

To what extent did independent game based learning influence children's mental mathematics

This action research paper looks at the effectiveness of a game based learning to improve children's mental mathematics. The paper will first consider the context of the school and why this research was chosen, while addressing the ethical considerations, then moving onto the bigger picture, reviewing the literature regarding mental calculation and game based learning. Afterwards, I will discuss the research design and why a triangulation approach was chosen. The findings will be presented, analysed and reflected upon. The conclusion will look back at the context for doing the study, examining whether the aims of the research were satisfied and identifying areas of further research.

Local context

The Year 6 Class Teacher joined the school at the start of the Autumn term, and as Head of Key Stage Two had observed that the mental mathematics across the Key Stage needed to become more prominent. After a few initial discussions we decided that this would be a useful action research project that I could begin with the 62 Year 6 children, with the intention that a number of Year 6 ambassadors would then introduce the program to Year 5. Over the course of the year this would be replicated down throughout the school. I chose Sumdog™¹ a free collection of educational games based online where children could practise mathematics, reading and writing, while giving the teacher full control over what the children could do. I was familiar with this website from working at a previous school and had seen the enthusiasm from the children who were eager to play it at any opportunity. This site has a number of useful features that include a learning engine that adapts and tailors questions to suit the level of the child and it is incredibly easy to set up a class/school, then use the automated live class tools to monitor the children's work.

An ethical consideration was the collection of personal information on the site. However they do not ask children to enter any information that, by itself, is considered personal information. They have an extensive Privacy Policy that I reviewed prior to enrolling the children onto Sumdog™². There is a premium service that grants schools access to reports and analytics that track children's progress and the children benefit because they can play premium games and take part in class competitions and challenges. I contacted Sumdog™ informing them of the research project and how useful it would be to have access to the reports and analytics. They granted the school temporary access to the premium package for three weeks. The Year 6 parents were informed by letter that their children would be enrolled onto Sumdog™ and given their own unique username and password, each letter included a laminated card with the necessary details. The letter also encouraged parents if it was practical to allow their children the opportunity to play on Sumdog™ at home, this did result in a few parents asking if their younger children could be given earlier access to the site³. However the CT chose to wait to assess the impact the program had on Year 6 before rolling it out to rest of the school. We chose to introduce children just to Sumdog™ mathematics, however a number of children discovered for themselves the reading and writing games.

The research took place over five weeks, the initial week was referred to as the beta week because only a select number of children, in waves, were introduced to the site. This was to allow us to monitor any issues, especially technical difficulties, so we could address them before enrolling all the children, the following week. The action research will only focus on the subsequent four weeks. The children all had 45 minutes on a Tuesday afternoon to play Sumdog™ mathematics. All of these sessions were monitored live using the classroom tool. Outside of this time children could play at home and there were opportunities during the school day for example wet break times, lunch breaks, and in the Sumdog™ morning mathematics club. This morning club was set up in week 3, in

response to children asking if they could play in the mornings before school. Letters were sent out to parents informing them, and if they wanted their child to avail of this opportunity they needed to sign the permission slip and return it.

The bigger picture

Mental arithmetic was first considered to be an integral part of mathematics teaching towards the end of the nineteenth century (Thompson, 2010: 161), since then it has moved in and out of fashion. During the 1920s there was a decline in teaching mental arithmetic, due to the 'backlash against the movement and the concept of 'mental discipline'' (Thompson, 2010: 161). Between the 1940s-60s it grew in importance, having its own separate heading on school reports. The move in the 1970s towards individualised learning, reducing the opportunity to teach the whole class as a group, and the broader syllabus of the modern mathematics meant less emphasis on arithmetic and instant recall.

The Cockcroft Report (Mathematics Counts) (1982: 92-3) discussed the topic of mental mathematics, within the chapter of 'Mathematics in the primary years'. They chose the term 'mental mathematics', rather than 'mental calculation' because they wanted to include both mental calculation (work 'in the head') and the oral work; the promotion of mathematical discussion in the classroom, which they felt was a crucial part in teaching primary mathematics. The report mentions how 'mental arithmetic' had been a regular part of the curriculum, and now occupied a far less important position. They argued for the reintroduction of mental arithmetic into the curriculum. They believed 'that the decline of mental and oral work within mathematics classrooms represents a failure to recognise the central place which working "done in the head" occupies throughout mathematics' (1982: 75). Even using traditional methods of recording calculations on paper, the written method, is usually based on steps that are done mentally.

Mental arithmetic was back on the agenda in the late 1980s with the arrival of the National Curriculum. However, in practice, mental arithmetic did not receive the attention that it deserved, because of the demands of the subject knowledge to be taught in the new curriculum (Thompson, 2010: 162). With the launch of the National Numeracy Project in 1996 and a decade later its development into the National Numeracy Strategy, 'mental calculation' succeeded in becoming a key feature of mathematics across most schools. Despite this renewed focus on mental calculation Ofsted (2008: 21) found children still relied heavily on formal written methods and were reluctant to use mental strategies or informal methods.

Thompson (2010: 163) after reviewing the literature suggested six reasons for teaching mental calculation.

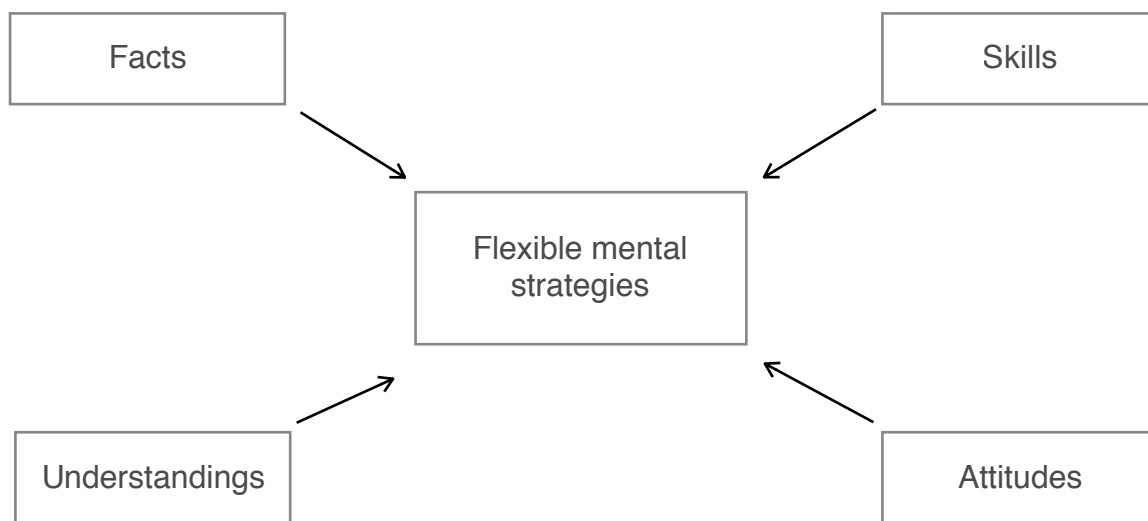
1. Most calculations in real life are done in the head rather than on paper.
2. Mental calculation promotes creative and independent thinking.
3. It contributes to the development of better problem-solving skills.
4. It develops sound number sense.
5. It is a basis for developing estimation skills
6. Mental work is important because there is a natural progression through informal written methods to standard methods.

As mentioned earlier in the Cockcroft Report (1982) mental calculation consisted of two parts. In the National Numeracy Strategy they were referred to as recall and strategic methods. The first dealt with knowing by heart specific number bonds and tables facts. The latter focused on using these facts to work out quickly sums of two or more digit numbers. To describe these two different aspects of mental calculation in England the phrases were 'knowing facts' and 'figuring out' (Thompson, 2010: 164).

Merttens (2012) believes children do not routinely memorise things as they once used to, learning by heart dozens of nursery rhymes, poems and prayers. 'Rhymes, jingles and songs to aid learning by repetition are indispensable to the teaching ... of number' (Adam, 1996). Mathematics relies to a greater extent upon memory because it can help if children have facts and skills internalised, so they can draw upon these when they develop more complicated mental calculation strategies and less intuitive written calculations.

There has been a lot of research since the 1970s into the mental calculation strategies used by children, particularly for the addition and subtraction of one- and two-digit numbers (Thompson, 2010: 164). However this is not the focus of this paper but would make an interesting second cycle of research, as this research would provide a useful foundation to inform my practice. 'Awareness of these strategies will help them (teachers) better understand children's explanations and provide appropriate support to develop, where appropriate, more efficient strategies' (Thompson, 2010: 167).

Thompson (2010: 167-8) developed a model (Figure 1) consisting of four elements that contribute towards the development of a child's mental calculation strategies. These elements are facts, skills, understandings and attitudes, and he believes that those who are successful in mental calculation possess all four attributes. Resulting in a hypothesis that has yet to be tested, that a 'weakness in any one area would likely have an adverse effect on the development of a wide range of efficient mental calculation strategies' (2010: 167).



A model of mental calculation (Thompson, 2010: 168)

Figure 1

Facts included knowledge of specific number bonds, awareness of addition and subtraction facts to 20 and knowledge of multiplication tables and division facts. The understanding referred to the 'varied properties of the number system' (Thompson, 2010: 168), for example counting on from the larger of the numbers. This also included understanding the properties of commutativity, associativity and distributivity. The skills Thompson mentions are techniques and labour-saving skills such as 'counting on as a development of counting all' (2010: 168). The final attribute that Thompson feels is overlooked is confidence. 'Children can have all the facts and skills, but if they do not have the confidence to 'have a go' or take risks they are unlikely to use these facts and skills to

generate an appropriate strategy' (Thompson, 2010: 170). The ethos has to be developed away from the attitude of 'I can't remember the method so I cannot solve the problem' to a more positive attitude of 'I can't remember how my teacher did it, but if I ...'. Thomson highlights the importance of attitude and confidence both of which need children to be motivated and that is why I chose game based learning as the medium.

Since the 1980s there has been a growing body of theoretical and applied research concerning the use of computer games in teaching, learning and education. Much of this research has been driven by two principles (Ellis et. al., 2006: 14):

1. The desire to harness the motivational power of games.
2. A belief that digital games offer a powerful learning tool.

Prensky (2006) concurs that motivation is important because learning requires putting out effort. The 'engagement power of electronic games for this generation (and those to come) may be the biggest learning motivator we have ever seen' (2006: 1). Prensky calls this generation 'digital natives', they are 'native speakers' of the digital language of computers, social media, video games and the Internet (2006: 2).

Ellis et. al. (2006: 15) cites research from Griffiths and Randel that digital games have potential in teaching, learning and education. Games can be particularly effective when 'designed to address a specific problem or to teach a certain skill' (Griffiths 2002: 47 cited in Ellis et. al., 2006: 15), encouraging learning in curriculum areas such as mathematics, physics, languages and arts, where specific objectives can be stated (Randel et al 1992 cited in Ellis et. al., 2006: 15). Even simple types of games can be designed to address specific learning outcomes, such as recall of factual content or as the basis for active involvement and discussion (Dempsey et al 1996; Blake and Goodman 1999 cited in Ellis et. al., 2006: 15).

Paul Gee (2003) and others have found game player's regularly exhibit persistence, risk-taking, attention to detail and problem solving skills, all behaviours that ideally would be regularly demonstrated in school. They also understand that game environments enable players to construct understanding actively, and at individual paces, and that well-designed games enable players to advance on different paths at different rates in response to each player's interests and abilities. This resonates with the work of Vygotsky (1978) and the zone of proximal development. The Teachers' Standards (DfE 2012) state that a teacher must set high expectations which inspire, motivate and challenge pupils. To achieve this a teacher must understand the needs and abilities of each child, because every child must be challenged at the right level and pace.

Research design

I used action research, a model of reflective practice (Bolton 2010, citing Carr and Kemmis, 1986 and Ghaye, 1998), with the self-reflective cycles of planning, questioning, observing and reflecting. Action research can be defined as 'the study of a social situation with a view to improving the quality of action within it' (Elliott, 1991). The purpose of triangulation in educational research is to increase the credibility and validity of the results (Davila, 2009: 1). Altrichter et al. (2008: 115) contend that triangulation "gives a more detailed and balanced picture of the situation." Cohen and Manion (1986: 254) define triangulation as an "attempt to map out, or explain more fully, the richness and complexity of human behaviour by studying it from more than one standpoint. Out of the identified types of triangulation I chose methodological triangulation - to use more than one method for gathering data (Denzin, 1970 cited by Davila, 2009: 1).

First, quantitative data was collected using the reports and analytics available from Sumdog™. The measures included the accuracy and speed (in seconds) which questions were answered correctly and the levels the children progressed through. Due to children's absence or other reasons, I have only included the children who took part in all four weeks so the data will comprise 54 children. Second, all 61 Year 6 children completed an online questionnaire at the end of the four weeks that was created using Google, to allow for the data to be collected digitally to save time coding. The questions were developed in concert with the teachers in Year 6 and consisted of subjective and behavioural questions (Appendix 2). The final part of the data consisted of interviews with a select number of children to have a clearer understanding of how they used the website, what their thoughts of it were and how could the experience be improved for the rest of the children in the school once the program was rolled out.

An aim of this research was to look at the quality of the questions answered over the duration of the project, to establish whether there was any improvement. The second aim to find evidence that the game based learning was motivating the children to play on Sumdog™ thereby spending more time in a risk free environment improving and practising their mental mathematics.

At this stage I will briefly discuss how Sumdog™ mathematics functions. The mathematical curriculum is distributed across 10 topics:

- Number
- Addition
- Subtraction
- Multiplication
- Division
- Fractions
- Decimals
- Percentages
- Expressions and equations
- Word Problems

Each topic consists of a dozen or more objectives that have to be met before the child can progress to the next level of questions within that topic. The site automatically starts children answering Level 1 questions at the beginning but once they have accurately answered these, several times, they then progress to the next level (Appendix 1). There are several games that children can pick from, within these games the question appear and they are given four possible answers. For example this is a question from the Number topic and the objective is 'Comparison within 100 - word problem'.

The image shows a screenshot of a digital learning interface. At the top, there is a purple header with the text 'Sample questions'. Below this is a darker purple bar with the text 'Comparison within 100 - word problems'. The main question is displayed in a light green box: 'John watched between 82 and 85 movies. How many movies might John have watched?'. Below the question are four green buttons, each containing a number: 83, 12, 99, and 77.

(source Sumdog™)

Answering the question correctly and quickly allows them to use a feature within the game, then another question appears this continues until the game finishes. At the end of a game coins are rewarded for correctly answered questions, which they can use in the shop that opens when school closes, and children receive feedback on which questions were not answered correctly. There's an opportunity here for the teacher to collate the incorrect answers and address them during lessons as a whole class or in smaller groups to discuss which strategies the children were using.

Analysis and results

An aim of this research was to establish whether or not game based learning improved children's mental calculations. Prensky (2006) believed game based learning could motivate children, and the literature showed that it was a crucial attribute in Thompson's (2010) mental calculation model. Will we see evidence of this motivation?

Figure 2 looks at the number of questions answered (blue) and the number of correct answers (red) over the four week period. There are a number of interesting observations to make. However the most significant was the number of questions answered over the four week period 145,087 or which 108,318 (75%) were correct. In

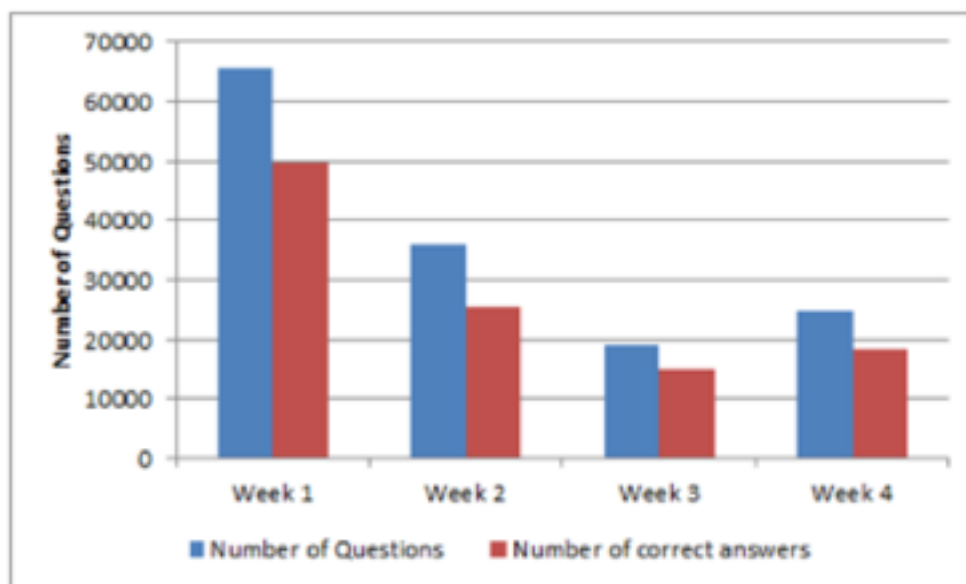


Figure 2

week one there was a lot of interest from the children but more significantly the majority of the questions were Level 1 which the children were all able to answer since by week 2 the system had stopped asking Level 1 questions. Children were answering on average during week one 1000 questions each. This settled to around 350 questions for the remaining weeks. Children were asked in the questionnaire how often in the week they logged into Sumdog™. Over 54% of the children logged in between 1-3 days (Appendix 3). Therefore children were going from answering no mental mathematics questions, beyond those asked in a mathematics lesson, to answering 100-300 questions a day.

The next chart (Figure 3) looks at the proportion of questions answered per week by level⁴ for 54 children. In week one you can clearly see at the bottom Level 1 (navy blue) but it is absent in the remaining weeks, as mentioned above. This chart shows the progression the children made across the levels. For example, in weeks 1 and 2 more time was spent answering Level 1-3 questions compared to weeks 3 and 4, where more time was spent answering questions at Level 4-6.

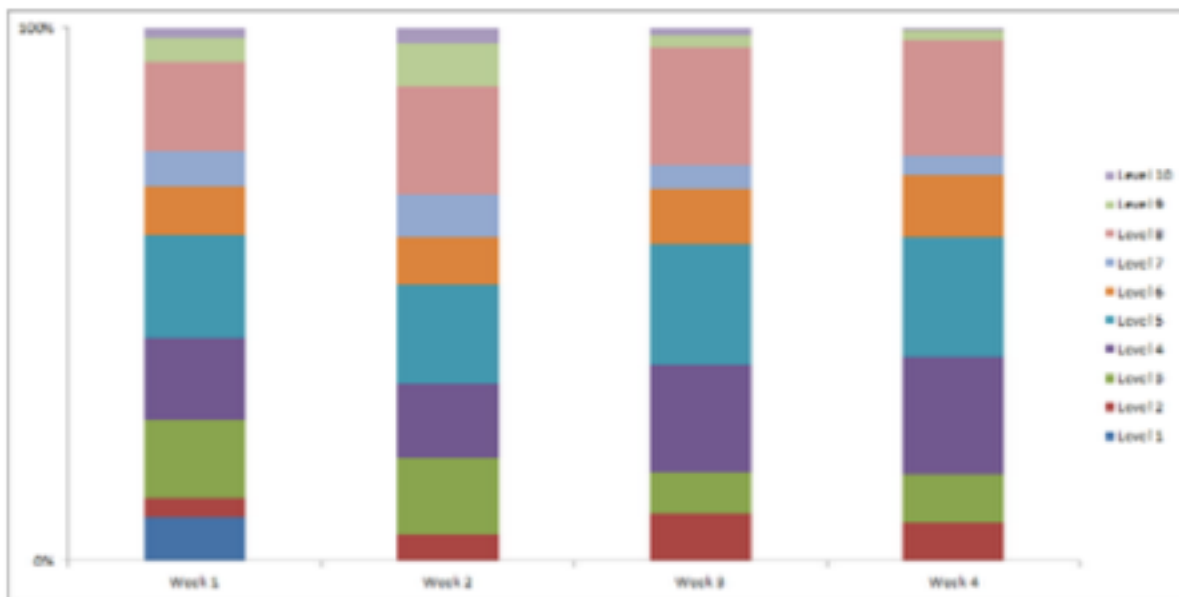


Figure 3

A key factor from the research that impacts upon players' motivation is a player's sense of challenge. From the questionnaire and interviews two fifths found the mathematics hard, however three fifths did not find the games themselves challenging (Appendix 3). I suspect the game has been designed in this manner to encourage the children to continue playing the games while slowly increasing the difficulty in the mathematics. If both elements were too challenging, it could alienate those children from playing this or any similar type of game in the future. Games tend to be at their most enjoyable when they are difficult but 'just do-able', rather than when they are too easy; they make demands that are at the edge of players' competence (Futurelab, 2005)

This cumulative distribution graph (Figure 4) compares the speed of correctly answered questions between weeks 1 and 4. The mean for week 1 was 4.47 seconds in week 4 it was 4.43 seconds. Therefore half the children were correctly answering questions within 4.4 seconds. The graph shows the children were fractionally faster, the upper limit for weeks 1 and 4 fell by 0.8 seconds.

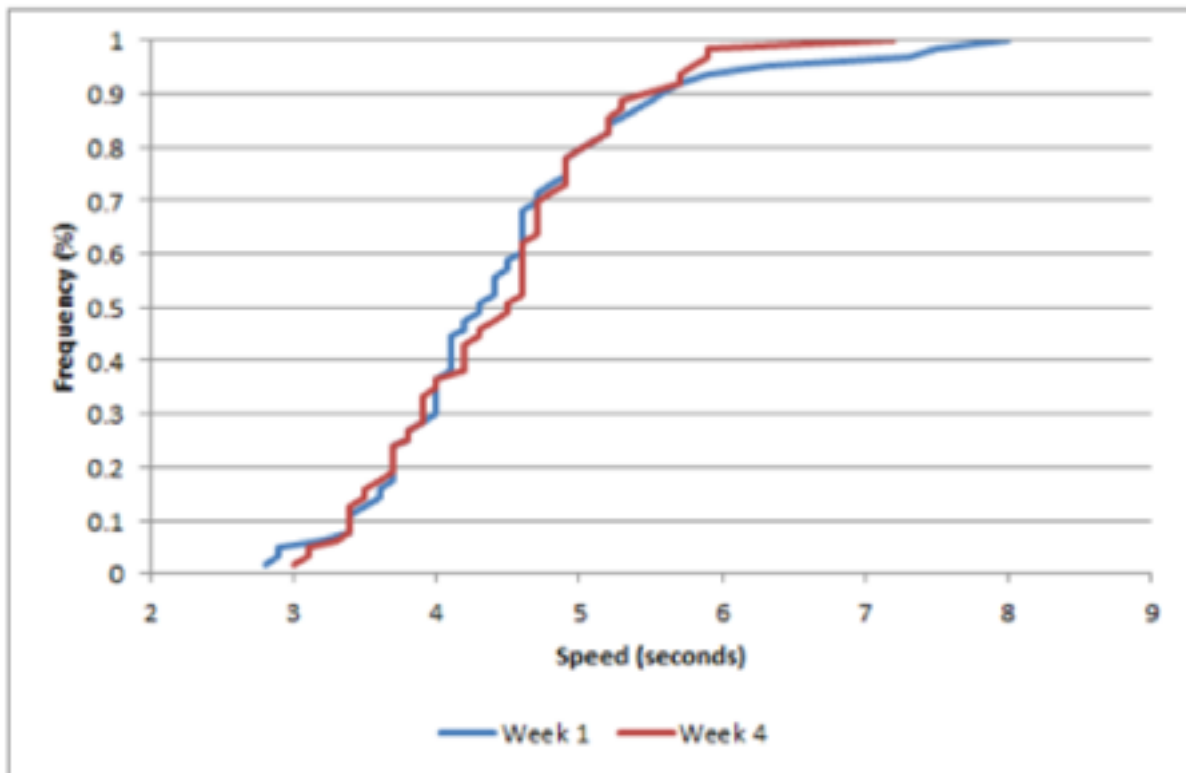


Figure 4

Over 95% of the children have access to the internet at home, of which 79% had access to tablet or smartphone and despite there been only two games currently available on these devices, 34% had played Sumdog™ using them. Talking to the children, I also discovered that some parents limited the time their children could spend on the computer. Those children who played on Sumdog™ more than 2 days a week progressed more quickly through the levels while maintaining or for some improving their speed. A potential barrier to using these games would be a lack of access to equipment and services and this would need to be monitored going forward.

The final cumulative distribution graph (Figure 5) measures the difference in accuracy⁵ across the four weeks. There is very little difference between weeks 1-3. During this period half the children correctly answered at or above 86.5% of the time. In week 4 this increased to 88.5%, an improvement of 2%. The accuracy in week one for 90% of the children was approximately 90%. At the end of week 4 this had increased by 3%. This graph shows that there was an improvement in the accuracy across the entire year.

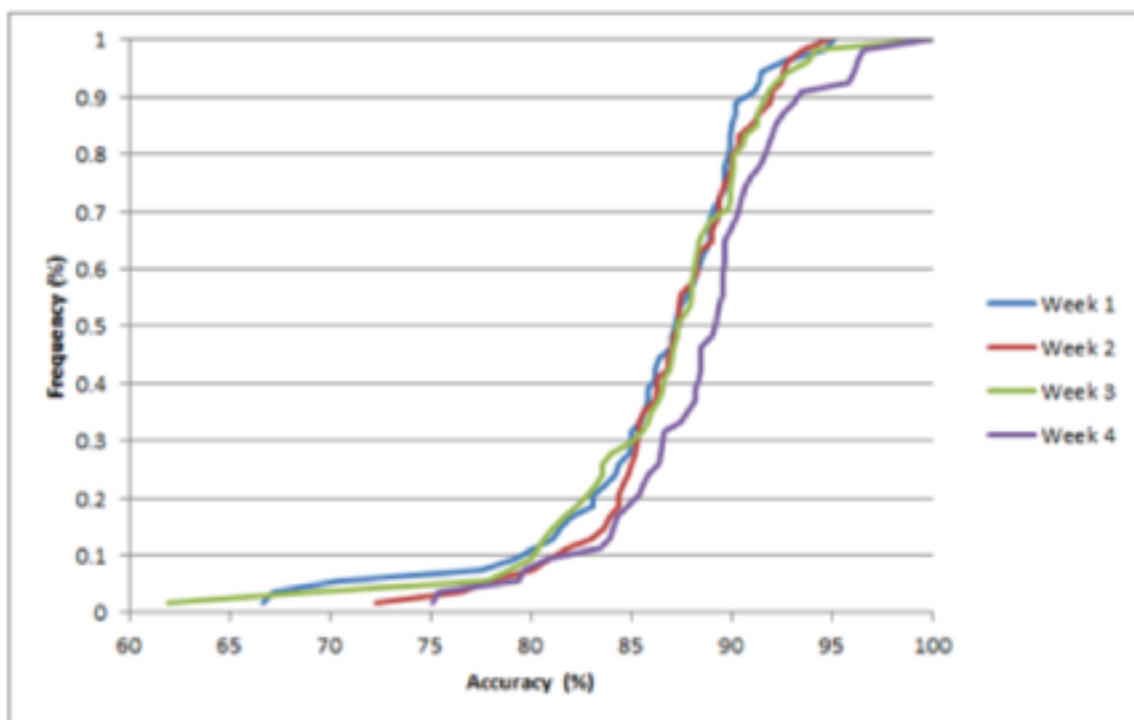


Figure 5

Two themes emerged from the questionnaire and interviews. They showed that the children had a positive attitude towards using Sumdog™. First 75% of children said Sumdog™ had given them more confidence in mathematics. This is a crucial statistic since this was one of Thompson's (2010) key attributes to be successful with mental calculation strategies. Over 80% of the children strongly agreed or agreed that Sumdog™ was fun which explains why over 80% were happy to play more than 2 days a week, with 66% saying they had played on the weekend.

Conclusion

At the start of this research I framed two aims to answer the question of this paper; the first was to look at the quality of the questions answered over the duration of the project, to establish whether there was any improvement; the second aim to find evidence that the game based learning was motivating the children to play on Sumdog™.

Progress was made by the children, despite taking into account the system calibrating in the first week to the children's actual levels. The children progressed through the levels accruing new knowledge, at the same time increasing their accuracy and speed. How much of this progress was a matter of remembering of facts or actually understanding the mathematics was not a mandate of this paper, however it would make for an interesting second cycle of research. It could focus on interviewing groups of children with regards to which skills and techniques they are using to answer questions. Are they using known facts or are they eliminating answers that don't look realistic - using test-taking skills (Nuthall, 2007: 44).

Motivation is key for effective learning, but that needs to be sustained through both informal and formal feedback responses, reflection and active involvement in order for designed learning to take place (Gaming Based Learning, 2007). The majority of children had a positive attitude towards playing the games, which improved their overall confidence in mental mathematics. Four fifths of Year 6 enjoyed playing on Sumdog™ therefore giving them opportunity to practise their skills over and over again. 'Repetition is vital in learning. It turns a learnt skill into an instinctive one. Self-motivation must very strong, and for the very young there should be a strong element of enjoyment' (Adams, 1996). Encouraging children to think and talk about mathematics is important (Straker, 1993), on this occasion there was no scope to monitor the language used by the children. In a new cycle of research this could be a focus along with integrating game based learning into formal lessons.

Notes

1 Sumdog™ is published by Crocodile Clips <http://www.sumdog.com/>

2 The Privacy Policy goes into great depth, and the protection they put in place to protect personal information http://www.sumdog.com/en/Privacy_Policy/

3 The website allows parents to create their own accounts, and then they can register their own children.

4 This is a 100% stacked column chart so can't be used to compare the number of questions asked by level across the four weeks.

5 Accuracy = correctly answered questions / questions answered

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