Evaluation of Introducing Programming to Younger School Children Using a Computer Game Making Tool

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Abstract: Computer games are an exceptionally popular medium across all age groups and have significantly impacted on the way that younger people and children spend their leisure time. Educationalists are hopeful that they will be able to utilise the positive attributes of computer games for educational purposes. There have been a number of studies associated with the application of computer games technology (or games-based learning) in tertiary education; however there is still insufficient evidence at this level to properly substantiate the use of computer games technology as a recognised educational approach. There have been even fewer studies gathering empirical evidence about the applicability of games-based learning in Primary Education. This paper will present the findings of an extensive literature review of the use of computer games and education with a specific focus on Primary Education where students have constructed their own computer games. This paper will also report the results of empirical work performed over an eight week period to introduce programming to younger school children using a computer game construction application. The results show that a sense of achievement was evident in most of the children as they participated in making a game.

Keywords: Evaluation, Primary Education, Literature Review, Achievement, Children, Programming, Game Construction.

1. Introduction

In the 2009/2010 school year the new Curriculum for Excellence (CfE) (Scottish Executive, 2006) was introduced into schools across Scotland. This reform of education, after much consultation (University of Glasgow, 2009) is one of the biggest Scotland has seen and intends to give a coherent curriculum for children from 3 years through to 18 years (Scottish Executive, 2008). Computing is one area of the curriculum that Her Majesty's Inspectorate of Education reported should be improved upon within the primary school sector in Scotland to provide children with increased opportunities to use computers (HMIE, 2009). However, the increase in computer usage needs to be beneficial and build on existing learning so that children are not simply put in front of a computer to do tasks that have no educational benefit. Computing in schools has been dominated by educational software that really does not stimulate the children (Stuart, 2005). The teacher's knowledge of computing is also a major influence on what is taught as some teachers are not fully comfortable using the technology (Stuart, 2005). Within this computing strand playing games and making games have now been introduced.

Computer games are a popular medium, 59% of 6-65 year olds in the UK play them (Byron, 2007). While there has been associations with violent behaviour and nightmares in children (Anderson and Dill, 2000; Schredl *et al*., 2008) there is little evidence to support this. Games-based learning (GBL) is the use of computer games for learning and educationalists hope to utilise the benefits of it within the class (McFarlane, Sparrowhawk and Heald, 2002; Groff, Howells and Cranmer, 2010).

This paper examines the literature on GBL approaches in the primary classroom, while also examining how computer programming is taught in primary schools. It will then present a study of introductory programming with Scratch for two classes of 7-9 year olds and discuss the results obtained. The paper concludes with a brief discussion on future research directions.

2. Literature Review

A literature review was carried out in late 2010/early 2011 to identify empirical evidence of games-based learning in primary schools using a number of electronic databases: ACM, Science Direct, EBSCO (including CINAHL PsycINFO, SocINDEX, Library, Information Science and Technology Abstracts), ERIC, Emerald, Ingenta and Infotrac. The following search terms derived from a previous search on the evaluation of computer games were used (Connolly, Stansfield and Hainey, 2007):

("computer games" OR "video games" OR "serious games" OR "simulation games" OR "games-based learning" OR "MMOG" OR "MMORPG" OR "M.U.D." OR "online games") AND (evaluation OR impacts OR outcomes OR effects OR learning OR education OR skills OR behaviour OR attitude OR engagement OR motivation OR affect)

With a starting point of the year 2000, the search collated 12,948 entries in total. This year was chosen due to the fact that it was a significant landmark year for the games industry with the release of the Sony Playstation 2 games console, which is still the biggest selling games console to date (Sony, 2011). The returned papers were then restricted to the use of GBL within education and working with children between 8-12 years of age. Table 1 shows the relevant papers that were found in the literature search and the methods used by the researchers.

Table 1: Methods and area of studies found

Authors	**Methods**	**Area**
Robertson and Howells (2008)	An exploratory study into the use of game making within a class of 30 P6 (9-10 year old) children, to develop opportunities for the children to achieve successful learning which is one of the four capacities set out under the CfE The study showed that game making does provide this opportunity, however to fully explore this lessons need to become teacher led.	CfE
Vos, van der Meijden and Denessen (2011)	This study compared the difference in learning between children playing games and children making games. The researcher took both lessons within four elementary schools comprised of 235 students from 9 classes split over 5th/6th grade age 10-12 years. 5 classes constructed the games and 4 classes played the games. It looked into the motivation of students who play vs. students who create games. Findings showed that the children who created games were more motivated in their learning.	Language
Rosas *et al*. (2003)	This study looked at the benefits of using games consoles in the class with educational games. 1274 children aged 6-8 years old participated. There were 3 groups the experimental group, an internal control group and an external control group. Research showed some benefits for the experimental group with learning gains in math and reading however further study is required.	Language and maths
Miller and Robertson (2010)	This study looked at using games consoles in the class to enhance children's learning in maths. Class Teachers were given a one hour training session with the brain training game and console. 32 classes of P6 (9-10 year old) children were involved some were control groups and other classes used the Brain Training game for 20 minutes a day for 9 weeks. The study compared computational accuracy and speed in mathematics as well as self motivation between both groups and concluded that while both groups showed an increase, the brain training groups' increase was twice that of the control group.	Maths
Sim, MacFarlane and Read (2006)	This study looked at the use of educational software in class and measuring the fun and usability of it. 25 children in one class age 7/8. Children were taken out of class in groups of 2 or 3 to do an activity with 1 of 3 pieces of software. They then used a tool to evaluate products with children (funsorter). The funsorter was reported as a promising evaluation tool for children.	Science
Bottino *et al*. (2007)	This study was a long term study of cognitive skills in children who played computer games. Two classes of children starting from when they were 7/8 now 9/10 and still continuing into their next school year. Using the computers to	Cognitive skills of game playing

	play games to develop their reasoning abilities. For 1 hour a week with the researcher and teacher in the class. Results concluded that while a positive impact on children's reasoning abilities further study was required.	
Mumtaz (2001)	This study looked at the attitudes of children who played games at home and at school. 322 children aged 8-10 who had access to a computer at home were involved. The children completed questionnaires – researcher explained to classes of younger children the questions then children filled out the answer. Findings concluded that 70% of the children played games at home and preferred it to school use of computers.	Attitudes to playing games at school and home
Skoric, Teo and Neo (2009)	This study looked at children's gaming habits and compared that with their academic ability. 333 children aged between 8-10 years from two schools participated. Their grades were compared to the questionnaire about their gaming habits and showed a positive association between playing video games on weekdays and English test scores, while conversely showing that gaming addiction is negatively associated with academic performance.	Gaming habits vs academic grades in children

The literature showed different approaches to introducing games-based learning into the class:

- Use popular games consoles and Commercial-off-the-Shelf (COTS) games (Miller and Robertson, 2010).
- Use educational games with modified Games Console (Rosas *et al*., 2002).
- Use computer games with additional plug-ins to allow students to modify the game (Robertson and Howells, 2008).
- Getting children to create games in class (Vos, van der Meijen and Denessen, 2011).

3. Programming tools for children

Since the development of Logo (the first programming language for children) in 1967, there have been many other programming tools attempting to encourage children/novice programmers. The Toontalk programming environment has a video game-like style with animations within it symbolising programming attributes; e.g. a house in Toontalk represents an object or actor in programming (Kahn, 1996) and has been used in a study with pre-school children (Morgado and Kahn, 2008). Adventure author is another example of a programming tool designed to make games and is aimed at children aged 10-14 (Robertson and Good, 2005). The tool enables children to create their own interactive story, which other children are then able to play. This is also similar to Storytelling Alice (Kelleher, Pausch and Kiesler, 2007), which was used as an approach to try to encourage girls to develop an interest in computer programming and is based on Alice (a freeware object-oriented educational programming language). Studies such as Cerulli, Chioccariello and Lemut (2005), Demo, Marciano and Siega (2008), Kafai, Ching and Marshall (1997) and Kahn (1996) use a cross curricular approach and combine programming with mathematics, which is now being promoted heavily within the new curriculum in Scotland is for teachers to introduce more cross curricular work into daily lessons.

Another approach to teaching children about computer programming is to use electronic toys such as programmable bricks (Wyeth and Purchase, 2000) and Lego toys such as *Mindstorms*. *Lego Mindstorms* was used to teach children over a period of six months basic computer concepts, the lessons were structured to be started off as being teacher-led and eventually leading to the pupils working on their own (Barrios-Aranibar *et al*., 2006). Today many educational suppliers offer toys such as Beebots (Primary ICT, 2010) and Probots, which are toys that even young children can use to learn about control and instructions. With programmable bricks, children under eight were able to explore some programming concepts without the need for a computer.

For the scope of this study we are interested in looking at how children can be taught computer programming concepts through game construction. Game construction tools such as Scratch, Kodu and Gamemaker are available for children as young as 7 to create their own games. A study of primary school children aged 10-12 years (Vos, van der Meijen and Denessen, 2011) looked at the differences in learning when children were constructing games compared to playing them. The results of this study suggested that the pupils were more motivated when creating games rather than playing games.

Scratch is a program that takes its inspiration from Logo (Papert, 1980). It is a visual-based tool and children are encouraged to create programs by simply snapping together the blocks provided to create their own program or script as it is known in Scratch. Figure 1 shows screens shots of Scratch.

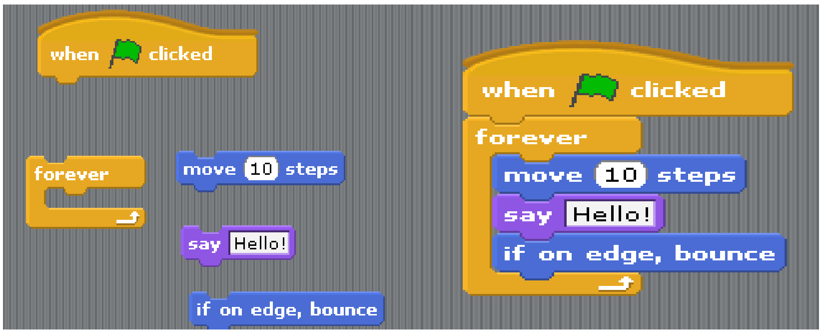

Figure 1: Screenshots of Scratch

Another literature search was then undertaken to look at Scratch and determine if it has been used within educational settings. The search was carried out using the electronic databases ACM, IEEE and Science Direct and using the Scratch site itself, which contained research papers from authors within the Scratch project. In total, 90 papers were collated relating to the Scratch construction tool. Much of the focus of these research projects is on how much the users enjoying Scratch or what blocks they are using most in creating projects. Other projects focus on children using Scratch in a workshop for 13-14 year olds (Sivilotti and Laugel, 2008) or at summer camps (Adams, 2010) or computer clubhouses (Maloney *et al.*, 2008) where children enjoyed creating multimedia projects.

Scratch is aimed at children aged around eight, however, statistics from the Scratch site show that the average age of users is 12 (MIT, 2011) and there is a wide age range of users for this tool. It was envisaged from the outset that while this project was to introduce computers to deprived areas eventually the informal educational benefits of it would be studied at a later date (Resnick, Kafai and Maeda, 2003). Although Scratch is being used at Harvard University as an introduction to programming for university students (Malan and Leitner, 2007; Malan, 2010), there is currently little published research on whether Scratch can be used as a tool for teaching programming concepts in a primary classroom setting.

4. Study

The main aim of this study was to evaluate the Scratch software and its effectiveness for teaching children about programming. This was done by working with children of the age group that Scratch is intended for and creating lessons for them from which they should be able to learn some of the basic concepts of programming within the new curriculum. From other studies conducted into using programming tools in the class (Barrios-Aranibar *et al.*, 2006; Bottino and Robotti, 2007; Cerulli,Chioccaiello and Lemut, 2005; Kafai,Ching and Marshall, 1997; Lindh and Holgersson, 2007) they were conducted over a period of months. As this was an exploratory study and time with the students was limited, in discussion with schools it was decided that the study would be conducted one hour a week, over eight weeks. During lessons when children were on the computer they were working in pairs, this was in part due to the limited resources of each school; however, collaborative work is actively encouraged within the CfE.

Two schools had agreed to participate in the project, School A and School B. Both schools are in the same neighbourhood and are similar in that the children attending come from similar social and economic backgrounds. Scratch was originally intended to be a program for children in disadvantaged areas (Resnick, Kafai and Maeda, 2003) which both schools can be considered to be within (Scottish Government, 2010). School A has over 400 pupils and therefore has two primary 4 classes although only one participated, this was class A. School B has only around 130 pupils and most classes are composite classes, therefore the primary 4/5 class took part in the project, this was class B.

- Class A comprised of 25 children: 13 boys and 12 girls, age 7-8 years.
- Class B comprised of 21 children: 5 girls and 16 boys, age 7-9 years.

The eight, one hour lessons were led by the researcher and were structured so that the researcher spoke for the first 5-10 minutes of the lesson and then the children worked in pairs on their computers. The class teacher was encouraged to help and became more involved in the work as the weeks moved on. The lessons introduced the basic concepts of programming to the children, namely:

- Sequence
- Iteration
- Conditional
- Coordination and Synchronisation.

These concepts were used to build the lessons along with the CfE (LTS, 2009) guidelines and the Cambridge test (University of Cambridge, 2010). Table 2 shows how each lesson fits with the CfE while using the concepts stated above.

Table 2: Lessons and matching outcomes/programming concepts

Lesson	Concept	Outcome
1	Sequence	In movement, games, and using technology I can use simple directions and describe positions. I can describe, follow and record routes and journeys using signs, words and angles associated with direction and turning
2	Sequence	
3	Sequence	
4	Sequence, Iteration	I can compare, describe and show number relationships, using appropriate vocabulary and the symbols for equals, not equal to, less than and greater than.
5	Sequence, Conditional	
6	Sequence, Conditional, Coordination and synchronisation	
7	Sequence, iteration, Coordination and Synchronisation	In movement, games, and using technology I can use simple directions and describe positions. I can describe, follow and record routes and journeys using signs, words and angles associated with direction and turning.
8	Sequence, Iteration	
All lessons		I can create, capture and manipulate sounds, text and images to communicate experiences, ideas and information in creative and engaging ways
		Using appropriate software, I can work collaboratively to design an interesting and entertaining game which incorporates a form of control technology or interactive multimedia.
		Having evaluated my work, I can adapt and improve, where appropriate, through trial and error or by using feedback.
		Through discovery, natural curiosity and imagination, I explore ways to construct models or solve problems
		I am developing problem-solving strategies, navigation and co-ordination skills, as I play and learn with electronic games, remote control or programmable toys.
		I explore software and use what I learn to solve problems and present my ideas, thoughts, or information

The lessons started with an introduction to Scratch to get the children used to the environment. They then progressed to the children looking at features they could put in their games then trying to make a simple maze game (See figure 2).

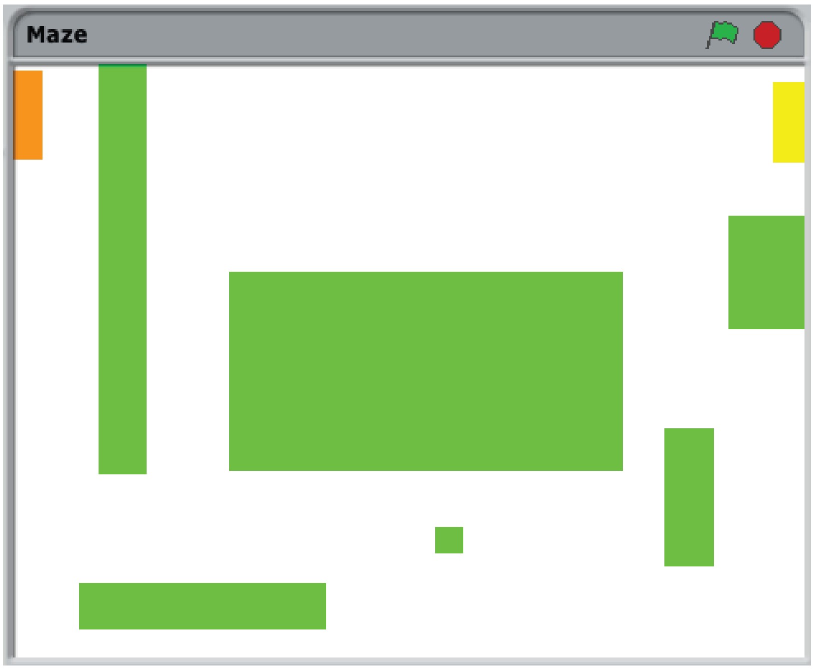

Figure 2 Maze game

In order to measure learning progress, the pupils were set some questions at two points during the term: Test-1 (week 3) and Test-2 (week 9). The questions were inspired by the Cambridge "ICT starters" syllabus for assessment of early progress in ICT skills (University of Cambridge, 2010). While the "ICT Starters" curriculum covers ICT skills from word processing and spreadsheets to email and web-browsing and authoring, it also includes control, which is more closely related to programming concepts. Children are to demonstrate control by giving simple commands to a device; and by using a sequence of commands to control a device, including inputs and outputs. The programming language to use for these activities is Logo. Our tests and scoring schemes were based on their assessment ideas, which allowed the children's' work to be judged and quantified as to the level of skill demonstrated. In order to show that children have developed some facility for control of a device, the curriculum requires that they produce a sequence of instructions that involve at least a certain number of line segments, and a certain number of 90-degree turns. (See figure 3)

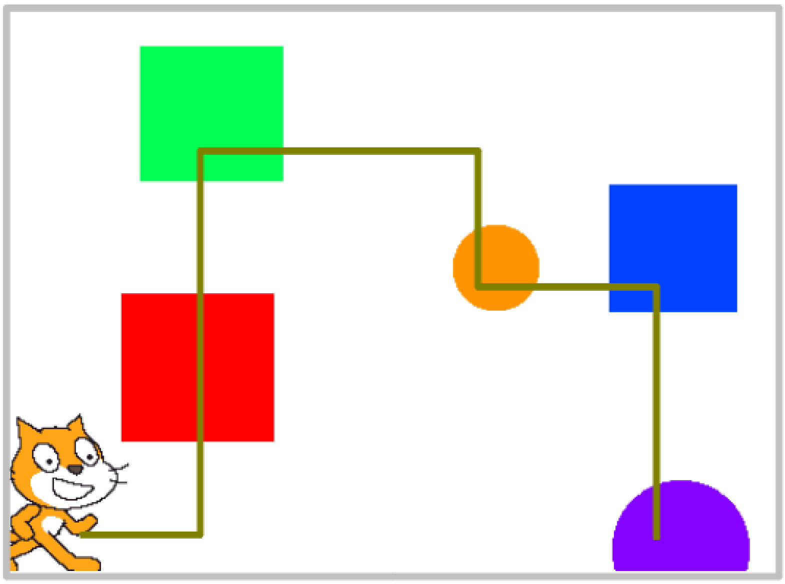

Figure 3 - test, showing a route that visits all the shapes

The class tests were devised to embed these requirements into the tasks set for the children, in making a sprite navigate around the canvas, visiting various locations on the way.

5. Results

5.1 Cognitive Results

The children's ability in Scratch was tested at week 3 and week 9 (after they had finished their last lesson) to see if they were learning anything from Scratch. On completion of the project there were some improvements in learning with Scratch. The average score in class A was for Test-1 was 65% and Test-2 76%. For most children there was an increase in scores though for one or two their scores did decrease. Three pupils scored 100% in the first test and so could not improve on this score. There were N = 22 pupils that had scores for both Test-1 and Test-2, which showed an improvement in the pupils' performance and a paired-sample t-test indicated that the difference was statistically significant at the 95% level ($t(21) = -2.203$, $p < 0.04$).

The average score in Class B was for Test-1 52% and Test-2 64%. There was a problem with Class B Test-2, in that it took place near the holidays, and several children were absent that day for that reason. Leaving out the missing values, there were only N = 12 pupils that had scores for both Test-1 and Test-2. Although this shows an improvement in the pupils' performance, a paired-sample t-test indicated that the difference was not statistically significant at the 95% level ($t(21.202) = 1.741$, $p < 0.10$).

5.2 Affective

At the end of each lesson, the children marked on their log-sheets how they felt about the lesson with Scratch. Answers were on a 3-point scale, shown by three cartoon faces (Figure 4), which were either sad or neutral or smiling.

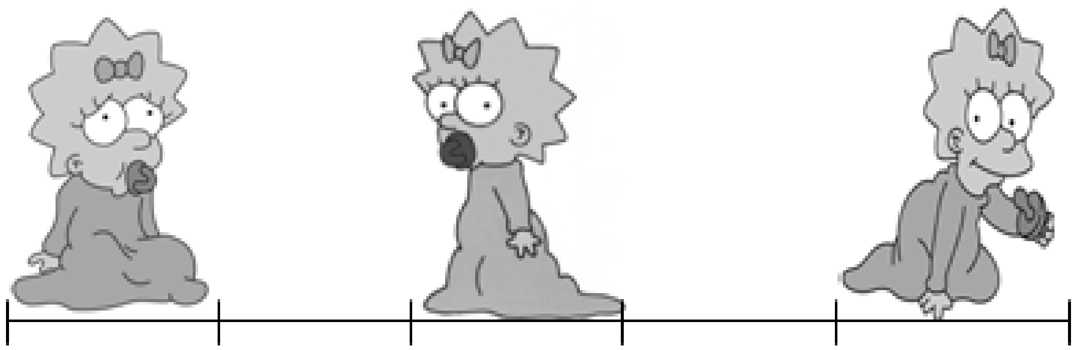

Figure 4: Cartoon Scale

Overall Tables 4 and 5 indicate that Scratch was a very enjoyable subject for the children with only a few children feeling neutral with the lesson. Only once did a child mark the lesson down as feeling sad – from observation though the child was unwell that week also (almost a third of the class that week had been absent from the lesson due to illness). The children from both classes enjoyed each lesson, even as the weeks moved on there was no real change in attitudes towards using Scratch. These results are similar to those of Adams (2010), who also showed that Scratch was an enjoyable tool to use, although this study was completed at a summer camp, where most of the children reported having a positive experience and that they would like to work with Scratch again.

Table 4: Class A affective responses

Lesson	1	2	3	4	5	6	7	8
Happy	20	19	20	23	22	14	24	21
Neutral	0	1	3	0	2	2	0	2
Sad	0	0	0	0	0	1	0	0
Absent	5	5	2	2	1	8	1	2

Table 5: Class B affective responses

Lesson	1	2*	3	4	5	6	7	8
Happy	19	-	20	20	18	18	18	15
Neutral	0	-	0	0	2	1	2	3
Sad	0	-	0	0	0	0	0	0
Absent	2	-	1	1	1	2	1	3

*Results not available for this week due to lesson finishing early

5.3 Teacher Views

All the lessons were led by one of the researchers, while the class teachers watched and helped, because this was new to them as well as their classes. At the end of the term, both teachers were interviewed for their personal assessment of their pupils' progress, because they knew them well and could compare their performance and enjoyment in our lessons with the way they were in other classes. Except for people's names, their answers are transcribed here verbatim, as follows:

Question: What expectations did you have at the beginning, and have they been met?
Teacher B: "*Without a doubt – they have been exceeded!"*
Teacher A: "*Well I had hoped the children would learn about programming and I think they did do that".*

Question: From at the test results, did any children do better or worse than you'd expected?
Teacher B: "*Yes: – one did much better, as he seems to be really good on the PC. He is good at maths too, but finds language difficult.*
– Another one made a great improvement.
– But I was surprised that two others did much worse than average in this class, while they are in the top group.
– It's obvious to me the less able pupils are doing better with Scratch. I'm surprised at those not doing well academically doing really well with Scratch. Some of them have language barriers as well."

Teacher A: "*Gabriella has come on leaps and bounds she doesn't have a pc at home. Wayne rooney didn't do as well I don't know if he's got access to a pc. A few have done better than would have been expected*
Pupil1c as well because he doesn't have a pc either and you could tell how much he enjoyed it especially after him getting so upset last week."

Question: Did you enjoy the lessons?
Answer: both teachers did

Question: Would you recommend Scratch to your colleagues as a tool to teach computing? Will you use Scratch yourself in future?
Teacher B: "*Yes, without a doubt — it's a great tool for teaching. We'd like you to come again and show us teachers more about it.*"
Teacher A: "*Yes I would,.*"

6. Discussion

The eight lessons covered the basics of Scratch, given the timeframe and age of children this was a basic introduction. If more time had been available then the children would have been able to progress to making more complex games and learning more programming concepts. However they did manage to get some of this over the time. Each week the children looked forward to their lesson and the children were always keen to get started on the computer. Sometimes if one child discovered a new feature in Scratch, they would tell a friend and within the space of 5 or 10 minutes it had gone right round the classroom. The test results for both classes were encouraging. While Class A did show some significant improvement in gains, Class B did not. However, only 12 children (57%) of Class B took both tests compared to 87% (22 children) of Class A. It did show that even within eight hours of lessons children were able to make progress with Scratch and their learning of programming. It showed especially in Class B that those children who were not doing as well academically were making good progress with Scratch and their test results were good, while conversely the more academic children had lower test scores. Class A's performance was better than Class B, however, some difficulties were also uncovered upon interview with the teacher of Class B. With test 2 the children in Class B were not expecting to be doing any more Scratch work and it was the day before a school holiday, which may have impacted on some of the scores for this test. Absence was high that day as well with almost a quarter of the class off sick.

Enjoyment was a key issue with Scratch, other observations of the lessons indicated that while some lessons were noisy, children were not disruptive. The children were excited about the work they were doing –in the last week one particular child got very upset because they could not get a turn. From the teachers' point of view they both saw Scratch as a success in their class. Teacher B found that her class were "more motivated" in the lessons. This was backed up by Teacher A, who pointed out that "*none of the children had to be kept on task instead they got on with the lesson*". Both teachers initially were a bit wary about Scratch, only because they had never heard of it and also they did not know how to use it. This came across strongly in the first lesson with teacher B, who seemed anxious to the researcher about the work. However, in the final interview she did say this was because she was unable to help and had to stand back and watch.

This was also evident when in the final discussion with the children they were asked how many of them wanted to use Scratch again and the whole class (both schools) said yes. The children were also unable to give any reason as to anything that was not fun about using Scratch – if anything the only problem they had was "not enough time" or "having to work with someone else". While working in pairs was not an apparent problem within the lessons, the children would have liked more time themselves to work on Scratch. Some of the children have now downloaded Scratch to use at home.

7. Further work

This paper has presented some important required empirical evidence in relation to the introduction of a computer game construction tool into Primary Education level to address the issue of the dearth of empirical evidence in the GBL literature. Further research will entail expansion of the study to include further Primary school institutions in the Glasgow region. This will involve inclusion of different age groups to attain further empirical results to produce more statistically significant evidence and assist in refining the instruments of evaluation through a series of pilot studies. The age groups targeted would be in the age range of eight to eleven at Primary five, six and seven level. This will enable comparisons between the different Primary school levels to ascertain the suitability of the computer game construction tool at different Primary educational levels. This study has particularly focused on the Glasgow region of Scotland, and further comparative analysis of results attained from different regions of Scotland to assess if the results are consistent will be performed. This will produce further empirical evidence in the GBL field and address if there are differences in suitability of this approach for different Scottish regions.

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