically focused on children in early years education, there is a lot of additional work/research to be conducted for pupils after the completion of the early years stage (when they move up to the next stage of their learning, "intermediate education"). This work can be summarised as follows:

- More investigation and development need to be carried out in relation to how to advance children's programming expertise as they get older; more programming concepts need to be taught and integrated with the use of game-based learning, such as Object Oriented Programming concepts with the use of different learning theories and pedagogical concepts that could be more suitable to their age and learning stage, for instance, “Intermediate Learning Stage”.

- Turgut et al. [121] suggested that further work could be conducted on the relationship of technology education and technology usage, as technology usage can affect children negatively. Nevertheless, recent studies have revealed that information technology education usage with appropriate guidance can affect children positively, such as improving their problem-solving, verbal, linguistic and even physical skills. Consequently, a further study is required on how technology education could support the development of children’s awareness about technology usage and how to avoid its dangerous aspects.

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Appendix 1

Ethical Approval

Full Ethical Approval: Application for Ethical Approval No.: 13/CMP/002

Dear Mohammed,

Proportionate Review – Full Ethical Approval: Application for Ethical Approval No: 13/CMP/002

Dr Sue Spiers has considered the application on behalf of Liverpool John Moores University Research Ethics Committee (REC). I am pleased to inform you that ethical approval has been granted and the study can now commence.

Please note that ethical approval is given for a period of five years from the date granted and therefore the expiry date for this project will be July 2018. An application for extension of approval must be submitted if the project continues after this date.

Yours sincerely

PP

Dr Sue Spiers
Chair of the LJMU REC

Date received	Initials	LJMU REC Ref

Ethical Approval of Undergraduate, Postgraduate or Staff Research involving Human Participants or the Use of Personal Data

Where research involving human participants or databases of personal information is being conducted by a member of staff or student LJMU Research Ethics Committee (REC) considers and advises researchers on the ethical implications of their study.

No research must be started without full, unconditional ethical approval. There are a number of routes for obtaining ethical approval depending on the potential participants and type of study involved – please complete the checklists below to determine which is the most appropriate route for your research study.

A. Pedagogic Research

To find out if your study can be conducted under the University's Code of Practice for Pedagogic Research please answer the

questions below.			
1.	Is the proposed study being undertaken by a member of LJMU staff?	Yes	**No**
2.	Is the purpose of the study to evaluate the effectiveness of LJMU teaching and learning practices by identifying areas for improvement, piloting changes and improvements to current practices or helping students identify and work on areas for improvement in their own study practices?	Yes	**No**
3.	Will the study be explained to staff and students and their informed consent obtained?	**Yes**	No
4.	Will participants have the right to refuse to participate and to withdraw from the study?	**Yes**	No
5.	Will the findings from the study be used **solely** for internal purposes? *e.g. there is no intention to publish or disseminate the findings in journal articles or external presentations*	Yes	**No**
If you have answered **Yes to all Qs1-4** your study may be eligible for consideration under the University's Code of Practice for Pedagogic Research. You should **not** complete this application form but seek further guidance at http://ljmu.ac.uk/RGSO/114123.htm or by contacting Sue Spiers s.spiers@ljmu.ac.uk.			
If you have answered **No to any of Qs1-4** you should complete the checklists below to determine which route you should use to apply for ethical approval of your study.			

B. National Research Ethics Service (NRES)

To find out if your study requires ethical approval through NRES answer the questions below.			
1.	Involve access to NHS patients or their data?	Yes	**No**
2.	Include adults who lack capacity to consent as research participants?	Yes	**No**
3.	Involve the collection and/or use of human tissue as	Yes	**No**

	defined by the Human Tissue Act 2004? **		

If you have answered **Yes to any of Qs1-3** you should **not** complete this application form. You must seek approval for your study through the NHS National Research Ethics Service (NRES). For further information and details of how to apply to NRES can be found at http://www.nres.nhs.uk/ *Please note that once ethical approval has been received from NRES University staff or students **must** submit a completed LJMU Research Governance Proforma and provide LJMU REC with written evidence of full, unconditional ethical approval from NRES prior to commencing their research. On receiving confirmation of NRES ethical approval formal notification of LJMU REC approval will be issued via Chair's action.*
If you have answered **No to all Qs1-3** you should complete the checklist below to determine whether your application is eligible for proportionate review or if a full review by the University's REC is required.
** *Studies involving the use of human tissue from healthy volunteers which are taking place within the University's Research Institute for Sports and Exercise Sciences (RISES) can apply for approval through the University REC (for further information contact Sue Spiers – s.spiers@ljmu.ac.uk)*

C. Full versus Proportionate Review

Does the proposed study:			
1.	Expose participants to high levels of risk, or levels of risks beyond those which the participant is likely to experience whilst participating in their everyday activities? These risks may be psychological, physical, social, economic, cause legal harm or devaluate a person's self-worth. *e.g. untrained volunteers exposed to high levels of physical exertion; participants purposefully exposed to stressful situations; research where participants are persuaded to reveal information which they would not otherwise disclose in the course of everyday life.*	Yes	**No**
2.	Involve the administration of drugs, medicines or nutritional supplements as part of the research design?	Yes	**No**

3.	Include adults who may be classed as vulnerable? *e.g. adults with learning disabilities or mental illness; drug/substance users; young offenders; prisoners/probationers; those in a dependent relationship with the researcher*	Yes	**No**
4.	Include children or young adults (below 18) where parental consent will not be sought?	Yes	**No**
5.	Involve the discussion or disclosure of topics which participants might find sensitive or distressing? *e.g. sexual activity; criminal activity; drug use; mental health; previous traumatic experiences; illness; bereavement*	Yes	**No**
6.	Use questionnaires which focus on highly sensitive areas? *e.g. illegal activity; criminal activity; disclosure and analysis of findings based on sensitive personal information as defined by Data Protection Act eg racial or ethnic origin; political opinions; religious beliefs; trade union membership; physical or mental health; sexual life*	Yes	**No**
7.	Incorporate interviews or focus groups which involve the discussion of highly sensitive areas? *e.g. illegal activity; criminal activity; disclosure and analysis of findings based on sensitive personal information as defined by Data Protection Act eg racial or ethnic origin; political opinions; religious beliefs; trade union membership; physical or mental health; sexual life*	Yes	**No**

8.	For research accessing and analysing existing datasets. Will the dataset include information which would allow the identification of individual participants?	Yes	**No**	NA
9.	Involve deliberately misleading participants in any way?		Yes	**No**

10.	Involve recruiting participants who have not been provided with a participant information sheet and asked to sign a consent form? *Please note that for questionnaire based studies a consent form is generally not request as consent is implied by the completion of the questionnaire. Applicants conducting* ***questionnaire-only*** *studies should answer NO*	Yes	**No**
11.	Involve the collection and/or use of human tissue from healthy volunteers? *Under these circumstances human tissue is as defined by the Human Tissue Act 2004 - "Any, and all, constituent part/s of the human body formed by cells." Research studies involving the use of plasma or serum are not covered by the HTA.*	Yes	**No**
12.	Involve high levels of risks to the researcher? *e.g. lone working at night; interviewing in your own or participants homes, observation in potentially volatile or sensitive situations*	Yes	**No**
If you have answered **No to all Qs1-12** your study is eligible for proportionate review. You should complete the following application form and submit it electronically with any supporting documentation e.g. participant information sheets, recruitment letters, consent forms to **EthicsPR@ljmu.ac.uk** . Your application will be reviewed by a sub-committee of the University REC and you will be informed of the outcome within 2 weeks. Please note that if the allocated reviewer finds that your application has been wrongly submitted for proportionate review you will be notified and your application will be forwarded for consideration at the next University REC.			

If you have answered **Yes to any of Qs1-12** your study is not eligible for proportionate review and will be considered at the next meeting of the University REC. You should complete the following application form and submit it electronically with any supporting documentation e.g. participant information sheets, recruitment letters, consent forms to **researchethics@ljmu.ac.uk** .

Please note that applications involving the use of human tissue originating from the School of Sports and Exercise Science should complete the Research Ethics Application Form for Studies Involving the Use of Human Tissue available at http://ljmu.ac.uk/RGSO/93717.htm

Guidance on completing the LJMU REC application form can be found at

http://ljmu.ac.uk/RGSO/93717.htm

Please note that following submission of your application to the relevant email address a signed copy of the application's signature page only must be sent to the Research Ethics Administrator, Research Support Office, 4th Floor Kingsway House, Hatton Garden.

Visit http://ljmu.ac.uk/RGSO/93126.htm for REC submission and meeting dates.

Where teaching practices involve invasive (psychological or physiological) procedures on students or others staff should refer to the guidance provided at http://ljmu.ac.uk/RGSO/93087.htm regarding the development of departmental/faculty codes of practice.

Research Mode

☐ Undergraduate – specify course

	Postgraduate

	MRes,
	MPhil,
x	PhD
	Prof Doc
	Other – please specify

	Postdoctoral
	Staff project
	Other – please specify

Has this application previously been submitted to the University REC for review? – Yes

If yes please state the original REC Ref Number and

N/A

the date of the REC meeting at which it was last reviewed

21/06/2013

Section A – The Applicant

A1a. Title of the Research

|SUPPORTING THE LEARNING OF COMPUTER PROGRAMMING IN AN EARLY YEARS EDUCATION.

A2. Principal Investigator (PI) *(Note that the in the case of postgraduate or undergraduate research the student is designated the PI. For research undertaken by staff inclusive of postdoctoral researchers and research assistants the staff member conducting the research is designated the PI.)*

Title	Mr	Forename	Mohammed	Surname	Alghamdi

Post: Research Student

Department / School / Faculty: CMP / TAE

Email	M.Y.Alghamdi@2012.ljmu.ac.uk	Telephone	07598 004942

Relevant experience / Qualifications

Master of Computer science from Royal Melbourne Institute of Technology University (RMIT), Australia.

A3. Co-applicants *(including student supervisors)*

Co-applicant 1

Title: Dr
Forename: Dhiya
Surname: Al-Jumeily

Post: Principal Lecturer

Department / School / Faculty: CMP / TAE

Email: D.Aljumeily@ljmu.ac.uk
Telephone: 0151 231 2578

Relevant experience / Qualifications

Principal Lecturer in eSystems Engineering

Head of Applied Computing Research Group

School of Computing and Mathematical Sciences, LJMU

Co-applicant 2

Title	Dr	Forename	Abir	Surname	Hussain

Post	Senior Lecturer

Department / School / Faculty	CMP / TAE

Email	A.Hussain@ljmu.ac.uk	Telephone	0151 231 2458

Relevant experience / Qualifications

Senior Lecturer

School of Computing and Mathematical Sciences, LJMU

Where there are more than 2 co-applicants please append an additional page to your application containing the relevant details

Co-applicant 2

Title	Dr	Forename	David	Surname	Lamb

Post: Researcher / Software Engineer

Department / School / Faculty: CMP / TAE

Email	D.J.Lamb@ljmu.ac.uk	Telephone	0151 231 2636

Relevant experience / Qualifications

Research Fellow

School of Computing and Mathematical Sciences, LJMU

SECTION B – PROJECT DETAILS

B1. Proposed Date for Commencement of Participant Recruitment *(Please enter the date when you propose to start recruiting participants – note that no recruitment can take place without full, unconditional ethical approval)*

Start Date	10/09/2013

B2. Scientific Justification. State the background and why this is an important area for research *(Note this must be completed in language comprehensible to a lay person. Do not simply refer to the protocol. Maximum length – 1 side of A4)*

The research will primarily investigate the pedagogical and technical concerns in developing an adaptive, guided-learning support and assessment system; similar to today's Tutoring Systems, but with "curriculum adaptation based on initial diagnostic and on-going assessment. The adaptive support system will be designed to support students of computer programming. Existing Tutoring Systems have lack the on-going assessment (Assessment for Learning), adaptive curriculum facilities.

B3. Give a summary of the purpose, design and methodology of the planned research

(Note this must be completed in language comprehensible to a lay person. Do not simply refer to the protocol. Maximum length – 1 side of A4)

This research project will largely be realised through the specification, design and development of a prototype evaluation software system, and as such, significant parts of the research methodology align with a software development methodology. However, significant phases of this research will follow a more traditional research methodology; in order to situate the research in the state-of-the-art, and then to evaluate the validity of the prototype and its design features. Furthermore, there will be some deliverables within each phase of this research project.

The first phase of the project is the analysis and literature review phase. This is already well underway at the time of submitting this report, and involved a survey of the relevant literature and existing contributory work, and identification of the areas that require further investigation and consideration. This phase will go on to analyse the identified limitations of the existing work, along with identifying research and technology with potential solutions. This phase will conclude with a requirements specification for the adaptive tutor support system, and a clear identification of the research questions to be evaluated via case study, interviews and appropriate mechanisms for these evaluations.

The next phase will apply the information to create designs and requirements for the proposed framework. This will also necessitate the creation of a precise, robust evaluation methodology to assess tutor and student experience with a prototype implementation. The design phase will require a combination of the research gleaned during the literature review phase with an evaluation of likely methodologies and algorithmic solutions, along with an evaluation of their suitability to the stated pedagogical aims. The design will be guided by the project's pedagogical inspiration; the Assessment for learning ideal, with its on-going assessment architecture facilitating the adaptive behaviour of the system. The following phase will develop a scope-limited prototype implementation of the framework, based on the previous designs and requirements. The key factor for the prototype implementation phase is that it provides a sufficiently-sophisticated system such that the stated requirements can be assessed for validity and effectiveness. The experimental design for evaluating the proposed system has been planned to take place locally (UK). The final phase will focus on finalising and disseminating the project findings, including evaluating the results of the project against the original research objectives in this document. This phase will culminate with the production of a thesis outlining the research investigation in-depth and its findings.

B5b. Where questionnaires are to be used have these previously been validated?

☐ **Yes** ☒ **No** ☐ **Not Applicable**

If yes, state by whom and when. If no, you ***must*** *append copies of the questionnaire to this application.*

B5c. Where interviews or focus groups (structured or semi-structured) are proposed you must append an outline of the questions you are going to ask your participants.

B6. Will individual or group interviews/questionnaires discuss any topics or issues that might be sensitive, embarrassing or upsetting or is it possible that criminal or other disclosures requiring action could take place during the study? (e.g during interviews or focus groups)

	Yes	X	**No**		**Not Applicable**

If yes give details of procedures in place to deal with these issues. Information given to participants should make it clear under what circumstances action may be taken

B7. Where will the intervention (s) take place?

X	**LJMU premises**		**NHS or other external organisations**		**Public places**

B8. How will the findings of the research be disseminated?*(eg thesis, dissertation, peer-reviewed articles, conference presentations, reports)*

Thesis, peer-reviewed articles and conference presentations

SECTION C – THE PARTICIPANTS

C1a. Identify the participants for the study *(LJMU staff, LJMU students, members of the public, other please specify)*

Groups of Participants *(eg students, staff, managers, children, parents, members of public)*	**Number of participants**
Primary school Pupils from two schools as well as some primary school teachers.	93.

C1b. How will the participants been selected, approached and recruited? If participants are to be approached by letter/email please append a copy of the letter/email. Please include details on how much time participants will have to decide if they want to take part.

C2a. How was the number of participants decided? *(eg was a sample size calculation performed)*

The number of participants decided to approximately be from 60 to 95. We have chosen this sample according to some of the previous studies that got an accurate result which their samples were in the same range.

C3a. Will any of the participants come from any of the following groups? (Please tick all that apply)

NO

Please note that the Mental Capacity Act 2005 requires that all research involving participation of any adult who lacks the capacity to consent through learning difficulties, brain injury or mental health problems be reviewed by an ethics committee operating under the National Research Ethics Service (NRES). For further information please see http://www.ljmu.ac.uk/RGSO/101579.htm

X	Children under 16
	Adults with learning disabilities
	Adults with mental illness (if yes please specify type of illness below)
	Drug / Substance users
	Young offenders
	Those with a dependant relationship with the investigator
	Other vulnerable groups please specify

Justify their inclusion

The inclusion of children is for the purpose of supporting them to learn computer programming effectively whereby learn programming through playing a game.

C3b. If you are proposing to undertake a research study involving interaction with children do you have current, valid clearance from the Criminal Records Bureau (CRB)

☐ **Yes** ☐ **No** ☒ **Not Applicable**

C4a. What are the inclusion criteria? *(Please include information on how you will ensure that your participants will be informed of your inclusion criteria and how you will ensure that any specific inclusion criteria are met)*

The inclusion criteria for this study would be for pupils in a primary school as well as school teachers.

C4b. What are the exclusion criteria? *(Please include information on how you will ensure that your participants will be informed of your exclusion criteria and how you will ensure that any specific exclusion criteria are met)*

The exclusion criteria for this research would be for those who are not in involved in primary schools.

C5. Will any payments/rewards or out of pocket expenses be made to participants?

☐ **Yes** ☒ **No**

If yes what or how much?

SECTION D – CONSENT

D1. Will informed consent be obtained from (please tick all that apply)

X	**The research participants?**
	The research participants' carers or guardians?
	Gatekeepers to the research participants?

(ie school authorities, treatment service providers)

D2. Will a signed record of consent be obtained? *Please note that were the study involves the administration of a questionnaire or survey a signed record of consent is not required for completion of the questionnaire as long as it is made clear in the information sheet that completion of the questionnaire is voluntary. Under these circumstances return of the completed questionnaire is taken as implied consent.*

In such cases the REC would expect a statement to be included at the start of the questionnaire where the respondent confirms that they have read the participant information sheet and are happy to complete the questionnaire.

Participation in any other interventions within the same study eg interviews, focus groups must be supported by obtaining appropriate written consent.

	Yes		**No**	X	**Implied consent for questionnaire**

If no please explain why not

D3. Will participants, and where applicable, carers, guardians or gatekeepers be provided with an information sheet regarding the nature, purpose, risks and benefits of the study?

X	Yes		No
If no please explain why not			

D4. Will participants be able to withhold consent or withdraw consent to the procedure?

X	Yes		No
If no please explain why not			

SECTION E - RISKS AND BENEFITS (Where risks are identified an LJMU risk assessment form must be completed)

E1. Describe in detail any potential adverse effects, risks or hazards, including any discomfort, distress or inconvenience, of involvement in the study for research participants. *Explain any risk management procedures which will be put in place.*

No risk.

E2. Explain any potential benefits of the proposed intervention for individual participants.

The student participants will improve their programming skills by utilising the proposed system.

E3. Describe in detail any potential adverse effects, risks or hazards (mild, moderate, high or severe) of involvement in the research for the researchers. *Explain any risk management procedures which will be put in place.*

No any risk.

SECTION F – DATA ACCESS AND STORAGE

F1.Personal Data Management

Will the study involve the collection and storage of personal, identifiable or sensitive information from participants? Please note that signed consent forms constitute personal data. *(eg names, addresses, telephone numbers, date of birth, full postcode, medical records, academic records)*

[ ] **Yes** [X] **No**

If yes please provide details of what personal information will be collected and stored

F2. Will you share personal, identifiable data with other organisations outside of LJMU or with people outside of your research team? *(eg supervisor, co-applicants)*

[ ] **Yes** [X] **No** [ ] **Not Applicable**

If yes please provide further details

F3. For how long will any personal, identifiable data collected during the study be stored?

Until the end of the study (15 September 2015) –at which point it will be

anonymised and the personal portion of the data will be destroyed."

Appendix 2

UK Teachers Survey

Teacher Questionnaire

Aim of this survey: the objective of this questionnaire would be to get some valuable information from teachers around the concept of teaching kids programming in an early schooling and how current developed technological programming tools could support those kids to learn better.

Programming: it is a new subject that has been recently added to the UK curriculum of primary school pupils. This subject is intended to help and support pupils with the problem solving skills as well as strengthen their computational thinking (e.g. how and why technology works).

	Strongly agree	***Agree***	***Don't know***	***Disagree***	***Strongly disagree***
1. Teaching kids programming is one of the ways to develop their problem solving skills and innovative thinking levels.					
2. I like my pupil to learn about programming and how technology works in their primary schooling.					
3. Teaching programming in an early schooling would decrease some of the challenges of learning programming for your pupil when he/she may specialise in computer science in the future (e.g. College).					
4. I need an assessment-driven learning tool to teach my pupil programing in the school or at home.					
5. An assessment-driven learning tool would reduce some of my workload when I am teaching my pupil programming.					

Teacher Questionnaire

The following section is related to the ICT teachers.

What are potential limitations that you may face in the school when you are teaching your pupil programming?

If your pupil has used the proposed programming tutoring technology, please answer the following in the next page.

How did you see his/her reaction after using it, Are there any suggested points that you wish to be considered in the proposed technology?

If your pupil has used another different technology from the proposed one (e.g. Scratch), please answer the next one.

What is it? And how is it compared to the proposed one?

Appendix 3

Pre-Run Student Survey

Questionnaire before learning

I am a pupil in a [ ] Year 3 [ ] Year 4 [ ] Year 5 [ ] Year 6

	Strongly agree	***Agree***	***Don't know***	***Disagree***	***Strongly disagree***
1. I like to use the Internet.					
2. I spend my free time in playing computer games when I finish my school homework.					
3. I like to learn about how technology works.					
4. I am happy to learn programming in my early schooling.					
5. I need a technological tool to help me better in how to code.					

Have you used any existing kids programming language?

If your answer is Yes in the above question, please answer the following:

What is it? What do you like and dislike about it?

Appendix 4

Post-Run Student Survey

Questionnaire After Learning

I am a pupil in a [ ] Year 3 [ ] Year 4 [ ] Year 5 [ ] Year 6.

Which learning method have you used?

[ ] Scratch [ ] Proposed System [ ] both (Scratch & Proposed System)

[ ] A traditional method (From a classroom teacher).

	Strongly agree	*Agree*	*Don't know*	*Disagree*	*Strongly disagree*
1. I have enjoyed learning programming.					
2. The used learning method has increased my progress in coding.					
3. I would like to recommend my friends to use the same method for learning programming.					
4. I would like to continue learning programming from recent developed programming tutoring systems such as Scratch, proposed tool and other technological tools.					
5. The used learning method for learning programming is interesting because it Considers my level of learning.					

After you started learning programming, how did find learning programming (easy and fun or difficult and boring) and why please?

Appendix 5

A Screenshot of the IBM SPSS Tool