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Increasing student's skills in STEM with the use of precision teaching : assessing the effectiveness of SAFMEDS

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Increasing student's skills in STEM with the use of Precision teaching: assessing the effectiveness of SAFMEDS.

Stacey Helen Hunter

Thesis submitted to the School of Psychology, Bangor University, in partial fulfilment for the degree of Doctor of Philosophy

September, 2014

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Summary

The focus of this thesis was to increase STEM (science, technology, engineering and maths) skills in students across North Wales. Initially the research evaluated local workshops that were designed to increase students' engagement in STEM were also evaluated. However, the main emphasis of the research came from supporting one of the workshops on the academic side, by introducing Precision Teaching (PT) techniques, more specifically flashcards, known as SAFMEDS (Say all fast minute everyday shuffled). Chapter 1 of this thesis begins with a brief overview of the STEM agenda. This chapter examined the current educational system and assessed new ways of improving learning. Chapter 2 assessed ongoing workshops aimed at raising motivation and learning in STEM topics. 10 workshops were assessed and found that the main impact of the workshops was an increase students' real world perception. The results of this study suggest that the main elements of a successful workshop are hands on learning, opportunities for collaborative work, increasing confidence in STEM fields and real world application. It is evident that workshops alone are not sufficient in altering students' perception towards STEM, therefore more research needs to be conducted on increasing students' abilities in STEM. Chapter 3 of this thesis comprised a set of studies aimed at evaluating the use of a low-tech procedure, of PT techniques into one of the workshops evaluated in Chapter 2. The researcher incorporated flashcards known as SAFMEDS into three Techno Camp workshops: Internet boot camp (*n*=101), robotics (*n*=105), and wearable technology (*n*=9). The results looked at the boot camps without the flashcards (control) and with the flashcards (experimental). The results showed that the students who attended the boot camps that incorporated SAFMEDS cards, when compared to the control group scored significantly higher. Due to the significant findings from chapter 3 this technique was then implemented into schools. Chapter 4 developed 5 studies that assessed the effectiveness of using SAFMEDS in primary school on a class-wide basis, to

increase maths skills (*n*=272). The results showed that the students in the experimental condition when compared to TAU scored significantly higher, students could maintain the information learnt after 1 and 6-months, students could transfer the knowledge learnt to real world scenarios, and could be sustained in a busy classroom. Chapter 5 comprised a small sample of 2 students, who had been highlighted as having maths difficulties, attending a main-stream primary school, therefore the class pack delivered in chapter 4 was not suitable for their learning needs. Additional packs were created for the 2 students, which were more suited to their ability. The students completed the sessions with the rest of the class. Both students showed gains pre- to post-test and maintained the information in the one month follow-up-test, providing further support and evidence into the effectiveness of using SAFMEDS to increase students' basic academic skills. Chapter 6 further generalised and provided support for the use of SAFMEDS to increase maths skills in primary school students by incorporating SAFMEDS as homework. The same cohort from chapter 4 were used to assess the use of SAFMEDS as homework (*n*=122) and found that using SAFMEDS as the new style for homework increased students maths skills and increased parental involvement. Chapter 7 assessed whether the same method from chapter 4 could be utilized in a high school setting (*n*=48). The results of this study showed that the students who had the addition of SAFMEDS in their maths lesson improved significantly higher than their peers who had TAU.

Overall, the evaluative research conducted with the workshops, highlighted the importance of students having interactions with industry to increase their real world acceptance of the importance of STEM: the studies reported in this thesis have provided preliminary evidence of impact, but a number of key questions require further research. The overall findings from Chapters 3-7 suggest that the low-tech procedure of using SAFMEDS was successful in increasing students' technology and maths skills on a class-wide basis. The immediate implications of this work suggest that schools could make significant improvements in learning of STEM subjects. Success in a subject is one key element in motivation to study further and possibly in decisions to focus on those subjects in higher education.

Chapter 1: Introduction

"*The only man who behaves sensibly is my tailor; he takes my measurements anew every time he sees me, while all the rest go on with their old measurements and expect me to fit them*"

George Bernard Shaw

What are the Problems/ Issues?

Every child has the right to an effective education (Barrett et al., 1991), it is important that students have a rich learning environment to ensure they develop basic skills (The Basic Skills Agency, 2001). However, it is evident that children living in deprived areas are leaving school without an effective education (Chowdry et al., 2010). Failing education can have a knock on effect into adult hood; individuals are less likely to be employed or have a financially viable career, and poorer health. If these individuals become parents they will be less equipped to support their children financially and academically (Connor & Neal, 2005; Currie & Thomas, 2001; Elsevier Health Sciences, 2006). It is important for parents to provide their children with a rich learning environment at home, especially in early development. Unfortunately children from deprived backgrounds tend to not have a rich home learning environment, this is normally due to the parents own lack of education (Chowdry et al., 2010).

STEM

STEM is an acronym referring to four academic disciplines, Science, Technology, Engineering and Maths. There is a growing concern about the low levels of individuals who have the sufficient skills to have a career in a STEM field (Roberts, 2002). There are fewer students taking STEM subjects in higher education and many are becoming demotivated in STEM as early as 9 years old (Murphy & Beggs, 2005). A recent study also showed that students' career aspirations have no relationship with jobs that will be available for their future employment, highlighting the need for students to be more aware of realistic career demand (Mann, Massey, Glover Kashefpadkel & Dawkins, 2013). There is a huge awareness of the STEM agenda, not just from an academic point of view but also from the government due to the knock of effect this has on the economy, which in turn has created more public awareness to the issue. Due to the greater awareness of the importance of STEM from the government, research and development funding continues to grow globally (UNESCO, 2010). It is evident that the current education system is failing as students are still leaving education without basic STEM skills. There are many initiatives being put in place to change this, however national statistics are not showing great improvements (Morrison & Bartlett, 2009).

Recently India and China have flourished in the STEM sector and are now leading producers of technicians and engineers. This has led to a huge growth in their economy, due to innovation and inventions which are the driving forces of the economy (Hughes, 2009). It has been suggested that the main reason for the growth in these countries is the adoption of policies to promote STEM and an increase in spending on research and development (UNESCO, 2010). India also increased the number of Universities to increase student enrolment in higher education (UNSESCO, 2010). Another potential reason for the shift is that Western countries are still recovering from the recession, which has also effected where academic leaders teach. Due to the fast growing economies in East Asian countries they can offer positions with large research budgets. To promote STEM employability in students' it is important that students have the correct skill sets and have the motivation to pursue a career in STEM (Roberts, 2012). A survey reported that approximately a third of companies do not employ school leavers because of their lack of numeracy and literacy skills. The survey also highlighted that 85% of companies wanted a stronger focus on developing numeracy and literacy skills at primary school level (Education and Skills Survey, 2014). Therefore it is important that the UK invest heavily in academia and research development to ensure that the best possible teaching methods are utilised in education and are being delivered and have input from lead academics in their field of study.

It is important to conduct longitudinal studies, however, these have mainly focused on literacy (Juel, 1988). The growing interest and concern for students becoming more and more innumerate should also focus on longitudinal studies. It is important to assess each individual student's growth in maths over time, as this will highlight which students need further academic support (Gersten, Jordan & Flojo, 2005). With approximately 20% of students being estimated to require further academic support, highlights the importance of continued assessment of each individual student (Burns, Appleton & Stehouwer, 2005; Linn & Gronlund, 2000).

Geary, Hamson and Hoard (2000) conducted a longitudinal study and found that students maths difficulties varied between one year and the next, highlighting the importance for continued assessment throughout the students' education. By each student having individual daily assessment sheets for each topic of maths throughout the years will help not only the student, but also the teacher to establish if a particular individual needs extra support.

Increasing Parental involvement in their children's education

It is important for children to not only have a rich learning environment in school but also at home. As stated before this is not always the case for children growing up in deprived areas. Parents are one of the biggest influences on their children when it comes to career choice, therefore it is important that parents are equipped to provide their children with accurate information and academic support (Domina, 2005; Fan, 2001; Simon, 2001). A report highlighted that only 37% of mothers living in deprived areas aspired for their child to go to university, in comparison to 81% of mothers from affluent areas (Chowdry et al., 2010).

There is a strong link between students failing academically and parents who are not involved in their child's education. Research points to a link between lack of parental involvement and parents own inabilities in STEM (Bynner & Parsons, 2006; Farrell & O'Connor, 2003; Peters, Seeds, Goldstein & Coleman, 2008).

Raising educational standards

It is not enough to merely ensure students attend school; measures are in place to ensure there are enough schools, staff and even transport to school. However there is a big difference between attending school and receiving a good quality education that sets children up for a career (Fredrick & Hummel, 2004). One of the main factors in increasing students up take in STEM is good quality teaching (Barber & Mourshed, 2007; Darling-Hammond, 2007). Therefore as researchers it is imperative that evidence based research is conducted and that the procedures are taught to not only the students but to the teachers to ensure sustainability of effective teaching methods. Ensuring students leave school with STEM skills is important for their success in adulthood. In the past good levels of basic skills were less important in gaining employment, but in the 1980's there was a shift in the labour market due to factory closures and the revolution of information technology (Bynner, 2002). This shift in the labour market meant a higher demand to have literate and numerate individuals. Many policies were put in place to compete with the changing economy. For example, the Skills for Life programme was developed in 1999 to reduce the number of individuals who were illiterate and innumerate. Although policies have been put in place we still face similar problems today. Bynner and Parsons' (1997) study showed that individuals who lacked numeracy and literacy skills showed the lowest rates of employment, it was also noted that being innumerate was the bigger contributing factor to unemployment (Bynner, 2002). Therefore it is important that students attending school have effective instruction. Fredrick and Hummel (2004) define effective instruction as "*instruction that enables students to* *demonstrate, maintain, and generalize competency on pre specified learning outcomes faster than students would be able to accomplish this either on their own or with less effective instruction."* pp10. During a child's education it is important to have clearly defined goals. This can be for example mastering the 5 times tables, for a child to master this skill it is important to give clear instructions on how to complete the task and provide precise modelling. It is also important for the child to have plenty of opportunities to practice the skill to mastery level.

Deep vs Surface learning

Deep learning refers to the ability to use knowledge that has been previously learnt and relate it to a new situation, or daily life (Beishuizen & Stoutjesdijk, 1999; Biggs, 1993; Entwistle, 1977). It has been suggested that students who demonstrate deep learning, show a high degree of academic success and intrinsic motivation to further develop their learning (Biggs, 1993). On the contrast surface learning refers to the ability to answer a question by relying on memory and not necessarily being able to comprehend why that is the answer. This learning approach focuses on memorising the information and the ability to recall the information learnt at a later date, for example on a test (Aharony, 2010). It has been suggested that students who demonstrate surface learning show a low degree of academic success and are extrinsically motivated (Aharony, 2010). Saljo (1979) identified five learning characteristics. The first three learning characteristics are related to surface learning, 1) The student learns to gain information and develop their current repertoire, 2) The student learns information by imitation, in order to transfer the information learnt in a new situation such as a test, 3) The student learns in a logical manner with the main goal to apply the learnt information. The final two characteristics are related to deep learning, 4) the students learns to understand and discover information about previously acquired knowledge and relate the information to a new situation, and 5) the student learns by interpreting the information to gain a true understanding of the topic under study. Research also suggests that age is a contributing factor into being a surface or deep learner; older students favour deep learning, whereas younger students favour the surface learning approach (Aaron & Skakun, 1999, Richardson, 1994; Watkins & Hattie, 1980; Wong, 1992). It is important to look at deep and surface learning to assess the level of academic understanding. This is especially important in maths, if a student can answer the sum correctly is one aspect, but students are also expected to be able to answer reasoning questions. The Welsh government (2014) introduced numerical reasoning, in order to assess students' ability to apply their knowledge of maths to solve numeracy problems in a variety of context. Therefore, it is important to not only assess rate and frequency of learning but also the students' ability to apply the information learnt to real world scenarios.

Response to Intervention (RTI)

RTI is "*a process that involves assignment of evidence-based instruction or interventions, monitoring of student progress, and the making of instructional or eligibility decisions based on progress-monitoring data*" (Ysseldyke, 2008 p3). Providing quality instruction, monitoring daily progress and providing additional support for students who are not progressing as expected will provide a more beneficial learning environment (Fuchs, Mock, Morgan & Young, 2003; Johnson & Street, 2013). Therefore RTI is a preventive approach; early identification of students who are potentially at risk of failing is a vital component in ensuring every child has an effective education, to ensure they are equipped for adulthood and a viable future.

Precision Teaching

Precision teaching (PT) was developed by Ogden Lindsley (1964), PT is a way of teaching and by the early 1970's had become well established in regular and special education. Teachers had begun to move students through the curriculum based on fluency standards of the individual with the use of the Standard Celeration Chart (SCC) (Pennypacker, Koenig & Lindsley, 1972). The SCC allows the teacher to immediately have an overview of a students' learning. By recording the day that the behaviour occurred can provide the teacher with more information, for example a particular student may have lower maths scores on Friday's compared to Tuesday's, which would lead you to the question "What happened on Friday?" (Calkin, 2003). Looking into this in more detail it may become apparent that on a Friday the student has his maths lesson just before lunch, which has been known to affect this particular students' concentration. PT is a well-established field with the first publication of the *Journal of Precision Teaching and Celeration* in 1980. It is important to note that PT is a measurement system and not a curriculum, it can be applied to any aspect of the educational curriculum and any aspect of human behaviour (Calkin, 2003; Lindsley, 1992). In the 1950s Lindsley was conducting free-operant research, (the participant responding at their own pace), this is where precision teaching began.

There is an abundant of current research supporting the use of precision teaching to significantly increase students' basic skills (Beverley, Hughes and Hastings, 2012; Lolich, McLaughlin & Weber, 2012; McDowell & Keenan, 2001). PT does not follow traditional classroom teaching (where the teacher stands at the front and lectures to the class); rather in PT teachers become passive and the student becomes an active learner (Lindsley, 1992a). Students become owners of their learning which has been shown to increase intrinsic motivation (Deci & Ryan, 1994). The main elements of PT are: The learner knows best, rate as a measure, continuous monitoring of learning, charting, fluency and immediate feedback.

The learner knows best, if the student is not progressing then the form of teaching is not appropriate for that particular individual, on the other hand if that student is progressing then the method of teaching is appropriate. Learning can only happen when the student is in the correct environment, therefore tracking the students' progress is the only way to ensure that the environment is right for the child (Cooper, 2000; Kubina Jr, Morrison, & Lee, 2002). *Rate as a measure* is used in precision teaching and refers to the number of responses per unit of time, which is normally calculated as number of responses per minute. *Continuous monitoring* is important to assess whether or not the student is learning. Daily monitoring has been shown to be a strong predictor of students' performance on annual tests, which have high importance (which grade set the student will enter, acceptance into higher education) (Ysseldyke, 2006). *Charting* is a useful method for students to see their progress and to help teachers monitor their learning. With the Standard Celeration Chart (SCC) you can use the graph for multiple topics, over a long period of time. The graph is dated so you can see if there is a pattern in the each individual student's data. Students plot the number of corrects and the number of in-corrects, the chart also shows timing. Another beneficial point of charting data is that when the student plots their own data they have a sense of ownership, also when the child plots their data they are practicing the skill of charting, which is a skill taught in maths. *Fluency* (digits correct per unit of time) is vital, as this is an important skill to acquire to gain proficiency in academia especially in maths (Codding, Archer & Connell, 2010; Miller, Hall & Heward, 1995). Fluency has been highlighted as an issue in schools, it is not sufficient for the student to answer correctly, they need to provide a high rate of correct responses in a short period of time (Binder 1996; Doughty, Chase, & O'Shields, 2004). Fluency is important in maths as it requires complex problem solving and higher order learning. Research has shown that using fluency data especially for maths is a more reliable measure than percentage correct (Burns, VanDerHeydan & Jiban, 2006; Gickling & Thompson, 1985). Therefore it is important to measure fluency during learning, as a child who can answer 10 sums correct in 1 minute is not as fluent as a child who can answer 50 sums within the same time frame (Burns, Codding, Bioce & Lukito, 2010; Fredrick & Hummel, 2004). *Feedback* is important for learning, however delayed feedback can have the adverse effect. The most effective form of feedback to increase learning is when feedback is provided immediately after the response (Ashby, Queller, & Berretty, 1999; Maddox, Ashby, & Bohil, 2003). Although it is clear feedback that is delivered immediately is more beneficial to learning, the type of feedback is also important, merely stating whether the response was correct or incorrect is not as sufficient as providing the correct answer (Pashler, Cepeda, Wixted, & Rohrer, 2005).

SAFMEDS

SAFMEDS (Say All Fast Minute Every Day Shuffled), developed by Ogden Lindsley and Stephen Graf in the 1970's, are a set of flashcards with a term on the front and the definition on the back, or a question on the front with the corresponding answer on the back (Eshleman, 2000). SAFMEDS are a tool used in PT, SAFMEDS are used to increase fluency. SAFMEDS use frequency as the main measure and are conducted using free operant responding, allowing the learner to respond at their own rate (Binder, 1996). SAFMEDS are normally completed in pairs with one students acting as tutor and the other as the tutee. SAFMEDS can be tailored to each individual and their abilities (*learner knows best*). The tutor times the tutee for one minute, the tutee has to go through as many cards as the can in the given time frame (*fluency*). The tutee looks at the question and says the answer out loud, the tutee then turns the card over to see if they got the answer correct (*immediate feedback*). The tutee places the cards in either the correct pile or incorrect pile or as termed in this study the "not yet" pile. At the end of the one minute the tutor says stop, the tutee then stops and counts the two piles (*continuous monitoring*). The tutee records the number of corrects and not yets on a table and after completing all four one minute timings the student then charts their best score of the day (*charting*). Before each session the tutee shuffles the pack to minimise ordering effects. The students swop roles allowing both to complete the flashcards.

Research has shown the effectiveness of using SAFMEDS across a wide population from students with additional learning needs to University students (Beverley, Hughes & Hastings, 2012; Casey, McLauglin, Weber & Everson, 2003; Cunningham, Mclaughlin & Weber, 2012; Erbey, McLaughlin, Derby & Everson, 2011; Hughes Stockwell & Eshleman, 2010). Stockwell and Eshleman conducted a study using a female university student to increase her rate of responding on the topic "verbal behaviour". The participant completed between 1-6 timings over 3 weeks, the results displayed that the participant showed a gradual increase in corrects and a gradual decrease in not yets, the results also showed the participant could maintain the information learnt after 3, 4 and 11 weeks. Beverley, Hughes and Hastings (2009) also looked at the use of SAFMEDS with University students but looked the topic of statistics. They used a larger sample size of 24 students and also compared them to a treatment as usual group (31 students). The students completed 3 one minute daily timings over the course of the semester, the findings showed that the students improved from pre- to post-test and also outperformed the TAU group. The two studies mentioned above focused on university students, other research has also focused on younger students and students' with learning disabilities, Cunningham, McLaughlin and Kimberly (2012) used SAFMEDS to teach an eight year old student with LD maths facts and found that the use of verbal prompts and SAFMEDS the student increase the number of correct maths sum they could recall.

Methods and Research

Experimental methodologies

This thesis used mixed methods, from single case to group designs (between subjects and within subjects). Although sometimes criticized and rarely used in the field of ABA group statistics do have benefits such as being able to generalise the average findings from one population to another similar population (Kazdin, 2010). Many group studies use tests to state whether or not there was a statistical significance, however in educational interventions clinical significance on an individual level is also important. Statistical significance can be greatly affected by the number of individuals in the study and furthermore do not show the scale of change on an individual level (Baguley, 2012; Field, 2009; Gravetter & Wallnau, 2007) Although group statistics have been utilised in the following chapters, the emphasis of the research was on an individual level, monitoring each student to ensure they were progressing and providing further support if needed. Therefore improvement graphs have been included with the use of the Reliable Change Index (RCI). RCI has been utilised for over 20 years and calculates what score needs to be achieved to say that there is a reliable change of improvement (Jacobson & Truax, 1991). This statistics shows how much the students skills have changed and whether the change is an improvement or a deterioration of performance. The RCI score indicates the magnitude of change needed to reach a point that when we can say that this change is a significant improvement for the individual. If the majority of the students meet the reliable change this is an indication that the data is reliable. Plotting the data on a bar graph with a line indicating the RCI, allows each individual scores to be assessed, showing whether the student has met the reliable change and shown a clinical increase in performance at post-test. RCI can only be computed when a comparison group is available which may be a reason for this measure not being a commonly used analysis in the field of Applied Behaviour Analysis (Zahra & Hedge, 2010).

Ethics and Consent

The experimenter was CRB checked before the research took place. All school studies gained initial consent from the head teacher and parental consent was gained for each student taking part in the research. Parents/ guardians were given an information sheet detailing the intervention. All students involved were told they had the right to withdraw at any point during the research sessions and also had the right to withdraw their data. Assent was monitored throughout the research. All data was kept in a locked cabinet which only the experimenter has access to and all names have been allocated a number to protect the students' identity. No names were used for this write up.

Structure of Thesis and Background to the Included Papers

Because a large percentage of students are leaving education without basic skills and research shows the importance of students needing basic skills to gain employment in the future my goal was to initially establish what is currently being used and being offered to students. I then aimed to tackle the issue of students being innumerate using precision teaching techniques more specifically SAFMEDS (say all fast minute everyday shuffled) flashcards.

The main emphasis of my thesis was to improve STEM skills and student's motivation; initially this entailed assessing ongoing workshops (chapter 2). However the main focus of this thesis was the use of SAFMEDS to increase technology (chapter 3) and maths skills in students (chapter 4-7). The research was conducted in educational settings, schools, workshops and home.

Chapter 2 assessed workshops in North Wales to evaluate what makes an effective workshop key principles were examined, Hands on learning activities, Projects having real life context and relevance, Opportunities for collaborative work, Increasing confidence in STEM fields, Providing contact with role models and mentors, Parental involvement and Providing career information (Liston, Peterson & Ragan, 2008). 10 workshops were evaluated before the students attended the workshop (pre) and after the workshop had completed (post) using a condensed version of the SRQ-A (Academic Self-Regulation Questionnaire) (Ryan & Connell, 1989). This questionnaire assessed student's intrinsic/extrinsic motivation, perception, perceived difficulty and real world application of STEM. The results of the workshops showed a significant increase in students' real world application of STEM. It may be suggested from the results of this paper that Hands on learning activities, Projects having real life context and relevance, Opportunities for collaborative work, Increasing confidence in STEM fields seem to be the most beneficial to increasing students real world application of STEM. However further analysis is needed to really assess what is needed, but it is evident that these workshops have an important part to play in students' education, but workshops alone are not sufficient in altering students' perception of STEM. From working closely with one of the workshops they asked for a more hands on approach instead of just an evaluative approach which led to chapter 3. Chapter 3 focused on not just evaluating student's attitudes towards STEM but also assessing students' academic gains.

Chapter 3 incorporated SAFMEDS into the Techno Camps workshops, a method that has ample evidence base on the effectiveness of increasing academic achievements in small groups. Each workshop consisted of approximately 20-30 students and to the knowledge of the researcher no known studies have been conducted on investigating the effects of using SAFMEDS on such a large number of students at the same time. Three Techno Camps took part in the research; Internet boot camp, Robotics and Wearable technology. The findings of this research showed that incorporating SAFMEDS into workshops successfully increased students' technology skills and also improved significantly better than workshops that did not use SAFMEDS. Due to the success of the findings from chapter 3, the research gained further funding from Reaching Wider to incorporate this technique into a local primary school which has been classed as a deprived area.

Chapter 4 is a multiple paper study looking at the effectiveness of using SAFMEDS on a class-wide basis to increase maths skills in primary school students. This study was completed with two local primary schools, with year groups 2-6. Multiple maths topics were completed with the students. The results showed that with the addition of SAFMEDS into students' typical maths lessons, significantly increased students learning and also showed significant improvements compared to TAU. A sub analysis of this study with 2 students who were highlighted as having maths difficulties is described in chapter 5.

Chapter 5 assessed 2 students with maths difficulties, who were part of a larger class-wide study (chapter 4) completing SAFMEDS to increase their basic maths skills. The class SAFMEDS pack (chapter 4) was too advanced for the individuals in this study, therefore additional packs tailored to the 2 students were created which were more appropriate for their learning. The results of this study showed that class inclusion with appropriate interventions can increase student maths academic gains with students with maths difficulties without the need for exclusion. The success of the findings from chapter 2 and 3 led to questioning whether or not SAFMEDS could be used as a new homework style.

Chapter 6 was a multiple study paper which assessed the same cohort from chapter 4 and 5, to investigate if SAFMEDS could increase students' compliance to complete and return homework. This study also assessed if using SAFMEDS as a new homework style could increase parental involvement in their child's maths homework. The overall results of this multiple study paper showed that SAFMEDS as a new homework style had a positive impact on students' maths skills, return and completion rates and parental involvement. Anecdotal evidence suggests that parents' involvement in school had also increased. Parents also noted that their own maths skills had increased from completing the SAFMEDS with their children, however further research is required to assess if completing SAFMEDS with their children can increase parents basic maths skills. Chapters 4-6 show the effectiveness of using SAFMEDS with a primary school population, and led to questioning whether or not this class-wide SAFMEDS intervention could be incorporated into a high school population.

The last paper in this thesis, chapter 7 utilises a small sample looking at two matched high school year 7 maths classes. This study assessed if the incorporation of SAFMEDS could significantly increase learning compared to TAU, in an older population. The results of this study showing that the addition of SAFMEDS led to high school students showed higher academic gains compared to teaching alone. Similar enthusiasm to completing SAFMEDS with primary school children (chapter 5) was also evident with the cohort from this study, although only two year 7 classes were used. It is therefore not possible to generalise the findings to the whole high school population, however their data does show promising indications to the effectiveness of using SAFMEDS to increase high school students maths skills. Further research is needed with other high school ages to assess if SAFMEDS can be rolled out high school wide as it was in primary school (chapter 5).

The final chapter of this thesis provides a summary of each chapter and the implications the research has on the current literature. Each chapter has been discussed highlighting the findings of the research, the limitations and future directions of the research.

Chapter 2 Review of workshops in North Wales increase STEM engagement in students

Abstract

Background Due to the growing number of students failing in STEM subjects and the political pressure, many schools take the opportunity to take part in local workshops. These workshops are designed to show students what career paths they could take by studying STEM subjects.

Aims This evaluation aimed to see what aspects make a successful workshop.

Participants A total of 303 participants took part in the evaluation aged 7-17 assessing multiple STEM workshops.

Method Students attending the workshops were given pre- post-questionnaires assessing their perception towards the STEM topic of the workshop.

Results The results of this evaluation seem to be coherent throughout all of the workshops that have been evaluated. Students attending workshops outside of a school setting mainly showed a significant increase in their real world application of STEM.

Conclusion It is obvious that there is a need for students to attend similar workshops as described in this paper to increase students' awareness of the potential careers they could embark on, but it may not be sufficient alone. The results showed positive outcomes for the students but not overly significant outcomes, therefore it may be suggested that one day workshops or even one week workshops are not sufficient in altering students' perceptions. More emphasis should be on increasing students' ability which in turn should increase their motivation towards learning STEM and taking the path of a STEM career.

Introduction

There is a growing concern with the number of students failing in STEM (Science, Technology, Engineering and Maths) subjects and there is currently a shortage of individuals who are qualified in STEM (Roberts, 2002). There is a need for individuals who are qualified in STEM subjects to ensure the growth of our economy, at present this is not the case making it increasingly difficult for the UK to compete against developing economies such as China and India (Leitch, 2006). Students are disengaged in STEM subjects, therefore it is important that engagement is addressed and that students understand the real world importance of what they are learning (Brown, Brown, & Bibby, 2008). Research has shown that students who take part in learning with real world application show an increase in their learning and are more engaged in the topic (Yazzie-Mintz, 2010). Therefore many educators make use of external resources such as local workshops to increase students' knowledge and enthusiasm towards STEM. It is important for local businesses to be involved in the running of these projects to provide students real life context of how studying STEM subjects can help them in the real world and helps them gain a successful career.

There is also a stigma attached to individuals who have a career in the STEM sector. They are often perceived as "geeks" who only focus on their career (IET, 2008). Students' perceptions of subjects are extremely important with regards to them pursuing a career in that field. Therefore, if students perceive the subject as too difficult and that individuals who have a career in STEM as boring or undesirable, this will affect their decision in taking STEM subjects in higher education (Morris, 2006). It is important for students to have contact with positive role models and mentors in STEM sectors to change their perception and for students to feel that this is a career that they would like to pursue. Downing, Crosby and Blake-Bear (2005) showed the importance of role models to increase the number of woman entering into science careers. They showed that more than 90% of the woman pursuing a science career had a positive female role model, emphasising the importance of having role models that the individual can relate to. Wynarczyk and Hale (2009) noted that there is a lack of evidence based research to establish the real impact of STEM workshops, therefore the aim of this paper was to establish what makes an effective workshop; by measuring students' attitudes towards the STEM subject of that particular workshop. Some of the workshops provided the opportunity to also measure student learning. 7 Key aspects have been defined by Liston, Peterson & Ragan (2008) that make an effective workshop: Hands on learning activities, projects having real life context and relevance, opportunities for collaborative work, increasing confidence in STEM fields, providing contact with role models and mentors, parental involvement and providing career information.

Hands on learning activities: Hands on learning refers to students learning by the act of doing (Bransford, Brown, & Cocking, 2000). Carlson and Sullivan (1999) noticed the importance of hands on learning for their engineering students and found that by adding a hands on component to their course, they saw a substantial improvement, and found that 80% compared to the normal 55% completed the course. Research has shown that hands-on learning provides a rich learning environment for students (Cooper & Miller, 1996; Behr, 1996; Regan & Sheppard, 1996). Hands on learning has been found to be more successful in learning abstract concepts in comparison to fact learning (Flori, 1997; Laurillard, 1993). Jensen and Bowe (1999) targeted engineering classes which had been receiving negative student feedback and incorporated hands on learning, the results of introducing the hands on component showed an considerable improvement in student feedback.

Projects having real life context and relevance: It is important that when learning, students can see the real life relevance of that particular topic, however traditional teaching rarely incorporates real world context in students' learning (Duffy & Cunningham, 1996). Research suggests that when students learn decontextualized information, it is stored merely as facts and is less likely to be used as a tool to solve real life problems (Bransford, Sherwood, Hasselbring, Kinzer, & Williams, 1990; Brown, 1997; Cole, 1990; Whitehead, 1932). Therefore students who learn in real life context have positive learning outcomes and increase student motivation (Duffy & Cunningham, 1996; Gordon, Rogers, Comfort, Gavula, & McGee, 2001; Liu, Hsieh, Cho, & Schallert, 2006; Schneider, Krajcik, Marx, & Soloway, 2002).

Opportunities for collaborative work: The simple definition for collaborative work is two or more students working on a specific learning problem to gain the solution (Dillenbourg, 1999). Panitz (1999), highlighted 5 principles of collaborative learning: creates deeper understanding compared to individual work; speaking, listening and written interactions promote learning and understanding; promotes social interactions; increased understanding can come from personal points; and students participate in a voluntarily manner which in turn can increasing intrinsic motivation (Deci & Ryan, 1987). Research has also shown that students who have peer to peer involvement, show an increase in engagement and are more likely to pursue a career in STEM (Dunleavy & Milton. 2009; Tai, Liu, Maltese, & Fan, 2006; Taylor & Parsons, 2011).

Increasing confidence in STEM fields: If students are confident in their abilities in STEM subjects, they will be more likely to pursue a career in a STEM field, therefore it is important to instil confidence in students at an early stage (Hannover & Kessels, 2004). Byars-Winstone, Estrada and Howard (2008) stated that one of the main reasons for students not taking a STEM subject in higher education is their confidence in their own ability to complete the course. Not only is it important to increase students’ confidence in their own abilities but also their career goals, ensuring students understand that there is and will be a demand for individuals qualified in STEM and the salary they could attain (Roberts, 2002).

Providing contact with role models and mentors: There is a perceived perception of individuals who are in the STEM field and this can have an impact on students pursuing a career in STEM. Therefore, although contact with role models and mentors provide their own benefits, it is important that students can relate to these individuals (Hannover & Kessel, 2004). Dunleavy and Milton (2009) assessed what students perceived as an ideal learning environment and one of the main aspects was to have contact with experts in the field they were learning. Therefore this should be considered as an important part of students' education.

Parental involvement: It is important to include parents in children's education. Parents can have a significant impact on their child's career choice and are one of the main role models that children turn to for career advice (Middleton & Loughead, 1993; Millward, Houston, Brown & Barrett 2006). If parents can see the relevance and potential career pathways for their children they can be one of the biggest influencers (Pollard, Jagger, Perryman, Van Gent & Mann, 2003). Parental involvement in their child's career normally stem from their academic aspirations for their children (Bandura, Barbaranelli, Caprara & Pastorelli, 2001). Research also shows that parents who have a strong belief that they can affect their children's career choices are stronger influencers. Therefore it is important that workshops provide parents with information to help them believe that they can have an impact on their child's future (Elder, 1995; Gross, Fogg, & Tucker, 1995).

Providing career information: It is important to provide students with career advice as many students are generally shaped by their parents or relatives careers and tend to take the same or similar paths (Gati & Saka, 2001). However, students that come from deprived backgrounds may have parents who are unemployed, so will have little to no family role models to base their career decision making on. Therefore, it is important for schools and colleges to provide students with careers advice, to enable students to make an informative decision on the career path they wish to embark on (Ofsted, 2012). Maxwell and Rubin (2000) compared career academies (high schools specifically designed for learning to be career orientated and provide links with employers) to traditional high schools. They found that students who attended career academies performed significantly better in grade attainment when compared to traditional high schools.

This review assessed 10 local STEM workshops.

Two forms of questionnaire were used to analyse the effectiveness of the workshops.

1. Pre/post questionnaire which includes five subscales of intrinsic motivation, Extrinsic Motivation, Perception, Perceived Difficulty and Real world application (see appendix I).
2. Intrinsic motivation inventory (IMI) using the 25-item version "Activity perception questionnaire" which includes three subscales of Value/usefulness, interest/enjoyment and perceived choice, with 40 being the maximum and 8 being the minimum score for interest/enjoyment and perceived choice and 45 being the maximum and 9 being the minimum score for value/usefulness domain (see appendix K).

Workshops

Table 1 highlights the workshops and whether they met any of the key 7 principles: 1. Hands on learning; 2. Projects having real life context and relevance; 3. Opportunities for collaborative work; 4. Increasing confidence in STEM fields; 5. Providing contact with role models and mentors; 6. Parental involvement; and 7. Providing career information (Liston, 2008).

Table 1

Name and duration of the workshops evaluated assessing the 7 key principles

Workshop	**Duration**	**7 Key Principles**						
		1	**2**	**3**	**4**	**5**	**6**	**7**
Techno Camp:								
➢ Build your own internet	3 days	✓	✓	✓	✓	✓	✓	✓
➢ Robotics	3 days	✓	✓	✓	✓	✓	✓	✓
➢ Wearable technology	3 days	✓	✓	x	✓	✓	x	✓
Photonics Summer School	2 weeks	✓	✓	✓	✓	✓	✓	x
Wylfa Primary:								
➢ Electrical Circuits	1 day	✓	✓	✓	✓	x	x	x
➢ Forces and Movement	1 day	✓	✓	✓	✓	x	x	x
➢ Sound	1 day	✓	✓	✓	✓	x	x	x
Wylfa Site tour BTEC engineering	1 day	x	✓	x	✓	✓	x	✓
Maths at Wylfa	1 day	✓	✓	x	✓	✓	x	✓
Reach the heights	1 lesson	✓	✓	✓	✓	✓	x	x

10 workshops were evaluated, each workshop has been described below detailing the number of students who attended and their age. An overall summary of what the workshop entailed and whether they met the 7 key aspects.

Techno Camps

Techno camps held three different workshops; Internet boot camp, Robotics and Wearable technology. The three workshops were conducted by Bangor University Computer Science department. The workshops were held over three days and were free to attend.

Workshop 1 - Internet boot camp

123 students aged 11-17 male (*n*=82) and female (*n*=41) attended a free 3 day workshop “build an internet”. The workshop was run by staff and students from the technology department providing students with the opportunity to have contact with role

models and mentors from this sector. The workshop also encouraged parental involvement by inviting parents in at the end of the workshop to see what their children had accomplished. As the workshop took on a very real life context it was an opportunity for students to see what it would entail to be a programmer and students were informed about what they would need to take this career path. The objectives of the workshop were for students to work in teams as a business, and to create a website to sell/advertise something and to create the network the website would run on. Through observing the workshop it was established by the researcher that this workshop met all 7 key aspects of a successful workshop. It provided students with hands on learning, students learnt about building websites by actually building their own website. It provided real life context as they had to produce a website that could be published and worked in a team providing collaborative work. Increasing confidence in STEM fields, as the element of working in teams also meant students taking roles within their "company" showing students what it would be like having a job in this sector of technology, this also provided students with career information. As stated earlier the workshop also provided contact with role models and mentors and it was run by academic staff and students in the field of technology. And finally the workshop also provided parental involvement, as parents were encouraged to attend the last session to observe what the students had creates. This also provided parents with the opportunity to speak to the staff at the workshop.

Workshop 2 - Robotics

103 students aged 11-17 male (*n*=76) and female (*n*=27) attended the free three day robotics workshop. The workshop provided students with a scenario in which they had to build a robot to complete a mission, therefore the workshop provided hands on learning for the students. The scenario was based on missions that robots had been used for in the real world, such as going into landmine areas, therefore providing the students with real life context. Students worked in groups providing them with collaborative work. Although there

was not an emphasis on providing career information due to the real context of the missions set provided students with the opportunity to see what it would entail to be an engineer designing robots. The workshop was supported by current PhD and degree students studying computer science providing the students with role models and mentors. The workshop provided students with the confidence in their abilities in STEM, more specifically in this workshop technology. At the end of the workshop parents were invited to observe their children completing the mission. The students then had the opportunity to show parents their robots and how they worked and how they programmed them to detect certain colours. Staff members were on hand to provide parents with more details about other workshops they conduct.

Workshop 3 - Wearable technology

10 students aged 11-15 attended a free three day all female wearable technology workshop. This workshop provided students with hands on learning where they had to design their own bracelet with LEDs. The project had real life context to the students and showed how wearable technology is currently being used in the real world (for example, google glass and run way designers.) Students worked on their bracelets individually therefore not having many opportunities for collaborative work. The workshop was directed at females as many STEM workshops tend to be a male orientated profession, this workshop wanted to show females that STEM does not have to be male orientated, therefore increasing females' confidence in pursuing a career in STEM. The workshop was run by females who have a career in STEM providing the students with the opportunity to have contact with role models in this field. There was no parental involvement during the workshop and students did not showcase their final product. Students were provided career information as the workshop informed students how the skills could be used in the real world and what subjects they would need to study to be able to pursue a career in this field.

Workshop 4 - Photonics Summer School

18 students aged 15 male (*n*=13) and female (*n*=5) attended a voluntary two week workshop Monday-Friday 9-5. The workshop was conducted by Ray Davies Photonics lecturer at Bangor University and was supported by a 3rd year photonics female student and a male PhD student, providing contact with role models and mentors. The workshop took place in the School of Electronics and Engineering in their lab space. The workshop comprised of tutorials – an introduction tutorial and then impromptu tutorials based on problems and solutions the students were having during the workshop. The students were expected to do homework every night. Students had hands on learning by using what they learnt in the tutorials to invent a device. The device had to be something that would be useful in the real world and novel, therefore providing real life context. The majority of students worked individually but a few students worked in a group providing opportunities for collaborative work. However, even though the majority of students worked individually, when students came across a problem, the whole class would be involved in helping with the solution. If students came across a problem, it was encouraged for the students to do their own problem solving, highlighting to them that even when a problem occurs they can find their own solution, promoting their confidence in STEM fields. By promoting students confidence shows the students that they can succeed in this field. Parents were invited at the end of the workshop for the students to demonstrate their inventions, therefore provided parental involvement. Although the workshop did not provide career information directly, students could see how photonics could be used in the real world and had the opportunity to speak to role models and mentors in the field of photonics. See image below of the projects the students had invented during the workshop:

Wylfa primary school workshops

The teaching centre at Wylfa nuclear power station offered three science workshops to local primary schools; these workshops include Electrical Circuits, Forces and Movement, and Sound. The pre- post-questionnaire was simplified for the use with primary school students (see appendix J).

Workshop 5 - Electrical Circuits

73 primary school students aged 7 – 11 male (*n*=43) and female (*n*=30) from Anglesey attended a one day workshop on electrical circuits located in the information centre of Wylfa power station. The workshop required students to complete a workbook and practical tasks, to answer questions in the workbook, which provided students with hands on learning and real life context. Students worked in teams during the practicals, which provided opportunities for collaborative work. The workshop showed students that they could solve problems and build circuits, therefore increasing their confidence and abilities in STEM fields. The workshop did not provide contact with role models and mentors, parents were not involved in the workshop and there was no emphasis on providing career information.

Workshop 6 - Forces and Movement

55 students aged 7-11 male (*n*=20) and female (*n*=35) attended the forces and movement workshop. This is a one day workshop for primary school children held at Wylfa information centre. Students were given a workbook to complete which entailed completing practical tasks to answer questions from the workbook, providing students with hands on

learning and the projects had real life context. The workshop showed students that they could solve problems and build circuits increasing their confidence and abilities in STEM fields. The workshop did not provide contact with role models and mentors, no parental involvement and no emphasis on providing career information.

Workshop 7 – Sound

17 primary school students aged 7-11 male (*n*=11) and female (*n*=6) attended a one day workshop held at Wylfa information centre. The students had a structure workbook to go through during the workshop, this entailed students taking part in hands on learning, working in groups providing students with the opportunity for collaborative work and promote their confidence in STEM fields. The workbook was based on everyday things giving the topic real world relevance. The workshop did not provide contact with role models and mentors, no parental involvement and no emphasis on providing career information.

Workshop 8 - Wylfa Site tour BTEC engineering

11 BTEC male (*n*=10) and female (*n*=1) engineering students took part in this workshop. The workshop entailed students having a site tour of Wylfa power station, providing students with real life context of STEM in the workplace. The students had the opportunity to meet employees who worked at the nuclear power station and to see what their role entailed and how they used STEM in the work place, therefore providing contact with role models and mentors. By having the opportunity to see what employees do and ask questions helps promotes students confidence in their STEM abilities and provides students with career information.

Workshop 9 - Maths at Wylfa

24 students aged 14-15 male (*n=9*) and female (*n=15*) attended Wylfa for a tour of the site and to speak with workers about how they use maths at work. The students were split into two groups, group one visited the site tour first, during the site tour students were split

into groups of 2-4 and were led around by a worker from Wylfa who answered questions about the site as they went around, providing students with contact with role models and mentors, Students visited different departments and were given an interview sheet with prompts to ask the employers questions, with the aim to increase students confidence in STEM fields. The students were informed about how each department used maths and what qualifications are needed, which provided students with career information. In some departments students had the opportunity to have hands on work e.g. checking the tyre pressure, tax and graphs.

Workshop 10 - Reach the heights – Winds of change

48 high school students male (*n*=27) and female (*n*=21) took part in the reach the heights – Winds of change workshop. The workshop was held at the students' school where professionals took the workshop for one lesson, this was organised by Careers Wales. (Note: The experimenter was not able to observe this workshop.) The main emphasis of the workshop was for students to have the opportunity to meet with role models and mentors in STEM professions and to increase their confidence in STEM fields. During the lessons students took part in activities, which provided them with hands on learning, the projects had real life context. Students worked in groups during the lessons, providing students with opportunities for collaborative work.

Results

Workshop 1 - internet boot camp

Table 2

Pre/post technology questionnaire looking at the 5 subsections

Subsection	*Mean Percentage*		*t(122)*	*p*
	Pre	*Post*		
Intrinsic motivation	49%	53%	*-2.788*	*.006*
Extrinsic motivation	37%	40%	*-2.239*	*.027*
Perceived Ease	50%	51%	-*.195*	*.846*
Perception	33%	38%	*-2.416*	*.017*
Real World application	13%	42%	*-8.763*	*<.001*

The results of the questionnaire showed that the workshop had a postive impact on students overall percetion towards technology, inparticularly showing a significant impact on students real world application of technology.

Results of the post activity perception questionnaire

The results of the Intrinsic motivation inventory (IMI) using the 25-item version "Activity perception questionnaire" which includes three subscales of Value/usefulness, interest/enjoyment and perceived choice, with 40 being the maximum score for interest/enjoyment and perceived choice and 45 for value/usefulness. The results of the scale for value/usefulness showed a mean score of 13.51, which suggests that the students perceived this workshop as not very useful and did not have value. Perceived choice showed a mean score of 12.19, which suggests that the students felt that they did not have a choice during the workshop. Interest/enjoyment showed a mean score of 14.34, which suggests that the students did not enjoy the workshop. The results of the career question showed that the majority of students did not change their career choice but 5 students changed their career choice to a computer engineer or some form of engineer suggesting that for at least these students the workshop affected their career choice.

Workshop 2 - Robotics

Table 3

Pre/post technology questionnaire looking at the 5 subsections

Subsection	*Mean Percentage*		*t(102)*	*p*
	Pre	*Post*		
Intrinsic motivation	71%	71%	.000	1.000
Extrinsic motivation	61%	59%	.653	.575
Perceived Ease	70%	65%	1.194	.325
Perception	54%	50%	1.559	.122
Real World application	36%	60%	-5.806	<.001

The results of the questionnaire showed that the work shop did not effect students perceptions of technology but this may be due to students already having a positive perception. However students real world application of technology significantly increased.

Results of the post activity perception questionnaire

The results of the IMI "Activity perception questionnaire" showed a mean score of 34.21 for value/usefulness which suggests that the students perceived this workshop as useful and had value; results showed a mean score of 29.26 for perceived choice which suggests that the students felt that they did have a choice during the workshop. Mean score of 33.58 for Interest/enjoyment which suggests that the students did enjoy the workshop. The results of the career questionnaire showed that 18 students changed their career path to a career that related to the workshop suggesting that the workshop had a positive impact on these students career choice.

Workshop 3 - Wearable technology

Table 4

Pre/post technology questionnaire looking at the 5 subsections

Subsection	*Mean Percentage*		*t(9)*	*p*
	Pre	*Post*		
Intrinsic motivation	77%	75%	.246	.881
Extrinsic motivation	53%	65%	-1.527	.161
Perceived Ease	50%	59%	-.484	.640
Perception	56%	70%	-3.195	.011
Real World application	20%	51%	-1.761	.112

Although the pre post questionnaire does not show any significant increases, there is an increase in each subsection with the exception of intrinsic motivation which although decreased, remained relatively positive. Students' perception and real world application of technology showed the biggest increase.

Results of the post activity perception questionnaire

The results of the IMI "Activity perception questionnaire" showed a mean score of 39.3 for value/usefulness, which suggests that the students perceived this workshop as useful and had value; results showed a mean score of 33.4 for perceived choice which, suggests that the students felt that they did have a choice during the workshop, mean score of 38.10 for Interest/enjoyment which, suggests that the students did enjoy the workshop. The results of the career question showed that one student changed their career choice to a related career of the workshop; however the majority of the students were still undecided on what career path they wanted to pursue.

Workshop 4 - Photonics

Table 5

Pre/post science questionnaire looking at the 5 subsections

Subsection	*Mean*		$t(17)$	*p*
	Pre	*Post*		
Intrinsic motivation	39%	49%	*-2.405*	*.028*
Extrinsic motivation	38%	35%	*.451*	*.658*
Perceived Ease	43%	54%	*-1.623*	*.123*
Perception	53%	52%	*.089*	*.930*
Real World application	31%	54%	*-3.268*	*.005*

The mean score of value/usefulness was 40, which suggests that the students perceived this workshop as very useful and had value, the results showed a mean score of perceived choice was 36.6, which suggests that the students felt that they did have a choice during the workshop. The mean score of Interest/enjoyment was 28.3, which suggests that the students did enjoy the workshop. The results of the career question showed that the majority of the students did not change their career path, however 4 of the students although choose engineering or a specific field in engineering in the pre questionnaire changed to electronic engineering, another student changed from accountant to scientist, suggesting that the workshop had effective their career choice.

Workshop 5 - Electrical circuits

The questionnaire showed the results of the five subdomains of the pre- post-questionnaire. The results showed that although students' scores increased in all but one domain (intrinsic motivation) there was not a significant increase, suggesting that the workshop did have a positive effect on the students just not significantly. However, there was a significant increase in students' real world application of science. The results of the career questionnaire showed that 5 of the students changed their career choice to scientist.

Table 6

Pre/post science questionnaire looking at the 5 subsections

Subsection	*Mean percentage*		*t*(72)	*p*
	Pre	*Post*		
Intrinsic motivation	41%	35%	*1.483*	*.142*
Extrinsic motivation	58%	64%	*-1.757*	*.083*
Perceived Ease	30%	34%	-*.686*	*.495*
Perception	38%	39%	-*.271*	*.787*
Real World application	9%	35%	*-4.499*	<*.001*

Pre- Post-test

56 students completed the 24 MCQ (see appendix L) before the workshop (M=14.89) and completed the same quiz after the workshop and showed a significant increase (M=20.89) pre- to post-test (p=.001). The students then completed the quiz one month after the workshop (M=20.43) and maintained similar results to the post-test (p=1.00). There was a significant main effect of time $F(2,110)=87.126$ $p<.001$ $\eta_p^2=.613$.

Workshop 6 - Forces and movement

The questionnaire shows the results of the five subdomains of the pre- post questionnaire. The results showed that although students' scores increased, there was not a significant increase, suggesting that the workshop did have a positive effect on the students just not significantly. The results of the career questionnaire showed that only 1 student changed their career choice to a career related to the workshop (scientist).

Table 7

Pre/post science questionnaire looking at the 5 subsections

Subsection	*Mean percentage*		*t(54)*	*p*
	Pre	*Post*		
Intrinsic motivation	10%	14%	-*.470*	*.640*
Extrinsic motivation	74%	78%	*.797*	*.429*
Perceived Ease	17%	23%	-*.866*	*.390*
Perception	29%	28%	-*.376*	*.709*
Real World application	67%	73%	*-1.552*	*.127*

Pre- Post-test

55 students completed the 15 MCQ (see appendix M) before the workshop (M=9.65) and completed the same quiz after the workshop and showed a significant increase (M=12.22) pre- to post-test $t(54)=-7.967$ $p<.001$.

Workshop 7 - Sound

Pre and post questionnaires were completed by the students. The results showed that there were a slight increase in intrinsic and extrinsic motivation and a larger increase in perceived ease and real world application of science. Students' perception of science remained relatively stable. The results of the career questionnaire showed that only 1 student changed their career choice to scientist, the rest of the students career choices were in a non-STEM related field and did not change after the workshop..

Table 8

Pre/post science questionnaire looking at the 5 subsections

Subsection	*Mean percentage*			
	Pre	*Post*	*t*(16)	*p*
Intrinsic motivation	51%	54%	-*.554*	*.587*
Extrinsic motivation	76%	82%	*-1.000*	*.332*
Perceived Ease	20%	47%	*-3.490*	*.003*
Perception	43%	42%	*.265*	*.795*
Real World application	7%	67%	*-3.425*	*.003*

MCQ Pre- Post-test

13 students completed the 17 MCQ (see appendix N) before the workshop (M=7.14) and completed the same quiz after the workshop and showed a significant increase (M=9) pre- to post-test (p=.001). The students then completed the quiz one month after the workshop (M=10) and maintained similar results to the post-test (p=1.00). There was a significant main effect of time $F(1,13)=15.205$ $p=.002$ $\eta_p^2=.539$.

Workshop 8 - Wylfa site tour

Table 9

Pre/post Engineer questionnaire looking at the 5 subsections

Subsection	*Mean Percentage*		*t(10)*	*p*
	Pre	*Post*		
Intrinsic motivation	74%	56%	2.932	.015
Extrinsic motivation	60%	64%	-.896	.391
Perceived Ease	73%	75%	-.410	.690
Perception	65%	70%	-1.014	.335
Real World application	72%	76%	-.809	.437

The Intrinsic motivation inventory (IMI) showed the mean score of value/usefulness of 32.1, which suggests that the students perceived this workshop as useful and had value. The mean score of perceived choice was 28.3, which suggests that the students felt that they did have a choice during the workshop. The mean score of Interest/enjoyment was 29.5, which suggests that the students did enjoy the workshop.

Workshop 9 – Maths at Wylfa

Table 10

Pre/post math questionnaire looking at the 5 subsections

Subsection	*Mean Percentage*		*t(23)*	*p*
	Pre	*Post*		
Intrinsic motivation	20%	19%	.440	.664
Extrinsic motivation	59%	64%	-2.245	.035
Perceived Ease	41%	41%	-.102	.920
Perception	27%	27%	-.031	.976
Real World application	3%	14%	-1.875	.073

The Intrinsic motivation inventory (IMI) showed the mean score of value/usefulness was 33.6, which suggests that the students perceived this workshop as useful and had value. The mean score of perceived choice was 32.5, which suggests that the students felt that they did have a choice during the workshop. The mean score of Interest/enjoyment was 29.2, which suggests that the students did enjoy the workshop.

The results of the career questionnaire showed that 6 of the 24 students were undecided on their career path and this remained the same on the post-test. The rest of the students had decided their career paths, with one student changing at post-test to undecided and another adding accountant to their potential career path (sports profession n=2/ navy pilot n=1/ lawyer n=1/ drugs squad n=1/ doctor n=5/ nuclear physicist n=2/ chemical engineer n=3/ performer n=1/ vet n=3/ neurologist n=1 / accountant n=1).

Workshop 10 - reach the heights

Table 11

Pre/post science questionnaire looking at the 5 subsections

Subsection	*Mean*		*t(47)*	*p*
	Pre	*Post*		
Intrinsic motivation	16%	15%	*.407*	*.686*
Extrinsic motivation	29%	26%	*1.265*	*.212*
Perceived Ease	19%	21%	-*.906*	*.370*
Perception	27%	35%	*-4.518*	<*.001*
Real World application	5%	25%	*-5.078*	<*.001*

Two school participated in the Activity perception questionnaire school 1 completed the questionnaire using the 5 point likert scale and school 2 completed the questionnaire using the 7 point likert scale for the full data set school 2's results were converted from the 7 point likert scale to 5. (The conversion used: 1-1 2-2 3-3 4-3 5-4 6-5 7-5).

The Intrinsic motivation inventory (IMI) showed the mean score of value/usefulness was 26.8, which suggests that the students perceived this workshop as useful and had value; results showed a mean score of perceived choice was 25.6, which suggests that the students felt that they did have a choice during the workshop. The mean score of Interest/enjoyment was 25.2, which suggests that the students did enjoy the workshop. The results of the career question showed that the students career choices had not change pre- to post-questionnaire (three students who had previously stated a career left that question blank on the post-questionnaire).

Discussion

Workshop 1 - Internet boot camp Overall the results of the pre- post-questionnaire showed that there was an increase in each subsection, with significant increases in intrinsic motivation and real world application. However, the results from the IMI suggest that the students did not perceive the workshop as useful and did not enjoy the workshop and suggests that they had little perceived choice. However, observations by the researcher contradict these findings. Students were observed enjoying the activities, verbally stating that they enjoyed the activities and some students attending the same workshop twice. One possible explanation for the results found here, could be due to the number of questionnaires the students had to fill in, the students were asked to complete a questionnaire at the beginning of the workshop and two at the end for the purpose of this research, but due to the workshop being free it relied on funding, therefore they had to gain evidence of the effectiveness of the workshop and asked students to fill in a questionnaire at the beginning and end of each day.

Workshop 2 – Robotics The results of the robotics workshop showed that students demonstrated a significant increase in their real world perception of technology, which at pre-test was relatively low. Although there was not a significant difference pre- to post-questionnaire for the other sections, this may have been due to students already having positive attitudes towards technology. This workshop was a voluntary workshop, therefore it can be assumed that the students attending already had high motivation towards technology. The results may have been more significant if the students attending had negative attitudes towards technology at the pre-phase.

Workshop 3 - Wearable technology Although the findings of the pre- post-questionnaire do not show any significant findings the students do show an increase in their perception and real world relevance of technology. Also students attended the workshop voluntarily, therefore it may be suggested that they already had positive views towards technology which is supported by students' intrinsic motivation scores in the pre-phase. A major limitation to this evaluation is the small sample size, significant results may have been found on a larger sample. The results of the post activity questionnaire showed a general positive attitude towards the workshop.

Workshop 4 – Photonics Similar results are evident in this workshop showing that students' real world perception of science significantly increased. Although the results of the other sub domains did not show a significant increase this could be due to the small sample size. The overall perception of the workshop in the activity perception questionnaire showed a positive outcome of the workshop.

Workshop 5 – Electrical circuits The results from the one day workshop showed that only real world application had a significant increase, this may be due to only one day not being sufficient in altering students perceptions of STEM. However, in this workshop students learning was also monitored and showed that the students showed a significant increase from pre- to post-test and maintained the results in the one month follow up-test. A longitudinal study could have been important here, to see if the workshop effected the students decisions in later education, although it would be difficult to state that the effects of the workshop were directly related to subject choice and grade attainment.

Workshop 6 – Forces and movement There were no significant findings from the pre-post questionnaire, suggesting that the workshop did not have an impact on the students perceptions towards STEM. However, similar results were also evident in the pre- post-test showing that the students' knowledge of the topic had increased significantly. A one month follow up was not conducted with this cohort, therefore we cannot state if the results were maintained. Future studies should include maintenance test and longitudinal studies as stated above.

Workshop 7 – Sound A slightly smaller cohort were evaluated in this workshop but showed the biggest change in overall perception towards STEM, showing a significant increase in real world perception and perceived ease of the topic. However, although the pre-post-test does show a significant increase, the increase is not as significant as the previous two workshops (Electrical circuits and Forces and Movement). This is an interesting finding as it may be expected that the test scores in the post-test should correlate with the students' perceived ease of the topic. The results of the maintenance test also showed that the students were able to maintain the knowledge learnt after one month.

Workshop 8 - Wylfa site tour The findings from this workshop, although show no significant increase after attending the workshop, could be due to the fact that the students had already selected engineering as one of their career choices, therefore already had a positive attitude and perception towards engineering. The results also showed that 9 of the 11 students had said they wanted to be some form of an engineer (civil/chemical/mechanical/electrical), one students wanted to be a welder and one student was undecided all of which remained the same at the post-test. Students intrinsic motivation showed a decrease in the pre-test this may have been due to the workshop not including hands on learning, collaborative work and parental involvement.

Workshop 9 - Maths at Wylfa Maths at Wylfa was a one day workshop which could account for the lack of significant change in students' scores. Although not significant the biggest increase similar to the other workshops was students' real world perception of science. Although workshops like this are encouraging for students in increasing their real world knowledge and potential job opportunities and in particular for this workshop the relevance of maths in the work place, one day may not be sufficient in changing students perception. Changing students perception as the saying goes will not happen over-night. This workshop also did not have elements of collaborative work and parental involvement, which could also account for the findings.

Workshop 10 - Reach the heights Although previously stated that one day may not be sufficient for changing students perceptions towards STEM this one lesson workshop seemed to have a positive effect on students perceptions and real world application towards science, however the results for this study were extremely low at pre-test. This workshop was a mandatory school based workshop which may account for the low results at the pre-test therefore the significant findings may have been attributed to the low scores at the pre-test as the post scores are although higher are not on the positive end of the scale. This workshop also included all but one of the key concepts which may have been another factor in the positive results found in this workshop evaluation.

For the majority of the workshops stated in this paper it is evident those workshops that provide: 1. Hands on learning; 2. Projects having real life context and relevance; 3. Opportunities for collaborative work; 4. Increasing confidence in STEM fields can significantly increase students real world perception of STEM. Interestingly 3 of the workshops that were one day in duration resulted in no significant improvements in intrinsic, extrinsic motivation, perceived ease, perception and real world application of STEM, which may suggest that workshops need to be longer than one day. However, the Reach the heights workshop spanned over one lesson and showed an increase in perceived ease and real world application of science, which would contradict the previous statement. Further research could focus on the duration of workshops, to see what the ideal length of time for a workshop is. The workshops that did not show significant improvements in the real world application did not incorporate hands on learning and or collaborative work, which may suggest that these two elements are important in changing students' real world perception of STEM.

Questionnaires can sometimes be an unreliable method of data collection especially, with the age groups of the students who participated in this study. Although questionnaires are an efficient method of data collection, semi-structured interviews may have yielded more reliable results, however this would be more time consuming. It was evident from observing students completing the questionnaires that they were not filled in with due care and attention, some students were observed merely ticking boxes without reading the questions.

This evaluation provides further support into the effectiveness of workshops and the importance of workshops including hands on learning (Carlson & Sullivan, 1999; Cooper & Miller, 1996; Behr, 1996; Flori, 1997; Jensen & Bowe, 1999; Laurillard, 1993; Regan & Sheppard,1996), projects having real life context (Duffy & Cunningham, 1996; Gordon, Rogers, Comfort, Gavula, & McGee, 2001; Liu, Hsieh, Cho, & Schallert, 2006; Schneider, Krajcik, Marx, & Soloway, 2002) opportunities for collaborative work (Dunleavy & Milton. 2009; Tai, Liu, Maltese, & Fan, 2006; Taylor & Parsons, 2011) and increasing confidence in STEM fields (Hannover & Kessels, 2004). These four concepts seem to be consistent in the workshops that showed significant increases in students' real world perception of STEM. Although these workshops did not show significant findings in the other subdomains (intrinsic/extrinsic motivation, perceived ease and perception), this may be due to the majority of the workshops were either attended on a voluntary basis or by students who had already chosen STEM as a field to pursue a career, therefore already showed high results in these subdomains at the pre-test. Although this paper suggests that four of the seven key concepts are key for a successful workshop, it does not discount the importance of providing contact with role models, parental involvement and providing career information. A more rigorous study looking at each individual key concepts and a combination of the concepts will provide a more accurate picture of which concepts are needed, or which mix of concepts are needed and to what intensity.

Chapter 3: The use of flashcards to reduce the barrier of technical jargon

Abstract

Background Many technical or scientific subjects have a lot of technical terminology or 'jargon' which may put students off, especially females.

Aims This study examined the effectiveness of using SAFMEDS flashcards to increase the number of technical terminology in the students' repertoire, in order to minimise the potential barrier of using technical language in the technology workshops (Internet boot camp, Robotics and Wearable technology) run by "Techno Camps".

Participants 215 students male (*n*=137) and female (*n*=78) aged 11-18 attended the techno camp workshops. 101 of those students attended the internet boot camp, 105 students attended the robotics boot camp, and 9 attended the wearable technology boot camp.

Method Students in the intervention group had the addition of completing SAFMEDS flashcards based on the workshop they were attending.

Results The results showed that the intervention groups when compared to the control groups showed significantly higher test scores. The improvement in the intervention group was seen when compared to children of a similar age, but also when compared to older children (in the control group), which demonstrates the power of the procedure even in younger children. Perhaps most importantly, girls in the intervention group showed better gains when compared to both the control group and also to boys in the intervention group.

Conclusion The results of this study showed that the use of the SAFMEDS procedure helps children learn technical vocabulary rapidly and may help reduce one of the barriers to studying and choosing scientific subjects, particularly in young females.

For the growth of the economy it is important for individuals to have skills in STEM subjects (Harrison, 2012). However, the UK is failing in comparison to other countries such as China and India in the STEM sector (Hughes, 2009). The projection of demand for qualified individuals in STEM careers show that there will be a lack of qualified individuals in the UK to take these positions (Harrison, 2012). This paper focused on the technology aspect of STEM, because this is the main aspect in competing against other countries (Ergas, 2005). The development of technology can help develop other aspects of STEM and other industries such as the medical sector (Davey, Brennan, Meenan & McAdam, 2011).

There has been a noticeable decline of female students taking technology based subjects in higher education. Ninety two percent of students sitting the A level computing exam in 2014 were males highlighting the clear gender gap (JCQ, 2014). Whilst it is likely that a number of reasons account for this decline, one factor may be the perceived (or real) barrier of technical vocabulary which may have a greater negative impact on female students (Hornig, 1992; Etzkowitz, Kemelgor, & Uzzi, 2000; and Wynarczyk, 2008). Due to the decline of uptake of students taking science and technology subjects in higher education and the lack of published research on interventions to reduce the barrier of the use of technical jargon, this study focused on teaching students the meaning of the technical terminology used for the workshop they were attending.

The use of SAFMEDS (Say All Fast Minute Every Day Shuffled) is a simple procedure to help students' acquisition and fluency of new facts (Graf & Lindsley, 2002). The procedure involves students being given a set a flashcards with a term on the front and a short definition of the term on the back. Students are given one minute to go through the SAFMEDS, this involves the students looking at the card and saying the answer out loud. The student will then turn the card over to see if they answered the question correctly, this provides the student with immediate feedback. The feedback is not only immediate but also does not just state if the answer was correct or incorrect but also provides the student with the correct answer. Research has shown that providing immediate corrective feedback is beneficial to students learning, as it can act as an immediate reinforcer and also reduces students practicing incorrect responses (Goldman & Pellegrino, 1987; Siegler & Shrager, 1984; Van Houten, 1984). If the student answered the card correctly they would place the card on the right hand side in their correct pile, however, if the student answered the card incorrectly they would say the correct answer out loud then place the card on the left hand side in their not yet pile. This allows the student to keep a track on which questions they could answer and the questions they were unsure of. At the end of the one minuet time probe the student counts both piles and records their scores on a table, by allowing the student to keep track of their learning increases their ownership and also provides them information on how they are progressing. Before the student completes another time probe, the student will complete error correction; this is where the student will review the questions they answered incorrectly. To minimise students memorising the answers the students have to shuffle the pack before the start of each timed session. After each daily session of a number of one minute timed sessions, the student graphs their best score onto a chart. This is usually a standard celeration chart (SCC), the SCC allows students to record their daily sessions across a long period of time. The graph provides a visual representation of the students' progress. The graph shows the number of cards answered correctly and incorrectly, and how long the timing sessions lasted.

Peer tutoring (Levin, Glass & Meister, 1987) which involves two students working together to prompt and monitor each other's learning- one as the tutor and one as the tutee has been shown to have many benefits to both tutor and tutee, such as increased academic achievement, social skills and self-esteem (Blanch, Duran, Flores & Valdebenito, 2012; Topping, 2005). Fantuzzo, Riggio, Connelly & Dimeff (1989) developed reciprocal peer tutoring (RPT) whereby the students interchange between the tutor and tutee roles, this has been shown to increase students motivation towards the activity and maximises the benefits of acting in both roles as research suggests that tutors show more gains than tutees (Greenwood, Carta, & Hall, 1988).

This current pilot study focused on teaching students the meaning of the technical terminology used for the workshops they were attending using the addition of SAFMEDS (Techno Camps – computer/ IT related). The hypothesis was that by employing SAFMEDS during the workshops the students would develop a better vocabulary and hence a better understanding.

Method

Internet boot camp

Participants

Students who had volunteered to attend the techno camp workshops and the workshops were randomly allocated to either control group or the intervention group. The inclusion criteria consisted of all students completing 90% of the SAFMEDS sessions and attending 100% of the workshop. The internet boot camp consisted of 101 students, male (n=70) and female (n=41) aged 11-15; 50 students in the intervention and 51 in the control group (due to one the groups in the internet boot-camp being a different age category (16-19) a sub analysis was completed with this group (n=15). The control group only took part in the pre- and post-tests and attended the workshop but did not receive the SAFMEDS intervention.

Setting

The intervention took place at a workshop conducted by Bangor University "Techno Camp", the workshop took place in the School of Engineering and Technology. During day one the procedure was conducted in the same room as the workshop, day two and three the procedure was conducted in the room joining onto the workshop. The pre- and post-tests were conducted in the same room as the workshops.

Apparatus

All of the daily sessions were timed using a handheld stop watch. The pre- and post-tests were timed using a digital timer on the computer which was projected onto the wall for all students to see.

Stimuli/ Measures

All students in the intervention group were given a pack of SAFMEDS cards based on material in the workshop they were attending, which they kept on their table. The students in both the control groups and intervention group were given a pre- and post-test to evaluate their knowledge of the technology. The test was devised by the experimenter based on the information given by the workshop leader. Half of the questions on the test were then produced on flashcards.

Materials

All students in the intervention group were given a sheet to record their daily SAFMEDS sessions on and a pack of SAFMEDS.

Design

The intervention used a between/within subject design; investigating the effects of the use of SAFMEDS to increase the knowledge of technical terminology.

The independent variable (IV) was the group the students were assigned to; the intervention or the control group and the dependent variable (DV) was the score on the pre- and post-tests. The control group only took part in the pre- and post-tests and did not receive the intervention.

Constant variables in the study were that all students in the intervention group had the same words on the SAFMEDS cards and completed the SAFMEDS cards nine times a day for the duration of the workshop (3/2 days). The experimenter attended all of the sessions for each workshop. The experimenter worked with seven of the students in the intervention group who then worked with the other students (peer tutoring), the experimenter and the other members of the workshop supervised ensuring all students were completing the procedure correctly.

Ethics and Consent

The experimenter was CRB checked before the study took place. A risk assessment was carried out by the workshop leader which was checked by the experimenter and any risks were identified and minimised to ensure the safety of all those taking part in the study.

The workshop gained parental consent for the students attending the workshop and included the intervention as an activity for the workshop. Parents were all given an information sheet and an opt out form (see appendix O) which explained the intervention and gave the parents the option to opt their child's data from being used. Due to the age of the second control group they were informed that they themselves could sign their form if they wished for their data not to be used, parents were still given the information sheet and the opt out form. Before the workshop began the experimenter taught the procedure to the other members working on the workshop. All students involved were told they had the right to withdraw at any point during the workshop and also had the right to withdraw their data. All data will be kept in a locked cabinet which only the experimenter has access to and all names have been allocated a number to protect the students' identity. No names were used for this write up.

Pre-tests

At the beginning of each workshop all students in both intervention and control groups were given a MCQ test to assess which questions the students already knew (see appendix P/Q/R). The students were given a deadline 10 minutes to complete the test and a timer was put onto the wall for students to see how long they had. Students were told to write the time taken to complete the test. The experimenter explained the instructions for the test which were also written at the top of the test. The students were explicitly told that they were not expected to know the answers of the test items and that they were technical terminology that they would come to learn throughout the course of the workshop. The students were told to complete the test as quickly as possible and that if they did not know the answer to put an X where the answer would go. There was an example question to demonstrate this.

For the internet boot camp, the intervention group were the last workshop, therefore the data collected from the control group were used to assess which questions would be used in the SAFMEDS procedure. If 60% of the students correctly answered a question this question was then eliminated from the procedure, in total there were 59 questions on the test and only 30 of those were used for the SAFMEDS procedure. This was done to avoid students spending time learning terminology that they already knew. Using the 60% correct eliminated some cards and the rest were randomly rejected from the procedure to leave 30 cards for the intervention. This was done to allow for duplication of the cards, which allowed for more learning opportunities and also to avoid having a ceiling effect as students would be unlikely to complete 60 cards in one minute. The fluency aim given to students was a frequency of > 40 cards correct and less than 2 incorrect per minute. In the other two boot camps the test consisted of 25 questions which were replicated on the SAFMEDS which only the intervention group completed.

Intervention

Once the students had received the demonstration by the two members on the workshop and given a detailed explanation of the procedure by the experimenter they were then asked to work in dyads and complete their 9 daily sessions. The sessions were split up into three morning sessions, three mid-morning sessions and three afternoon sessions. The students were told to complete their three sessions then swop over roles as the observer/timer.

The experimenter and other members of the workshop observed the students and provided support when needed. The experimenter noticed that the majority of the students were completing the procedure incorrectly; when the student did not know the answer they would just say don't know and put it in the learning opportunity pile instead of turning the card over and reading the answer out loud. At the end of the first day the experimenter collected the data sheets in and noticed that the students were not making gains and the majority had not completed the 9 sessions for the day. For day two the experimenter took 5 students out at a time to observe more closely and work with the students. The students who were completing the procedure correctly acted as peer tutors for the other students, ensuring the highest number of students were completing the procedure correctly. Staff members continued observing the students completing their SAFMEDS to ensure the procedure was completed correctly. On day three of the workshop the same procedure continued but with the added incentive of a reward (sweets) once all of the sessions had been completed. This ensured that all sessions were completed for all students.

Post-tests

At the end of each workshop the students were all give the post-test which was identical to the pre-test and again a timer was projected onto the wall for students to record the time taken to complete the test. The only difference was the writing and instructions at the top of the test, this time they were not told that they were not expected to know the questions, but they were told that the majority of the questions had been taught/used on the workshop but not all of the questions and to still not worry if they did not know some of the answers.

Results

Internet Boot Camp

There were three important findings of this pilot study. (1) Overall the intervention group significantly increased their knowledge of technical terminology in comparison to the control groups. (2) The increased number of correct technical terminology was seen in the intervention group in comparison to both age-matched controls and also older students (who might be expected to be at an advantage). (3) Females in the experimental group showed a significant benefit from the intervention. In fact, their gains were greater than both the control groups and boys in the intervention group.

Figure 1 shows the overall results of the internet boot-camp, showing that students in the intervention group significantly outperformed the control group. Time $F(1,99) = 293.56$ $p < .001$ $\eta_p^2 = .75$. Time * group $F(1,99) = 136.403$ $p < .001$ $\eta_p^2 = .58$. Intercept $F(1,99) = 359.288$ $p < .001$ $\eta_p^2 = .78$. Group $F(1,99) = 20.325$ $p < .001$ $\eta_p^2 = .17$.

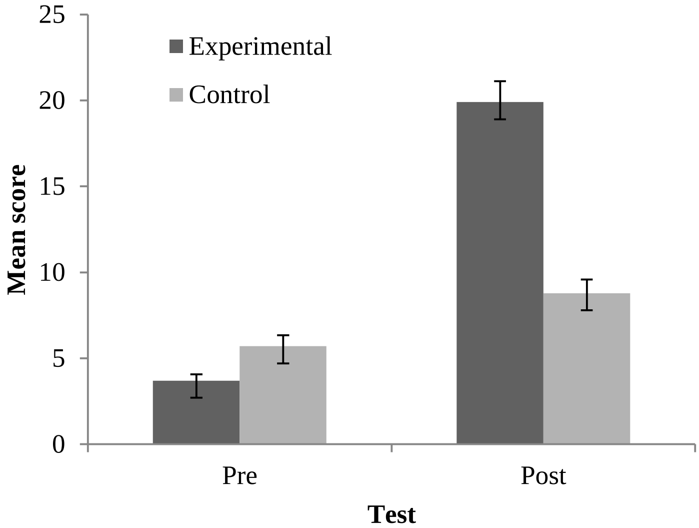

Figure 1: Mean pre- and post-test scores for the control and experimental group.

Figure two shows the mean pre- and post-test scores for the control and both experimental groups looking at the questions used with SAFMEDS and questions that were not used with SAFMEDS. There was a main effect of time $F(1,99) = 215.448$ $p<.001$ $\eta_p^2 = .69$ and a significant time * group interaction $F(1,99) = 128.978$ $p<.001$ $\eta_p^2 = .57$ and a significant main effect of group $F(1,99) = 75.859$ $p<.001$ $\eta_p^2 = .43$. The results clearly show that the students in the experimental group significantly outperformed the students in the control group when looking at the SAFMEDS questions. The results also show that although gains are seen pre- to post-test on the non SAFMEDS questions $F(1,99) = 35.071$ $p<.001$ $\eta_p^2=.26$, there is not a significant time * group interaction $F(1,99) = 14.602$ $p=.082$ $\eta_p^2=.03$ and no significant difference between the groups $F(1,99) = 1.125$ $p=.291$ $\eta_p^2=.01$.

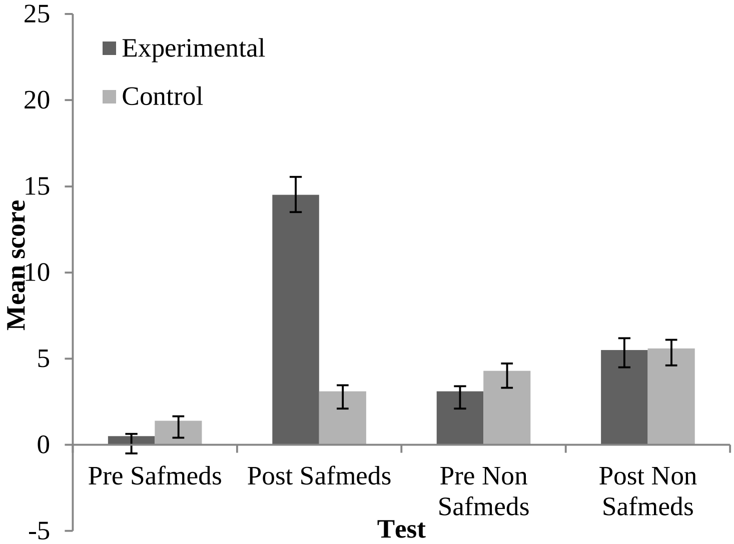

Figure 2: Mean pre- and post-test scores looking at the SAFMEDS and non SAFMEDS questions for both the control and experimental group.

Figure 3 shows the individual improvement scores pre- to post-test for the control and experimental group. The reliable change criterion was calculated at 3.21 showing that all but one of the students in the intervention group met and surpassed this criterion with a mean improvement of 16.2, whereas only 52% of the control group met the reliable change criterion with a mean improvement of 3.1.

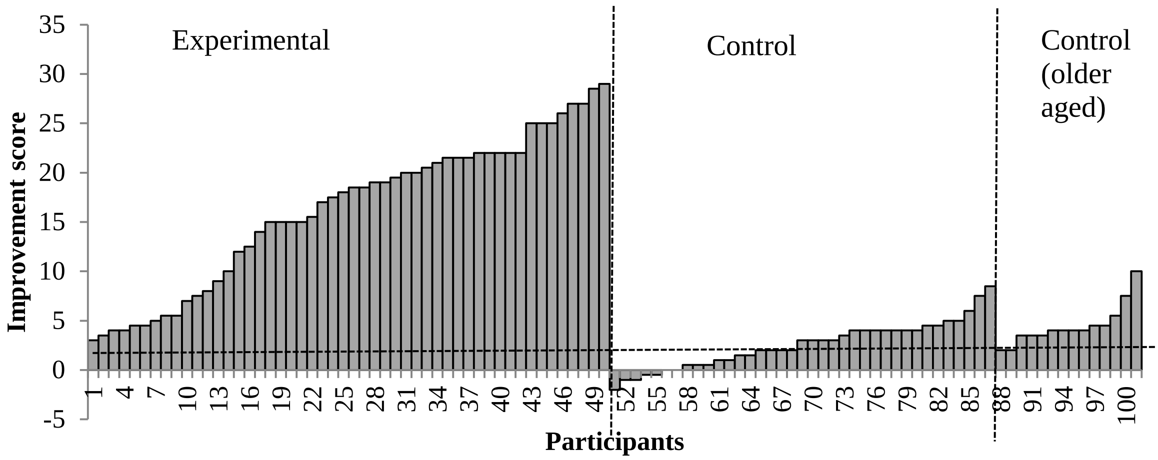

Figure 3. Improvement pre- to post-test scores for each student in the control and experimental group (RCI was 3.21).

Looking at the gender comparisons for the control groups the males showed a higher improvement rate than the females but in the intervention group the females showed a higher improvement rate than males. In all groups the female students' pre-tests scores were lower than the male students' scores.

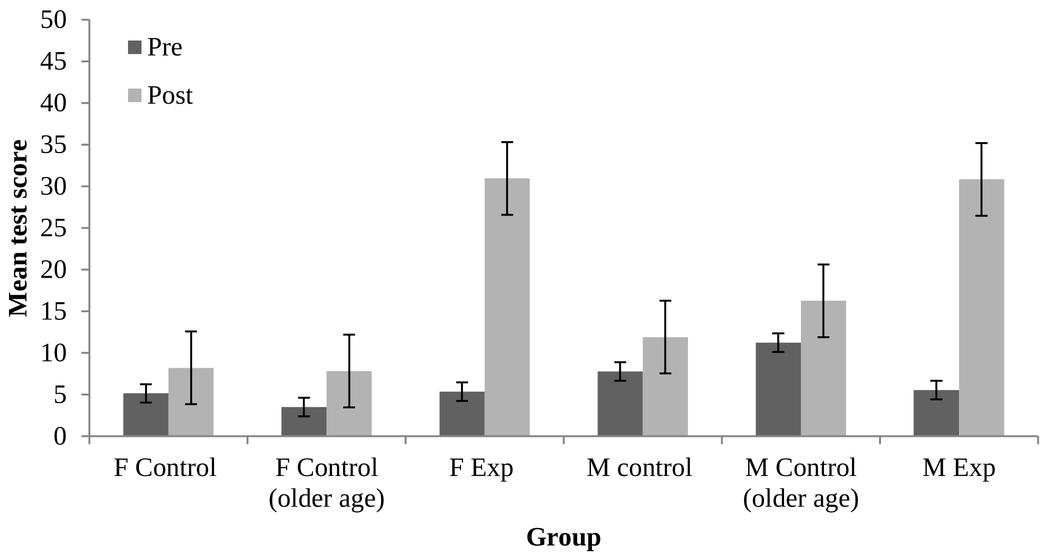

Figure 4: Mean pre- and post-test scores of males and females in the control and experimental group with the sub group of the older students.

Robotics Boot camp

Participants

The robotics boot-camp consisted of 105 students male and female aged 11-15; 63 in the intervention and 42 in the control group. The inclusion criteria consisted of 90% of the SAFMEDS being completed and attending the full workshop. Due to this inclusion criterion 8 students were removed from the analysis. The intervention group consisted of 55 students and 42 in the control group.

Results

Figure 5 shows the mean test score pre and post for both the control and experimental group. The results show that for the experimental group there was a main effect of time $F(1,54) = 461.050$ $p < .001$ $\eta_p^2 = .895$. The control group showed that they also show a main effect of time $F(1,41) = 48.733$ $p < .001$ $\eta_p^2 = .543$. When looking at both groups there was a main effect of time $F(1,95) = 414.956$ $p < .001$ $\eta_p^2 = .814$ but there was also a significant time * group interaction $F(1,95) = 188.034$ $p < .001$ $\eta_p^2 = .664$ suggesting that with the addition of SAFMEDS into the robotics workshop student significantly increased the amount of technical terminology they could recall.

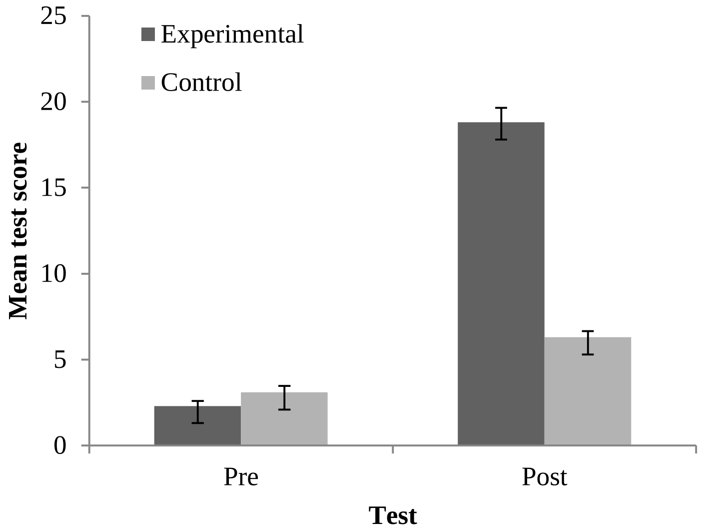

Figure 5: Mean pre- and post-test scores for the intervention and control group.

Figure 6 shows the mean pre post rate of response scores for the intervention and control group. The results show that the experimental group also showed an increase in rate of response pre- to post-test and outperformed the control group.

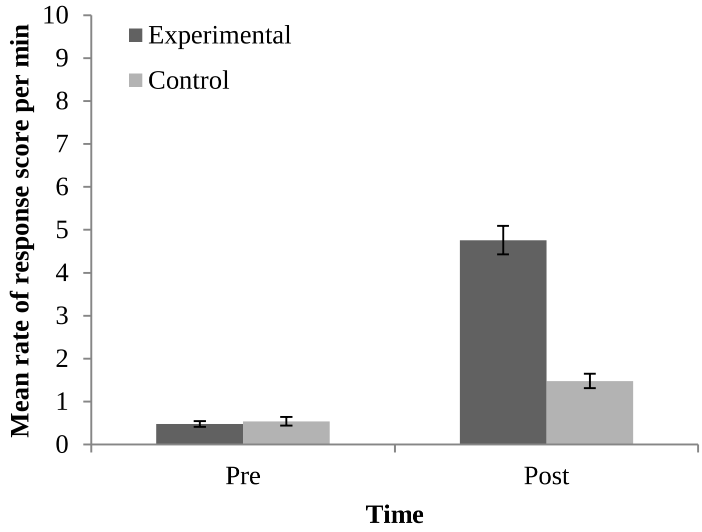

Figure 6. Mean pre- post-test rate of response scores for the experimental and control group.

Wearable technology workshop

Participants

This was an all-female 3 day work shop for students aged 11-15. 9 students attended the workshop, all 9 students took part in the intervention.

Results

Figure 7 shows that the students significantly increased the number of correct answers on the test pre to post $F(1,8) = 147.866$ $p < .001$ $\eta_p^2 = .949$.

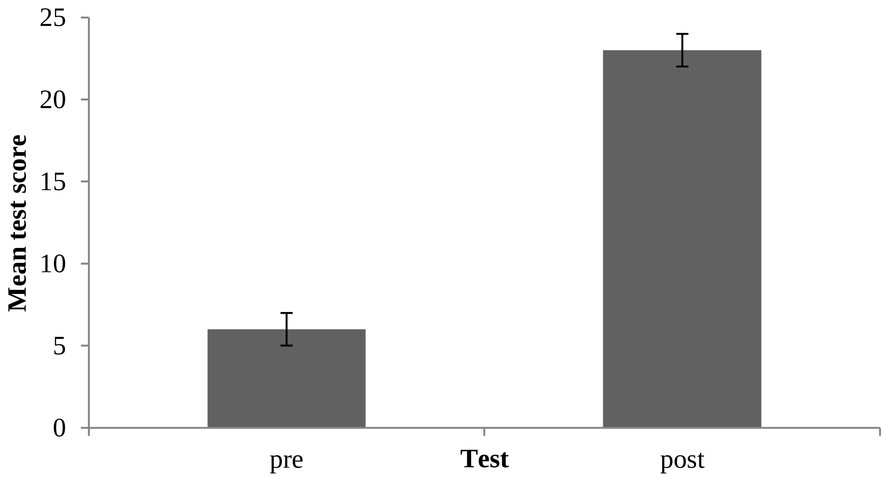

Figure 7: Mean pre- and post-test scores for the experimental group.

Conclusion and future directions

The results of the internet boot camp show clear gains made by the inclusion of SAFMEDS to increase understanding of technical terminology by students. The findings also showed that the experimental group not only outperformed their peers but also outperformed older students who initially showed more knowledge in the topic area. This study also compared the number of technical terminology that was included as SAFMEDS and that taught in the workshop without the additional aid of SAFMEDS. The results from this study strongly suggest that the inclusion of SAFMEDS increased the number of technical terminology in the students' repertoire. The results from the questions that were not included as SAFMEDS show no difference between the experimental group and both control groups in the number of technical terminology the students could answer correctly. When looking at gender, interestingly in the pre-test males outperformed females in each group, however in the post-test the females in the experimental group outperformed the males in the control group and showed similar gains to the males in the experimental group.

The results from the robotics study mirror the findings seen in the internet boot camp groups, showing a clear increase in the number of technical terminology in the experimental group compared to the control group. The statistics also show that the students in the experimental group not only answered more questions correctly but also showed higher rates of responding. The last boot camp was an all-female workshop, which compared to the other two studies had a small sample size of 9 students. However, the results still show clear improvement pre- to post-test, although there was no control group to compare the academic benefits.

The results of this pilot study are very clear and provide further support for the use of the SAFMEDS procedure as an educational tool to promote learning and to increase students' knowledge of technical terminology. The results also show the potential value in promoting

STEM subjects specifically in girls. This study also provides further support to the use of peer tutoring techniques (Topping, 2005) and provides further support into the effectiveness of using SAFMEDS to increase learning (Graf & Lindsley, 2002) and new evidence for the effectiveness of using SAFMEDS for increasing technical vocabulary in a class-wide setting. However, it is important to note that there were several components to this study, the use of SAFMEDS, fluency building, repeated practice and peer-tutoring. Therefore, it is not possible to determine the effects of each component individually, but that all of the components played a part in the number of technical terminology the students called recall.

One important future aim would be to see whether motivation to engage in STEM subjects improves in line with increases in learning. So, for example, as a student's vocabulary develops, do they also grow in confidence about the subject and does their motivation to learn also improve? Likewise, would this approach work for all STEM-related subjects and for all students, or are there constraints to its efficacy. So although the current study produced encouraging pilot data, there remain a number of important unknowns. Future work should focus on a more systematic exploration of the role of precision teaching in promoting learning and motivation in STEM subjects, particularly with respect to female students.

Chapter 4: The use of SAFMEDS to increase maths skills in primary school students

Abstract

Background. Most precision teaching interventions are based on a one-to-one or a small group basis to increase students' academic gains, and are rarely used in a class-wide setting.

Aims. The series of studies in this paper aimed to provide evidence that a low-tech learning key fact flashcard procedure known as SAFMEDS (Say All Fast Minute Everyday Shuffled) can increase students' basic maths skills. Study 1 investigated the effectiveness of the addition of SAFMEDS into a primary school on a class-wide basis in comparison to teaching as usual (TAU). Study 2 investigated the novelty effect of introducing SAFMEDS and whether or not students could apply basic knowledge to real world scenarios. Study 3 investigated the time element of incorporating SAFMEDS on a class-wide basis by reducing in class time, by requiring all students to complete the flashcards at the same time. Study 4 investigated the feasibility of incorporating SAFMEDS into the classroom with minimal support.

Participants. The study involved a total sample of 272 primary schools students aged 6-11.

Method. Students were given curriculum relevant maths flashcards with key facts to learn.

Results. The results from the four studies implementing SAFMEDS on a class-wide basis showed that students' number of basic maths facts increased significantly, that students could maintain the information after a period of 1- and 6-months, that they could apply this to real world scenarios, and that the method can be used to teach a variety of maths concepts practically in a busy classroom.

Conclusion. The studies suggest that this intervention provides a cost-effective procedure that can significantly contribute to the learning of basic maths concepts in school settings.

Introduction

Students failing in maths and English are more likely to drop out of High school (Kennelly & Monrad, 2007; Hammond, Linton, Smink & Drew, 2007). This will likely have a knock on effect in adulthood, as students who have not completed or have had a poor education, are less likely to be employed (Currie & Thomas, 2001; Connor & Neal, 2005). Research has suggested that individuals, who are numerate, are more employable and tend to earn more (Tariq & Durrani, 2009; Smith, McArdle, & Willis, 2010). Therefore, being innumerate could potentially have a negative impact on their health and well-being (Elsevier Health Sciences, 2006).

Recent statistics from the Organisation for Economic Co-operation and Development (OECD, 2012) report showed that maths is an area of education that is in need of significant improvement. For example, 24 countries worldwide were analysed in the report and England was ranked 21st for numeracy. The Welsh Assembly released figures for maths achievement for 2011/12 at GCSE level and stated only 57% of students in Wales achieved a grade A*-C. To be able to succeed at GCSE level, students must have mastered the basic concepts of maths. If students have mastered these basic concepts, they will have the ability and necessary prerequisite skills to be able to solve more complex maths equations in high school, further education and in everyday life. If students are not targeted early on and their perceptions of maths have already been formed, it can be more difficult to alter this perception towards a positive view of maths (Dowker, 2005). It is therefore important to address the problem of a high number of individuals being innumerate, before it becomes a greater problem (Cawley, Parmar, Yan & Miller, 1998). Studies have shown that waiting for students to fail and then providing additional support does not adequately help students catch up with their peers and gain adequate grades (Ramey & Ramey 2004). Consequently it is important to look at preventive measures by providing primary school students with effective learning opportunities (Gersten, Jordan & Flojo, 2005). To ensure the intervention is successful, studies have highlighted the importance of providing teacher training, therefore ensuring that the techniques will be incorporated into the curriculum (Ramey & Ramey 2004).

It has been suggested in order for students to compute complex maths skills, not only must students accurately answer basic maths questions, but must also be fluent in these skills (Johnson & Street, 2013; Rhymer, Dittmer, Skinner & Jackson, 2000). To attain maths fluency, students must have adequate practice of the skill; this then enables the student to answer the questions accurately, with few to no errors in a rapid rate (Houchins, Shippen & Flores, 2004). When responding becomes automatic, students have the capacity to focus their attention on more challenging maths equations (Binder, 1994).

Precision teaching (PT) is an approach that focuses on increasing acquisition and fluency building (number correct per unit of time) in basic skills. The main principles of precision teaching are continuous monitoring of learning, and rate of response. Fluency is shown when an individual provides the correct response but also without hesitation. Mastery of a skill is not only being fluent, but also relates to five main learning outcomes; maintenance, endurance, stability, application, and generativity (Binder, 1996). Johnson and Street (2013) stated that to assess for fluency one must test for maintenance (student is able to perform the task at a later date without prior practice), endurance (the student is able to continue for longer periods of time), stability (the student is able to perform in a loud distracting environment), application (the student is able to apply the information learnt to a new/novel situation) and generativity (the student is able to combine learning to solve a novel problem).

There are numerous studies to support the benefits of PT on a one-to-one basis or in small groups, across multiple ages and topics (Hughes, Beverley & Whitehead, 2007). Using some of the principles of PT, this study aimed to show the effectiveness of using flashcards known as SAFMEDS (Say All Fast Minute Every Day Shuffled) on a class-wide basis. SAFMEDS are based on the principles of PT; immediate feedback, fluency and measuring learning. Fluency is an important aspect of SAFMEDS and has also been noted to be fundamental for maths. To become fluent, individuals must be able to increase the speed in which they recall the answer; the timed element of SAFMEDS provides students with a set of cards and a short time frame to complete them, providing the students with the opportunity to increase the speed in their answering, to be able to get through more cards (Lerner, 2003).

Measuring learning is important for both the teacher and students. Allowing students to record their own data allows students' ownership of their studying, which has been shown to increase their learning and motivation (Brookhart, Andolina, Zuza and Furman, 2004; Deci & Ryan, 1987; Wood & Frank, 2000). Brookhart et al (2004) conducted an evaluation using teacher self-reports to assess what teachers thought attributed to the success or failure of their students' academic gains. The reports stated that students receiving consistent feedback and graphing their own data was suggested to be the main reason for the students success. The teachers self-reports also noted that students graphing their own data increased their maths skill of plotting data. Graphing data also provides students a clear visual representation of their learning.

Another element incorporated into the procedure is working in dyads; one student takes the roll of the timer and the other student will go through the flashcards, students then review the incorrect cards together. There are several benefits to students working in dyads; minimising teacher time, enabling the teacher to monitor the class as a whole. Students working in groups show higher academic achievement in comparison to students' who work alone (Hooper, Temiyakarn & Williams, 1993).

Brookhart et al (2004) focused on increasing primary school student's multiplication skills using 5-minute timed multiplication tests. During classroom time students were given flashcards and worked in pairs to practice their timetables. The results from this study showed that 80% of the students noted that using flashcards was attributed to their success on the tests. There have been numerous studies that have shown the effectiveness of using flashcards to improve maths skills with a small sample size of 2-3 students with a learning disability (Brasch, Williams, & McLaughlin, 2008; Glover, McLaughlin, Derby & Gower 2010; Erbey, McLaughlin, Derby & Everson, 2011; Glover, McLaughlin, Jolivette, Lingo, Houchins, Barton-Arwood & Shippen, 2006; Hayter, Scott, McLaughlin & Weber, 2007; Sante-Delli, McLaughlin & Weber, 2001). This paper aimed to provide further support into the effectiveness of using flashcards to further enhance students' maths skills and to provide new evidence into the effectiveness of using flashcards on a class-wide basis in main stream schools.

This paper reports four studies examining the effectiveness of using SAFMEDS in education and the benefits it has on students' maths knowledge. Study 1 aimed to use SAFMEDS on a class-wide basis to increase basic maths skills in primary school pupils. Study 2 aimed to replicate the findings from study 1 with the same cohort from the intervention group to investigate whether positive findings from Study 1 were explainable by novelty of the task. Study 2 also tested for application of basic skills into 10 real world scenarios. Study 3 aimed to replicate the findings from study 2 while attempting to reduce the time resources required conducting the intervention by using the flashcards on a simultaneously class-wide procedure. Study 4 investigated the efficacy of a teacher-led procedure.

Method

Study 1

Participants

A total of 218 (119 intervention, & 99 TAU) students male (*n*=122) and female (*n*=96) aged 6-11 participated. The inclusion criteria consisted of all students completing 90% of the SAFMEDS sessions and completing all testing times; pre- post-test and both one- and six-month follow ups. Due to the inclusion criteria 46 students were removed in the pre-post-test analysis and a further 15 students were removed from the full data analysis leaving 89 students in the intervention and 68 in the TAU group.

Intervention	TAU
Group A – Year 6	Group G – Year 6
Group B – Year 5	Group H – Year 5
Group C – Year 4	Group I – Year 4
Group D – Year 3	Group J – Year 3
Group E – Year 2	Group K – Year 2

Setting, stimuli and apparatus

The intervention took place in the student's usual classroom in two schools in North Wales. A digital hand held timer was used to time the daily sessions and was also used to time the pre- post-tests.

SAFMEDS flashcards were made available to students; each year group had different packs based on their school year curriculum. Year two SAFMEDS pack 1 *Fractions*; Year three SAFMEDS pack 1 *Addition*; Year four SAFMEDS pack 1 *Multiplication*; Year five SAFMEDS pack 1 *Multiplication and Divide*; Year six SAFMEDS pack 1 *Divide*. All students in the intervention group were given a sheet to record their daily SAFMEDS sessions and a Chart to record their best timing of the day. A plastic wallet was provided for each child to keep their table, chart, flashcards and timer in.

Measures

The students were given a 50 question pre-, post- and one- and six-month follow-up tests (see appendix U) to evaluate their knowledge of maths in the topic area that related to their flashcards. The flashcards were based on the new maths curriculum creating a pack for each question, designed by the experimenter.

Design

The intervention used a mixed design. The between group variable was whether the students received the SAFMEDS intervention or teaching as usual and the within subject variable of time (pre- post- and follow up-tests); investigating the effects of the use of flashcards to increase maths skills in primary school children. The independent variable (IV) was the students completing SAFMEDS sessions. The dependent variable (DV) was the score on the pre- and post-tests.

Ethics and Consent

Ethical approval was obtained from the School of Psychology Ethics Governance Board, and consent was obtained from the School Governors, Head teacher, and the parents of participating children, in line with BPS guidelines.

Procedure

Pre-tests

Students were given 10 minutes to complete a quiz based on the curriculum for their year group in exam conditions (no talking, only look at your own work). The students were instructed that if they did not know the answer to put an 'X' where the answer would go; there was an example question to demonstrate this at the top of the quiz.

Student/teacher training session. Training was given to ensure that the teachers and students were familiar with the flashcard procedure and how to complete the learning chart (see appendix W) and table (see appendix V) before the intervention started.

Weekly aims were given to students in the intervention group at the beginning of each week with the exception of week one, the aims were based on the previous weeks results on the chart.

Intervention

SAFMEDS Procedure. Flashcards were designed by the experimenter based on the new maths tests. Each 50 card pack was based on one topic, with each card having a different question. On the front of the card there would be a question (e.g., 5 x 5 = _____) and on the back of the card would be the answer (i.e., 25). Each session would consist of four one minute timed sessions. Students worked in pairs, one taking the role as the tutor and the other as the tutee. The tutee would shuffle the pack and wait to be instructed to start. The tutor would then say start and begin the stop watch, once instructed to start the tutee would look at the front of the card and say the answer out loud. The student would then turn over the card gaining immediate feedback on whether they had answered the question correctly. If the student had answered the card correctly they would place the card down on the left hand side (correct pile), if the student answered the card incorrectly they would say the correct answer out loud and place the card on the right side (not yet pile). At the end of the one minute timing the tutor would say “stop”. The tutee would then count both piles of cards and fill in their data sheet.. This was repeated for each 1-minute attempt. The student acting as the tutor went through the tutees incorrect pile by holding up each flashcard and asking the students the question, for example “What is 5 X 5?” the tutor gave the tutee a couple of seconds to answer if the tutee failed to answer or gave an incorrect answer the tutor turned the card over showing and verbalising the answer. The same card was asked immediately again until the tutee gave the correct answer, the tutor then placed the card to the back of the not yet pile and repeated until the student gave the correct response immediately without prompting. Once the tutee had gone through their not yet pile the tutee then put all the cards back together, shuffled and completed the next one minute timing. Students completed four one minute timings three times a week. Each pair swapped roles ensuring all students had three one minute timings in each session.

Constant variables in the study were that all students in each year group had the same set of flashcards. If a child was absent for any session, they completed the session they missed with a member of teaching staff, allowing the student to complete more timings as they only acted as the tutee for that session. This ensured that all students completed the flashcards an equal amount of times before the test. The experimenters attended all of the sessions to ensure the procedure was completed correctly and provided support when required such as verbal prompting, positive feedback, adjusting dyads, and demonstrations from students who were completing the procedure correctly.

Post-tests

At the end of the four-week school intervention the students from both the intervention and TAU group were all given the post-test (which was identical to the pre-test). Follow-up maintenance tests at 1- and 6-months were conducted following the intervention.

Data Analysis Approach

The results were analysed using a repeated measures ANOVA to investigate changes in the mean over the three/four time points and the difference in mean scores across the two conditions (SAFMEDS v TAU). Improvement graphs were utilised to show students' individual pre- to post-test improvement. To assess the change the Reliable Change Index (RCI) was used. RCI is a statistic to assess whether there is a statistical significant in individual students' improvement score. This was calculated by the change in the students score divided by the standard error of the difference for the test. If the improvement is greater than 1.96 (95% confidence interval) this can be considered as educationally significant gains.

Results

Mean test scores for each year group pre-, post- and one/six month follow up tests for the experimental and TAU groups are shown in Table 1. A repeated measures ANOVA was conducted on the data comparing the groups in each year. The results suggest that the intervention group significantly improved pre- to post-test and maintained the information in the one and six month follow up and also showed a significant interaction.

Table 1

Pre- post-test and both one- and six-month follow up for both experimental and TAU group for each year group.

	Experimental				TAU						
	Pre	Post	One Month	Six Month	Pre	Post	One Month	Six Month	Time * Group interaction		
Year Group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	*P*	η_p^2
6	6.1 (6.5)	25.7 (9.8)	20.8 (10.3)		15.8 (8.2)	20.4 (8.9)	24 (7.1)		(2,32) = 86.28	<.001	.84
5	9.8 (8.5)	22.4 (10.6)	21.2 (9.3)	20.5 (9.2)	15.2 (6.5)	18.9 (8.60	20.1 (7.4)	24 (7.7)	(3,93) = 7.95	<.001	.20
4	2.9 (3.9)	16.1 (9.9)	15.9 (10)	13.3 (9)	10.1 (8.3)	9.9 (8.3)	11.8 (8.1)	16.5 (10.2)	(3,99) = 18.77	<.001	.36
3	11.1 (11.9)	25.6 (15.6)	19.9 (16.2)	23.4 (18.2)	6.9 (7.7)	7.9 (11.4)	10.6 (12.3)	18 (18)	(3,63) = 3.12	.025	.14
2	13.8 (17.7)	48.7 (2.3)	48.7 (1.8)	34.7 (21.6)	22.9 (17.8)	37.9 (15)	34 (19.4)	12.4(1 8.6)	(2,74)=.9.12	<.001	.21

The Bonferonni post hoc results show that all of the year groups in the intervention group were significant pre- to post-test which is where the significant difference is expected, this was not the case for the TAU group only year 6, 5 and 2 showed a significant difference at pre- to post-test. The intervention year groups with the exception of year 3 also showed a significant difference from pre to post and all showed a significant difference from pre to 6 month follow up. There is not an expected difference to be seen between post and both one- and six-month follow up as the students are expected to maintain the information learnt. Year 4 and 2 in the TAU group showed a significant difference between post and six month and one month and six month which is not what we expected to see as students are expected to maintain the information learnt but without continued learning we would not expect students to continue improving at a significant rate unless learning continued.

Analysis of individual's pre to post improvement

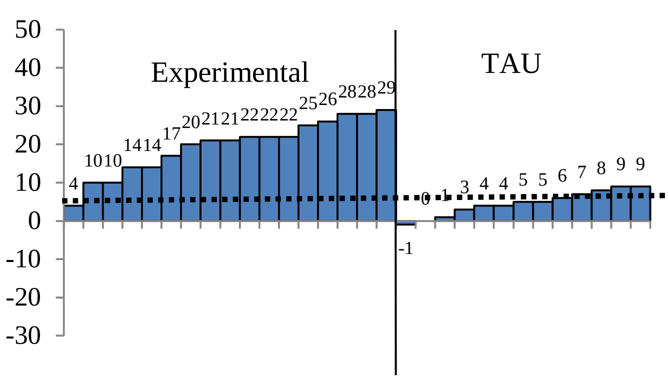

Figure 1. Individual pre- post-improvement score for Year 6 (RCI was 6.62)

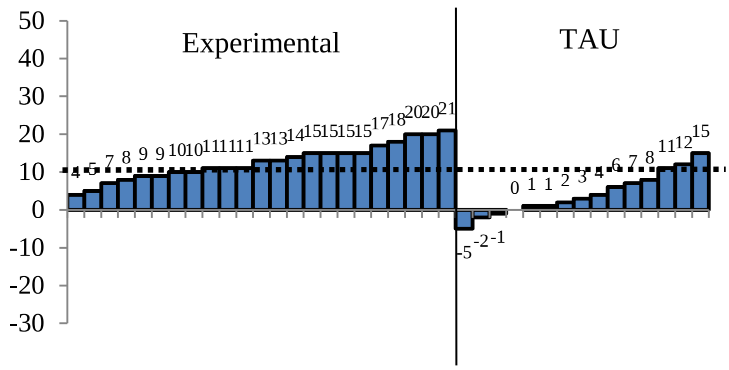

Figure 2. Individual pre- post-improvement score for Year 5 (RCI was 10.77)

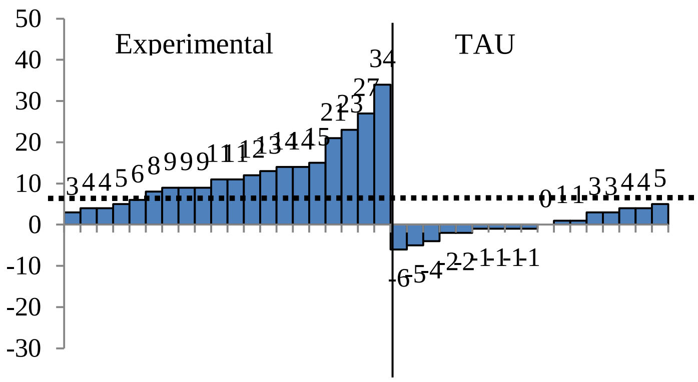

Figure 3. Individual pre- post-improvement score for Year 4 (RCI was 5.48).

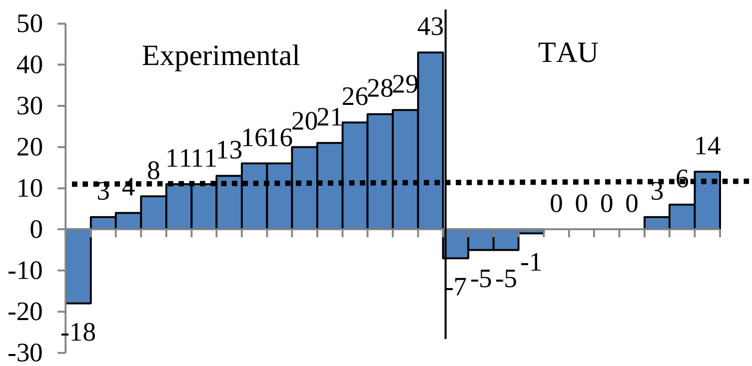

Figure 4. Individual pre- post-improvement score for Year 3 (RCI was 11.01).

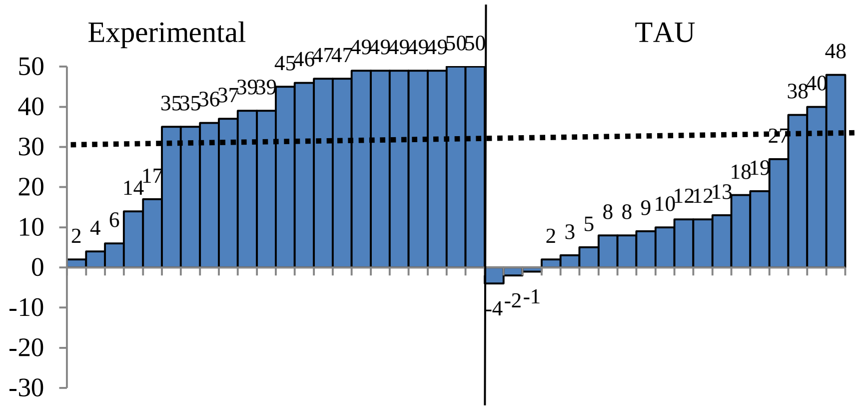

Figure 5. Individual pre- post-improvement score for Year 2 (RCI was 30.08).

All year groups in the intervention showed significant improvements pre- to post-test ($p<.001$) when compared to the control group.

Year 6 – The experimental group showed a mean improvement of 19.6, whereas the TAU group only showed a mean improvement of 4.6 ($t(28)=7.00$ $p<.001$); *Year 5* – The experimental group showed a mean improvement of 12.7, whereas the TAU group only showed a mean improvement of 4.1 ($t(36)=5.05 p<.001$); *Year 4* – The experimental group showed a mean improvement of 12.6, whereas the TAU group did not show an improvement -0.1 ($t(35)=6.04$ $p<.001$); *Year 3* – The experimental group showed a mean improvement of 15.4, whereas the TAU group only showed a mean improvement of 0.5 ($t(23)=4.72$ $p<.001$); *Year 2* – The experimental group showed a mean improvement of 36.1, whereas the TAU group only showed a mean improvement of 13.9 ($t(36)=4.04$ $p<.001$).

The improvement graphs also highlighted that more students in the intervention group met the RCI; *Year 6*: 16 students met the RCI compared to only 4 in the control group, *Year 5:* 15 students met the RCI compared to only 3 in the control group, *Year 4*: 16 students met the RCI compared to 0 in the control group, *Year 3*: 9 students met the RCI compared to only 1 in the control group, *Year 2*: 17 students met the RCI compared to only 3 in the control group.

Analysis of Fluency pre- post-test and both one- and six-month follow ups

Table 2

Mean and standard deviation fluency scores at pre- post-test and both one- and six-month follow up stage.

	Experimental				TAU						
	Pre	Post	One Month	Six Month	Pre	Post	One Month	Six Month	Time * Group interaction		
Year Group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	*P*	η_p^2
6	0.6 (0.2)	4.6 (0.6)	3.7 (0.8)		1.7 (0.3)	2.8 (0.4)	3.6 (0.6)		(1,26)=27.80	<.001	.68
5	1 (0.2)	4 (0.6)	3.9 (0.7)	3.4 (0.6)	1.7 (0.2)	2.6 (0.5)	2.9 (0.5)	2.8 (0.3)	(2,64)=12.18	.053	.08
4	0.3 (0.09)	1.7 (0.3)	1.7 (0.3)	1.4 (0.2)	1.3 (0.3)	1.4 (0.3)	1.7 (0.3)	2 (0.4)	(3,30)=4.62	.009	.32
3	1.1 (0.3)	3.3 (0.7)	2.8 (0.7)	2.8 (0.6)	0.7 (0.3)	0.8 (0.4)	1.1 (0.4)	2.1 (0.7)	(2,14)=.830	.441	.04
2	1 (0.3)	6.5 (0.6)	6.5 (0.4)	5 (0.8)	1.8 (0.4)	3.8 (0.5)	4.4 (0.7)	1.6 (0.6)	(2,76)=9.10	<.001	.21

The Bonferonni post hoc results show that all of the intervention group show a significant increase from pre- to post-test, although an increase is also seen in the TAU group the increase is significantly larger in the intervention groups for each year group with the exception of year 3. The results also show that in the one month and six month follow up phases the students in both the experimental and TAU, with the exception of year 2 in the TAU group, show relatively similar results suggesting that they could maintain the rate of responding as seen in the post-test. These results are similar to the number of correct responses presented in table 1, which may suggest that there is a link between number of correct responses and rate of responses.

Discussion

The results of study 1 provide clear evidence of the efficacy of incorporating SAFMEDS into primary school students' education on a class-wide basis to increase numeracy skill acquisition. The study showed gains for the intervention group for all years and also demonstrated that the students become more fluent, as well as gaining higher scores on tests of curriculum content when compared to TAU. Additionally we looked at the maintenance of skills taught in this short intervention and provide preliminary evidence that information can be retained after one month and six months post intervention.

However, one weakness in the present study was the possibility of the novelty of the flashcards effecting the students' engagement in learning maths, therefore potentially impacting the results. This confound, along with the issue of application was investigated in Study 2. Application refers to the students' ability to apply the information learnt to real world scenarios.

Study 2

The aim of Study 2 was to replicate the findings of study 1, using the same cohort from the experimental group to rule out novelty effects of having SAFMEDS as a tool to increase maths skills. A secondary aim of Study 2 was to test if the pupils could generalise the information learnt to 10 real world application questions. Study 1 looked at surface learning assessing whether or not the students could reproduce the information learnt from the flashcards to the tests, whereas with the inclusion of the scenarios tests in study 2 also assessed students' ability to understand the concept being taught aiding deeper learning.

This study replicated study 1 following groups B, C, D and K into the next school year. The application tests were administered to students after the quiz at all stages pre- post- and follow up test. An example question was, "James buys 2 bags of sweets. There are 20 sweets in each bag. How many sweets did James buy in total?"

Method

Participants

This study consisted of 104 students male (*n*=58) and female (*n*=46) aged 8-11. Due to the inclusion criteria (all quizzes pre- post- and follow up-test to be completed) 28 students were removed from the final analysis leaving a total of 76 students.

Setting, stimuli and apparatus

The intervention was conducted in the same setting as study 1, in the students' usual classroom. A digital hand held timer was also used in this study. SAFMEDS packs were made available to students; each year group had different packs based on their school year curriculum. Year three SAFMEDS pack 2 adding; Year four SAFMEDS pack 2 multiplication; Year five SAFMEDS pack 2 multiplication and divide; Year six SAFMEDS pack 2 division. Students were all given a sheet to record their daily SAFMEDS sessions and a chart to record their best timing of the day. As in study 1 the students' were given a plastic wallet to keep their table, chart, flashcards and timer in.

Measures

The students were given a 50 question pre-, post- and one-month follow up test to evaluate their knowledge of maths in the chosen topic area that related to their flashcards. Students were also given a 10 question application quiz pre-, post- and one-month follow up test to evaluate if the students could generalise the information learnt to a real world scenario.

Design

The intervention used a within group design of time (pre- post- and follow up-test) and pack (pack 1 and pack 2); investigating the effects of the use and maintenance of flashcards to increase maths acquisition in primary school children over time and topics, a secondary aim of the study was to investigate if the students could generalise the information learnt to real world scenarios. The IV was the students completing SAFMEDS sessions. The DV was the score on the pre- and post-tests.

Procedure

Pre-tests

Students were given 10 minutes to complete the 50 question quiz based on the curriculum for their year group (the same instructions as study 1 were given to the students). Once all students had completed the quiz or the 10 minutes was up, the experimenter collected all of the quizzes in. The students were then given the application test directly after the first quiz. Students were provided with the same instructions for the application quiz but also told to read the questions carefully.

No further training sessions were provided as the study used the same cohort from study 1 who had been previously trained on how to use SAFMEDS.

Intervention

SAFMEDS Procedure. Students completed the SAFMEDS procedure identical to study 1 and completed the same number of sessions.

Post-test

At the end of the four-week school intervention the students completed the 50 question quiz and the application quiz (which was identical to the pre-test). Follow-up maintenance tests were conducted one month following the intervention (this was identical to the pre- and post-test).

Data Analysis Approach

The results were analysed using a repeated measures ANOVA to investigate changed in the mean over the three time points and the difference in mean scores across the two packs (pack 1 and pack 2). Improvement graphs were utilised to show students' individual pre- to post-test improvement.

Results

The results of this study suggest that novelty was not a confounding factor, providing further evidence to support the use of this procedure to aid learning of numerous maths concepts. Table 3 shows students mean and standard deviation pre- post-test and one-month follow up for pack one which was administered in study 1 and the pack two for this study.

Table 3
Mean and standard deviation pre- post-test and one-month follow up scores for both pack one from study one and pack two from the current study.

	Pack 1			Pack 2			Main effect of time			Time * pack			Main effect of pack		
	Pre	Post	One month	Pre	Post	One month									
Year (Group)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2	*F*	*p*	η_p^2	*F*	*p*	η_p^2
5/6 (B)	9.8 (8.5)	22.4 (10.6)	21.2 (9.3)	9.5 (8.6)	29.8 (10.9)	22.4 (13.3)	(2,70)= 144.439	<.001	.81	(2,70)= 8.215	.001	.19	(1,35)= .778	.384	.02
4/5 (C)	2.9 (3.9)	16.1 (9.9)	15.9 (10)	6.8 (6.1)	16.5 (7.7)	13 (6.6)	(2,76)= 83.288	<.001	.69	(2,76)= 6.335	.003	.14	(1,38)= .057	.813	.00
3/4 (D)	11.1 (11.9)	25.6 (15.6)	19.9 (16.2)	4.4 (5.6)	15.1 (10.9)	14 (9.7)	(2,52)= 21.840	<.001	.46	(2,52)= .754	.475	.03	(1,26)= 3.739	.064	.13
2/3 (K)	13.8 (17.7)	48.7 (2.3)	48.7 (1.8)	4.6 (6)	19.4 (12.9)	18.8 (14.8)	(2,82)= 120.797	<.001	.75	(2,82)= 20.789	<.001	.34	(1,41)= 70.555	<.001	.63

The results show that for year 6 the students showed a greater improvement in pack 2, this may have been more evident in this group as the previous pack in year 5 (pack 1) was multiplication and division which provided the basis for the year 6 division pack. The results show a main effect of time for pack 2 $F(2,32) = 73.358$ $p<.001$ $\eta_p^2 = .82$.

Similar findings were also evident in year 5, the SAFMEDS pack in the previous year was multiplication (pack 1) which again as seen in year 6, may have provided the students the basis for the year 5 pack - multiplication and division (pack 2). The results also show that the students scored significantly higher ($p<.001$) in the pre-test in pack 2 compared to pack 1. This could be due to the students being able to generalise the information they learnt from pack 1 to pack 2. Students showed similar results in the post and follow up tests suggesting that novelty was not a contributing factor in the observed test results. The results show a main effect of time for pack 2 $F(2,42) = 44.193$ $p<.001$ $\eta_p^2 = .68$.

The results for group D do not replicate the results for Group B and C. Although not directly linked to the multiplication pack, the adding is a relevant component skill needed for multiplication. The students may have benefited from a simpler multiplication pack prior to the mixed multiplication pack set for their year group. Although the results are not similar in the post-test when compared to pack 1, the students still showed similar gains, as in pack 1 the students rate of responding was significantly higher after the intervention in pack 2. The results show a main effect of time for pack 2 $F(2,36) = 16.967$ $p<.001$ $\eta_p^2 = .57$.

Although students in group K performed significantly higher in pack 1 students still showed a significant increase in pack 2 $F(2,46) = 34.439$ $p<.001$ $\eta_p^2 = .60$. The reason for this could have been due to the difference in the two packs fraction – adding. If the students had received the year 2 adding pack then the year 3 adding pack there might have been an increase in gains for the year 3 adding pack.

Improvement

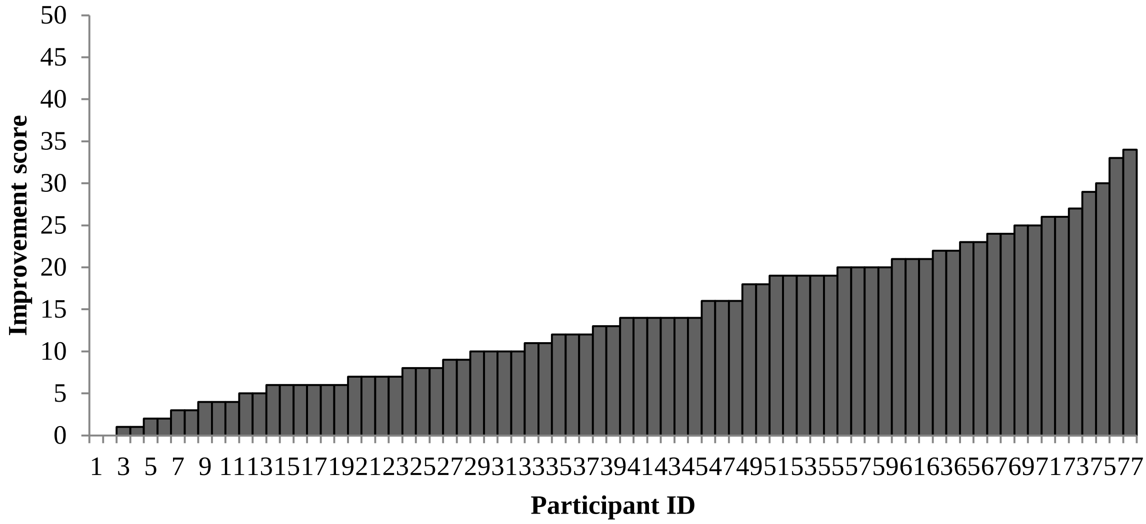

Figure 6. Individual pre- post-improvement score for all year groups.

Fluency

Table 4
Fluency mean test scores for each year group at pre- post-test and one-month follow up score.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	F	p	η_p^2
5/6 (B)	1.5 (1.7)	6.2 (1.2)	4.7 (.8)	(2,32)=23.124	<.001	.59
4/5 (C)	.7 (.1)	2 (.3)	1.9 (.3)	(2,42)=21.571	<.001	.51
3/4 (D)	.7 (.2)	2 (.4)	2.2 (.4)	(2,26)=8.909	=.001	.41
2/3 (K)	.5 (.6)	3.2 (6)	2 (1.6)	(2,46)=4.084	=.023	.15

The fluency results also show that the students do not only just increase the number of correct maths sums on the quiz, they also become more fluent in the chosen maths topic. This is evident for three of the year groups and replicates the findings found in study one.

Application test

Table 5

Mean scores for the application test for each year group at pre- post-test and one-month follow up phase.

	Pre	Post	One month	Main effect of time		
Year (Group)	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6 (B)	2.8 (2)	5.9 (3.1)	6.2 (3.3)	(2,26)=8.909	.001	.41
4/5 (C)	1.9 (2.4)	3.1 (2.2)	3.2 (1.8)	(2,32)=4.911	.012	.19
3/4 (D)	3.1 (3)	4.4 (3.1)	3.4 (3.4)	(2,26)=2.307	.120	.15
2/3 (K)	3.8 (3.4)	5.3 (3.8)	6.3 (3.7)	(2,46)=23.928	<.001	.51

The application test suggests that the students did have the ability to generalise the information learnt from the SAFMEDS to the real world scenario questions. The results also suggest that students showed deeper learning rather than just surface learning.

Application Fluency

Table 6

Mean fluency scores for the application test for each year group at pre- post-test and one-month follow up phase.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6 (B)	.9 (.8)	5.5 (7.6)	7.3 (10.4)	(2,32)=6.804	.003	.30
4/5 (C)	.3 (.4)	.7 (.7)	.7 (.6)	(2,42)=4.580	.016	.18
3/4 (D)	.8 (.9)	1.9 (1.7)	1.8 (2.3)	(2,26)=4.371	.023	.25
2/3 (K)	.6 (.5)	1.8 (1.8)	2.4 (2.1)	(2,46)=16.335	<.001	.42

The fluency results for the application test also suggest that the students also become more fluent on the application test as well as the quiz.

Discussion

The results of study 2 support the hypothesis, that SAFMEDS do increase students' acquisition of maths skills as well as fluency in the maths topic. Furthermore, the findings from this study suggest that the results from study 1 were not a result of the novelty of introducing SAFMEDS into students' maths lessons. The results replicate the findings of study 1 and further support the use of SAFMEDS on a class-wide basis. The results extend previous findings by showing that students are able to generalise the information learnt to real world scenarios suggesting deeper learning. However, due to the curriculum, teachers were limited in the time available for the intervention, therefore the amount of time needed to go through the flashcards needed to be reduced without limiting the amount of time students spent completing the flashcards. Therefore in study 3 the time taken to complete SAFMEDS was reduced by altering the procedure.

Study 3

This study replicated the previous studies mentioned above with one slight alteration, instead of the students timing each other the teacher timed the whole class at the same time completing the one minute timings together, students then had two minutes to go through their "not yet" pile (error correction) with their partner. This new procedure reduces the in-class time of the intervention without compromising the amount of learning time the students received and still incorporate working in dyads. *Phase one* intervention consisted of groups K and L and TAU groups E and F. *In Phase* two the groups swapped having K and L now as the TAU group and E and F as the intervention group.

Method

Participants

This study consisted of a total of 105 male (*n*=65) and female (*n*=40) students aged 6-8 (intervention *n*=55 TAU *n*=50). This study looked at 3 new cohorts and a previous cohort group K. Due to the inclusion criteria in ***phase 1*** 27 students were removed (intervention *n* =47 TAU *n*=31) and in ***phase 2*** 28 students were removed (intervention *n*= 32 and TAU *n*=45).

Setting, stimuli and apparatus

The intervention took place in the same location as the previous studies mentioned above, in the student's classroom. SAFMEDS packs were made available to students; each year group had different packs based on their school year curriculum. ***Phase 1*** Year two SAFMEDS pack 3 *Clock*; Year three SAFMEDS pack 3 *Minus*. ***Phase 2*** Year two SAFMEDS pack 4 *Adding*; Year three SAFMEDS pack 4 *Doubling*. Students in the intervention sessions were give a plastic wallet with their daily SAFMEDS table, chart and flashcards.

Measures

The students in both groups were given a 50 question pre-, post-test and one month follow up to evaluate their knowledge of maths in the topic area related to their flashcards and lesson. Students were also given a 10 question application test, to evaluate if the students could relate the information learnt from the SAFMEDS or maths lesson to real world scenarios.

Design

The intervention used a mixed design. The between group variable was whether the students received the SAFMEDS intervention or teaching as usual and the within subject variable of time (pre- post- and follow up-test); investigating the effects of the use of flashcards to increase maths skills in primary school students with the addition of seeing if the procedure is effective when all students are timed at the same time class-wide. The IV was the students completing the SAFMEDS sessions and the DV was the score on the pre- and post-tests.

Pre-test

The same testing format was utilised in this study as the previous studies, students were given 10 minutes to complete the 50 question test, completing the test in exam conditions. Once the students had completed the 50 question test they were then collected in by the research and given the application test to complete, the students were given 10 minutes to complete the test. Weekly aims were given to the students in the intervention group.

Intervention

SAFMEDS procedure. Each student in the intervention group were given a set of 50 flashcards with the relevant maths topic. Students completed the SAFMEDS 4 times a day, three times a week over a four week period (as in the previous studies). However, in this study the teacher would act as the timer for all students, the teacher would tell the whole class to start, and each student would go through their SAFMEDS. The teacher would then time the students for one minute and say stop after the one minute was up. Students would then count both piles (correct and not yet) and fill in their table. The students were then given two minutes to go through their not yet pile (error correction) with the student sat next to them. Once the students had completed their error correction in pairs the teacher would tell the students to get ready for the next session, giving their partner their cards back and shuffle the pack before the next one minute timing. At the end of each daily session (4- one minute timings) the students would chart their best score.

At the end of the four week procedure both group completed the post-test which was identical to the pre-test, students also completed the same tests one month following the intervention.

Data Analysis Approach

The results were analysed using a repeated measures ANOVA to investigate the change in the mean over the three time points and the difference in mean scores across the two groups (SAFMEDS v TAU). Improvement graphs were also used to highlight each individual students' improvement pre- to post-test. The RCI was used to assess the change in improvement.

After the completion of phase 1 the same procedure was then completed for phase 2. This involved the wait-list group from phase 1 becoming the intervention group and the intervention group from phase 1 now acting as the control group.

Phase 1 - Results

Table 7

Mean pre- post-test and one month follow up scores for both experimental and TAU groups in year 3 and 2

	Experimental			TAU					
	Pre	Post	One Month	Pre	Post	One Month	Time * Group interaction		
Yr. Grp.	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	*p*	η_p^2
3	10.3 (1.5)	26.3 (2.7)	23.2 (3.1)	6.1 (1.8)	16.3 (2.4)	15.4 (2.5)	(2,78)=1.719	.186	.04
2	7.5 (1.6)	19.6 (2.4)	19.4 (2.9)	7.3 (1.2)	6.5 (1.8)	10.8 (1.7)	(2,70)=13.527	<.001	.28

The results show that both year three and year two in the experimental group show significant gains pre- to post-test and the results are maintained in the one month follow up.

The TAU group in year three also showed gains but not as significant as the experimental group. Year group two in the experimental group show significantly higher gains than the TAU group who actually show a reduction in knowledge from pre- to post-test, however showing a slight increase in the one-month follow up.

Analysis of individual's pre- post-improvement

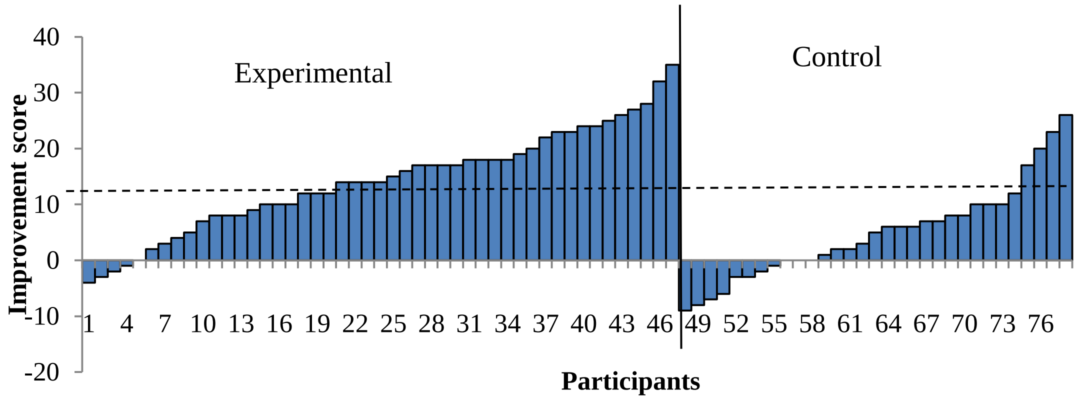

Figure 7. Individual pre-post- improvement score for year 2 and 3. (RCI was 14.01)

Fluency

Table 8

Mean pre- post- and one-month follow up fluency scores for year 2 and 3.

	Experimental			TAU					
	Pre	Post	One Month	Pre	Post	One Month	Time * Group interaction		
Yr. Grp.	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	*p*	η_p^2
3	1 (0.2)	3 (0.4)	2.8 (0.4)	0.7 (0.2)	1.9 (0.4)	1.6 (0.3)	(2,78)=2.177	.120	.05
2	0.8 (0.2)	2 (0.2)	2 (0.3)	0.7 (0.1)	0.6 (0.2)	1.2 (0.2)	(2,70)=13.527	<.001	.28

The results suggest that the intervention had a positive impact on students' fluency, although only significant in year two, year three, although not significant, do show increased fluency in the maths topic subtraction in comparison to the TAU group.

Application

Table 9

Mean pre- post-test and one-month follow up scores of the application tests for year 3 + 2 of the TAU and experimental group.

	Experimental			TAU					
	Pre	Post	One month	Pre	Post	One month	Time * Group interaction		
Year Group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	p	η_p^2
3	4.4 (2.9)	6.5 (3.1)	6.3 (3.2)	3.3 (2.4)	5.5 (2.8)	5.1 (2.9)	(2,78)=.028	=.972	.00
2	2 (2.2)	8.8 (1.6)	5.8 (3.9)	1.4 (1.1)	2.9 (2.7)	5.6 (3.3)	(2,70)=20.781	<.001	.37

The results of the application test suggest that both the experimental and TAU group of year three were able to generalise the information learnt to the application test with no significant difference between the two groups. However, for year 2 the experimental group showed a significant increase in the maths topic the clock, when compared to the TAU group.

Application Fluency

Table 10

Mean pre- post-test and one-month follow up fluency scores of the application test for Year 3 and 2 for the TAU and experimental group.

	Experimental			TAU					
	Pre	Post	One month	Pre	Post	One month	Time * Group interaction		
Year Group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	p	η_p^2
3	1.5 (2.2)	3.2 (2.6)	4.4 (4.9)	.7 (.8)	2.9 (7.1)	1.2 (1.2)	(2,78)=4.236	=.105	.06
2	.4 (.5)	1.4 (.3)	1.1 (.9)	.4 (.1)	.5 (.2)	1.1 (.2)	(2,70)=11.569	<.001	.25

The students in the experimental group show an increase in fluency as well as scores in the application test, although only year 2 shows a significant improvement in comparison to the TAU group.

Phase 2 - Results

Table 11

Mean pre-post-test and one month follow up test scores for year3 and 2 for both the TAU and experimental group.

	Experimental			TAU					
	Pre	Post	One month	Pre	Post	One month	Time * Group interaction		
Year Group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	p	η_p^2
3	12.4 (3.2)	27.5 (2.8)	29.5 (3.3)	18.5 (2.9)	28.1 (3)	31.6 (2.9)	(2,72)=2.009	.142	.05
2	16.4 (3.9)	31.9 (3.8)	31.3 (2.5)	23.8 (3.4)	34.4 (3.2)	36.8 (2.5)	(2,74)=.867	.424	.02

The results of this study show that both groups show an increase from pre- to post-test and maintain the scores in the one month follow up test, however there is no significant difference between the experimental and TAU group.

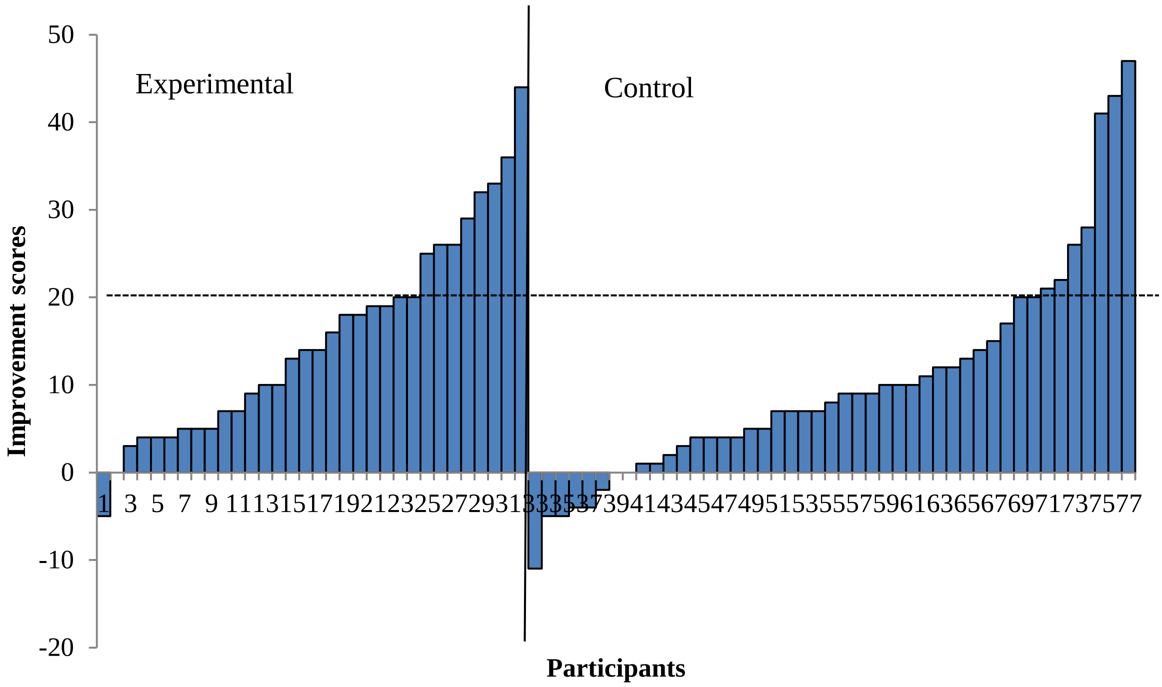

Figure 8. Individual pre- post-improvement score for year 2 and 3 (RCI was 23.76).

Table 12

Mean pre-post-test and one month follow up fluency test scores for year3 and 2 for both the TAU and experimental group

	Experimental			TAU			Time * Group interaction		
	Pre	Post	One month	Pre	Post	One month			
Year Group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	p	η_p^2
3	1.6 (0.5)	4.4 (0.9)	3.6 (0.6)	2.1 (0.3)	3.8 (0.5)	4.1 (0.5)	(2,72)=3.220	.046	.08
2	1.6 (0.4)	3.9 (0.6)	3.8 (0.6)	2.7 (0.5)	4.6 (0.6)	6.2 (0.8)	(2,74)=3.776	.028	.09

Similar results are seen in the fluency scores showing both groups increasing their fluency from pre- to post-test and maintaining but no significant difference between the two groups.

Table 13

Mean and standard deviation scores for pre- post-test and one month follow up Application results for the experimental and TAU.

	Experimental			TAU					
	Pre	Post	One month	Pre	Post	One month	Time * Group interaction		
Year Group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	p	η_p^2
3	2.5 (2.2)	6.6 (2.6)	5.5 (2.4)	.8 (.9)	4.5 (1.9)	6.3 (2.5)	(2,66)=6.364	=.003	.16
2	5.7 (3)	7.5 (2.8)	7.7 (1.9)	6.3 (2.4)	8.7 (1.7)	9 (.8)	(2,74)=.637	=.532	.02

Fluency Application test

Table 14

Mean pre- post-test and one-month follow up application fluency results for the experimental and TAU group.

	Experimental				TAU				
	Pre	Post	One month		Pre	Post	One month	Time * Group interaction	
Year Group	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	F	p	η_p^2
3	.4 (.5)	1.3 (1.2)	.7 (.4)	.2 (.1)	1 (.2)	1.3 (.1)	(2,66)=6.040	=.004	.16
2	1.6 (1.4)	3.9 (2.2)	3.8 (2.2)	2.7 (2.1)	.6 (2.9)	.8 (3.7)	(2,74)=3.766	=.028	.09

The results suggest that the experimental group in both years showed greater fluency when compared to the TAU group.

Discussion

The new procedure of having students complete the timings together showed similar findings to the previous studies mentioned above. Therefore suggesting that the new procedure allows SAFMEDS to remain beneficial to student learning and reducing the time spent in class. It also provides the teacher the opportunity to observe all children highlighting the students who may need more support. However, although the results are promising the experimenter provided hands-on support in conducting the SAFMEDS and scheduled in the sessions. Therefore, it is not evident whether or not this is something that could be maintained in school. To assess the sustainability of the intervention study 4 used the same procedure used in study 3 but was implemented solely by the teachers without the support of the experimenter.

Study 4

Method

Participants

This study consisted of a total of 104 students male and female aged 7-11. 30 students were removed from the final analysis due to the inclusion criteria leaving 74 students in the final analysis. This study used cohorts B, C, D and K from the previous studies.

Setting, stimuli and apparatus

The intervention took place in the same setting as the previous studies, in the students classroom. SAFMEDS packs were made available to students; each year group had different packs based on their school year curriculum. Year three SAFMEDS pack 5 *Counting money*; Year four SAFMEDS pack 5 *What is the number*; Year five SAFMEDS pack 5 *Measurement*; Year six SAFMEDS pack 5 *Fractions.*

Measures

The students were given a 50 question pre- post- and one month follow up-tests to evaluate their knowledge of the maths topic relating to the SAFMEDS. Students in year 5 and 6 were also given an application test in the form of 10 real world scenario questions.

Design

The intervention used a within subject variable of time (pre- post- and one month follow up-test); investigating if SAFMEDS can be teacher led and sustained in a busy class-room environment. The IV was the students completing the SAFMEDS sessions. The DV was the score on the pre- post-tests.

Pre-tests

This study followed the same procedure as the previous studies with the students given 10 minutes to complete the 50 questions pre-test, this test was then collected in and the students were then given 10 minutes to complete the application test (only year 5 and 6 completed the application test year 3 and 4 were not given an application test due to the pack they were given). Both tests were completed in exam conditions.

Intervention

SAFMEDS Procedure – This study followed the same procedure as the previous studies taking the same format as study 3 whereby the teacher would time the whole class completing their SAFMEDS. Students completed 4 one minute timings a day, three times a week for a four week period. Students completed pair work for 2 minutes going through error correction after each one minute timing.

Post-tests

At the end of the four week school intervention the students were all given the post-test (which was identical to the pre-test). A one month follow up maintenance test was conducted after the intervention.

Results

Table 15

Mean pre- post-test and one-month follow up scores for each year group.

	Pre	Post	One month	Main effect of time		
Year/ Group	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
6 (B)	5.7 (6.1)	12.3 (10.8)	9.5 (9.2)	(2,38)=11.139	<.001	.37
5 (C)	4 (4.9)	28.8 (14.3)	18.6 (14.7)	(2,32)=30.581	<.001	.66
4 (D)	21.4 (19.5)	42 (12.7)	41.1 (13.4)	(2,32)=22.769	<.001	.59
3 (K)	26.3 (11.1)	30.6 (11.1)	36.8 (11.7)	(2,38)=19.591	<.001	.51

Fluency

Table 16

Mean pre- post-test and one-month follow up fluency scores for each year group.

		Pre	Post	One month	Main effect of time		
Year	Group	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
6	B	1.5 (2.3)	2.1 (2.1)	1.3 (1.4)	(2,38)=2.32	=.112	.11
5	C	.6 (.7)	4.7 (3.2)	2.7 (2.8)	(2,32)=18.590	<.001	.54
4	D	3.9 (3.6)	10.1 (4.7)	9.4 (4.5)	(2,32)=40.321	<.001	.72
3	K	2.7 (1.1)	3.4 (1.5)	3.9 (1.4)	(2,38)=14.373	<.001	.43

The results show that all year groups with the exception of year 6 show that they increased their fluency across time.

Application test

Year 5 and 6 also completed an application test, due to the nature of year 3 and 4's pack they did not complete an application test as the packs were picture/graph orientated.

Year 6 did not show a main effect of time pre (*M*=2.4 *SD* = 1.9) post (*M*=3.8 *SD*=3.8) follow up (*M*=4.3 *SD*=2.7) $F(2,38)=3.531$ $p=.039$ $\eta_p^2=.16$. Year 5 showed a main effect of time pre (*M*=5.2 *SD* = 1.9) post (*M*=6.4 *SD*=1.7) follow up (*M*=7.4 *SD*=2.2) $F(2,32)=10.989$ $p<.001$ $\eta_p^2=.41$.

Similar results were found in the fluency results, year 6 did not show a main effect of time pre (*M*=0.9 *SD* = 0.2) post (*M*=1 *SD*=1.2) follow up (*M*=1.1 *SD*=1.3) $F(2,38)=.261$ $p=.772$ $\eta_p^2=.01$. Year 5 showed a main effect of time pre (*M*=1.5 *SD* =0.8) post (*M*=2.7 *SD*=1.9) follow up (*M*=2.8 *SD*=1.9) $F(2,32)=7.610$ $p=.002$ $\eta_p^2=.32$.

Discussion

The findings of study four suggest that the results can be sustained in the classroom being teacher-led. Although the results from year 6 do not show significant improvements this could be due to the students not completing all of the sessions. Therefore, future studies need to address this problem to ensure all sessions are completed. This study also suggests that students need to complete 4 sessions three times a week for four weeks to have a significant impact on the students' maths knowledge. The results suggest that the students still showed significant improvements across the three time points when teacher-led. Although, when compared to previous studies group B showed a mean improvement of 12.6 in study one and 20.2 in study two although they showed an improvement in this study there was only a mean improvement of 6.6; group K showed a mean improvement of 34.9 in study one, 14.8 in study two , 16 in study 3 and only a 4.3 in the current study however the students showed higher pre-test scores in this study, so although showing less improvement similar post-tests results were evident in all studies for this year group. However this was not the case for Group C and D who showed the greatest improvement in this final study.   Future studies needs to focus more on integrating this procedure into teachers curriculum, and can be spread out across other subjects.

Study 5

Method

Waiting list TAU group – Experimental phase

This study consisted of the TAU waiting list group from study one receiving the intervention. The same procedure as study 3 was used.

Participants

This study consisted of students from group H, I and J. 59 students took part in the study, but due to the inclusion criteria for this study students must have completed pre- post- and follow up-tests from study one and the current study therefore 27 students were removed from the final analysis.

Setting, stimuli and apparatus

Group H, I and J received flashcards based on multiplying for their year group. The students were all given a plastic wallet, table to record their daily SAFMEDS sessions and a chart to record their best score of the day.

Measures

The students were given a 50 question pre- post- and one month follow up-tests to evaluate their knowledge of the maths topic, multiplication.

Design

The intervention used a within subject variable of time (pre- post- and one month follow up-test) and of condition (SAFMEDS or TAU); investigating the effects of the use of flashcards to increase maths skills in primary school students.

Procedure

Students in group H, I and J initially acted as the TAU group in study one, as they were a wait list group they received the intervention in the following school year. In study one Group H received their TAU for multiplying and dividing in year 5, the students then received SAFMEDS for multiplying in year 6. Group I received their TAU for the multiplying pack in year 4 and received SAFMEDS for multiplying in year 5. Group J received their TAU for addition in year 3 and in year 4 completed the SAFMEDS multiplication pack. The students complete the SAFMEDS using the same procedure as study 3, where by the students completed 4 one minute timings a day, 3 days a week for a four week period. The teacher timed the whole class for each one minute timing. After the one-minute timings students would complete error correction in pairs, this was timed for 2 minutes.

Post-tests

At the end of the four week school intervention the students completed the post-test (this was identical to the pre-test). Students also completed the same test one-month after the intervention.

Results

Overall the results of all groups show a significant main effect of time $F(2,124) = 53.493$ $p<.001$ $\eta_p^2 = .46$ a significant time * group interaction $F(2,124) = 26.915$ $p<.001$ $\eta_p^2 = .30$ and a significant main effect of group $F(1,62) = 10.165$ $p=.002$ $\eta_p^2 = .14$.

Table 17

Mean pre- post-test and one-month follow up *score for each year group for pack one in the TAU and pack two with SAFMEDS.*

	Pack 1 TAU			Pack 2 Experimental			Main effect of time			Time * pack			Main effect of group		
	Pre	Post	One month	Pre	Post	One month									
Y (G)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2	*F*	*p*	η_p^2	*F*	*p*	η_p^2
5/6 (H)	16.6 (6.7)	19.7 (9)	21.1 (8.1)	26.3 (14.4)	35.5 (12.5)	33.7 (13.3)	(2,36)= 16.574	<.001	.48	(2,36)= 3.159	.054	.15	(1,18)= 7.208	.015	.29
4/5 (I)	7.7 (7.2)	7.7 (6.7)	10.1 (7.5)	10 (10)	23.3 (6.9)	25.2 (9.2)	(2,48)= 30.222	<.001	.56	(2,48)= 20.471	<.001	.46	(1,24)= 14.100	.001	.39
3/4 (J)	7.8 (7.3)	8.3 11.1)	10.1 (12.5)	2.6 (5.1)	14.8 (6)	11.4 (5.9)	(2,32=11.755	<.001	.42	(2,32)= 8.272	.001	.34	(1,16)= .005	.818	.00

The results show that in all three year groups the students show significantly higher improvements when SAFMEDS are incorporated into their lesson compared to TAU.

Discussion

The results of this study provide further evidence of the effectiveness of incorporating SAFMEDS into students' maths lesson. This study used the same group of students and the same teacher with the only difference being the incorporation of SAFMEDS. Group I received their TAU lesson on multiplying and received SAFMEDS on multiplication in the following year, it could be hypothesised that due to the previous lesson that the students should have the basis to support them in the following pack which does not seem to be the case as the pre-test scores are relatively the same as the TAU pre-test scores. The results also show that the students showed an increase in learning with SAFMEDS in comparison to

TAU. Group H show slightly different results, suggesting that the previous TAU lesson on multiplying and division may have affected the SAFMEDS pack, as the pre-test scores were considerably higher, but at the same time the students showed higher improvements in the SAFMEDS pack compared to the TAU.

Conclusion and future directions

This study aimed to provide further evidence into the effectiveness of using SAFMEDS to increase maths skills and provide new evidence to show that this procedure can be used on a class-wide basis in mainstream schools and not just on a small scale or one-to-one basis (Brasch, Williams, McLaughlin, 2008; Erbey, McLaughlin, Derby and Everson, 2011; Glover, McLaughlin, Derby & Gower 2010; Hayter, Scott, McLaughlin & Weber, 2007; Jolivette, Lingo, Houchins, & Barton-Arwood, 2006; Sante-Delli, McLaughlin & Weber, 2001.)

The results of the studies reported here are conclusive in showing that with the addition of SAFMEDS into maths lessons students showed a significant improvement in their maths test scores pre- to post- test. The results were also maintained after a prolonged period of no continued teaching of the selected maths topic. The results also provide evidence that students would not show these gains in their typical lessons, the results from study one and three, where a TAU group was utilised, showed that the intervention group performed significantly better than TAU. The results also show that the students who had the addition of the flashcards in their maths lesson became more fluent in the maths concept they were being taught.

Study 2, 3 and 4 also show that the results from study one were not due to the novelty of introducing flashcards into the classroom, showing that the effects of using SAFMEDS can be sustainable over the years for different maths topics. Study 2, 3, and 4 assessed if the students could generalise the information learnt to real world scenarios; the results of all three studies show that the students were able to generalise the information learnt to the 10 scenario questions. Due to time constraints in schools study 3 adopted a slightly different procedure to limit in class time, by having all students completing the flashcards at the same time. The results of study 3 showed that the new procedure did not reduce the effectiveness of the flashcards. This paper also looked into the sustainability of the project to see if teachers could sustain this intervention and provided further support for the procedure change seen in study 3; the results of study four suggests that this procedure can be sustained in class. By providing in-house support to ensure teachers and students were competent in the procedure allowed for this project to be effectively run by the teachers in class.

The studies showed that the students could learn the maths topic verbally and were able to use the information learnt verbally and use that information on the written test. This research further supports the use of flashcards in an educational setting and shows new evidence on the effectiveness of flashcards being used on a class-wide/school-wide scale.

Although there is evidence into the effectiveness of using SAFMEDS to increase learning in a one-to-one or small group basis, there is little evidence regarding the use of SAFMEDS class-wide, this research provides an evidence base into the effectiveness of using SAFMEDS class-wide. However, there were some limitations in the studies discussed. In study 4 there was an issue with fidelity, the procedure was not implemented regularly and some year groups did not complete all of the required sessions. One possible solution for this could be to use active support approaches. For example, boards could be put up in class where the teacher must tick when the sessions have been completed, therefore acting as a reminder and a reinforcer to ensure the SAFMEDS sessions are completed frequently.

To further support the maintenance of using flashcards in schools, packs should be made available to schools to ensure they have the resources to continue with SAFMEDS across the academic year. Also electing a teacher to be the schools SAFMEDS co-ordinator to ensure that all year groups are incorporating SAFMEDS into their maths lessons will further help to maintain the use of SAFMEDS.

The studies reported here focused on basic maths skills. Future studies could look at using this approach with other subjects and other age ranges such as high school students. Stability is another element that could be considered, this is when the students can still perform the task in distracting environments, but due to the environment being class-wide it was naturally a distracting and loud environment. Past literature on the use of SAFMEDS have typically been completed on a small scale and for stability to be assessed students would be required to complete SAFMEDS in a distracting environment, for this study this was not the case. Therefore it may be concluded that stability has been achieved, as the intervention was conducted in a busy classroom with students simultaneously working on their SAFMEDS. Future studies of this kind where SAFMEDS are completed in a busy classroom/environment could reverse stability by students completing a set of timings in a quiet area once fluency has been achieved. Endurance is another aspect that could be explored more in depth, students in this study completed timings for one minute per timing; future research could look into 2-5 minute timing to show endurance. Another area that could be explored to assess further for fluency, would be generativity which is the development of a new skill which has not been explicitly taught (Johnson & Street, 2013). Therefore would teaching two SAFMEDS packs lead to students being able to complete a test on a new topic prior to learning.

It is important to note that students completing this procedure were trained in how to use SAFMEDS before starting the intervention. This is essential, if students are not completing all aspects of the procedure correctly then the results seen in this study may not have been found. Students who were observed completing the procedure incorrectly were also the students who were not performing as well as the rest of the class. Every aspect of the procedure seems to be important for the success of SAFMEDS. Students were observed starring at one card for the one minute timing, this meant that they would not have a not yet pile, therefore could not do error corrections. Error corrections were an important aspect of this procedure, students who had a lot of errors at the beginning and completed their error corrections made large improvements. The results of this study supports previous findings of fluency, showing that the use of SAFMEDS increased the students' fluency in the maths topic selected, which is an essential skill to have in maths, as those who are fluent in maths are able to generalise and maintain the information learnt (Ivarie, 1986; Stokes & Baer, 1977). Speed is essential for students to become fluent, with the rapid succession of one minute timings with 50 cards students were observed completing the cards in a rapid fashion. This provides further evidence in the effectiveness of one minute timed trails in maths lesson (Lerner, 2003; Miller, Hall & Heward, 1995).

This study provides further evidence base on the effectiveness of measuring learning, and more importantly students have ownership of their learning (Brookhart, Andolina, Zuza & Furman, 2004; Deci & Ryan, 1987; Wood and Frank, 2000). Similar anecdotal evidence from teachers and students supports Brookhart et al (2004) findings of the benefits of students graphing their own data. Class observations showed that the students were highly motivated to try and do well, making statements such as "I am going to beat my personal best this time". In future research questionnaires or semi-structured interviews could be used to assess students' confidence and attitudes towards maths. The studies reported here also provides further evidence on the effectiveness of immediate feedback, showing that the typical teaching style which tends to give delayed feedback was not as effective as receiving immediate feedback with the flashcards (Brookhart et al 2004).

The studies clearly demonstrate SAFMEDS as an educational tool with many benefits on students' learning. SAFMEDS can be easily implemented into the school curriculum and are cost effective. The results of the five studies show the impact SAFMEDS can have on students' attainment in maths, which is crucial, as the current academic scores in Britain, more specifically Wales, for maths is below satisfactory. If SAFMEDS were to be rolled out at the start of the academic year, it is highly likely that the end of year tests will show significant improvements from the previous years, where SAFMEDS were not used. PT methods should be a crucial element in educating children, ensuring that no child is left behind.

Chapter 5 – Improving maths skills for students with maths difficulties with the use of SAFMEDS

Abstract

Background Maths is an area that many students struggle with; previous research has shown that SAFMEDS can improve maths skills in students who have maths difficulties.

Aim The aim of this study was to replicate findings of previous studies using SAFMEDS to increase maths skills in 2 students who had particular maths difficulties in a new setting (class-wide).

Participants The study consisted of 2 students aged 6-8 who had been identified as having maths difficulties (class-wide results have been reported in Chapter 4).

Method SAFMEDS were used class-wide; the 2 students in this study completed the SAFMEDS cards with the class, but received packs individually designed for their ability level, and had additional teacher support (see chapter 4 for class-wide study).

Results The results of this study showed that both students showed an improvement pre- to post-test. The results also show that the students could maintain the information in the one month follow up tests.

Conclusion This study provides further support to the use of SAFMEDS to increase maths skills with students who have maths difficulties and also provides new evidence that students' who are struggling academically, can continue effective learning on a class-wide basis. With the flexibility of SAFMEDS, students who have maths difficulties can learn on a class-wide scale, but at their own skill level and pace.

Early intervention ensures that students have mastered basic skills to aid them to succeed in more complex tasks. Maths is an area where early identification of students who are at risk of failing is essential (Ramey & Ramey, 2004). Therefore, adequate interventions are needed to ensure delays in learning are not prevalent in later education (Dowker, 2005). Due to maths being such an important life skill to acquire, it is important that students' primary school education provides them with effective learning environments (Gersten, Jordan & Flojo, 2005; Tariq & Durrani, 2009).

Precision Teaching (PT) has been shown to be a useful tool in helping students who are struggling academically (Hughes, Beverley & Whitehead, 2007; McDowell & Keenan, 2001). PT interventions are typically structured to ensure students learn at their own rate, if the child is not learning then the teaching style is altered to suit the child (*the learner knows best*) (Cooper, 2000; Johnson & Street, 2013). It may be that the topic being taught is at a level that the child cannot comprehend, therefore it is important to evaluate the child's learning rate. In some cases it may be beneficial for the child, to reduce the difficulty level of the topic, thus enabling the child to acquire the correct skill-set to then master more complex tasks. For example, if a child is asked to complete a task on double digit adding (e.g. 13+18), it is important that they have already mastered single digit adding (e.g. 3+8). If this is not the case, then the child may struggle to complete the double digit task, therefore it might be suitable for the child to go back to single digit adding until mastery level (where the child can give the accurate answer at an appropriate rate) has been reached before attempting to master double digit adding.

In order to monitor students learning it is important to keep a record of their progress. In PT intervention daily scores are recorded on a Standard Celeration Chart (SCC). The SCC allows the learner or the teacher to record the number of correct and incorrect responses and the time in which it took to complete the task (Calkin, 2005; Graf & Lindsley, 2002).

Measuring time is an important element because this will enable fluency to be measured. Fluency is an important aspect in learning, to reach fluency the student must be able to recall the answer immediately (Lerner, 2003). This is especially important for learning maths, as the student needs to be able to compute simple maths relatively quickly in order to compute more complex maths (Rhymer, Dittmer, Skinner & Jackson, 2000).

SAFMEDS (Say All Fast Minute Every Day Shuffled) developed by Ogden Lindsley in the 1970s, are flashcards which have a question on the front of the card and the corresponding answer on the back. SAFMEDS follow the principles of PT (Eshleman, 2000). Students can use the flashcards to learn basic key facts in an area. Within the PT approach the teacher usually organises one or a number of one-minute timings to quickly measure current performance and whether the practice is improving fluency. Each session is recorded onto a table and the students' best score of the day is recorded on a SCC. This provides the learner and teacher with a visual representation of how the child is progressing, allowing the teacher to make informed decisions about the child's learning. The timing element allows fluency to be monitored and also provides a game element to learning maths. As the answer is on the back of the card, the students receive immediate feedback on whether or not they answered the question correctly. Research has shown immediate feedback is crucial in student learning (Ashby, Queller, & Berretty, 1999; Maddox, Ashby, & Bohil, 2003).

This research aimed to replicate previous findings that have used SAFMEDS to increase maths skills with students with maths difficulties (Casey, McLaughlin, Weber, & Everson, 2003; Cunningham, McLaughlin, & Weber, 2012). However, in previous studies, the students were taken out of the classroom into a quiet room to complete their SAFMEDS. Two important aspects of fluency are (1) the ability to generalise across learning context and (2) to build upon the original foundations of fluent learning to acquire more complex skills. Therefore, we aimed to see if we could replicate the findings found in previous studies, showing that students can use SAFMEDS to increase basic maths skills, generalise across topic areas, and build on fluency of topics to enable the students to complete more complex sums. However, this research was completed on a class-wide basis in students allocated maths time for SAFMEDS instead of additional time and being in a one-to-one environment.

Method

Participants

The study consisted of 2 students, one male and female who had been highlighted by the teacher as students who had maths difficulties aged 6-8 attending a main stream primary school in North Wales, United Kingdom.

Setting, Stimuli and apparatus

The intervention took place in the students' normal classroom, in their allocated maths lesson timeslot. A children's hand-held digital timer (see appendix X) was used to time each session and were also used to time the pre-, post-, and follow-up tests. Students were given SAFMEDS packs for various skill sets: adding, counting money, and multiplication. The students were provided with a table to record their daily SAFMEDS sessions (see appendix V) and a simplified chart to record their best daily score (see appendix W). The students in the current study had simplified versions of the topic being taught to the rest of the class.

Measures, design

The students were given a 50 question pre-, post-, and one-month follow-up tests to evaluate their knowledge of the maths topic being taught; Pack 1: Adding, Pack 2: Counting money and Pack 3: Multiplication. Each pack consisted of 50 cards, and the corresponding tests consisted of the same 50 questions. The packs were designed by the researcher based on the new maths curriculum in Wales. The study was a single case design, where each child was monitored in each daily session throughout the study. Due to the single case design no statistical tests can be computed.

Procedure

Pre-tests

Before the start of each pack, students were given a 50 question pre-test to assess their current knowledge of the topic area being taught. Students were given 20 minutes to complete the test. The students were instructed that if they did not know the answer to put a cross and move on to the next answer and not to worry if they could not answer the questions, as their following maths lessons will help them to learn the answers.

Intervention

All students and teachers were trained in the procedure. Once all students were fluent in the procedure the intervention began.

Pack 1 Adding was the first pack the students completed and they were given four weeks to learn the pack. The sessions were completed 3 times a week, in each session the students completed 4 one-minute timings. The pack was split into difficulty level—easy, medium and hard. Students were given 10 of the easy cards to begin with; once the students could answer the cards correctly with no prompting, additional cards were added to the pack. The students would not have more than 30 cards at a given period, as the students found it awkward holding more than 30 cards. Therefore, as more difficult cards were introduced, the easy cards were taken out (this only happened when the student could give the answer to the card immediately, thus demonstrating fluent responding). The students would work in pairs (dyads) or with a teaching assistant (TA). When working in peer dyads, one student would take the roll as the timer (tutor) and the other student would complete the pack (tutee). The tutor would tell the tutee to start, the tutee would then go through the pack answering the question out loud as quickly as possible, the cards the tutee answered correctly was placed on the right hand side and the incorrect cards were placed on the left side. Once the tutee had completed the one minute session, the tutor would say stop. The tutee would then stop going through the cards and count both piles and record the scores in their table. Before the next session, the tutor would go through the incorrect pile with the tutee, asking them the question and waiting for the answer. If the tutee did not know the answer, the tutor would tell the tutee the answer and ask the card again. Once the tutee had completed this, they would then complete 3 more timings. At the beginning of each session the tutee would shuffle the cards. The students would then swap over roles. At the end of the 4 sessions, the tutee would then go through the whole pack with the TA in order and the TA would provide support on the cards the student was struggling with (counting fingers or pencils). At the end of the four weeks, the students would complete the post-test (this was identical to the pre-test). One month after the post-test, the students completed a follow up test (identical to the pre- and post-test).

Pack 2 was then introduced to the students (counting money). The same procedure as pack 1 was followed for this pack. At the end of the four week period, students completed the post-test. The students were then given this pack to take home as homework for another four weeks. At the end of this four week period, the students completed another post-test (identical to the pre- and post-tests).

Pack 3 was then introduced to the students (multiplication), the same procedure as pack 2 was followed for this pack. Students did not move on to the next pack until the post-test for the previous pack had been completed.

Results

Figure 1 shows the results of Pack 1 (Adding) for both of students. At the pre-test, both students scored relatively low, suggesting that the students needed further support in this area. Following the four week intervention, student A showed an increase of 31 correct maths sums at the post-test, and student B showed an increase of 12 correct maths sums, with the maximum score students could attain of 50 correct maths sums. Student A showed maintenance of this knowledge during the four week follow-up test. However, student B not only showed maintenance of knowledge but also increased by a further 17 correct maths sums.

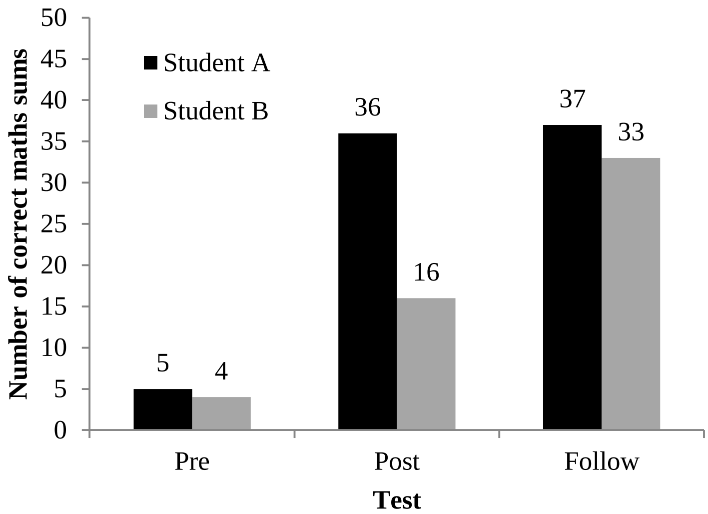

Figure 1. Pre-, post- and follow-up-test scores for both students for Adding (Pack 1).

Figure 2 and 3 shows students A and B’s SCC for adding. The results show that the students showed improvements of the number of correct maths sums through the four week period.

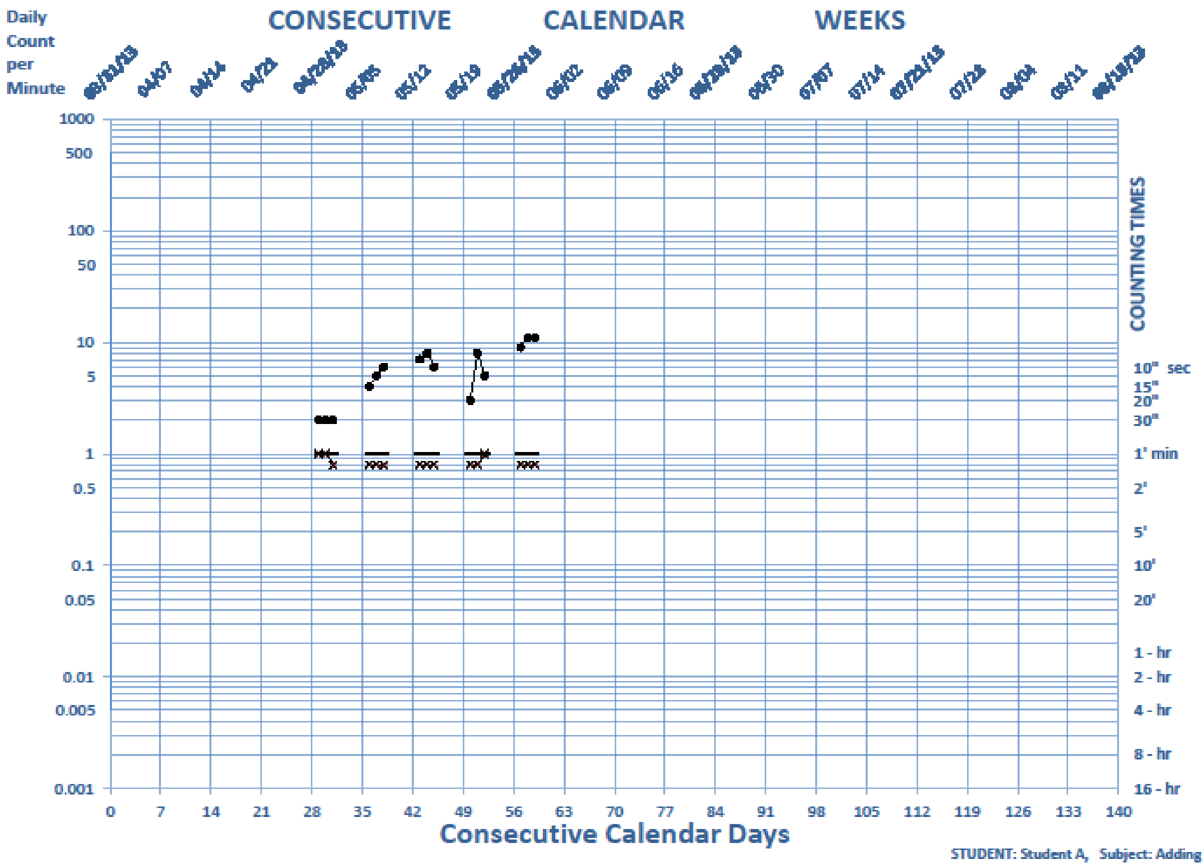

Figure 2: Student A's daily per minute standard celeration chart for adding. Correct responses per minute are represented by dots and incorrect responses by X.

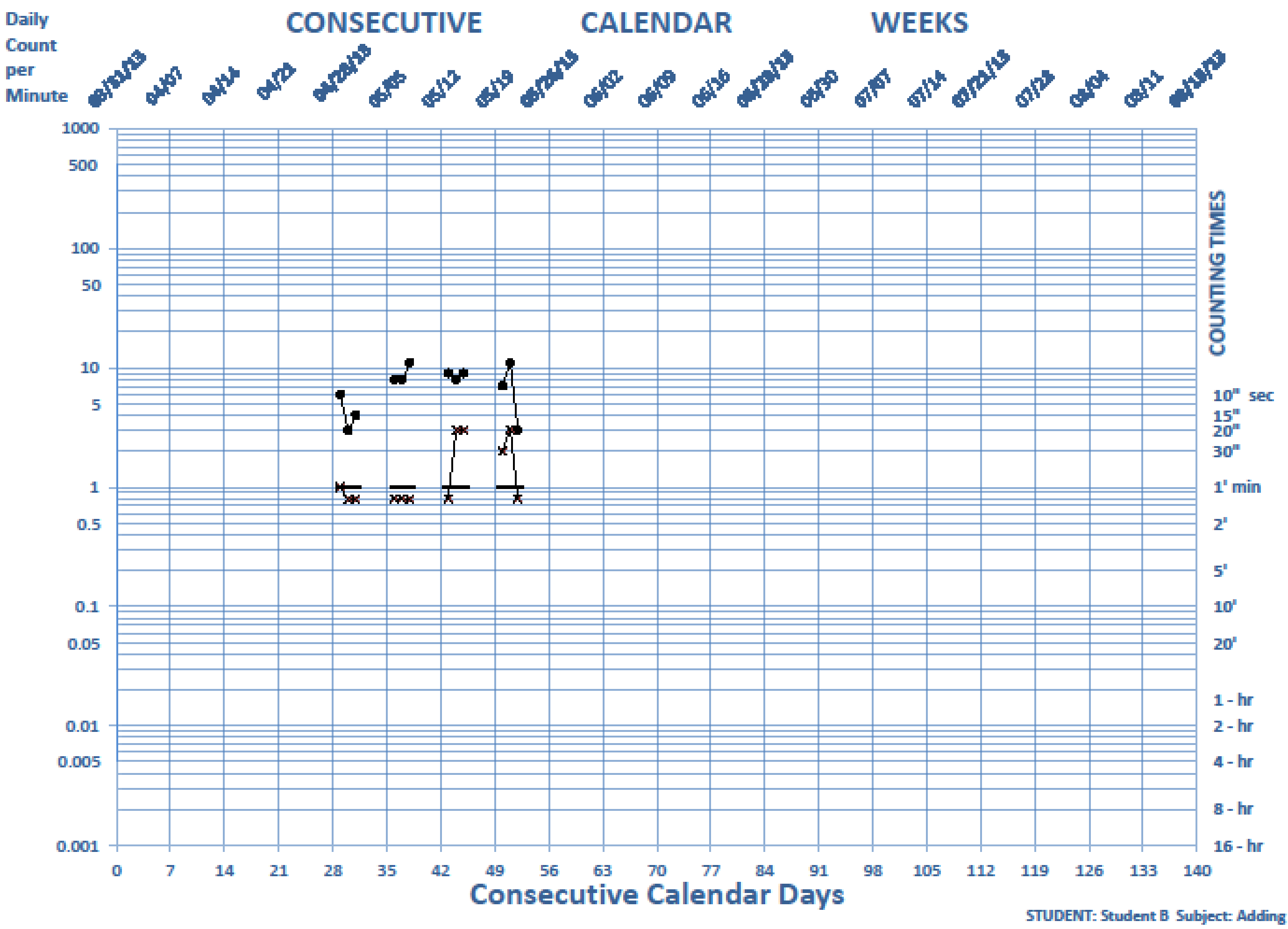

Figure 3: Student B’s daily per minute standard celeration chart for adding. Correct responses per minute are represented by dots and incorrect responses by X.

Figure 4 shows the two students results of the second pack (counting money). The results at the pre-test suggest that the students may have been able to transfer some of the information learnt in pack 1 to pack 2, as both students’ scores has almost doubled in the pre-test in comparison to the pre-test in pack 1. This pack was introduced to the students in difficulty level; stage 1 of the pack involved recognition of a single coin, stage 2 of the pack was 2 of the same coin and stage 3 was 2 different coins. Stage 1 and 2 were completed in school and stage 3 was set for homework. The results show an increase from pre- to post-test (stage 1 + 2), student A showed an increase of 6 correct sums and student B showed an increase of 4 correct sums. Both students show a further increase at post-test 2 (stage 3 homework), student A showed a further increase of 10 correct maths sums and student B shows a further increase of 4.5 correct sums. The maximum the students could score on the test was 50 correct maths sums.

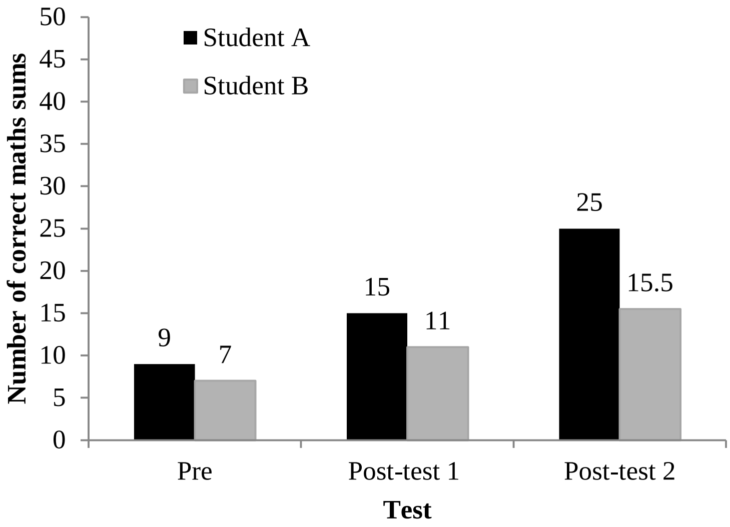

Figure 4. Pre-, post-test 1 and post-test 2 for both students for counting money (Pack 2).

Figure 5 and 6 shows students A and B's SCC for the second pack counting money. Student A's SCC shows both the school phase and homework phase for the counting money pack. Student B only completed 3 weeks of the school phase and 1 week of the homework phase, which could account for the results on the tests seen in figure 4.

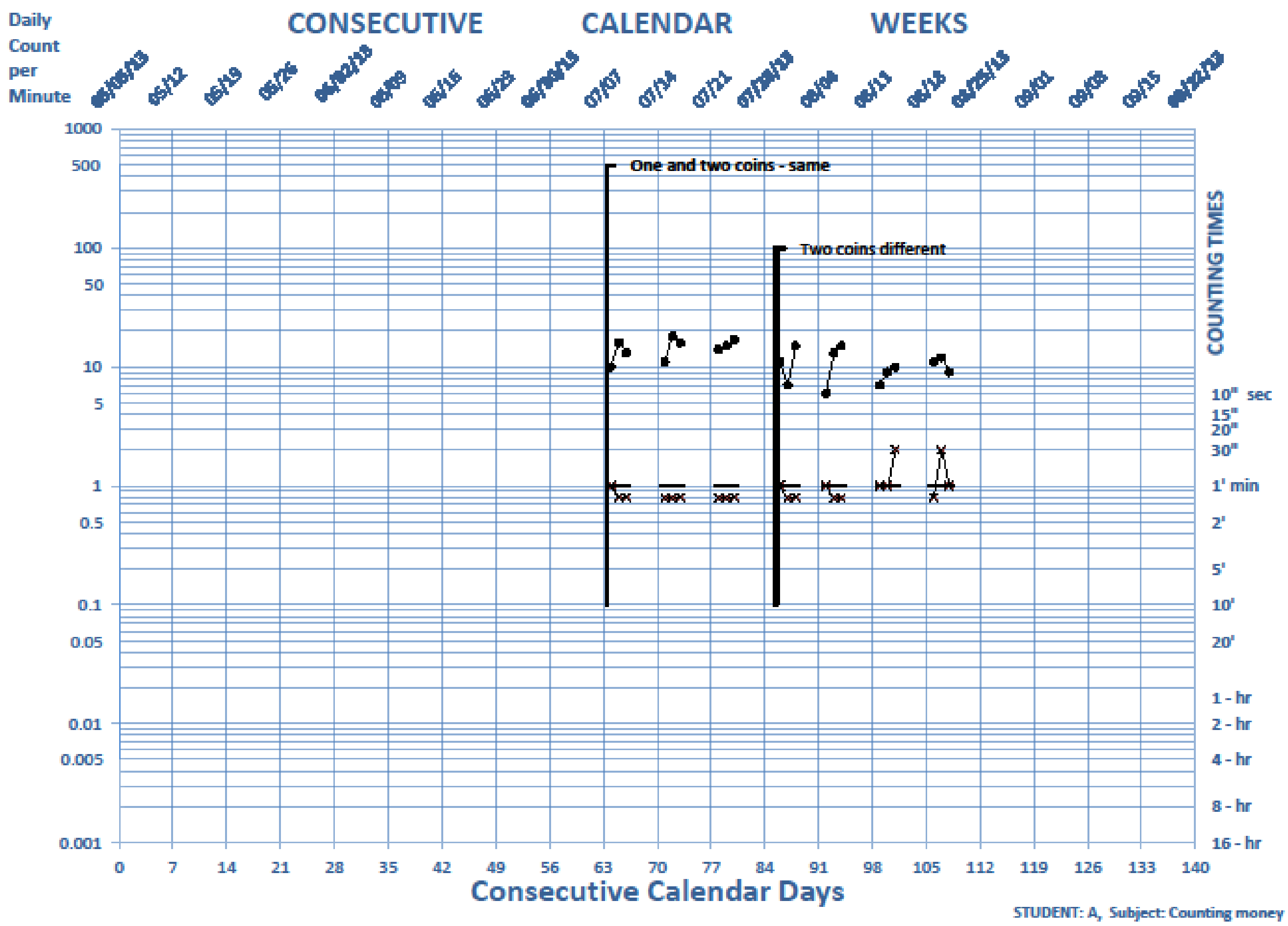

Figure 5: Student A's daily per minute standard celeration chart for counting money. Correct responses per minute are represented by dots and incorrect responses by X.

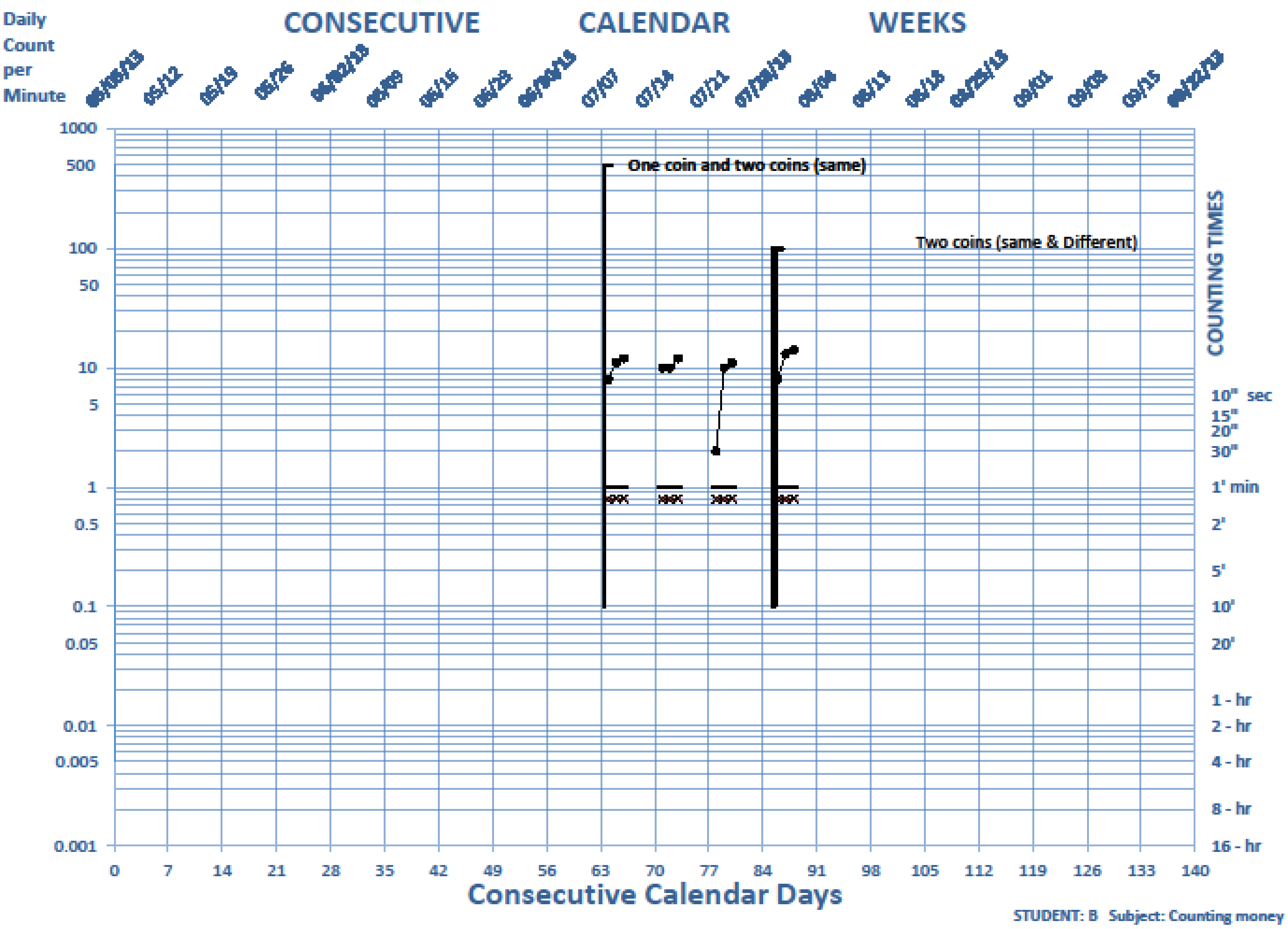

Figure 6: Student B's daily per minute standard celeration chart for counting money. Correct responses per minute are represented by dots and incorrect responses by X.

Figure 7 shows the pre- and post-test 1 & 2 results for both students for the multiplication pack (pack 3). Student A scored zero at pre-test, showing that they had no prior knowledge of the topic. Student B showed some knowledge of the topic at pre-test. The results demonstrated that both students showed an increase from pre- to post-test, with student A showing the biggest increase. Both students then showed a further increase in the second post-test after the homework phase, with the maximum number of 50 correct maths sums.

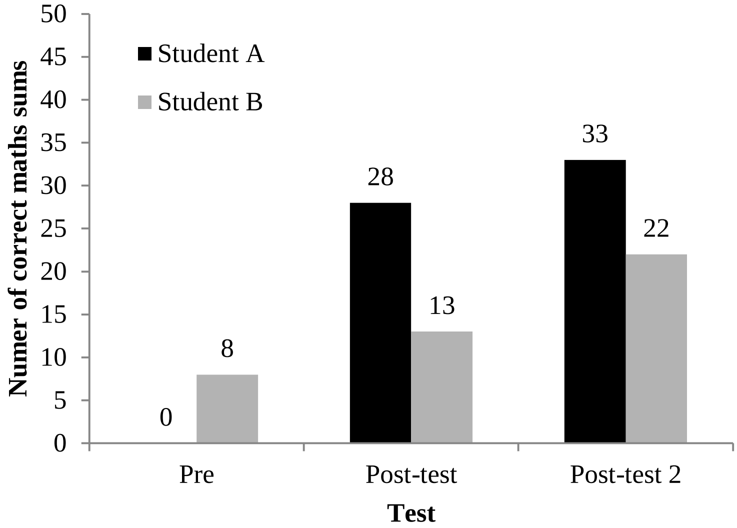

Figure 7. Pre-, post-test 1 and 2 for both students for multiplication (Pack 3).

Figure 8 and 9 shows students A and B's SCC for multiplication. Student A's SCC shows the daily per minute scores for the school phase and homework phase, highlighting the difficulty of the cards. Student B however, only shows the school phase daily per minute scores, as the homework folder was not returned. Although student B did not return their homework folder, the results from the second post-test suggests that the student had continued learning of this topic. Therefore, we might hypothesise that the student had completed part of their homework.

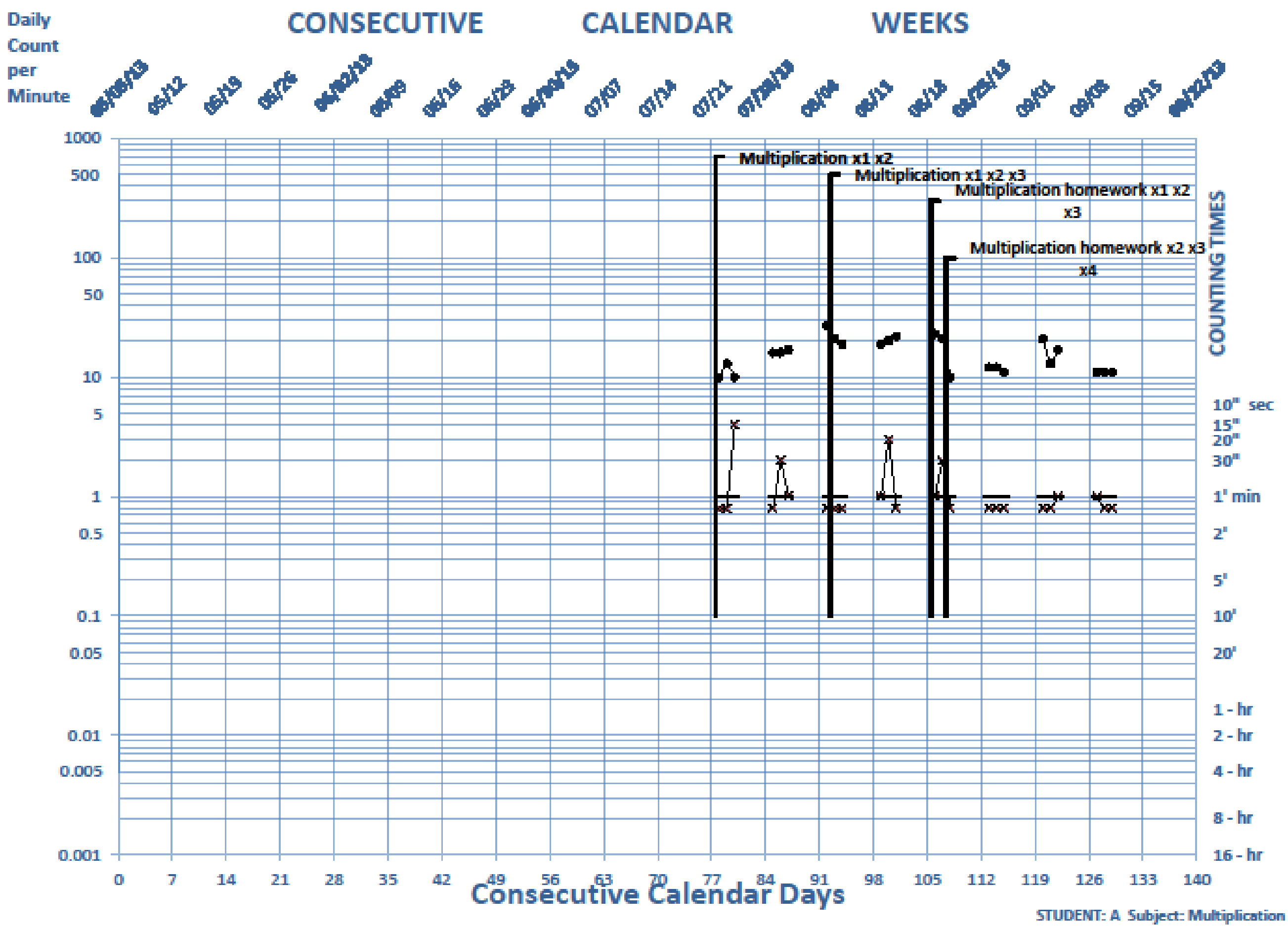

Figure 8: Student A's daily per minute standard celeration chart for multiplication. Correct responses per minute are represented by dots and incorrect responses by X.

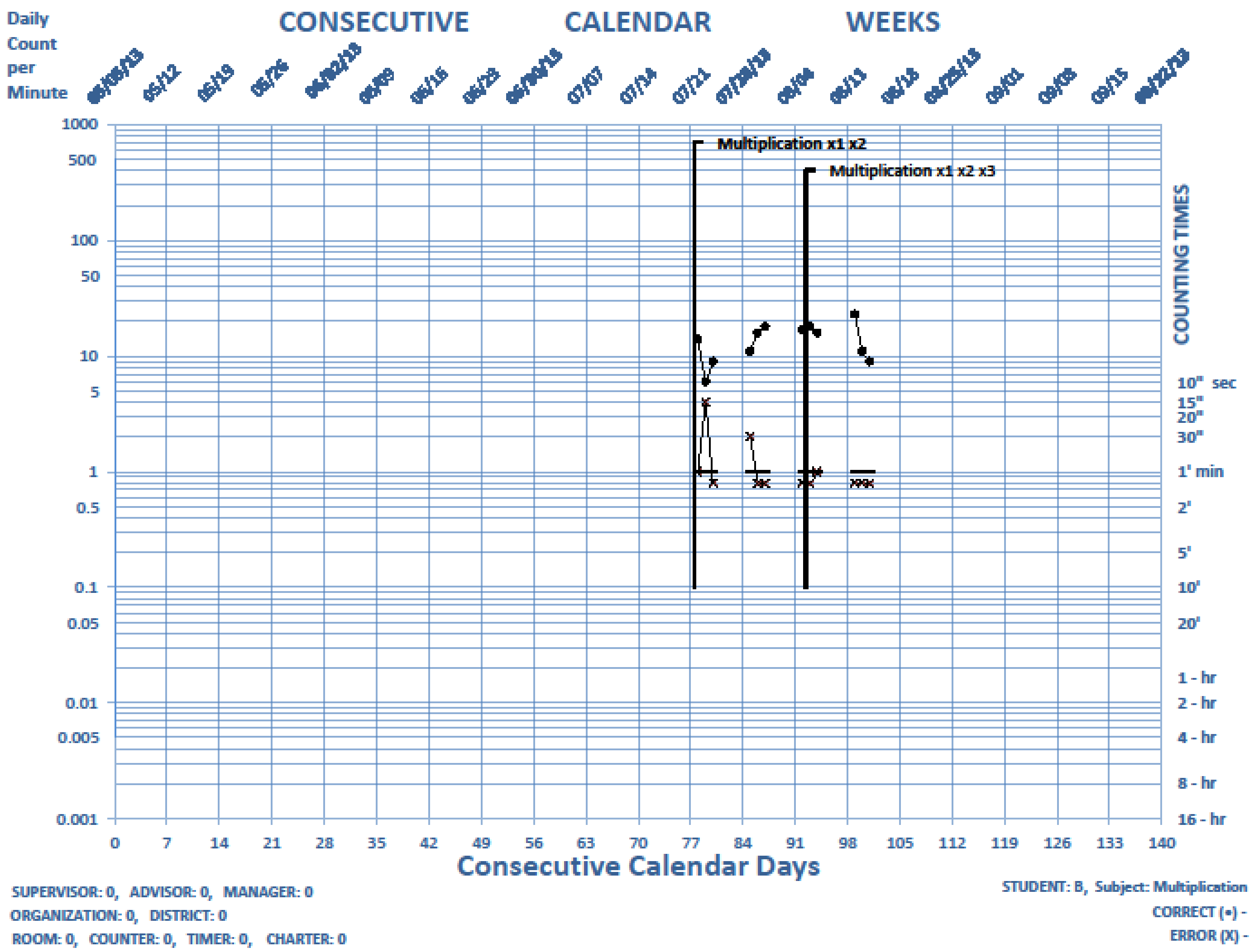

Figure 9: Student B's daily per minute standard celeration chart for multiplication. Correct responses per minute are represented by dots and incorrect responses by X.

Discussion

Overall, the findings from this study showed that both students' who were highlighted as students with math difficulties, were able to show improvements in the number of correct maths sums pre- to post-test in all three topics (Adding, Counting Money and Multiplication.) The results from the first topic showed that the students not only showed an increase in the number of correct maths sums pre- to post-test, but could also maintain the information learnt in the one month follow-up-test. Student B not only showed maintenance, but demonstrated a further increase in the number of correct maths sums in the one month follow-up-test. A possible explanation for this result was that the TA had continued working with this student, using the SAFMEDS on the topic. Interestingly it appears that both students were able to generalise the information learnt from pack 1 (adding) to pack 2 (counting money), as both pre-test scores on pack 2 were roughly doubled, when compared to pack 1 pre-test scores. The results from pack 2 and 3 demonstrate that the students showed an increase from pre- to post-test in the school phase, and when the pack was set for homework, the students showed further gains in the second post-test. Highlighting that completing SAFMEDS cards, in both school and home settings benefitted the students' academically.

This study aimed to replicate findings from previous studies on increasing students maths abilities in a new setting (class-wide; see chapter 5 for full class results) (Casey, McLaughlin, Weber, & Everson, 2003; Cunningham, McLaughlin, & Weber, 2012). The results of this study clearly provide further support for the use of SAFMEDS to increase maths skills in students with maths difficulties. It is important to note that the students were completing their SAFMEDS cards at the same time as the whole class, therefore, the environment was a distracting loud environment. Teacher resources and additional classrooms are normally needed for this kind of intervention, but the results of this study showed that the students could remain in the normal teaching class with the rest of their peers and still show improvements. It is important to note that the class that took part in this study had a TA allocated to the class at all times. The TA was on hand to provide the additional support needed in the classroom, therefore in classrooms where a TA is not allocated, this intervention may not be feasible. During the intervention it was apparent that when students were working in peer dyads, frustration was sometimes apparent, whereas when working with the TA or experimenter, the students showed gains in each session. The main reason behind conducting this research on a class-wide basis was to increase inclusion. Although it is evident that a student receiving one-to-one interventions in a quiet environment is beneficial to their learning, it is important that the student is also able to learn in different environments, such as in a busy classroom, therefore being able to generalise to different settings. There were a number of limitations to this research. The sample was small so further research is needed with a larger sample to assess the generalisation of the findings. To further strengthen the findings of this study a comparison of completing SAFMEDS in a quiet environment to a class-wide setting could be conducted. Although gains by each student were shown in each topic, would their gains have been greater in a one-to-one quiet learning environment? Nonetheless, this study does provide further evidence to the growing body of research on the effectiveness of using SAFMEDS cards with students with maths difficulties, to increase their basic maths skills. Overall this study showed that both students showed an increase in their basic math skills, they also showed that they could transfer to other maths topics, and increased complexity, which is an important aspect of developmental learning.

Chapter 6: Introducing SAFMEDS at home to increase parental involvement in students maths homework

Abstract

Background. There is a growing concern of the number of individuals who are innumerate in the UK. It is important for students to have a learning partnership at home and school to ensure a rich learning environment. Unfortunately there is a growing decline in parental involvement in their children's education, this could be for several reasons, lack of time, parents own inability to comprehend maths, and parents not seeing this as part of their role.

Aims. The aim of the studies reported here was to investigate ways of increasing students' engagement in maths homework and parental involvement in their child's education.

Participants. This study consisted of a total sample of 121 primary school students and their families.

Method. Students were given curriculum relevant maths flashcards with key facts to learn for homework with their parents.

Results. The results indicate that the use of flashcards increased maths performance on the tests and showed that the students could maintain the knowledge learnt in the one month follow up. The results also show that from the data returned, there was a high percentage of parental involvement.

Conclusions. Flashcards have been shown to be a suitable learning tool for homework and increasing parental involvement.

Introduction

Currently there is a strong public awareness about the low achievement in numeracy in the UK (OECD, 2012). The need to have a society that is numerate is essential for the growth of the economy (Hughes, 2009). Students' education does not start and finish at school. Homework plays an important role in students' academic achievement, especially in maths achievement (Cooper, Robinson & Patall, 2006; Pelletier, & Normore, 2007; Trautwein, 2007). Paulu (1998) stated 5 benefits of homework: to evaluate and practice topics learned in class, to prepare for a new topic, opportunities to use different learning resources (library, internet, and community), opportunities to explore topics further and finally to promote and develop time management and organisational skills which can be transferred into higher education and the work place. However, students seem to be disengaged with homework. Paulu (1998) suggested that the period of time taken to complete homework should be factored in and that primary school students should be set homework that lasts no longer than 20 minutes per night. By having a time limit on homework ensures students do not get bored and research has shown that homework that is time consuming can be disruptive to the home environment (Bennett & Kalish, 2006; Kralovec & Buell, 2000). Research has also shown that spending longer on homework does not necessarily correlate with higher grade attainment (Black, 1996; Corno, 1996). It is important that students understand what is expected of them when it comes to homework, in a class-setting teachers are there to consistently keep students on track which is not as easy for homework. Therefore ensuring both students and parents understand what the homework is and when it is due back is essential for success (Patton, 1994). Consistency is important, if students receive homework every Monday and Thursday then it becomes a routine, which will aid and support the completion of homework. Parents will also be prepared that Monday night is homework night, therefore ensuring that no other activities conflict with homework time (Patton, 1994).

Finally it important that homework provides adequate feedback not merely that it is completed, as this will hinder future homework standards (Butler, 1987; Lenard, 1997; Paschal, Weinstein, & Walberg, 1984).

It is also evident that parental involvement is a key factor in their child's education and parents are one of the main and earliest influencers on their children's motivation to learn (Lumsden, 1994; National Research Council NRC, 2001). Parental involvement covers a wide range of definitions, however, for the purpose of this study when we refer to parental involvement we are referring to the parent's involvement in their child's education; this can be attending school meetings, providing support with homework and providing a positive attitude towards education highlighting the importance of succeeding at school (Fishel & Ramierz, 2005; Walberg, 1984) with the emphasis on support with their child's homework.

There have been numerous studies highlighting the importance of parental involvement; Fan and Chen (2001) found a positive correlation between parents who had high aspirations for their child's education and student's grades, but found the opposite effect when looking at parental involvement in school activities such as volunteering. Similarly, Domina (2005) noted that students whose parents checked their homework, showed higher academic achievement than those who did not. Parental involvement has been shown to be vital in students having a successful education, not just in grade attainment, but studies have also found that parental involvement is linked to lower rates of behavioural problems and higher attendance rates (Domina, 2005; Rumberger, 1995; Simon, 2001).

Parental involvement has not only been highlighted by research as an important factor in children's education but also in government policies such as No Child Left Behind act (2001). This policy and similar policies state that it is a schools obligation to ensure active involvement from parents in their child's education. Students do not just learn at school, their home environment should also be a place where valuable learning can take place (Patton, 1994).

There are many reasons for parents not being involved in their child's education. A few examples could be due to work commitment, other children, and also difficulties with their own basic literacy and numeracy skills (Bynner & Parsons, 2006; Farrell & O'Connor, 2003; Peters, Seeds, Goldstein & Coleman, 2008). There is extensive research supporting that parents who feel that they can contribute to their child's education are more likely to engage, therefore parents who have poor basic skills may not feel that they are in the position to support their children in their education (Hoover- Dempsey, Bassler & Brissie, 1992). Research suggests that when teachers have parental involvement as a regular part of students education, parents are more likely to help and feel able to help (Ames, 1993; Epstein, 1991). Research has found that programmes that involve parents and children working together do not only improve students learning, but can also have a positive effect on the parent child relationship (OFSTED, 2000). It is evident that homework and parental involvement is essential in students' academic achievement but the question arises how to increase student engagement and parental involvement in homework.

Research has shown that providing workshops aimed at parents to help support their children with their education can increase parental involvement (Muir, 2009; Pratt, Green, MacVicar, & Bountrogianni, 1992; Shaver & Walls, 1998; Shumow, 1998; Starkey & Klein, 2000). Incentives such as certificates, stickers and trophies have been well documented in the educational literature at increasing students' academic skills and engagement (Kosfeld & Neckermann, 2011). Incentives have also been shown to increase students' homework completion (Radhakrishnan, Lam & Ho, 2009). There have also been debates on the immediacy of the reward, research has found the smaller more immediate incentives are more appealing to students than larger delayed incentives , this can be accounted to delayed discounting; when a prize is delayed it becomes devalued (Green, & Myerson, 2004; McClure, Ericson, Laibson, Loewenstein & Cohen, 2007).

Student engagement is essential in learning, if the student is not engaged they simply will not learn (Kuh, 2009). Harris and Haydn (2008) noted that students prefer learning when it is active and participatory compared to traditional learning. Therefore, this study used Precision Teaching techniques with the use of SAFMEDS to increase student engagement.

Lindsley (1992) describes five steps to precision teaching: Step 1: A learning goal is defined to the learner to master; Step 2: Materials are prepared to enable the student to master the skill; Step 3: Learning is timed to monitor the students' performance and count its frequency; Step 4: Learning is charted on a Standard Celeration Chart (SCC); and Step 5: Learning can be reviewed on the chart and decisions can be made. The SCC allows the learner and teacher to assess and monitor quickly if learning is taking place and if this is not the case then interventions can be put into place for that student.

SAFMEDS

As previously stated, research has shown the effectiveness of the use of SAFMEDS to increase students maths skills in a school setting (Brasch, Williams, & McLaughlin, 2008; Erbey, McLaughlin, Derby & Everson, 2011; Glover, McLaughlin, Derby & Gower 2010; Jolivette, Lingo, Houchins, Barton-Arwood & Shippen, 2006; Hayter, Scott, McLaughlin & Weber, 2007; Hughes, Beverley & Whitehead, 2007; Sante-Delli, McLaughlin & Weber, 2001). The previous chapters provided further support into the effectiveness of using SAFMEDS class-wide to increase the number of correct maths sums students could answer. As stated previously homework that is engaging, has clear instructions, set on regular days and is not time consuming can increase students' completion (Bennett & Kalish, 2006; Butler, 1987; Kralovec & Buell, 2000; Kuh, 2009; Lenard, 1997; Paschal, Weinstein, &

Walberg, 1984; Patton, 1994; Paulu, 1998), therefore it is hypothesised that SAFMEDS can be an effective homework style.

Study 1 aimed to provide further evidence of the effectiveness of the use of SAFMEDS to increase student learning and further extend the research to show the effectiveness of using SAFMEDS in the home environment to increase parental involvement in students' maths homework. It has been noted that by providing tools for parents to help their children with homework may lead to higher parental involvement (Grolnick, Benjet, Kurowski, Apostoleris, 1997). Therefore, this study provided parents with materials and information to be able to complete the procedure at home. As stated previously, the typical classroom style homework is not always the best method as it can be disruptive to family life and too time consuming (Bennett & Kalish, 2006; Kralovec & Buell, 2000). However, as stated previously research has shown clear academic benefits of the completion of homework (Cooper, Robinson & Patall, 2006; Pelletier, & Normore, 2007; Trautwein, 2007), therefore using flashcards, which are time efficient, including a game element and being able to visually see their child's learning increase, should have a positive impact on parental involvement (Cooper et al 2006).

Study 2 aimed to further increase parental involvement by encouraging parents to attend a workshop. To ensure parents come on board with the intervention incentives were provided for parents to attend the workshop (for example, free pizza and raffle prizes). There is limited research highlighting which aspects of parental involvement are attributed to high academic achievement, therefore this study assessed the proportion of homework checked by parents in relation to test scores. The use of certificates, stickers and trophies were utilised in this study as previous research has shown this to be a driving tool in increasing student engagement (Kosfeld & Neckermann, 2011) Students were awarded certificates for completion of homework and two trophies were awarded at the end of the study for the most improved and highest achiever in each class.

Study 3 replicated study 2 and aimed to provide further evidence into the effectiveness of using flashcards as homework by extending the intervention to lower year groups. To further increase student completion weekly raffle tickets were also provided to students with a chance of winning a prize at the end.

Study 4 replicated study 2 and aimed to provide further support for the use of SAFMEDS and further increase student completion by providing weekly incentives instead of raffle tickets.

Study 5 replicated study 4 but provided different weekly prizes based on class preference assessments.

Study 1- Method

Participants

The pilot study consisted of 39 students male (*n*=18) and female (*n*=21) aged 9-11 using the same cohort from the school study (Chapter 4) and their family (family involvement varied from child to child, some students had parental involvement from both parents, some students also had involvement from grandparents and some students only had involvement from one parent). The inclusion criteria consisted of all students completing all of the quizzes pre- post- and follow up-tests.

Setting, stimuli and apparatus

The intervention took place in a school in North Wales that has been classed as deprived. The homework intervention took place in the student's home. SAFMEDS packs were made available to students; two packs were set for the homework phase. Year 6 – SAFMEDS number order pack, Year 5/6 – SAFMEDS multiply and divide pack. A children’s digital hand held timer was used to time the daily sessions and were also used to time the pre/post-tests.

Measures, Materials

The students were given a 50 question pre- and post-test to evaluate their knowledge of the maths topic area. All students were given a sheet to record their daily SAFMEDS sessions on and a chart to record their best timing of the day. A plastic wallet was provided for each student to keep their table, chart, SAFMEDS pack and timer in. End of topic completion certificate was awarded to the students who completed their homework.

Design

The intervention used a within subject design; investigating the effects of the use of SAFMEDS to increase maths skills in primary school students.

The independent variable was the students completing SAFMEDS sessions. The dependent variable (DV) was the score on the pre- and post-tests.

Constant variables in the study were that all students in year 6 had the same pack of SAFMEDS cards and all students in year 5 had the same pack of SAFMEDS cards. All students completed the SAFMEDS cards four times a day for three days in a two week period. The students had already completed school packs where the experimenter ensured that the students were fluent in the procedure (See Chapter 4).

Procedure

Initially consent was gained via the head teacher for the study to take place at the school. Parental consent was then gained for all students taking part in the intervention. Parents were all given an information sheet and a consent form which explained the intervention. Prior to the homework phase a previous study involved students been trained in using SAFMEDS and completed a four week intervention in school (see Chapter 4).

Pre-tests

Students were given a 50 question quiz to complete based on their SAFMEDS homework pack (example question: Q1. 224 ÷ 2 = _____). The students were explicitly told that they were not expected to know the answers of the quiz and that they were maths equations that they had not been taught yet, this was also printed on the top of the test. This was done to ensure that the students' were not negatively affected from completing the test. Students were informed that the test needed to be completed in exam conditions (no talking, only look at your own work). The students were told that they had 10 minutes to complete the test. The students were instructed that if they did not know the answer to put an X where the answer would go. There was an example question to demonstrate this at the top of the test.

Fluency aims were given weekly to students at the start of each week with the exception of week one, the aims were based on the previous weeks results on the chart. The main fluency aim for this project was a frequency of > 40 cards correct and less than 2 incorrect per minute.

Intervention

Students were given their homework folders at the start of the week to take home and complete their SAFMEDS homework with their parents over a two week period 3 times a week completing 4 daily sessions. Homework was completed on Mondays, Wednesday and Thursday and this remained constant throughout the study. Students were told to bring their homework back at the end of each week for the researcher to assess. Students were given weekly aims based on their previous week scores. Students worked with a parent to complete their SAFMEDS, with the parent taking the role as the timer. The student is given one minute to go through as many flashcards as quickly as they can, saying the answer out loud, depending on whether the answer is correct or not the student places the card in their correct pile or their not yet pile. At the end of the session the student counts the number of cards in each pile and fills in their table (number of cards correct, not yet, timed for one minute and checked by mum/dad). Once the child has filled in their table, they then spend a couple of minutes going through their not yet pile with their parent (*error correction*). This involved the parent going back through the cards with their child that they answered incorrectly, asking each question in turn until the child gave the correct response (if the child did not give the correct response immediately the parent would tell the child the answer). Once the child has completed their four timings for the day they then highlighted their best score and plotted their data on their learning chart.

Post-/ follow up-test

After the two weeks students were then given a post-test identical to the pre-test, six weeks after this, students were then given a follow up test to assess for maintenance. Students who completed the homework were also awarded an end of topic completion certificate.

Results

Table 1

Mean pre- post-test and follow up scores for year 5 and 6.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
6	28.1 (11.3)	41.9 (5.5)	41.1 (7.8)	(2,32)=25.376	<.001	.61
5/6	6.5 (7.5)	40.1 (13.7)	31.1 (17.8)	(2,42)=53.876	<.001	.72

The results show that both year groups made significant improvements in the number of correct maths sums they called recall and also maintained the skills learnt in the one month follow up.

Table 2
Mean fluency pre- post-test and follow up scores for year 5 and 6.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
6	3.2 (1.2)	5.4 (1.8)	5.9 (3)	(2,32)=17.958	<.001	.53
5/6	.9 (1.1)	6.3 (3.3)	5.2 (3.1)	(2,42)=36.968	<.001	.64

The fluency results show that not only did both year groups show an increase in their acquisition (number of correct maths sums) the students also showed an increase in their fluency scores.

Parental involvement was assessed based on the number of sessions that was checked off by a parent. Table 3 shows the number of folders that were returned from each year group. Based on the number of folders returned they were assessed on the percentage that had actually completed every session, and also the percentage of parental involvement.

Table 3

Number of folders returned, completed, and how many were completed with a parent (it is assumed that those not returned were not complete therefore had no parental involvement – therefore the percentages below can only be a guestimate. Percentages are based on the entire class for each section).

Year	**Folders returned**	**Folders completed**	**Completed with parent**
6	99%	88%	28%
5/6	72%	52%	16%

Discussion

The results of study 1 are promising with regard to the effectiveness of using SAFMEDS as homework to increase homework completion and increase parental involvement. However, further research is needed to increase parental involvement in their child's maths homework. Previous studies have found the use of school led workshops have been successful in increasing parental involvement in students homework (Pratt, Green, MacVicar, & Bountrogianni, 1992; Shaver & Walls, 1998; Shumow, 1998 Starkey & Klein, 2000). However, parents that typically attend parent workshops are normally the parents that are already involved in their child's education. In study 1 we saw roughly 50% parental involvement in the SAFMEDS homework suggesting that (a) these parents would typically get involved in their child's homework or (b) that the new style of homework was appealing to parents and students. But it is important to target the parents that tend to not typically get involved in their child's education, therefore the use of incentives were utilised in study 2 to increase parental involvement.

Study 2 - Method

Participants

This study used the same cohort from study 1.

Setting, stimuli and apparatus

The parent workshop took place in the schools hall and the homework intervention took place in the student's home. SAFMEDS packs were made available to the students, Year 6 – SAFMEDS measurement pack and Year 5/6 – SAFMEDS multiply and divide by 10 pack. End of topic certificates, stickers, highest achiever and most improved trophies. All students were given a plastic wallet with their SAFMEDS pack, table to record their daily sessions, chart and a timer.

Measures

Students were given a 50 question pre- post-test to evaluate their knowledge of the maths topic. Students were given the same instructions as the previous study, 10 minutes to complete the quiz and to be completed under exam conditions.

Procedure

To further increase parental involvement this study looked at the same cohort from study 1 by inviting their Parents/Guardians to attend a workshop. The workshop was aimed at informing parents how they can help their children with maths and its importance. Certain factors were considered when organising the workshop, as parent workshops tend to have low attendance (Epstein, 1991). The workshop was held at the school at the end of the school day (3pm-4pm), as this would be a convenient time, as parents would normally be attending school at this time to pick up their children. To attempt to overcome the barriers of attendance, traditional school letters which may get lost were accompanied by a brightly coloured flyer. To further encourage attendance the emphasis on the flyer was free pizza and the chance to win a luxury hamper. Another potential barrier is that some parents have other younger children, therefore siblings were also invited to ensure child care was not an issue for parents being able to attend.

The workshop consisted of the researcher welcoming the parents and providing them with information of how students have been benefiting from using SAFMEDS in their maths lessons. A brief description of how to use SAFMEDS was presented to the parents then two students demonstrated the procedure at the workshop. Parents were then invited to complete the SAFMEDS with their children. The experimenters were there to answer any questions parents might have about the intervention.

SAFMEDS procedure - This study replicated the intervention of study 1 but the students were given four weeks to complete this homework pack. At the end of each week folders were returned and stickers were given to the students for each completed day.

Post-tests

After the four week homework intervention the students competed the post-test (this was identical to the pre-test). Students then completed the same test after one month.

At the end of the study parents were invited back to school for an award ceremony, students who completed their homework were awarded an end of topic certificate, and in each year group the students who scored the highest on the post-test was awarded a trophy “Highest Achiever” and the student who improved the most from pre- to post-test was also awarded a trophy “Most improved”.

Results

Table 4
Mean pre- post-test and follow up scores for both year 5 and 6.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
6	3.7 (2.6)	8.6 (6.8)	7.5 (5.3)	(2,28)=6.496	=.005	.32
5/6	6.3 (7.9)	21 (15.8)	20.5 (15.4)	(2,44)=27.310	<.001	.55

The results show that the students in both year groups showed a significant increase in the number of correct maths sums recalled after the homework phase and also showed that they could maintain the information learnt in the one month follow up.

Table 5
Mean pre- post- and follow-up fluency scores for both year 5 and 6.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
6	.7 (.1)	2.2 (1.8)	2.1 (1.5)	(2,28)=11.186	<.001	.44
5/6	1.1 (1)	3.8 (2.7)	4.3 (3)	(2,44)=28.574	<.001	.57

Similar results are found when looking at the fluency results showing a significant increase in the students' fluency on the maths quiz and also showing that they could maintain the fluency after one month.

Table 6

Number of folders returned and completed (2+ weeks), and how many were completed with a parent.

Year	Folders returned	Folders completed	Completed with parent
6	53%	33%	33%
5/6	36%	30%	14%

The results show that there is an increase of parental involvement for year 6 and a slight decrease for year 5/6 when compared to study 1. We also see a reduction of the number of folders returned. Due to the number of folders not returned (therefore assumed not completed) a sub analysis was conducted comparing the results of the students who completed a minimum of two weeks compared to those who did not complete their homework.

Sub Analysis

Table 7

Mean pre- post-test and follow up scores for all year groups comparing student who completed their homework to those who did not, showing the main effect of group.

	Completed Homework			Non completion of homework			Main effect of group		
Year	Pre (SD)	Post (SD)	Follow (SD)	Pre (SD)	Post (SD)	Follow (SD)	*F*	*P*	η_p^2
6	2 (1.22)	10.4 (8.47)	10 (6.63)	4.5 (2.68)	7.7 (6.09)	6.2 (4.34)	(1,13)=.339	.570	.03
5	12 (11.56)	36.14 (13.81)	35.43 (13.34)	3.88 (4.06)	14.38 (11.71)	14 (11.33)	(1,21)=17.051	<.001	.45

Analysis of individual's pre to post improvement

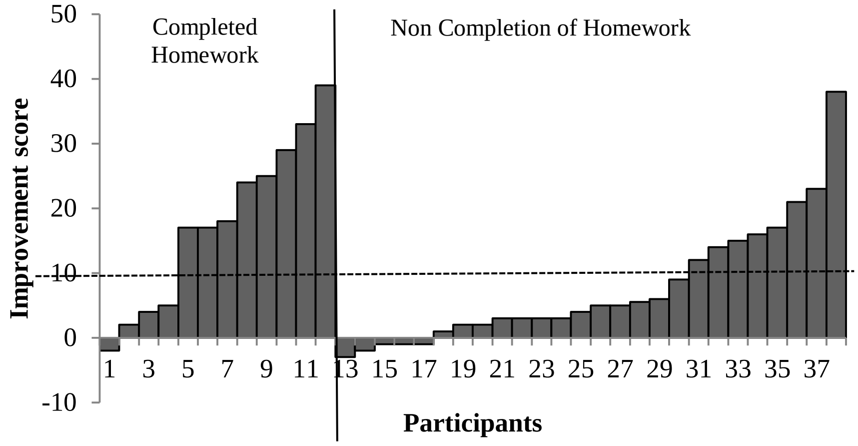

Figure 1. Individual pre- post-improvement score for year 6 and 5 (RCI was 13.96).

Discussion

The results of this study show a 5% increase in parental involvement in year 6 but a 2% decrease in parental involvement in year 5. There was also a decrease in the number of folders returned and completed; one possible explanation for this could have been the timing the last week of the study was the week before the students summer holiday, after two weeks there was a considerable reduction in the number of folders being returned in week 3 and 4 another potential explanation could be due to study 1 only being a two week study, whereas the current study was 4 weeks. It may be hypothesised that the parental workshop had no effect on parental involvement or another hypothesis could be that the parents that were involved in study 1 were the same parents that turned up to the parent workshop.

The next study aimed to increase the number of folders returned and completed with the use of incentives. The study was also extended to lower year groups to assess the effectiveness of the use of SAFMEDS as homework in a larger age range.

Study 3 – Method

Participants

The study consisted of 104 students male (*n*=56) and female (*n*=38) aged 7-11 and their families. The inclusion criteria consisted of all quizzes pre- post- and follow up-tests being completed, the final analysis consisted of 81 students.

Measures, Materials, Stimuli

Pre- Post-tests used to evaluate the students' knowledge of the maths topic. SAFMEDS cards were made available to each student; each year group has a pack based on the school curriculum for their year group; Year 5/6 – SAFMEDS measurement; Year 5 – SAFMEDS measurement; Year 4 – SAFMEDS measurement; Year 3 – SAFMEDS Temperature. Incentives were used: Stickers certificates, trophies, raffle prizes.

Pre-test

Students were given 10 minutes to complete a 50 question quiz based on their SADMEEDS pack. Students were given the same instructions given in the previous studies.

Intervention

Study 3 replicated study 2 with the exception of no parent workshop, but employed an incentive scheme to increase the return rate of the student's homework. Students had to return their folders at the end of each week and in return received a raffle ticket for each session completed with a parent and a sticker for completed sessions.

Post-test

At the end of the four week homework intervention the students completed the post-test (identical to the pre-test). Students completed the same test one month after the intervention phase.

At the end of the four week period parents were invited to school to see the students' results (mean scores were presented to the parents not individual scores), receive their certificate and draw the raffle prizes. Two trophies were also presented, the highest achiever for each year group and most improved students for each year group.

Results

Table 8

Mean pre- post-test and follow up scores for year 3-6

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	3.4 (4)	11.1 (12.6)	6.2 (9.3)	(2,34)=8.326	=.001	.33
5	5.3 (3.7)	26.5 (18.8)	24.5 (18)	(2,40)=29.816	<.001	.75
4	0 (.0)	29.4 (16.2)	30.4 (17.4)	(2,26)=39.468	<.001	.75
3	19.4 (7.1)	37.5 (9.6)	38.2 (8.7)	(2,48)=84.178	<.001	.78

The results show that all of the year groups showed a significant improvement in the number of correct maths sums recalled on the quiz. The results highlight the effectiveness of using SAFMEDS for homework.

Table 9

Mean pre- post-test and follow up fluency scores for year 3-6.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	1 (1)	4.3 (3.5)	2.5 (2.6)	(2,34)=11.546	<.001	.40
5	.6 (.4)	3.2 (2.6)	4 (3.6)	(2,40)=17.706	<.001	.47
4	.0 (.0)	6.3 (4.2)	8 (5.7)	(2,26)=22.964	<.001	.64
3	2.6 (1)	6.5 (3.1)	6.5 (2.9)	(2,48)=42.438	<.001	.33

Similar results were found when looking at the students fluency in the number of correct maths sums, which show not only could the students correctly answer more questions but they were also more fluent in the maths topic.

Table 10

Percentages of folders returned, completed and completed with a parent.

Year	**Folders returned**	**Folders completed**	**Completed with parent**
5/6	66%	54%	46%
5	64%	54%	48%
4	70%	55%	63%
3	80%	80%	80%

The results show that the procedure can be generalised across year groups. Year 5 from study 1 and 2 have been followed into year 6 for this study, showing a higher proportion of folders returned and completed suggesting the incentive technique is crucial in ensuring students return and complete their homework. Year 5/6 also show an increase in parental involvement from 16% in study 1 a reduction to 14% in study 2 to 46% in the current study showing a 32% increase in parental involvement from the last study. The other groups show over half of parents being involved in their Childs' homework with the slight exception of year 5 who are just below 50%. Due to just over half of the students completing homework a sub analysis was conducting comparing the students who completed their homework and those that did not completed their homework (due to not all folders being returned we assume that they are incomplete).

Sub analysis

Table 11

Mean pre- post-test and follow up scores for all year groups comparing student who completed their homework to those who did not, showing the main effect of group.

	Completed Homework			Non completion of homework			Main effect of group		
Year	Pre (SD)	Post (SD)	Follow (SD)	Pre (SD)	Post (SD)	Follow (SD)	*F*	*P*	η_p^2
5/6	6.07 (4.94)	20.86 (13.39)	13.64 (11.93)	3 (2.45)	5.5 (4.51)	0 (0)	(1,16)=4.940	.041	.24
5	7.08 (3.66)	39.46 (10.16)	35.62 (13.33)	2.5 (1.51)	5.38 (3.34)	6.38 (4.17)	(1,19)=60.535	<.001	.76
4	0 (0)	31 (16.85)	33 (17.69)	0 (0)	23.33 (15.04)	20.67 (15.31)	(1,12)=.871	.369	.07
3	19.91 (7.29)	39 (8.87)	38.82 (8.830	16 (15.29)	26.67 (8.62)	34 (7)	(1,23)=2.803	.108	.11

Analysis of individual's pre to post improvement

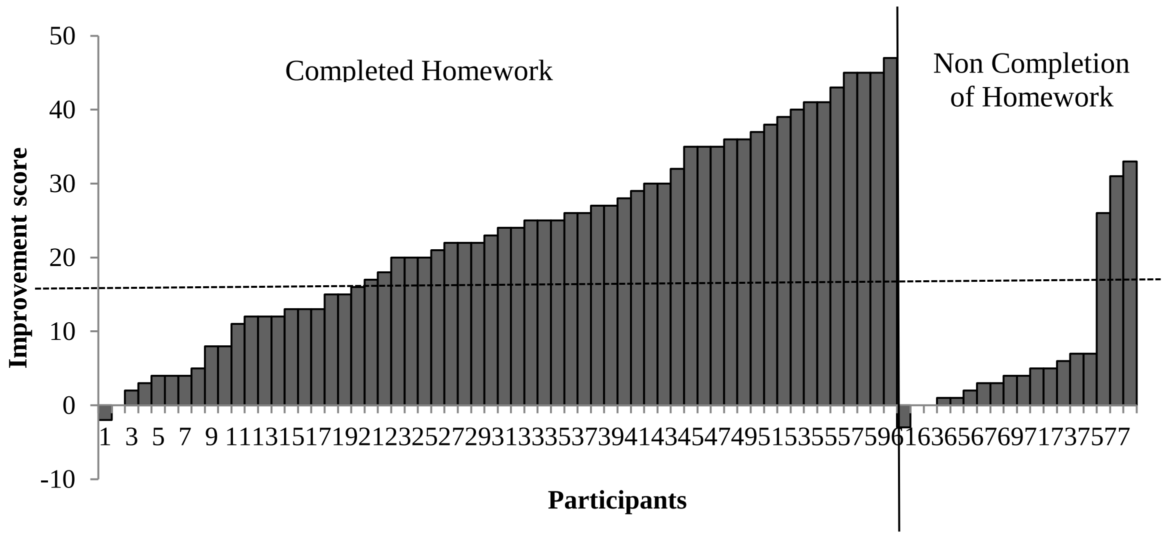

Figure 2. Individual Pre- Post- Improvement score for year 5/6, 5, 4 and 3 (RCI was 19.40).

Discussion

This study showed that SAFMEDS were successful in all year groups at increasing the number of correctly recalled maths sums on the test and increased students maths fluency in the given topic. The results also showed that a high proportion of students in each year group returned their homework, which the school had stated to be a problem. Although only a comparison can be made for year 5/6 showing that this study had the biggest impact on parental involvement we see similar results in year 5 showing nearly half parental involvement. Year 4 and 3 show over half parental involvement suggesting that ensuring students have the incentive to complete their homework can have the biggest impact on parents compared to a parent workshop. However, it is important to note that parents were invited to school to attend a ceremony as research has shown that it is important for parents to attend school events (Fishel & Ramierz, 2005)

The results of the sub analysis only show a significant difference between students completing their homework and not completing their homework for the two older year groups (Year 6 and 5). However, although not significantly different, the students in the lower year groups (Year 4 and 3) who did complete their homework show higher scores in the post-test when compared to the students who did not complete their homework. Another point to note, the students who did not complete all three tests were excluded from the analysis and these were also normally the students who did not complete their homework. It may be interesting to further analyse the data based on students attendance to schools, it may be hypothesised that the students with low attendance have low homework completion and low test results.

Anecdotal evidence from the head teacher suggested that parent attendance at the award ceremony was high, also comments from parents regarding the new style of homework was extremely positive such as “It was amazing seeing my daughter improve each day when you can see how well they are doing it helps them to keep going getting better and better. I don't want my daughter just to be stacking shelves I am so proud at how well she is doing at maths now, this has really helped." And "My maths has also improved from doing the cards, they are great."

There has been numerous of studies that have looked at the difference between immediate and delayed incentives (Green, & Myerson, 2004; McClure, Ericson, Laibson, Loewenstein & Cohen, 2007). In this study students received raffle tickets at the end of the week for returning and completing homework but the tangible incentive was a delayed incentive with the chance of not receiving the incentive due to the raffle ticket nature. Although this method worked for some students it was not successful for all students, which is evident in the number of folders returned and completed. Therefore, the next study made use of more immediate incentives (stationary) that were given weekly to every student who returned and completed their homework. It could be argued that this is still a delayed incentive as the students do not receive the incentive directly after completing their SAFMEDS session. However, the incentive is mainly being utilised in this study for students to actually return their completed homework, therefore immediately reinforcing the behaviour of students handing in their homework folders.

Study 4 – Method

Participants

This study used the same cohort from study 3 (Year 3 did not take part in this study). The study consisted of 73 students male (*n*=43) and female (*n*=30) aged 8-11. Due to the inclusion criteria 21 students were removed leaving 52 students in the final analysis.

Measures, Materials and Stimuli

Pre- post-tests were used to evaluate students' maths knowledge applications tests were also used to evaluate students' real world knowledge to the maths topic. SAFMEDS packs were made available to each student based on their year group: Year 5/6 – SAFMEDS multiplication; Year 5 – SAFMEDS 24hour clock; Year 4 – SAFMEDS multiplication. Incentives: Stickers, certificates, and prizes.

Pre-test

Students were given a 50 question quiz based on their SAFMEDS pack. Students were given the same instructions as the previous studies, 10 minutes to complete the quiz and to be completed under exam conditions. Students also completed a application quiz in the form of 10 scenario questions based on their SAFMEDS packs, the same instructions as the previous quiz were given for this quiz. All of the 50 question quizzes were collected prior to the students completing the application quiz.

Intervention

This study replicated study three with the exception of the raffle tickets; instead of the raffle ticket each student was given a small prize for completing their homework on a weekly basis. Students had to return their completed folders at the end of each week to receive their prize. As in the previous studies the students were expected to complete 4 one minute timings, 3 days a week for a four week period.

Post-test

After the four week homework intervention the students completed both post-tests (identical to the pre-test). The students completed the same tests one month after the intervention. All students who completed their homework were presented with a certificate in their classroom (parents were not invited to an award ceremony). In each year group a student who scored the highest score on the post-test was presented a trophy for the highest achiever and the students who had shown the most improvement in the number of correct maths sums from pre- to post-test was presented a trophy for the most improved student.

Results

Table 12

Mean pre- post-test and follow-up-test scores of all three year groups and the main effect of time.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	20.3 (10.6)	27 (9.7)	21.4 (13)	(2,30)=5.079	.013	.25
5	12.5 (15.8)	30.8 (21.1	29.7 (18.7)	(2,42)=17.372	<.001	.45
4	22 (17.9)	23.7 (15.1)	22.5 (18.4)	(2,26)=.417	.663	.03

The results show that year 5 and 6 show significant gains but year 4 remain relatively stable at each time point.

Table 13

Mean pre- post-test and follow-up fluency scores of all three year groups and the main effect of time.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	2.8 (1.6)	5.5 (5.20	4.2 (3.4)	(2.30)=4.983	.014	.25
5	1.4 (1.7)	4.4 (3.5)	4.8 (3.9)	(2,42)=18.186	<.001	.46
4	3.8 (3.1)	5 (4.3)	4.7 (4.1)	(2,26)=1.619	.217	.11

The fluency results show that each year group became more fluent but only year 5 show significant improvements.

Application results

Table 14

Mean pre- post-test and follow-up application scores of all three year groups and the main effect of time.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	3.6 (3)	4.4 (3.6)	3.7 (3.1)	(2,32)=1.299	.287	.08
5	5.2 (3.4)	7.2 (3.4)	6.5 (3.7)	(2.42)=9.600	<.001	.31
4	3.8 (3.1)	3.1 (2.7	1.9 (2.9)	(2,26)=4.923	.015	.28

The results of the application test show that year 5 improved significantly in the number of correct maths sums, although year 6 did show an improvement in the number of correct maths sums, it was not a significant improvement. Year 4 did not show a significant improvement in the number of correct maths sums and showed a slight reduction in scores.

Table 15

Mean pre- post-test and follow up fluency application scores of all three year groups and the main effect of time.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	1.2 (1.4)	3.4 (4.5)	7.1 (9.5)	(2,32)=6.058	.006	.28
5	1.3 (1.3)	2.7 (2)	2.5 (1.8)	(2,42)=11.559	<.001	.36
4	.6 (.6)	1.2 (.9)	1.1 (1.4)	(2,26)=1.880	.173	.13

Similar findings are seen in the students' fluency scores of the application test, showing that both year 5 and 6 improved significantly in the fluency of correctly answering the maths sums, whereas year 4 showed an improvement but not a significant improvement in their fluency scores on the test.

Table 16

Percentages of folders returned, completed and completed with a parent (It is assumed that the folders there were not returned were not completed).

Year	Folders returned	Folders completed	Completed with parent
5/6	50%	19%	34%
5	39%	18%	32%
4	38%	33%	25%

This table may explain the findings seen above in Table 10 and 12 as there is a low return and complete rate for all students in each year group. Due to the low completion rates a sub analysis was conducted comparing the students who completed the homework to those who did not complete their homework.

Sub analysis

Table 17

Mean pre- post-test and follow up scores for all year groups comparing student who completed their homework to those who did not complete their homework showing the main effect of group

	Completed Homework			Non completion of homework			Main effect of group		
Year	Pre (SD)	Post (SD)	Follow (SD)	Pre (SD)	Post (SD)	Follow (SD)	*F*	*P*	η_p^2
5/6	23.4 (11.84)	33.4 (10.9)	26.6 (15.87)	18.91 (10.22)	24.09 (7.98)	19 (11.53)	(1,14)=1.895	.190	.12
5	17.5 (17.83)	42.8 (15.24)	40.7 (15.02)	8.25 (13.27)	20.83 (20.6)	20.5 (16.69)	(1,20)=8.334	.009	.29
4	35 (13.44)	34.75 (8.02)	32.75 (16.56)	16.8 (17.25)	19.3 (15.28)	18.5 (18.21)	(1.12)=3.021	.108	.20

Analysis of individual's pre to post improvement

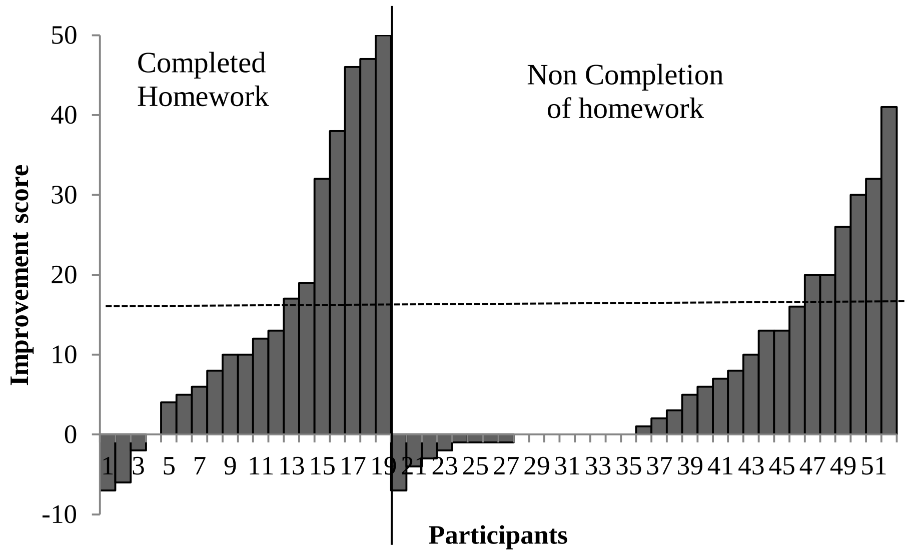

Figure 3. Individual Pre- Post- Improvement score for year 5/6, 5 and 4 (RCI was 23.89).

Discussion

This study showed a decrease in return, completed and parental involvement in each year group compared to study 3. The timing of this study could have impacted the results; the first two weeks of the study showed a higher return and complete rate, but the last week was before the Christmas holidays, therefore possibly impacting the return and completion rate considerably. Therefore, a replication of this study was conducted to assess if students (a) got bored of the pack after two weeks (b) the incentives were not sufficient for the effort students felt they had to put in and or (c) the timing of the last study impacted the results.

Study 5 – Weekly incentives replicated

Due to the limitations of the timing of study four this study is a replication of the previous study. The experimenter spoke to the students in each year group and asked if they liked the prizes from the last study, there was a resounding yes but due to the lack of folders being returned the experimenter did a preference assessment survey. Based on the feedback from the students the incentives were altered.

Method

Participants

This study used the same cohort from study four. The study consisted of 73 students male (*n*=43) and female (*n*=30) aged 8-11. Due to the inclusion criteria 16 students were removed leaving 57 students in the final analysis.

Measures, Materials and Stimuli

Pre- Post-tests were given to evaluate students maths knowledge and application tests were used to evaluate students' real world knowledge of the maths topic. SAFMEDS packs were made available to each student; the packs were based on the students' curriculum for their year group: Year 5/6 – SAFMEDS Equal sums; Year 5 – SAFMEDS times and divide by 10; Year 4 – SAFMEDS round to the nearest 10. Incentives: Stickers, certificates, weekly prizes and trophies.

Pre-test

Students were given the 50 question quiz to complete, and were given the same instructions as the previous studies and 10 minutes to complete the quiz. Once the students had completed the quiz, the researcher collected the quizzed and gave the students the 10 question application quiz to complete. The students were given the same instructions for the application quiz.

Intervention

This study replicated the previous studies; the students were given four weeks to complete 4 one minute timings three times a week. At the end of each week the students had to return their completed homework folder to receive the incentive.

Post-test

At the end of the four week intervention the students were given the 50 question quiz and the application quiz to complete (the same format from the pre-test was used). Students also completed both quizzes one month after the intervention. The students who completed the homework were presented with a certificate in their classroom. The student from each year group who score the highest score was presented with a trophy for the highest achiever, and the student who improved the most from the pre- to post-tes was presented with a trophy for the most improved.

Results

Table 18

Mean pre- post-test and follow up-test scores for all three year groups.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	8.1 (7.6)	11.9 (12.7)	12.7 (13.5)	(2,38)=3.996	.027	.17
5	11.7 (10.8)	20.9 (18.4)	19.9 (18.3)	(2,36)=6.307	.004	.26
4	19.7 (21.2)	38.2 (17.4)	37.2 (19)	(2,34)=12.833	<.001	.43

The results show that all year groups show significant improvements with the exception of year 5/6 that just show a small increase.

Table 19

Mean pre- post-test and follow up fluency-test scores for all three year groups.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	1 (.8)	1.4 (1.5)	1.4 (1.4)	(2,38)=2.261	.118	.11
5	1.2 (1.1)	2.7 (3.1)	2.5 (2.6)	(2,36)=7.018	.003	.28
4	3.8 (4.2)	11.2 (7.9)	12.7 (8.4)	(2,34)=18.993	<.001	.53

The fluency results show similar findings showing an improvement for all but only significant improvements for year 5 and 4.

Application

Table 20

Mean pre- post-test and follow-up application test scores for all three year groups.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	3.5 (3.4)	3.5 (2.9)	4.4 (3.7)	(2,36)=1.193	.315	.06
5	4.4 (3.2)	5.6 (3.7)	7.5 (5.1)	(2,36)=3.386	.045	.16
4	4.9 (2.9)	5.5 (3.5)	7 (3.3)	(2,28)=2.117	.139	.13

The application results show minimal improvement in each year group.

Table 21

Mean pre- post-test and follow up application fluency test scores for all three year groups.

	Pre	Post	One month	Main effect of time		
Year	M (SD)	M (SD)	M (SD)	*F*	*p*	η_p^2
5/6	.8 (1)	1.1 (1.4)	1.5 (1.4)	(2,36)=3.219	.052	.15
5	.7 (.6)	1.8 (2.1)	2.5 (2.5)	(2,36)=4.496	.018	.20
4	2.3 (2)	5.6 (9.6)	11.1 (14.8)	(2,28)=4.385	.022	.24

Table 22

Percentage of folders returned completed and completed with parent percentages for each year group.

Year	Folders returned	Folders completed	Completed with parent
5/6	35%	30%	23%
5	25%	21%	19%
4	33%	33%	26%

Sub analysis

Table 23

Mean pre- post-test and follow up scores for all year groups comparing student who completed their homework to those who did not, showing the main effect of group

	Completed Homework			Non completion of homework			Main effect of group		
Year	Pre (SD)	Post (SD)	Follow (SD)	Pre (SD)	Post (SD)	Follow (SD)	*F*	*P*	η_p^2
5/6	8.7 (8.77)	18.6 (13.61)	18 (14.34)	6.82 (6.63)	5.82 (7.31)	7.18 (10.38)	(1,19)=3.988	.060	.17
5	20 (14.59)	39.17 (14.93)	33.67 (19.12)	7.92 (5.96)	12.54 (13.06)	13.54 (14.55)	(1.17)=12.019	.003	.41
4	20.57 (21.48)	37.14 (20.73)	40.71 (15.2)	19.18 (22.03)	38.81 (16.02)	35 (37.22)	(1,16)=.049	.828	.00

Analysis of individual's pre to post improvement

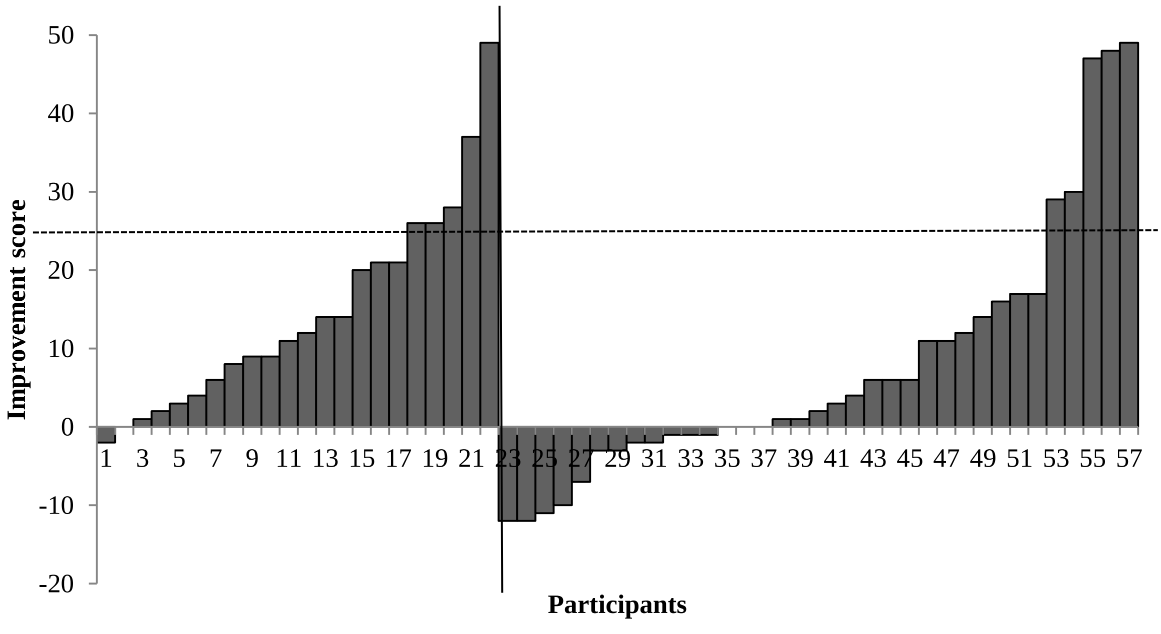

Figure 4. Individual Pre- Post- Improvement score for year 5/6, 5 and 4 (RCI was 27.37).

Discussion

Although results show a slight increase in the number of folders being completed in year 5/6 and 5, they also show a further decrease in parental involvement. Year 4 remain relatively stable in study 4 and 5. Therefore, it may be hypothesised that the timing in study 4 was not a factor in the results. Year 5 show a significant difference between students who completed their homework compared to those who did not, however although not significant, students in year 6 who completed their homework scored higher than those who did not complete their homework. Although year 4 show no difference in score at the post-test between the two groups this may have been due to a few students who scored relatively high on the pre-test did not complete their homework.

General Conclusion and future directions

Overall we can suggest that using SAFMEDS for homework can be an effective tool for increasing students' maths skills and provides further evidence on the effectiveness of using this procedure to increase maths abilities in students (Brasch, Williams, & McLaughlin, 2008; Erbey, McLaughlin, Derby & Everson, 2011; Glover, McLaughlin, Derby & Gower 2010; Jolivette, Lingo, Houchins, Barton-Arwood & Shippen, 2006; Hayter, Scott, McLaughlin & Weber, 2007; Hughes, Beverley & Whitehead, 2007; Sante-Delli, McLaughlin & Weber, 2001). This study provides further evidence to Domina (2005) of the importance of parents checking their children's homework to increase academic gains. The results of the studies also provide further evidence on the effectiveness the use of incentives to increase homework completion (Green, & Myerson, 2004; Radhakrishnan, Lam & Ho, 2009). However, study 3 with the delayed incentive which had a high monetary value seemed to be the most beneficial which contradicts with previous research, but the delayed discounting effect may not have discounted the prizes in study 3 to the value of the prizes in study 4 and 5 (Kosfeld & Neckermann, 2011; McClure, Ericson, Laibson, Loewenstein & Cohen, 2007).

When analysing the overall results for year 6 from study 1 and 2 we see a drop in return and completed homework, but an increase in parental involvement. The results may have seen a reduction in folders completed from study 1 to 2 as the students lacked the parental support they needed, therefore did not complete the homework in study 2.

Year 5 from study 1 and 2 who were followed into the next academic year, year 6 in study 3, 4 and 5 show interesting findings. We see a high return rate in study 1 of 72% but this falls considerably in study 2 to 36%. The return rate increases in study 3 to 66% and remains relatively stable in study 4 at 50% but reduces further in study 5 to 35%. Study 4 and 5 focused mainly on the students, providing them with incentives to complete their homework. Children can be parents' biggest reinforcers, but for this study that was not the case. The students who continually completed and returned the homework did so throughout the project, initially we see a decrease in parental involvement from study 1 to 2, but then see a dramatic increase in parental involvement in study 3, yet these results are not maintained in study 4 and 5. Therefore, it could be hypothesised that incentives that are for the whole family instead of individual incentives for each student are more beneficial to both increasing return rates and parental involvement.

Similar findings were found in year 5 and 4, where the return rates and parental involvement decreased in each study. These findings highlight further the need for parental involvement; students need the support and motivation from their parents to ensure they complete their homework and therefore attain better grades.

Further analysis of all students results show that the students who returned their folders completed showed a mean improvement of 14.4 whereas those who did not return their homework only showed a mean improvement of 7. Although we cannot say for certain that those who handed in their folders actually completed their homework (students could have filled in their table and chart without actually completing the SAFMEDS cards) and those that did not return their folders did not complete their homework, the overall results suggests that completed homework has superior academic gains when tested.

The students from this study were the same cohort from the school study (Chapter 4). Year 5/6 completed 5 homework packs and showed a mean improvement of 13.3 and three school packs with a mean improvement of 13.2. Year 4/5 completed 3 homework and school packs showing a mean improvement of 16.2 in the homework packs and 15.9 for the school packs. Year 3/4 completed 3 homework and school packs showing a mean improvement of 16.5 in the homework packs and 15.3 for the school packs.

Anecdotal evidence from the teachers suggests that using SAFMEDS for homework saw higher return rates than traditional styles of homework. The results were not as expected, as the return rates and completion rates were still relatively low although the homework that was being returned saw high parental involvement. However, further research needs to be conducted to increase the number of students completing and returning homework. It may have been the case that although previous research has shown that parent workshops are beneficial in increasing parental involvement, the workshops that are aimed at providing information and tools may not be as beneficial as those that targeted increasing parents own maths abilities (Muir, 2009). Although SAFMEDS provided a tool for parents to use no prior training was completed on the maths topic, therefore if parents had a workshop based on learning the topic with SAFMEDS prior to the homework may have seen increased return rates and parental involvement. This study did not use technology, but it could be a useful tool such as using text messages to remind parents that their child has homework to complete (Nielsen & Webb, 2011).

A limitation of the current research is that is does not allow for generalisation as the studies used the same cohort. The topic could also have been a factor in the results as some topics may have been perceived as easier than others; a more robust study would need to be conducted to evaluate which method is the most effective in ensuring students completed their homework. Another limitation is that students may have been filling in the homework without actually completing it, a possible solution to ensure that homework scores are accurate would be for the students to complete one timing with a TA to verify the scores, however, this would be time consuming.

Overall this study supports previous research that students whose parents are involved in their education outperform their peers. The research also provides promising results into the effectiveness of using SAFMEDS as homework.

Chapter 7: Increasing high school students' math skills with the use of SAFMEDS

Abstract

Background Previous research into the class-wide use of SAFMEDS cards (Chapter 4) has shown that it can increase maths skills in primary school students, but has not shown the effectiveness of using this procedure with older students on class-wide basis.

Aims The aim of this study was to replicate the findings from Chapter 4, which incorporated SAFMEDS into primary school students' maths lessons. This study aimed to provide new evidence of the effectiveness of SAFMEDS in a High School population.

Participants The study involved a sample of 48 High School students aged 11-12.

Method Students were given curriculum relevant maths flashcards (SAFMEDS) with key facts to learn using precision teaching principles.

Results The results of this study showed that the addition of SAFMEDS cards in students' maths lessons, can further increase students maths skills compared to TAU from pre- to post-test. The results also showed that the information could be maintained in the one-month follow-up-test. Similar findings were evident in the application test, suggesting that the students could transfer the information learnt to real world questions.

Conclusions This study not only provided further support into the effectiveness of using SAFMEDS on a class-wide basis, but also presents new evidence into the use of SAFMEDS with High School students.

It is evident that early interventions have the best outcomes; Camilli, Vargas, Ryan and Barnett (2010) meta-analysis of early interventions showed that early interventions have great cognitive impact, which has been found to be maintained after 5-10 years. Maths is an area that early intervention indeed is the most appropriate, as it has been shown that students develop maths difficulties early on (Schopman & Van Luit, 1996). However, what does this mean for High School students? Ideally early intervention is the most effective in increasing students rate of response in maths, however some students reach high school without the basic maths skills they should have acquired in primary school. So, can we still have an impact on students' maths skills in High School? Statistics show that maths is an area that needs improving considerably, especially in the UK (Organisation for Economic Co-operation and Development [OECD], 2012). Maths is a skill that is essential for everyday life; without maths our economy would be greatly affected (Hannover & Kessels, 2004). Many employers require their employees to have a range of maths skills; if students are not competent in maths, their employment rate decreases considerably (Tariq & Durrani, 2009). The UK statistics suggests that the current education system is failing students (OECD, 2012). Therefore, a new approach needs to be considered to alter the current statistics.

As mentioned in the previous chapter's precision teaching (PT) and SAFMEDS have been shown as an effective tool to increase basic skills in students (Chiesa & Robertson, 2000; Hughes, Beverley, & Whitehead, 2007). Many PT interventions using SAFMEDS have been done on a one-to-one or small group basis (Chapman, Ewing, & Mozzoni, 2005; Chiesa & Robertson, 2000; Hughes, Beverley, & Whitehead, 2007). In Chapter 4 PT techniques with SAFMEDS cards were used on a class-wide basis in primary school and showed that integrating SAFMEDS on a class-wide/school-wide scale in students' maths lessons can improve students' rate of response in maths. Therefore, this study wanted to replicate the previous findings from Chapter 4, on the effectiveness of using SAFMEDS on a class-wide basis, but with an older population to see if similar findings would be found.

Method

Participants

The study consisted of a total of 48 students male (*n*=21) and female (*n*=27) aged 11-12 in year 7 from a High School in North Wales. In the school there are 7 year 7 sets. The students in this study were two middle set classes. The final analysis consisted of 19 students in the intervention and 16 students in the control group, due to the inclusion criteria 6 students were removed from each group.

Setting, stimuli and apparatus

The intervention took place in a school in the student's usual classroom in their usual maths lesson time slots. A children digital hand held timer was used to time the daily sessions and was also used to time the pre-, post- and one month follow-up tests. The students in the intervention group were each given a SAFMEDS pack which was created based on the new curriculum the selected topic for this study was percentages of money.

Measures, materials

The students were given pre-, post- and one month follow up-tests to evaluate their knowledge of maths in the topic area of percentage of money, which related to their SAFMEDS pack. A stability/application test based on the SAFMEDS pack was created in the form of 10 scenarios, this was also given pre- post- and one month follow up-test to assess for stability/application and dual retention. All students in the intervention group were given a sheet to record their daily SAFMEDS sessions on and a chart to record their best timing of the day. A plastic wallet was provided for each student to keep their table, chart, SAFMEDS pack and a pencil.

Design

The intervention used a mixed design, between group variable was the group students were assigned to (SAFMEDS or TAU) and within subject variable of time (pre- post- and follow up-tests); investigating the effects of the use of SAFMEDS to increase maths skills in High school students. The independent variable (IV) was the condition the students were allocated to either SAFMEDS or TAU. The dependent variable (DV) was the score on the pre-, post- and one month follow up-tests.

Constant variables in the study were that all students in the intervention group had the same SAFMEDS pack. The time allocated to learning this topic area was the same for both the control and intervention group. All students in the intervention completed the SAFMEDS cards four times a day for three days in a four week period (If a student was absent for any session they completed the sessions they missed ensuring all students completed the SAFMEDS an equal amount of times before the test). The experimenter attended all of the intervention sessions. The experimenter observed the students to ensure the procedure was implemented correctly and provided support when needed.

Procedure

Initially consent was gained via the head teachers for the study to take place at their school. Parental consent was then gained for all students taking part in the study. Parents were all given an information sheet and a consent form which explained the intervention. Before the study began the experimenter had a meeting with the maths teacher to ensure the pack was suitable and to go over the procedure so that the teacher was fluent in the application of using SAFMEDS in the classroom.

Pre-tests

At the beginning of the study, all students in both SAFMEDS and TAU were asked to complete the pre-test based on the SAFMEDS pack percentage of money. The students were explicitly told that they were not expected to know the answers of the quiz and that they were based on a topic that they had not been taught yet, this was also printed on the top of the quiz. This was done to ensure that the students' self-esteem was not affected. Students were informed that the quiz needed to be completed in exam conditions (no talking, only look at your own work). The students were told that they had 10 minutes to complete the quiz; the students had a timer on the table so they could see how long they had left. The students were instructed that if they did not know the answer to put an X where the answer would go, there was an example question to demonstrate this at the top of the quiz. The students also completed an application quiz which was a 10 question quiz based on real scenarios using percentages students were given the same instructions as the previous quiz and given 10 minutes to complete the quiz. If students had finished the quiz before the 10 minutes they were told to write the time taken at the bottom of the sheet and then to check through the answers and to wait quietly whilst the other students finished the quiz.

Three of the students in the intervention group had been part of the initial pilot study conducted in the previous year in their primary school. These three students spent 30 minutes with the experimenter creating a script to inform the rest of their class about SAFMEDS and the benefits they had using SAFMEDS in their primary school. The students then provided step by step instructions on how to use SAFMEDS and provided a demonstration. The students were then given a practice session to ensure they were all completing the procedure correctly.

Fluency aims were given weekly to students in the intervention group at the start of each week with the exception of week one, the aims were based on the previous weeks results. The main fluency aim for this project was a frequency of > 40 cards correct and < 2 incorrect per minute.

Intervention

All students completed the sessions at the same time, the teacher or experimenter took the role of the timer. All students had to shuffle the pack at the beginning of each one minute session. The students had to read the question (in their head) and say the answer out loud (due to all students saying the answers at the same time they were told to say the answer out loud but quietly), they then turned the card over to reveal the answer, then placed the card either in the correct or not yet pile, if the students did not know the answer within seconds they were supposed to turn the card over and say the answer out loud and place in their not yet pile. After the one minute was up the teacher/experimenter would say stop; all the students then stopped that session, counted both piles of cards, and filled in the table. Students were then given two minutes to work in pairs to go over their incorrect pile (this was termed “not yet” in the intervention) pile. In each session the students completed four timings they then had to select their best score for that day and fill in the chart. The sessions were completed on a Monday, Wednesday and Friday for a four week period. The sessions took place in the last 20 minutes of the students allocated maths lessons. The teacher in the control group was given access to the quiz and students received their TAU on the topic area of percentages of money.

Post-tests

At the end of the four week school intervention, the students from both the intervention and control group were all given the post-test quiz and application quiz which was identical to the pre-tests. The same instructions were given to the students with the exception of the writing and instructions at the top of the quiz this time they were not told that they were not expected to know the questions but they were told that the questions on the quiz were on the SAFMEDS cards but were also reassured that there were 50 questions and not to worry if they could not answer all the questions but to try their best. The control group had slightly different instructions and were told that their maths lessons had been based on this quiz and were given the same reassurance.

Follow up-tests

Four weeks after the post-test students were given a follow up test identical to the pre- and post-tests to assess the student’s maintenance/retention.

Ethics and Consent

The experimenter was CRB checked before the study took place. Parental consent was gained for the students taking part in the research parents/ guardians were given an information sheet detailing the intervention. All students and parents were told they had the right to withdraw at any point during the SAFMEDS sessions and also had the right to withdraw their data. Assent was monitored during the intervention. All data will be kept in a locked cabinet which only the experimenter has access to and all names have been allocated a number to protect the students’ identity. Confidentiality was also assured.

Results

The overall results show that with the integration of SAFMEDS into students' maths lessons had a significant improvement on the number of correct maths sums and showed significant improvements when compared to the control group, suggesting that with the addition of SAFMEDS cards incorporated into students maths lessons can have a significant positive impact on student learning compared to TAU. Due to the inclusion criteria 12 students were removed from the final analysis as a result of incompletion of data due to student absence.

Pre- Post- Follow up-test

Figure 1 shows the pre- post- and one-month follow up mean test scores for the experimental and control group. There was not a significant difference at pre-test $t(33) = -1.881$ $p = .790$ between the control and intervention group. An ANOVA was run to analyse the data. The results show a main effect of time $F(2, 66) = 105.420$ $p<.001$ $\eta_p^2=.76$ a significant time * group interaction $F(2, 66) = 4.438$ $p<.001$ $\eta_p^2=.55$ and a significant main effect of group $F(1, 33) = 16.552$ $p<.001$ $\eta_p^2=.33$. The pair wise comparisons show significant main effect at time between pre- and post-test ($p<.001$) and pre- and follow-up-test ($p<.001$), but no significant difference between post- and follow-up-test ($p=.119$) which is the expected results as it shows that the students' maintained the knowledge learnt in the one month follow-up-test. The results suggest that with the addition of SAFMEDS incorporated into maths lessons have a significant effect on learning compared to TAU.

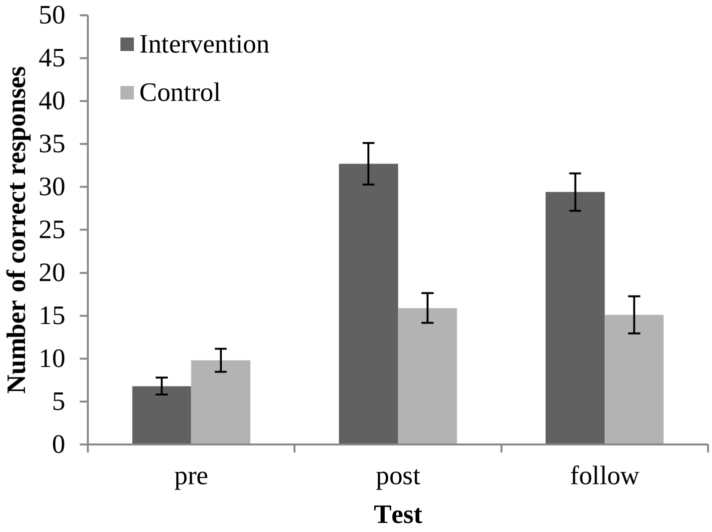

Figure 1. Mean pre- post- and one-month follow up-tests for both the control and intervention group.

Figure two shows the improvements scores for the experimental and control group. Improvement scores were calculated by taking the post-test score away from the pre-test score for each student. Scores below zero show a decrease in test scores, scores at zero show students maintained the scores from pre-test and any scores above zero show an improvement in the maths test. All students in the experimental group showed an increase in scores from pre- to post-test and all the students met the RCI, whereas the control group show a decrease and maintenance scores with only half of the students showing an increase from pre- to post-test and only 5 students' met the RCI.

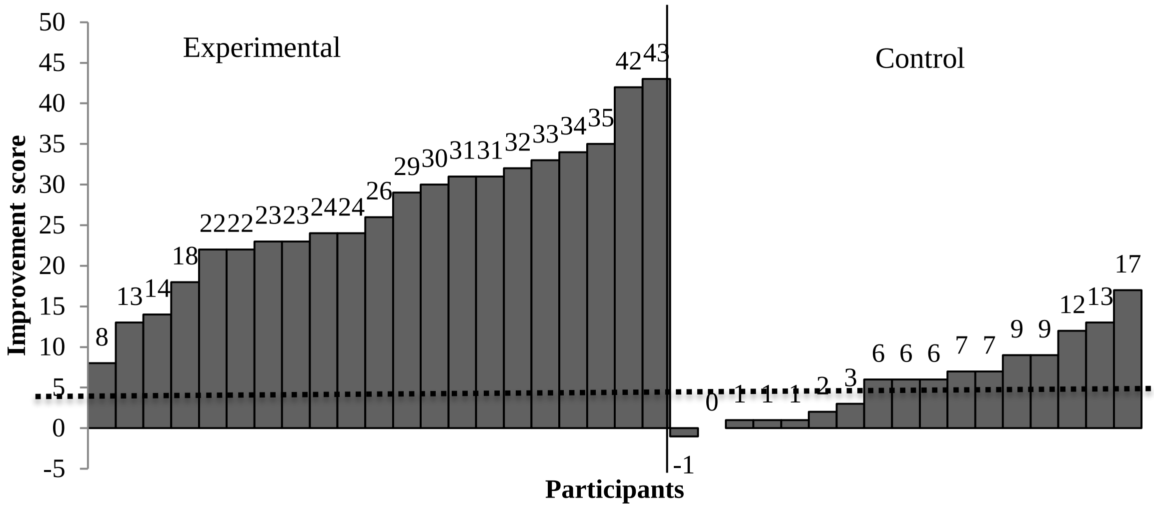

Figure 2. Individuals pre- post- improvement score (RCI was 7.49.)

Fluency

Figure 3 shows the pre- post- and one-month follow up mean test scores for the experimental and control group. There was not a significant difference at pre-test $t(33) = .178$ $p = .11$ between the control and intervention group. An ANOVA was run to analyse the data. The results show a main effect of time $F(2, 66) = 42.601$ $p<.001$ $\eta_p^2 = .56$ a significant time * group interaction $F(2, 66) = 17.291$ $p<.001$ $\eta_p^2 = .34$ and a significant main effect of group $F(2, 33) = 9.713$ $p=.004$ $\eta_p^2 = .23$. The pair wise comparisons show significant main effect of time between pre- and post-test ($p<.001$) showing that the students became more fluent and pre- and follow-up-test ($p<.001$), but no significant difference between post- and follow-up-test (p=.077) which is the expected results as it shows that the students' maintained the fluency level in the one month follow-up-test. The results suggest that not only do the students in the intervention group score significantly higher but are also more fluent.

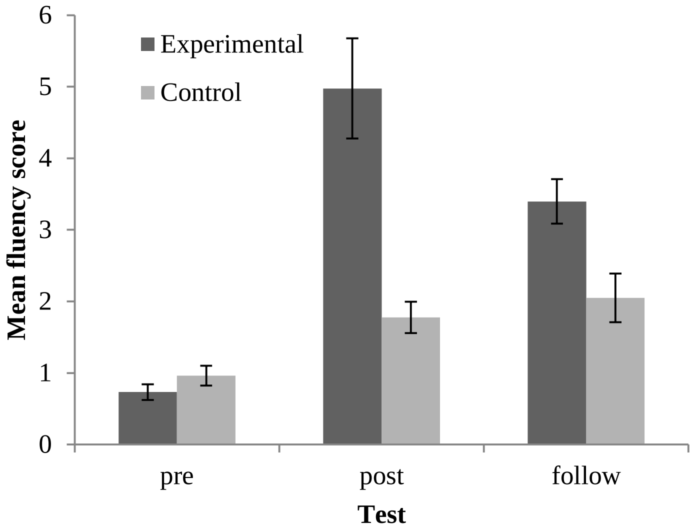

Figure 3. Mean fluency pre- post and one month follow up-tests for both the control and intervention group.

Application test

Figure 4 shows the pre- post- and follow up mean application test results for both the intervention and control group. The results show a main effect of time $F(2, 66) = 22.559$ $p<.001$ $\eta_p^2 = .41$ a significant interaction $F(2, 66) = 5.754$ $p=.005$ $\eta_p^2 = .15$ but there was not a significant main effect of group $F(1, 33) = .002$ $p=.961$ $\eta_p^2 = .00$. The pair wise comparisons show significant main effect at time between pre- and post-test ($p=.001$), pre- and follow-up-test ($p<.001$), and post- and follow-up-test ($p=.006$). It is not expected that a significant difference should be seen between the post- and follow-up-test as maintenance is expected in the follow-up, however, the students showed further increase in the follow-up-test.

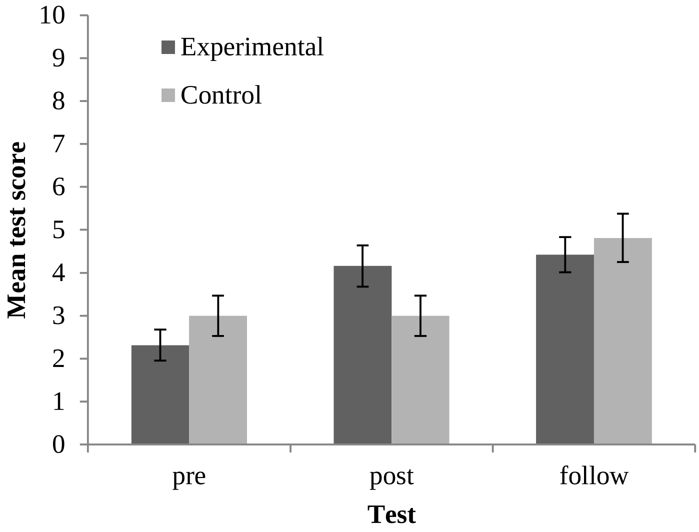

Figure 4. Mean application pre- post and one month follow up-tests for both the control and intervention group.

Fluency

Figure 5 shows the pre- post- and follow up mean application test results for both the intervention and control group. The results show a main effect of time $F(2, 66) = 18.653$ $p<.001$ $\eta_p^2=.36$ but there was not a significant interaction $F(2, 66) = .075$ $p=.075$ $\eta_p^2=.08$ or a significant main effect of group $F(1, 33) = .136$ $p=.715$ $\eta_p^2=.00$. The pair wise comparisons show significant main effect at time between pre- and post-test ($p<.001$), pre- and follow-up-test ($p<.001$), and post- and follow-up-test ($p=.010$). It is not expected that a significant difference should be seen between the post- and follow-up-test as maintenance is expected in the follow-up, however, the students showed further increase in their fluency scores at the follow-up-test.

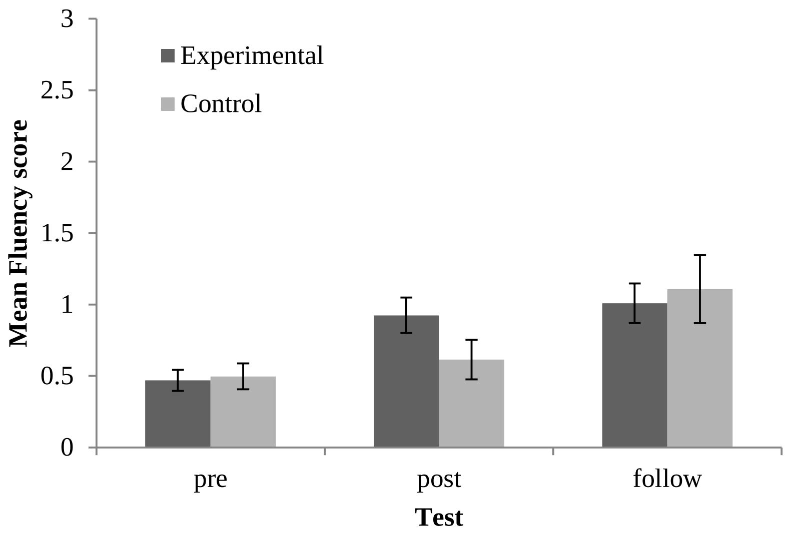

Figure 5. Mean fluency application pre- post and one month follow up-tests for both the control and intervention group.

Conclusion and future directions

The overall results of this study demonstrated clear gains for the students who had the addition of SAFMEDS into their maths lesson, showing significant gains in the number of correct maths sums pre- to post-test. Not only was there a significant increase in the number of correct maths sums in the SAFMEDS group, the results also showed that when compared to the control group (TAU) superior gains in the number of correct maths sum were evident. The application results demonstrate similar findings, showing that although both groups show an increase pre- to post-test, the experimental group show significantly higher gains in the number of correct responses. However, the maintenance results were not as expected, the control group showed an increase from the post-test to the one month follow up test. The experimental group although still scoring significantly higher when compared to the pre-test, showed a reduction in scores from post-test to follow-up test. One reason for this could be due to the timing, students were preparing for their exams and the control group had recapped their lesson on percentages in preparation for the exam. This study hypothesised that the findings from Chapter 4 could be replicated to High School. The results clearly support this hypothesis, showing that with the addition of SAFMEDS into schools maths lesson students could recall more maths equations. It is important to note that although the intervention group had the addition of SAFMEDS into their maths lessons, they did not receive any longer learning maths than their peers in the control group. The benefits of integrating SAFMEDS into students' maths lessons are clear, providing students with an engaging activity which increases their skills. Although only anecdotal evidence, students in the intervention group seemed a lot happier taking the tests than the control group suggesting that they felt more confident in answering the questions. Students in the intervention group also showed enjoyment during the SAFMEDS sessions, when asked if they would like to continue using SAFMEDS the majority of the class said they would. If students are enjoying what they are learning that is half the battle, providing further support that SAFMEDS increase engagement, therefore increasing students intrinsic motivation (Deci & Ryan, 1987).

The findings from this study provide further evidence to support the use of SAFMEDS to learn basic maths skills and the benefits of PT techniques in an education setting (Chapman, Ewing, & Mozzoni, 2005; Chiesa & Robertson, 2000; Hughes, Beverley, & Whitehead, 2007), and provides additional evidence to further support the use of SAFMEDS on a class-wide basis (Chapter 5). The results of the fluency highlights further the need to not only measure accuracy but fluency as well, by providing the timing element in this study suggests that it can aid students learning and increase fluency leading to the mastery of skills (Binder, 1996). This study also provides further support for students to verbalise the answer instead of the traditional learning in silence (Meara, 1996).

Although the current paper and previous findings from Chapter 5 showed that SAFMEDS can be used for a range of maths topics and for a range of ages, further research needs to be conducted in other subject areas. Chapter 4 showed the effectiveness of using SAFMEDS on a class-wide basis in a summer technology camp increasing students' technical terminology, but more needs to be done to really integrate PT techniques into the educations system. Further training needs to be provided to more schools in the use of PT and SAFMEDS and resources need to be made available to schools for a wide range of topics. Although this paper has shown that SAFMEDS can be successful implemented in a high school this study only looked at students in year 7 students on a small scale. To further support these findings of the effectiveness of using SAFMEDS to aid learning this procedure needs to be introduced on a school wide basis in High School.

Quote from Ffion Jones Year 7 Maths teacher *"SAFMEDS was introduced to my class as a resource to enhance the teaching/learning of calculating percentages of amounts. The pupils instantly engaged with the activity and enjoyed using the cards and testing their own achievements. Stacey came in for 25 mins 3 times a week and was well organised taking no more time than was essential. Pupils were actively involved in tracking their own progress and could clearly see their own improvement over the sessions. Pupils were very keen to participate and enjoyed using them. SAFMEDS is a teacher and pupil friendly resource that could be adapted to any topic or question."* Ffion Jones also noted that students were performing better than expected in their homework based on percentages.

Chapter 8: Discussion of Thesis

Chapter Analysis

The main aim of this thesis was to examine effective strategies for increasing students STEM skills and to assess student's motivation for STEM. Initially the thesis focused on evaluating current STEM workshops and the use of 3D technology in schools. However, the main focus of the thesis was increasing STEM skills with the use of precision teaching techniques (SAFMEDS – fluency building and repeated practice).

Chapter 2 evaluated the effectiveness of 10 local workshops to increase STEM skills in students. Two questionnaires were utilised in this study, one that assessed students pre-post intrinsic and extrinsic motivation, perceived ease, perception and real world application of the STEM topic that the workshop was based on. The second questionnaire was given only at the end of the workshop to assess students' value/usefulness of the workshop, perceived choice during the workshop and interest/enjoyment of the workshop. It can be suggested that effective workshops incorporate, hands on leaning, real life context and relevance, opportunities for collaborative work and increasing confidence in STEM fields. It seems that the main influencing factor of students attending workshops was increasing real world application of STEM.

Chapter 3 evaluated the use of SAFMEDS to increase technology terminology in three Techno camps workshops (internet boot camp, robotics and wearable technology.) The results showed that when SAFMEDS are incorporated into the workshop students showed better knowledge of the technical terms delivered in the workshop compared to the workshops that did not incorporate the SAFMEDS. The results of this study provided new evidence into the use of SAFMEDS in a class-wide setting.

Chapter 4 used the same method as Chapter 4, using SAFMEDS on a class-wide scale, however this study focused on increasing maths skills, across multiple topics, in primary school students. 272 primary schools students took part in the study. The results of the study are relatively conclusive suggesting that maths lessons that incorporate SAFMEDS into their practice result in greater gains for students than TAU. The results also conclude that the findings were not due to the novelty of introducing the new style of learning.

Chapter 5 evaluated the effectiveness of using SAFMEDS with students with maths difficulties in class-wide inclusion to improve their maths skills. This study consisted of 2 students who were highlighted as having maths difficulties. The students worked alongside their class with SAFMEDS cards more suited to their ability. The results of this study showed that students with maths difficulties can show academic gains in a class-wide setting with the addition of SAFMEDS. Providing further evidence into the use of SAFMEDS to increase basic maths skills with students with learning difficulties in a main stream busy classroom instead of a one-to-one learning environment, which is normally used for students with additional learning needs. Research has shown the benefits and gains students can make in a one-to-one learning environment (Casey, McLaughlin, Weber & Everson, 2003; Cunningham, McLaughlin & Weber, 2012; Hughes, Beverley & Whitehead, 2007), however, this study shows that if schools do not have the resources to provide one-to-one support, this procedure allows students to improve basic maths skills and also remain in a class-wide setting, which is important for inclusion.

Chapter 6 evaluated the use of SAFMEDS as a new homework style to increase students' maths skills and parental involvement. The same cohort from chapter 5, were used in this study, ensuring that the students were fully trained in completing SAFMEDS. Although the new homework style of SAFMEDS provided a solution to many reasons why students do not complete homework, such as limited time, it was evident from this multiple study paper that incentives are required to ensure the completion and return of homework. This chapter provided further evidence into the importance of equipping parents to be able to support their child academically (Domina, 2005; Fan, 2000; Simon, 2001). Anecdotal evidence from speaking with the parents at the workshop and awards ceremony highlighted and provided further evidence that one of the main reasons parents were not involved in their childs education is their own personal experience of school and their lack of ability in STEM topics (Bynner & Parsons, 2006; Farrell, & O'Connor, 2003)

Chapter 7 evaluated the use of SAFMEDS in high school to increase students' maths skills. This study aimed to further extend the findings from paper 4 showing that SAFMEDS work on a class-wide basis in an older population to increase maths skills. The overall finding of the study showed that SAFMEDS used on a class-wide basis in high school can result in higher gains in the rate of response in the maths topic than TAU. Although utilising a small sample, the results of this study provide promising results for incorporating SAFMEDS into high school maths lessons.

Broad Overview

For the growth of the UK's economy it is vital that we prepare children for the future. Ensuring students have STEM qualification is important in this process, therefore ensuring students learning environment is the best it possibly can be, should be of the up most importance. Therefore, we need to provide evidence based approaches to ensure every child reaches their full potential, which was the aim of this thesis. This research was conducted in the real world providing real world evidence in students' classrooms. Conducting research in real world settings such as schools provided the researcher with the opportunity to train and equip staff in providing effective learning environments for each child. Daily data collection provides teachers with evidence on whether or not the teaching environment is effective for each individual child. If a child is not progressing at the pace that is expected, than further interventions can be put in place quickly ensuring the child does not fall too far behind the rest of their peers. The field of applied behaviour analysis (ABA) has a growing body of research on the positive effects precision teaching and SAFMEDS can have on increasing basic skills with individuals with LD (Brasch, Williams & McLaughlin, 2008; Hughes, Beverley & Whitehead, 2007; McDowell & Keenan, 2001). Therefore this thesis provided further evidence on the effectiveness of using ABA in main stream education working with typically developing children and children with additional needs, on a class-wide basis.

This research was conducted in real life settings showing the effectiveness of the interventions in the real world. Chapter 4, 5 and 7 were all conducted in school settings showing the effectiveness of the research in a real world education setting. Chapters 3, 4, 5, 6 and 7 all used similar methodology (using SAFMEDS to increase basic skills). Chapter 3 showed the effects of using SAFMEDS to increase technical terminology and showed the same results across three different boot camps highlighting the effectiveness of the methodology, by showing generalizability and stability of this procedure. To further support these findings chapters 4-7 showed the effectiveness of using the same procedure in another topic area, maths. The overall findings from these chapters showed similar results showing that the students who received SAFMEDS significantly increased their maths skills and in some of the studies showed significant gains when compared to a TAU group. The results were generalizable across different ages 6-18 and different topics in maths (division, multiplication, time, adding, subtraction and so on) and technology (internet, robotics, wearable technology), and across settings (workshops, classrooms, home). Multiple pedagogic staff members were trained with ease in using SAFMEDS to teach basic skills to students highlighting the efficacy of the program. The program was easily implemented into the class-setting and was a cost effective program.

Methodological Limitations of the Research

Although there are many benefits to applied/real world research, there are limitations such as not being able to control and manipulate variables. However, this research showed the same results in multiple settings, individuals and topics.

Chapter 2 had the limitation of a small sample size. Both studies were conducted with the same sample reducing the generalizability of the results. Although two topics were used in this study they assessed two different research questions (2D v 3D and 3D v TAU). To further generalise the findings other year groups and classes need to be assessed.

Chapter 3 had the limitation in the design method of using questionnaires. Self-reported questionnaires have the limitation of relying on the individual to answer the questions accurately and honestly. Questionnaires can also be open to interpretation, the age of the students although developed to be age appropriate some students may have misunderstood questions (however, the researcher had explained some questions that I felt may have been misunderstood and provided support when needed). Some of the workshops analysed also had a small sample size, making it difficult to generalise the findings, however combining all of the workshops showed similar findings.

Chapter 4 had the limitation of one of the workshops being a small sample and no control group to compare findings to, however the other two workshops had a large sample size and a comparative control group.

Chapter 5 had the limitation of only using two local schools, to further support and generalise the findings this procedure needs to be rolled out in numerous of schools. Maths was also the only topic area of focus, although chapter 4 showed the procedure was effective for increasing technology terminology, the procedure may or may not be generalizable to other topics such as science, geography, history etc. Another limitation is that the sample was restricted to only primary school; however chapter 6 overcame this limitation to an extent by extending the procedure and findings to a high school population.

Chapter 6 had the limitation of only 2 students with maths difficulties using SAFMEDS on a class-wide basis, therefore it is difficult to generalise the findings. There was no control group either to compare the findings to.

Chapter 7 had the limitation of using a small sample and only extending the findings of using SAFMEDS in a high school population to the first year group (year 7). This study also only looked at one topic area of maths (percentages). However various topics were assessed in chapter 5, which showed similar results across several maths topics.

Chapter 8 had the limitation of not comparing the style of homework to the “normal” style of homework (just anecdotal evidence from the teachers that students were not completing homework). The findings also may not be generalizable as only two local primary schools were utilised.

Overall another limitation of the study were that the pre-post-tests were not standardised, they were created by the researcher based on each topic, also the questions were not randomised and given in the same order at each stage. Arguably the students were also taught to the test, the SAFMEDS were identical to the questions on the test, however the teachers in the control school were also given the test to base their lesson on.

Future Directions

This research has clearly shown the effectiveness of using SAFMEDS to increase maths skills in primary school students. Further research could focus on older students to assess if similar findings can be found; the pilot study in chapter 7 suggests that this will be the case. It is evident that this procedure works for increasing maths skills and technology terminology but how effective is it in other subject areas? Previous research has shown the use of SAFMEDS to increase psychology terminology, statistics, reading and learning new languages, however, there is little to no research showing the effectiveness of using this procedure with other topics such as science or history (REF). Future research therefore could extend the findings to multiple topic areas, to assess if the procedure can be generalised to other topics. Future research could also look at generalising the findings further to see if questions on the same topic but a different sum could gain the same results as teaching to the test. Teaching as Usual was utilised in this thesis but other treatment methods such as "see say write", could have been used to assess how effective SAFMEDS are compared to other teaching styles.

SAFMEDS packs could be made available to schools to ensure they have the resources to complete the procedure in school. Training is essential for the sustainability of using SAFMEDS in an education setting. An important step forward would be introducing precision teaching principles into the teaching training, embedding these principles into new teachers at the beginning.

Overall the aim of these studies was to evaluate a focused intervention on specific skills. To our knowledge we have not found class-wide and school-wide demonstrations of this low-tech approach. We have demonstrated the effectiveness with a specific focused intervention with a set of specific curriculum areas. The extent to which this would achieve the same outcomes in other curriculum areas is a matter for future research. However we did see similar effects across all curriculum areas we focused on in maths and technology. Because of this focused curriculum strategy, it is unlikely, in our opinion, that our results would impact standardised tests of ability in these areas because the scope of those tests is typically larger than what we focused on here. That said, future research should aim to expand the use of these methods to multiple areas in a curriculum and include in the data pre- and post-tests scored on recognised standardised tests.

Conclusions

This thesis provides clear support for the use of SAFMEDS and applying precision teaching techniques into education. It is evident from the research that students are not performing to an adequate standard in STEM subjects, therefore by incorporating SAFMEDS into STEM lessons, can have a positive impact on students learning. It is critical for continuous monitoring of learning to ensure students do not fall so far behind their peers that it is virtually impossible for them to catch up and effects their adulthood. Overall, this thesis provides evidence into the effectiveness of using SAFMEDS in mainstream education on a class-wide basis. I have secured further funding to continue this research, and aim to train local teachers in the use of precision teaching techniques, and deliver SAFMEDS for the entire curriculum of maths. By ensuring teachers are adequately trained in the delivery of precision teaching will provide a more scientific approach to learning. Therefore it is expected that the students who have the addition of SAFMEDS across the whole maths curriculum will see improvements in the annual tests.

References

Aaron, S., & Skakun, E. (1999). Correlation of students' characteristics with their learning styles as they begin medical-school. *Academic Medicine, 74,* 260–262.

Aharony, N. (2010). The use of deep and surface learning strategies among students learning English as a foreign language in an Internet environment. *British Journal of Educational Psychology, 76,* 851-867.

Ames, C. (1993) Parent involvement: The relationship between school-to home communication and parents' perception and beliefs (Rep. No. 15.) *Lansing: Michigan State University, Center on Families, communities, schools and children's learning.*

Ashby, F. G., Queller, S., & Berretty, P. T. (1999). On the dominance of unidimensional rules in unsupervised categorization. *Perception & Psychophysics, 61,* 1178–1199.

Atkinson, R. C. (1972). Optimizing the learning of a second-language vocabulary. Journal of Experimental Psychology, 96(1), 124–129.

Baguley, T. (2012). Can we be confident with our statistics? *The Psychologist, 25,* 128-129. doi: 10.3758/s13428-011-0123-7

Bandura, A., Barbaranelli, C., Caprara, G. V., & Pastorelli, C. (2001). Self-efficacy beliefs as shapers of children's aspirations and career trajectories. *Child Development*, 72, 187-206.

Barber, M., & Mourshed, M. (2007). *How the world's best-performing school systems come out on top*: McKinsey & Company.

Barrett, B. H., Beck, R., Binder, C., Cook, D. A., Engelmann, S., Greer, R. D., Watkins, C. L. (1991). The right to effective education. *The Behavior Analyst, 14,* 79-82.

Bennett, S., & Kalish, N. (2006). *The case against homework: How homework is hurting our children and what we can do about it*. New York: Crown.

Beverley, M., Hughes, C., & Hastings, R. (2012). Using flashcards to assist language learners to acquire second language vocabulary. Unpublished manuscript.

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education, 32,* 347–364.

Binder, C. (1994). Measurably superior instructional methods: Do we need sales and marketing? In R. Gardner III, D. M. Sainato, J. O. Cooper, T. E. Heron, W. L. Heward, J. W. Eshleman, & T. A. Grossi (Eds.), *Behavior analysis in education: Focus on measurably superior instruction* (pp. 21-41). Pacific Grove, CA: Brooks/Cole.

Binder, C. (1996). Behavioral fluency: Evolution of a new paradigm. *The Behavior Analyst, 19,* 163-197.

Binder, C., Haughton, E., & Van Eyk, D. (1990). Increasing endurance by building fluency: Precision teaching attention span. *Teaching Exceptional Children, 22*(3), 24-27.

Binder, C., & Watkins, C. L. (1990). Precision teaching and direct instruction: Measurably superior instructional technology in schools. *Performance Improvement Quarterly, 3*(4), 74-96.

Black, S. (1996). The truth about homework. *American School Board Journal, 183(10),* 48-51.

Blanch, S., Duran, D., Flores, M., & Valdebenito, V. (2012). The effects of a peer tutoring programme to improve the reading comprehension competence involving primary students at school and their families at home. *Procedia-Social and Behavioral Sciences, 46*, 1684-1688.

Boaler, J. (2002). Experiencing school mathematics. Revised and expanded edition. Traditional and reform approaches to teaching and their impact on student learning. Lawrence Erlbaum Associates, Inc.

Bower, B., & Orgel, R. (1981). To err is divine. Journal of Precision Teaching, 2(1), 3-12.

Bransford, J. D., Brown, A. L., and Cocking, R. (2000). *How People Learn*, National Academy Press,Washington, DC

Bransford, J.D., Vye, N., Kinzer, C., & Risko, V. (1990). Teaching thinking and content knowledge: Toward an integrated approach. In B.F. Jones & L. Idol (Eds.), *Dimensions of Thinking and Cognitive Instruction* (pp. 381-413). Hillsdale, NJ: Lawrence Erlbaum Associates.

Brasch, T. L., Williams, R . L., & McLaughlin, T. F. (2008). The effects of a direct instruction flashcard system on multiplication fact mastery by two high school students with ADHD and ODD. *Child & Family Behaviour Therapy, 30,* 51-59.

Brookhart, S. M., Andolina, M., ZuZa, M., & Furman, R. (2004). Minute math: an action research study of student self-assessment. *Educational Studies in Mathematics, 57,* 213-227.

Brown, A.L. (1997). Transforming schools into communities of thinking and learning about serious matters. *American Psychologist, 52*(4), 399-413.

Brown, M., Brown, P., & Bibby, T. (2008). “I would rather die”: Reasons given by 16-year-olds for not continuing their study of mathematics. *Research in Mathematics Education, 10*(1), 3-18.

Buckley, B. C. (2000). Interactive multimedia and model-based learning in biology. *International Journal of Science Education, 22,* 895–935.

Burns, M. K., Appleton, J. J., & Stehouwer, J. D. (2005). Meta-analysis of response-to-intervention research: Examining field-based and research-implemented models. *Journal of Psychoeducational Assessment, 23,* 381-394.

Burns, M. K., Codding, R . S., Boice, C . H., & Lukito, G. (2010). Meta-Analysis of acquisition and fluency math interventions with instructional and frustration level skills: Evidence for a skill-by-treatment interaction. *School Psychology Review, 39*, 69-83.

Burns, M. K., VanDerHeyden, A. M., & Jiban, C. (2006). Assessing the instructional level for mathematics: A comparison of methods. *School Psychology Review, 35.* 401-418.

Butler, J.A. (1987). Homework. In School Improvement Research Series (SIRS): Research you can use (Close-Up No. 1). Portland, OR: Northwest Regional Educational Laboratory. Retrieved http://www. nwrel.org/scpd/sirs/1/cu1.htm

Byars-Winston, A., Estrada, Y., & Howard, C. (2008). Increasing STEM retention for underrepresented students: Factors that matter. *Commission on professionals in Science and Technology, STEM workforce data project.* http://www.cpst.org

Bynner, J. (2002). Literacy, numeracy and employability. In Adult Literacy and Numeracy Australian Research Consortium (ALNARC) On-Line Forum funded by the ANTANational Literacy. Project by the Commonwealth through Department of Education,Science and Training (DEST): :www.staff.vu.edu.au/alnarc/onlineforum

Bynner, J & Parsons, S. (1997). Does numeracy matter? London: Basic Skills Agency.

Bynner, J & Parsons, S. (2006). New light on literacy and numeracy. Research report. National research development centre for adult literacy and numeracy. London: Institute of education.

Calkin, A. B. (2003). The Course of Precision Teaching. *European Journal of Behaviour Analysis, 4,* 87-96.

Calkin, A. B. (2005). Precision Teaching: The standard celeration chart. *European Journal of Behavior Analysis, 4*(1 &2), 1-4

Camilli, G., Vargas, S., Ryan, S., & Barnett, W. S. (2010). Meta-analysis of the effects of early education interventions on cognitive and social development. *The Teachers College Record, 112*(3).

Carlson, L. E., & Sullivan, J. F. (1999). Hands-on Engineering: Learning by doing in the integrated teaching and learning program. *Journal of engineering education, 15,* 20-31.

Casey, J., McLaughlin, T. F., Weber, K. P., Everson, M. (2003). The effects of five minute practice, unlimited practice, with SAFMED cards on correct and error rate in math facts for two elementary school children with learning disabilities. *International Journal of Special Education, 18,* 66-72.

Cates, G. L., & Rhymer, K. N. (2003). Examining the relationship between math anxiety and math performance. An instructional hierarchy perspective. *Journal of Behavioral Education, 12,* 23–34.

Cawley, J. F., Parmar, R. S., Yan, W., & Miller, J. H. (1998). Arithmetic computation performance of students with learning disabilities: Implications for curriculum. *Learning Disabilities Research & Practice, 13(2),* 68–74.

Chapman, S. S., Ewing, C. B., & Mozzoni, M. P. (2005). Precision teaching and fluency training across cognitive, physical and academic tasks in children with traumatic brain injury: A multiple baseline study. *Behavioural intervention, 20*, 37-49.

Chowdry, H., Crawford, C., Dearden, L., Joyce, R., Sibieta, L., Sylvia, K., Washbrook, E., Goodman, A., Gregg, P. (2010). Poorer children's educational attainment: how important are attitudes and behaviour?. http://www.jrf.org.uk/system/files/poorer-children-education-full.pdf

Chiesa, M., & Robertson, A. (2000) Precision teaching and fluency training: making maths easier for pupils and teachers. *Educational psychology in practice, 16,* 297-310.

Codding, R. S., Archer, J., & Connell, J. (2010). A systematic replication and extension of using incremental rehearsal to improve multiplication skills: An investigation of generalization. *Journal of Behavioural Education, 19*, 93-105.

Cole, N. (1990). Conceptions of educational achievement. *Educational Researcher*, *19*(3), 2-7.

Connor, J., & Neal, D. (2005). *Everyday learning about maths*. Canberra, ACT: ECA.

Cooper, J. O (2000). Tutoring Joe: winning the precision teaching team. In W. L. Hewars (Ed.), Exceptional children: An introduction to special education (6th ed., pp. 268 - 270). Upper Saddle River, NJ: Merrill.

Cooper, S. C., & Miller, G. R. (1996) "A Suite of Computer-Based Tools for Teaching Mechanics of Materials," *Computer Applications in Engineering Education*, 41-49.

Cooper, H., Robinson, J. C., & Patall, E. A. (2006). Does homework improve academic achievement? A synthesis of research, 1987–2003. *Review of Educational Research*, *76*(1), 1–62.

Corno, L. (1996). Homework is a complicated thing. *Educational Researcher, 25(8),* 27-30.

Cordova, D. I. & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: beneficial effects of contextualization, personalization, and choice. *Journal of Educational Psychology*, *88*, 4, 715–730.

Cunningham, D., McLaughlin, T. F., & Weber, K. P. (2012). The use and evaluation of verbal prompting with see to say problems and answers and SAFMEDS to teach math facts to a student with learning disabilities. *Internation Journal of Advances in Psychology*, *1,* 37-39.

Currie, J., & Thomas, D. (2001). Early test scores, school quality and SES: Longrun effects on wage and employment outcomes. *Worker wellbeing in a changing labor market, 20,* 103-132.

Daly, E. J., Martens, B. K., Barnett, D., Witt, J. C., & Olson, S. C. (2007). Varying intervention delivery in response to intervention: Confronting and resolving challenges with measurement instruction and intensity. *School Psychology Review, 36,* 562–581.

Daniels, H. (1996). An Introduction to Vygotsky. London: Routledge.

Darling-Hammond, L. (2007). The Flat Earth and Education: How America's Committment to Equity will Determine Our Future. *Educational Researcher, 36*(6), 318-334.

Davey, S. M., Brennan, M., Meenan, B. J., & McAdam, R. (2011). Innovation in the medical device sector: an open business model approach for high-tech small firms. *Technology Analysis & Strategic Management*, *23*(8), 807-824.

Davis, A. (1998). Monograph of educational assessments. *Journal of Philosophy of Education, 32,* 1-152.

Deci, E. L., & Ryan, R. M. (1987). The support of autonomy and the control of behaviour. *Journal of Personality and Social Psychology, 53,* 1024-1037.

Deci, E. L., & Ryan, R. M. (1994). Promoting self-determined education. *Scandinavian Journal of Educational Research*, *38*(1), 3-14.

Dewey, J. (1966). Democracy and Education. New York: Free Press.

Dillenbourg P. (1999) What do you mean by collaborative learning?. In P. Dillenbourg (Ed) *Collaborative-learning: Cognitive and Computational Approaches*. (pp.1-19). Oxford: Elsevier.

Domina, T. (2005). Levelling the Home Advantage: Assessing the Effectiveness of Parental Involvement in Elementary School. *Sociology of Education, 78(3),* 233-233.

Doughty, S. S., Chase, P. N., & O'Shields, E. M. (2004). Effects of rate building on fluent performance: A review and commentary. *The Behavior Analyst, 27,* 7-23.

Dowker, A. (2005) Early identification and intervention for students with Mathematics Difficulties. *Journal of Learning Disabilities, 38,* 324-332 DOI: 10.1177/00222194050380040801

Downing, R. A., Crosby, F. J., Blake-Beard, S. (2005). The perceived importance of developmental relationships on women undergraduate "Pursuit of Science". *Psychology of Women Quarterly, 4,* 419-426. DOI 10.1111/j.1471-6402.2005.00242.x

Duan, M. (2009). Businesses untangle the Gen Y knot. Business Journal Retrieved from: http://www.bizjournals.com/sanjose/stories/2009/08/03/focus1.html?page=all

Duffy, T. & Cunningham, D. (1996). Constructivism: Implications for the Design and Delivery of Instruction. In D. Jonassen (Ed.), *Handbook of research on educational communications and technology*. New York: Simon & Schuster.

Dunleavy, J. & Milton, P. (2009). *What did you do in school today? Exploring the concept of Student Engagement and its implications for Teaching and Learning in Canada.* Toronto: Canadian Education Association (CEA), 1-22.

Education and skills survey (2014). Gateway to Growth. CBI/ Pearson. Retrieved from http://www.cbi.org.uk/media/2809181/embargo_00.01_4_july_cbi_pearson_education_and_skills_survey_2014.pdf

Elder, G. H. (1995). Life trajectories in changing societies. In A. Bandura (Ed.). Self-efficacy in changing societies (pp. 46-68) New York: Cambridge University press.

Elsevier Health Sciences (2006). Understanding Food Nutrition Labels Challenging For Many People. Science Daily. Retrieved January 15, 2014, from http://www.sciencedaily.com- /releases/2006/09/060926072110.htm

Entwistle, N. J. (1977). Strategies of learning and studying: Recent research findings. *British Journal of Educational Studies, 25*, 225–237.

Epstein, J. L. (1991). Effects of teacher practices of parent involvement on student achievement in reading and math, in S Silvern (Ed.), Literacy through family, community and school interaction pp. 261-279. Greenwich, CT: JAI.

Epstein, M. L., Epstein, B. B., & Brosvic, G. M. (2001). Immediate feedback during academic testing. *Psychological Reports, 88*, 889-894.

Erbey, R., McLaughlin, T. F., Derby, K.M., & Everson, M. (2011). The effects of using flashcards with reading racetrack to teach letter sounds, sight words, and math facts to elementary students with learning disabilities. *International Electronic Journal of Elementary Education, 3,* 213-226. http://www.iejee.com/3_3_2011/3_3_213_226.pdf

Ergas, H. (2005). 3 The importance of technology policy. *Economic policy and technological performance*, 51.

Eshleman, J. E. (2000). SAFMEDS on the Web: Guidelines and Considerations for SAFMEDS. Retrieved from http://standardcelerationcharttopics.pbworks.com/SAFMEDS-on-the-Web

Etzkowitz, H., Kemelgor, C. & Uzzi, B.(2000). Athena Unbound, CUP, Cambridge

Eysink, N. Y. S., Dijkstra, S., & Kuper, J. (2001). Cognitive processes in solving variants of computer-based problems used in logic teaching. *Computers in Human Behavior, 17,* 1–19.

Fan, X.T., & Chen, M. (2001). Parental involvement and students' academic achievement: A meta-analysis. *Educational Psychology Review, 13,* 1-22.

Farrell, C., & O'Connor, W. (2003). Low income families and household spending, DWP research report series No. 192.

Field, A. (2009). *Discovering statistics using SPSS* (3rd ed.). London: Sage Publications Limited.

Fishel, M., & Ramirez, L. (2005). Evidence based parent involvement interventions with school aged children. *School Psychology Quarterly, 20,* 371-402.

Fitzgerald, M., & Riva, G. (2001) Virtual Reality, in Telemedicine Glossary, L. Beolchi, Ed.: European Commission-DG INFSO, 327-329.

Frank A. (2005). What do students value in built environment education? *CEBE Transactions, 2* (3), p. 21-29.

Frederick, L. D., & Hummel, J. H. (2004). The need for evidence-based educational methods. In D. J. Moran & R. W. Malott (Eds.), *Evidence-based educational methods* (pp. 9-22). San Diego, California: Elsevier Academic Press.

Flori, R. E. (1997). Perspectives on the Role of Educational Technologies," *Journal of Engineering Education*, 269-272.

Fuchs, L, S., Fuchs, D., Prentice, K., Burch, M., Hamlett, C, L., et al (2003). Enhancing third-grade student' mathematical problem solving with self-regulated learning strategies. *Journal of Educational Psychology, 95,* 306-315.

Fuchs, D., Mock, D., Morgan, P. L., & Young, C. L. (2003). Responsiveness-to-intervention: Definitions, evidence, and implications for the learning disabilities construct. *Learning Disabilities Research & Practice, 18,* 157-171.

Garris, R., Ahlers, R. & Driskell, J. (2002). Games, motivation and learning: a research and practice model. *Simulation & Gaming, 33*, 4, 441–467.

Gati, I., & Saka, N. (2001). High school students' career-related decision-making difficulties. *Journal of Counseling and Development*, 79(3), 331-340.

Geary, D. C., Hamson, C. O., & Hoard, M. K. (2000). Numerical and arithmetical cognition: A longitudinal study of process and concept deficits in children with learning disability. *Journal of Experimental Child Psychology, 77*, 236–263.

Geary, D. C. (2011). Cognitive predictors of achievement growth in mathematics: A five-year longitudinal study. *Development Psychology, 47*(6), 1539-1552. Doi: 10.1037/a0025510. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3210883/#R52.

Gersten, R., & Chard, D. (1999). Number sense: Rethinking arithmetic instruction for students with mathematical disabilities. *Journal of Special Education*, *33*, 18–28.

Gersten, R., Jordan, N, C., & Flojo, J, R. (2005). Early identification and interventions for students with mathematics difficulties. *Journal of Learning Disabilities, 38,* 293. DOI: 10.1177/00222194050380040301

Gickling, E., & Thompson, V. (1985). A personal view of curriculum-based assessment. *Exceptional Children, 52,* 205-218.

Glover, P., McLaughlin, T., Derby, K. M., Gower, J. (2010). Using a Direct instruction flashcard system with two students with learning disabilities. *Electronic Journal of research in educational psychology, 8,* 457 – 472.

Goldman, S. R., & Pellegrino, J. W. (1987). Information processing and elementary mathematics. *Journal of Learning Disabilities, 20,* 23-32.

Gordon, P. R., Rogers, A. M., Comfort, M., Gavula, N., & McGee, B. P. (2001). A Taste of Problem-Based Learning Increases Achievement of Urban Minority Middle-School Students. *Educational Horizons, 79*(4), 171-175.

Graf, S., & Lindsley, O. (2002). Standard Celeration Charting 2002. Youngstown, OH: Graf Implements.

Grant, L. & Evans, A. (1994). Principles of behavior analysis. New York: Harper Collins College Publishers.

Gravetter, F. J., & Wallnau, L. B. (2007). Statistics for the behavioural sciences (7th ed.). Belmont, CA: Wadsworth.

Green, L., & Myerson, J. (2004). A discounting framework for choice with delayed and probabilistic rewards. *Psychological Bulletin*, *130*(5), 769.

Greenwood, C. R., Carta, J. J., & Hall, R. V. (1988). The use of peer tutoring strategies in classroom management and educational instruction. *School Psychology Review, 17,* 258-275.

Grey, Louis D. (1991) "John Allen Paulos, Innumeracy: Mathematical Illiteracy and its Consequences," Sacred Heart University Review: Vol. 11: Iss. 1, Article 5. Available at: http://digitalcommons.sacredheart.edu/shureview/vol11/iss1/5

Grolnick, W. S., Benjet, C., Kurowski, C. O., & Apostoleris, N. H. (1997). Predictors of parent involvement in children's schooling. *Journal of Educational Psychology*, *89*(3), 538.

Gross, D., Fogg, L., & Tucker, S. (1995). The efficacy of parent training for promoting positive parent-toddler relationships. Research in Nursing & Health, 18, 486-499.

Hammond, C., Linton, D., Smink, J., & Drew, S. (2007). *Dropout risk factors and exemplary programs.* Retrieved from National Dropout Prevention Center, Communities In Schools,Inc.Website: http://www.dropoutprevention.org/resource/major_reports/communities_in_schools/Dropout%20Risk%20Factors%20and%20Exemplary%20Programs%20FINAL%205-16-07.pdf

Hannover, B., & Kessels, U. (2004). Self-to-prototype matching as a strategy for making academic choices. Why high school students do not like math and science. *Journal of Learning and Instruction 51-67.*

Harris, R., & Haydn, T. (2008). Children's ideas about school history and why they matter. *Teaching History, 132*, 10-48.

Harrison, M. (2012). Jobs and growth: the importance of engineering skills to the UK economy. *Royal Academy of Engineering*. Retrieved from www.raeng.org.uk/jobsandgrowth.

Hayter, S., Scott, E., Mclaughlin, T. F., & Weber, K. P. (2007). The use of a modifies direct instruction flashcard system with two high school students with developmental disabilities. *Journal of Developmental and Physical Disabilities, 19,* 409-415.

Hooper, S., Temiyakarn, C., & Williams, M. D. (1993). The effects of cooperative learning and learner control on high- and average-ability students. *Educational Technology Research and Development, 31 (3),* 27-40.

Hoover-Dempsy, K. V., Bassler, O.C., & Brissie, J.S. (1992). Explorations in parent-school relations. *Journal of Educational Research, 85,* 287-294.

Hornig, S., (1992), 'Gender Differences in Response to News about Science and Technology', *Science, Technology and Human Values*, 532-542.

Houchins, D. E., Shippen, M. E., & Flores, M. M.(2004). Math assessment and instruction for students at-risk. In R. Colarusso & C. O'Rourke (Eds.), *Special education for all teachers* (3rd ed.). Dubuque, IA: Kendall/Hunt Publishing.

Hughes, B. (2009). How to start a STEM team. *The Technology Teacher, 69*(2), 27-29.

Hughes, C., Beverley., & Whitehead, J. (2007). Using precision teaching to increase the fluency of word reading with problem readers. *European Journal of Behaviour Analysis, 221-238.*

IET (2008). Studying STEM: What are the Barriers – A literature review of the choices pupils make. Stevenage: IET. www.theiet.org/stem.

Ivarie, J. J. (1986). Effects of proficiency rates on later performance of a recall and writing behavior. *Remedial and Special Education*, *7*(5), 25–30.

Jacobson, N. S., & Truax, P. (1991). Clinical significance: A statistical approach to defining meaningful change in psychotherapy research. *Journal of Consulting and Clinical psychology, 59,* 12–19.

JCQ Joint councils for Qualifications (2014). A level results retrieved from http://www.jcq.org.uk/examination-results/a-levels

Jeffrey, B. & Craft, A. (2004). Teaching creatively and teaching for creativity, distinctions and relationships, *Journal of Educational Studies*, 30, 77–87.

Jensen, D.D., & Bowe, M. J. (1999). Hands-on experiences to enhance learning of design: Effectiveness in a redesign context when correlated with MBTI and VARK types. Proceedings of ASEE Annual conference, Charlotte NC.

Johnson, K. R., & Layng, T. V. J. (1992). Breaking the structuralist barrier: Literacy and numeracy with fluency. American Psychologist, 47, 1475-1490.

Johnson, K. R., & Layng, T. V. J. (1994). The Morningside Model of generative instruction. In R. Gardner III, D. M. Sainato, J. O. Cooper, T. E. Heron, W. L. Heward, J. Eshleman, & T. A. Grossi (Eds.), Behavior analysis in education: Focus on measurably superior instruction (pp. 173-197). Monterey, CA: Brooks/Cole.

Johnson, K., & Street, E. M., (2013). Response to intervention and precision teaching; creating synergy in the classroom. Guilford press. New York London.

Jolivette, K., Lingo, A. S., Houchins, D, E., Barton-Arwood, S. M. (2006). Building math fluency for students with developmental disabilities and attentional difficulties using great leaps math. *Education and Training in Developmental Disabilities, 41,* 392-400.

Jonassen, D. H. (1992). Evaluating constructivist learning. In T. M. Duffy & D. H. Jonassen (Eds.), *Constructivism and the technology of instruction,* 137–148. Hillsdale, NJ: Erlbaum Associates.

Jonassen, D. H. (1999). Designing constructivist learning environments. In C. M. Reigeluth (Ed.), *Instructional design theories and models,2,* 215–239). Mahwah, NJ: Erlbaum Associates.

Jordan, N.C., Kaplan, D., Ramineni, C., & Locuniak, M,N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology., 45,* 850–867.

Juel, C. (1988). Learning to read and write: A longitudinal study of 54 children from first through fourth grades. *Journal of Educational Psychology, 80,* 437–447.

Kaye, L, K. (2011). The methodological mayhem of experimental videogame research. *The British Psychological Society, 78*, 20-22.

Kazdin, A. E. (2010). Single-case research designs: Methods for clinical and applied settings. 2. New York, NY: Oxford University Press.

Kennelly, L. & Monrad, M. (2007). Approaches to dropout prevention: Heeding early warning signs with appropriate interventions. Washington, DC: National High School Center at the American Institutes for Research. Retrieved from http://www.betterhighschools.com/docs/NHSC_ApproachestoDropoutPrevention.pdf

Kosfeld, M., & Neckermann, S. (2011). Getting more work for nothing? Symbolic awards and worker performance. *American Economic Journal: Microeconomics*, 86-99.

Kralovec, E., & Buell, J. (2000). *The end of homework: How homework disrupts families, overburdens children, and limits learning*. Boston: Beacon.

Kubina Jr, R. M., Morrison, R., & Lee, D. L. (2002). Benefits of Adding precision teaching to behavioural intervention for students with autism. *Behavioural Interventions, 17,* 233-246.

Kuh, G. D. (2009). The national survey of student engagement: Conceptual and empirical foundations. *New Directions for Institutional Research, 2009*(141), 5-20.

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic processing in reading. *Cognitive Psychology, 6,* 293–323.

Laurillard, D. (1993). Rethinking University Teaching: A Framework for Effective Use of Technology," Routledge, New York.

Lave, J., & Wenger, E. (1991). Situated learning: Legitimate peripheral participation. Cambridge, MA: Cambridge University Press.

Leitch, S. (2006) Prosperity for all in the global economy world class skills. Final report of the Leitch Review of Skills. (London: HMSO/HM Treasury).

Lenard, W. (1997). The homework scam. Teacher Magazine, 9(1),60-61. Retrieved September 19, 2000, from the World Wide Web: http://www.edweek.org/tm/1997/01lenard.h09

Lerner, J. (2003). Learning disabilities: Theories, diagnosis, and teaching strategies (9th ed.). Boston: Houghton Mifflin.

Levin, H. M., Glass, G. V., and Meister, G. (1987) Cost-Effectiveness of Computer-Assisted Instruction. *Evaluation Review, 11,* 50–72.

Lindsley, O. R. (1964). Direct measurement and prosthesis of retarded behavior. *Journal of Education, 147,* 62-81.

Lindsley, O. R. (1990). Precision Teaching: By children for teachers. *Teaching Exceptional Children, 22*(3), 10-15.

Lindsley, O. R. (1990a). Our aims, discoveries, failures, and problem. *Journal of Precision Teaching, 7,* 7-17.

Lindsley, O. R. (1991). Precision teaching's unique legacy from B. F. Skinner. *Journal of Behavioral Education, 1,* 253-266.

Lindsley, O. R. (1992a). Precision teaching: Discoveries and effects. *Journal of Applied Behavior Analysis, 25,* 51-57.

Lindsley, O. R. (1992b). Why aren’t effective teaching tools widely adopted? *Journal of Applied Behavior Analysis, 25,* 21-26.

Lindsley, O. R. (1995). Ten products of fluency. *Journal of Precision Teaching, 13*, 2-11.

Lindsley, O. R. (1972). From Skinner to precision teaching: The child knows best. In J. B. Jordan & L. S. Robbins (Eds.), *Let's try doing something else kind of thing* (pp. 1-12), Arlington, VA: Council for Exceptional Children.

Linn, R. L., & Gronlund, N. E. (2000). *Measurement and assessment in teaching* (8eth ed.) Upper Saddle River, NJ: Merrill.

Liston, C., Peterson, K., & Ragan, V. (2008). Guide to evaluating promising practices in informal science, technology, engineering, and mathematics (STEM) education for girls. Seattle, WA: Puget Sound Center for Teaching, Learning and Technology.

Liu, M., Hsieh, P., Cho, Y. J., & Schallert, D. L. (2006). Middle School Students’ Self-efficacy, Attitudes, and Achievement in a Computer-Enhanced Problem-Based Learning Environment. *Journal of Interactive Learning Research, 17*(3), 225-242.

Lolich, E., McLaughlin, T. F., & Weber, K. P. (2012). The effects of using reading racetracks combined with direct instruction precision teaching and a token economy to improve the reading performance for a 12-year-old student with learning disabilities. *Academic Research International, 3,* 245 – 252.

Lumsden, L.S. (1994). Student motivation to learn (ERIC Digest No. 92). Eugene, OR: ERIC Clearinghouse on Educational Management. (ERIC Document Reproduction Service No. ED 370 200)

Maddox, W. T., Ashby, F. G., & Bohil, C. J. (2003). Delayed feedback effects on rule-based and information-integration category learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 650-662.

Mann, A., Massey, D., Glover., Kashefpadkel, E. T., Dawkins, J. (2013). Nothing in common: The career aspirations of young Britons mapped against projected labour market demand (2010-2020). *Education and employers taskforce.*

Martin, G. & Pear, J. (1998). Behavior modification: What it is and how to do it (6th ed.). Upper Saddle River, NJ: Prentice Hall.

Maxwell, N. L., & Rubin, V. (2000). *High school career academies: a pathway to educational reform in urban school districts?*. WE Upjohn Institute.

McClure, S. M., Ericson, K. M., Laibson, D. I., Loewenstein, G., & Cohen, J. D. (2007). Time discounting for primary rewards. *The Journal of Neuroscience*, *27*(21), 5796-5804.

McDade, C. E. (1992). Computer-based precision learning: A course builder application. *Behavior Research Methods, Instruments, & Computers, 24,* 269-272.

McDade, C. E., & Olander, C. P. (1987). Precision Management of instructional technology: A program update. *Educational Technology, 27,* 44-46.

McDowell, C., & Keenan, M. (2001). Developing fluency and endurance in a child diagnosed with attention deficit hyperactivity disorder. *Journal of Applied behaviour analysis, 34,* 345-348.

McGreevy, P. (1983). Teaching and learning in plain English. Kansas City, MO: Plain English Publications (University of Missouri).

McLellan, H. (2004). Virtual realities. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology*, 461–497. Mahwah, NJ:Lawrence Erlbaum.

McLellan, H (1996) Virtual Realities. In: Jonassen, D.H., (Ed.) Handbook ofResearch for Educational Communications and Technology, 457-490. New York: Simon and Schuster.

Meara, P. (1996). The classical research in L2 vocabulary acquisition. In G. Anderman, & M. Rogers (Eds.),Words, words, words: the translator and the language learner. Clevedon: Multilingual Matters.

Meindl, J, N., Ivy, J, W., Miller, N., Neef, N, A., & Williamson, R, L. (2013). An Examination of Stimulus Control in Fluency-Based Strategies: SAFMEDS and Generalization. *Journal of Behavioural Education,* 229-252.

Middleton E. B., & Loughead, T. A. (1993). Parental influence on career development: An integrative framework for adolescent career counselling. *Journal of Career Development, 19,* 161-173.

Miller, A.D., Hall, S. W., & Heward, W. L. (1995). Effects of sequential 1-minute time trails with and without inter-trail feedback and self-correction on general and special education students' fluency with math facts. *Journal of behavioural education, 5,* 319-345.

Millward, L., Houston, D.M., Brown, D. & Barrett, M. (2006) *Young People's Job Perceptions and Preferences*. London: DTI. www.berr.gov.uk/files/file28575.pdf

Moran, D. J., & Malott, R. W. (Eds.). (2004). *Evidence-based educational methods*. Academic Press.

Morris, M. (2006). Pupil subject choice in schools. ESRC Commissioned briefing for policy makers. Swindon: Economic and Social research council.

Morrison, J. & Bartlett, B. (2009). *STEM as a curriculum: An experimental approach*. Retrieved from http://www.lab-aids.com/docs/stem/EdWeekArticleSTEM.pdf

Muir, T. (2009). At home with numeracy: Empowering parents to be active participants in their child's numeracy development. In R. Hunter, B. Bicknell & T. Burgess (Eds.), Crossing divides. (Proceedings of the 32nd annual conference of the Mathematics Education Research Group of Australasia, pp. 395-402). Wellington, NZ: MERGA.

Mulero, J.; Segura, L.; Sepulcre, J.M. (2013). Is Maths everywhere? Our students respond. INTED 2013 Proceedings, International Association of Technology Education and Development (IATED): pp: 4287-4296.

Muller, D., Eklund, J., & Shanna, M. (2006). The future of multimedia learning. Australia: *Essential Issues for Research University of Sydney NSW.*

National Research Council. (2001). *Eager to learn: Educating our preschoolers.* Washington, DC: National Academy Press.

Nielsen, L., & Webb, W. (2011). *Teaching generation text: Using cell phones to enhance learning*. John Wiley & Sons.

Nores, M., & Barnett, W, S. (2010) Benefits of early childhood interventions across the world: (Under) Investing in the very young. National Institute for Early Education Research, Rutgers, The State University of New Jersey, 120 Albany Street, Suite 500, NewBrunswick,NJ08901,UnitedStates http://www.sciencedirect.com/science/article/pii/S027277570900106X

OECD (2003) The PISA Assessment Framework, p. 24. Download on 6/6/2012 from http://www.oecd.org/dataoecd/46/14/33694881.pdf

OECD. (2012). Programme for international student assessment (PISA). Results from PISA 2012: United Kingdom. Retrieved from http://www.oecd.org/pisa/keyfindings/PISA-2012-results-UK.pdf

OFSTED. (2000) Family learning: A survey of current practice. London: Ofsted

OFSTED (2012). Going in the right direction? Careers guidance in schools from September 2012. Retrieved from www.ofsted.gov.uk/resources/130114.

Panitz, T. (1999). Collaborative versus Cooperative Learning: A Comparison of the Two Concepts Which Will Help Us Understand the Underlying Nature of Interactive Learning.

Papert, S (1980). Mindstorms: Children, Computers and Powerful Ideas. New York: Basic Books, Inc.

Paschal, R. A., Weinstein, T., & Walberg, H. J. (1984). The effects of homework on learning: A quantitative synthesis. *Journal of Educational Research, 78,* 97–104.

Pashler, H., Cepeda, N. J., Wixted, J. T., & Rohrer, D. (2005). When does feedback facilitate learning of words? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31(1),* 3–8.

Patton, J.R. (1994). Practical recommendations for using homework with students with learning disabilities. *Journal of Learning Disabilities, 27,* 570-578

Paulu, N. (1998). Helping your students with homework: A guide for teachers. Washington, DC: U.S. Department of Education, Office of Educational Research. Retrieved http://www.ed.gov/pubs/HelpingStudents

Pelletier, R. & Normore, A. H. (2007). The predictive power of homework assignments on student achievement in mathematics. InS. M. Nielson & M. S. Plakhotnik (Eds), Proceedings of the Sixth Annual College of Education Research Conference: Urban and International Education Section Miami; Florida.

Pennypacker, H. S., Heckler, J. B., & Pennypacker, S. F. (1977). The personalized learning center: A university wide system of personalized instruction. In T. A. Brigham & A. C. Catania (Eds.), Handbook of Applied Behavioral Research (pp. 591-617). New York: Irvington Press.

Pennypacker, H. S., Koenig, C. H., & Lindsley, O. R. (1972). Handbook of the Standard Behavior Chart. Kansas City, KS: Precision Media.

Peters, M., Seeds, K., Goldsteing, A., & Coleman, N (2008). Parental involvement in Children’s education 2007. Research Report. RW004.

Pollard, E., Jagger, N., Perryman, S., Van Gent, M. & Mann, K. (2003) *Ready SET GO A Review of SET Study & Careers Choices.* Warwick: IES. http://www.etechb.co.uk/_db/_documents/ReadySETGo.pdf

Pratt, M. W., Green, D., MacVicar, J., & Bountrogianni, M. (1992). The mathematical parent: Parental scaffolding, parenting style, and learning outcomes in long-division mathematics homework. *Journal of Applied Developmental Psychology,* **13,** 17–34.

Radhakrishnan, P., Lam, D., & Ho, G. (2009). Giving University Students Incentives to Do Homework Improves Their Performance. *Journal of Instructional Psychology*, *36*(3), 219-225.

Ramey, C .T., & Ramey, S. L. (2004). Early learning and school readiness: Can early intervention make a difference? *Merrill-Palmer Quarterly, 50*, 471-491.

Regan, M., & Sheppard, S. (1996). Interactive Multimedia Courseware and the Hands-on Learning Experience: An Assessment. *Journal of Engineering Education*, 123-131.

Richardson, J. T. E. (1994). Mature students in higher education: A literature survey on approaches to studying. *Studies in Higher Education, 19*, 309–325.

Roberts, A. (2012) A justification for STEM Education. *Technology and Engineering Teachers* 1-5.

Roberts, G. (2002).SET for Success: The supply of people with science, technology, engineering and mathematical skills. London: The Stationary Office.

Roth, W, M., Bowen, G, M., & McGinn, M, K. (1999). Differences in graph-related practices between high school biology textbooks and scientific ecology journals. *Journal of Research in Science Teaching, 36,* 977-1019.

Rumberger, R. W. (1995). Dropping out of middle school: A multilevel analysis of students and schools. *American Educational Research Journal, 32,*583–625.

Rhymer, K. N., Dittmer, K. I., Skinner, C. H., & Jackson, B. (2000). Effectiveness of a multicomponents treatment for improving mathematics fluency. *School Psychology Quarterly, 15,* 40–51.

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and Extrinsic Motivationa: Classic Definitions and New Directions. *Contemporary Educational psychology, 25,* 54-67.

Ryan, R.M., & Connell, J.P. (1989). Perceived locus of causality and internalization: Examining reasons for acting in two domains. *Journal of Personality and Social Psychology, 57*, 749-761.

Sante-Delli, A., McLaughlin, T. F., & Weber, K. P. (2001). The use and evaluation of direct instruction flash card strategy on multiplication facts mastery with two students with ADHD. *Journal of Precision Teaching and Celeration, 17,* 68-75.

Schmidt, R. A., Young, D. E., Swinnen, S., & Shapiro, D. C. (1989). Summary knowledge of results for skill acquisition: support for the guidance hypothesis. *Journal of experimental psychology: Learning memory and cognition, 15,* 352-359.

Schneider, R. M., Krajcik, J., Marx, R. W., & Soloway, E. (2002). Performance of Students in Project Based Science Classrooms on a National Measure of Science Achievement.

Schooler, L. J., & Anderson , J. R. (2008). The disruptive potential of immediate feedback. Department of psychology Carnegie Mellon University research show case.

Schopman, E. A. M., & Van Luit, J. E. H. (1996). Learning and transfer of preparatory arithmetic strategies among young children with a developmental lag. *Journal of Cognitive Education, 5,* 117–131.

Shapiro, E. S. (2004). *Academic skills problems: Direct assessment and intervention* (3rd ed.). New York: Guilford Press.

Shaver, A. V., & Walls, R. T. (1998). Effect of Title I parent involvement on student reading and mathematics achievement. *Journal of Research and Development in Education, 31*(2), 90–97.

Shaw, G. B as cited in Lack, C. W., Dewan, N. A., Lorenzi, N. M., Einstein, A., & Shaw, G. B. (2010). Evaluating 11 Healthcare Informatics Impact of Behavioral. *Information Technology Essentials for Behavioral Health Clinicians*, 181.

Shumow, L. (1998). Promoting parental atonement to children's mathematical reasoning through parent education. *Journal of Applied Developmental Psychology*, *19*, 109–127.

Sidman, M. (1994). Equivalence relations and behavior: A research story. Boston: Authors Cooperative.

Siegler, R. S., & Shrager, J. (1984). Strategy choices in addition and subtraction: How do children know what to do? In C. Sophian (Ed.), Origins of cognitive skills (pp.229-293). Hillsdale, NJ: Lawerence Erlbaum.

Simon, B. S. (2001). Family involvement in high school: Predictors and effects. *NASSP Bulletin, 85 (627),* 8-19.

Skinner, B. F. (1938). The behavior of organisms. Englewood Cliffs, NJ: Prentice-Hall.

Slater, M. (1999). Measuring presence: a response to the Witmer and Singer questionnaire. *Presence*, *8*, 5, 560–566.

Smith, J. P., McArdle, J. J., & Willis, R. (2010). Financial Decision Making and Cognition in a Family Context. *The Economic Journal, 120,* 548. F363 DOI: 10.1111/j.1468-0297.2010.02394.

Starkey, P., & Klein, A. (2000). Fostering parental support for children's mathematical development: An intervention with Head Start families. *Early Education and Development, 11*(5), 659–680.

Stockwell, F., & Eshleman, J. (2010). A Case Study Using SAFMEDS to Promote Fluency with Skinner's Verbal Behaviour Terms. *Journal of Precision Teaching and Celeration, 26,* 33-40

Stokes, T. F., & Baer, D. M. (1977). An implicit technology of generalization. *Journal of Applied Behavior Analysis, 10,* 349–367.

Tai, R. T., Liu, C. Q., Maltese, A. V., & Fan, X. T. (2006). Planning early for careers in science. *Science, 312(5777),* 1143 – 1144

Tariq, V., & Durrani, N. (2009). Every student counts: Promoting numeracy and enhancing employability. *MSOR connections, 9, 7-11*.

Taylor, L. & Parsons, J. (2011). Improving Student Engagement. *Current Issues in Education,* 14(1). Retrieved from http://cie.asu.edu/

Topping, K. J. (2005). Trends in peer learning. *Educational psychology*, *25*(6), 631-645.

Trautwein, U. (2007). The homework-achievement relation reconsidered: Differentiating homework time, homework frequency, and homework effort. *Learning and Instruction,*17(3), 372-388. doi: 10.1 016/j.leaminstruc.2007.02.009

UNESCO (2010). Science Report: The current status of science around the World. *United Nations Educational, Scientific and Cultural Organization, Pariz, France.*

Van Houten, R. (1984). Setting up performance feedback systems in the classroom. In W. L. Heward, T. E. Heron, J. Trap-Porter, & D. S. Hill (Eds.), *Focus upon applied behaviour analysis in education* (pp. 114-125). Columbus, OH: Charles Merrill.

Veenman, M., & Spaans, M. (2005). Relation between intellectual and metacognitive skills: Age and task differences. *Learning and Individual Differences, 15,* 159–176.

Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.

Walberg, H, J. (1984). Families as partners in educational productivity. *Phi Delta Kappan, 65,* 397-400.

Watkins, D. A., & Hattie, J. (1980). An investigation of the internal structure of the Biggs Study Process Questionnaire. *Educational and Psychological Measurement, 40,* 1125–1130.

Welsh Government. (2014). Learning Wales, Raising Standards Together. Retrieved from http://learning.gov.wales/resources/learningpacks/reasoning-in-the-classroom/?lang=en

West, R. P., & Young, K. R. (1992). Precision teaching. In R. P. West & L. A. Hamerlynck (Eds.), Designs for excellence in education: The legacy of B. F. Skinner (pp. 113-146). Longmont, CO: Sopris West, Inc.

White, O. R. (1986). Precision teaching—Precision learning. *Exceptional Children, 52,* 522-534.

White, O. R., & Haring, N. G. (1980). Exceptional teaching (2nd Ed.). Columbus, OH: Merrill.

Whitehead, A.N. (1932). *The aims of education and other essays*. London: Ernest Benn Limited.

Wong, S. (1992). Approaches to study of distance education students. *Research in Distance Education, 4,* 11–17.

Wood, D.K., & Frank, A.R. (2000). Using memory-enhancing strategies to learn multiplication facts. *Teaching Exceptional Children* 32(5), 78–82.

Wynarczyk, P., (2008), ‘An Overview of Initiatives in Science, Technology, and Engineering Across England, Scotland and Wales’, Report commissioned by the UK Resource Centre for Women in Science, Engineering and Technology (UKRC) project Women in SET, National and Regional Activity, forthcoming.

Wynarczyk, P. & Hale, S. (2009). Improving Take Up of Science and Technology Subjects in Schools and Colleges: A Synthesis Review. London: ESRC.

Yazzie-Mintz, E. (2010). Charting the Path from Engagement to Achievement: A Report on the 2009 High School Survey of Student Engagement.

Ysseldyke, J. E. (2006). *Using continuous progress monitoring data to make accountability decision.* Paper presented at the annual meeting of the National Association of School Psychologist, Anaheim, CA.

Ysseldyke, J. E. (2008). *Frequently asked questions about response to intervention (RtI).* Wisconsin Rapids, WI: Renaissance Learning.

Ysseldyke, J. E., Thill, T., Pohl, J., & Bolt, D. (2005). Using Math Facts in a Flash to enhance Computation

Zahra, D., & Hedge, C. (2010). The Reliable Change Index: Why isn't it more popular in academic psychology? *PsyPag Quarterly, 76*, 14-19.

Zimmerman, B. J. (1995). Self-efficacy and educational development. In A. Bandura (Ed.), *Self-efficacy in changing societies* (pp. 202–231). New York: Cambridge Univ. Press.

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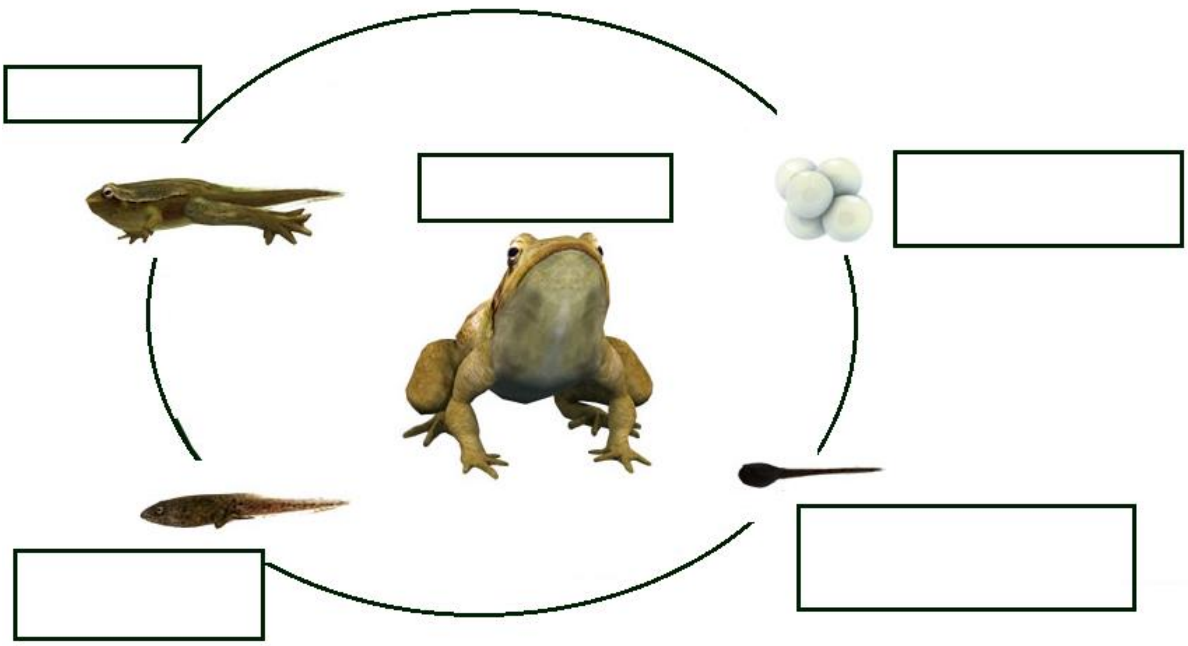
Appendix A – Pre-Post-test Frog

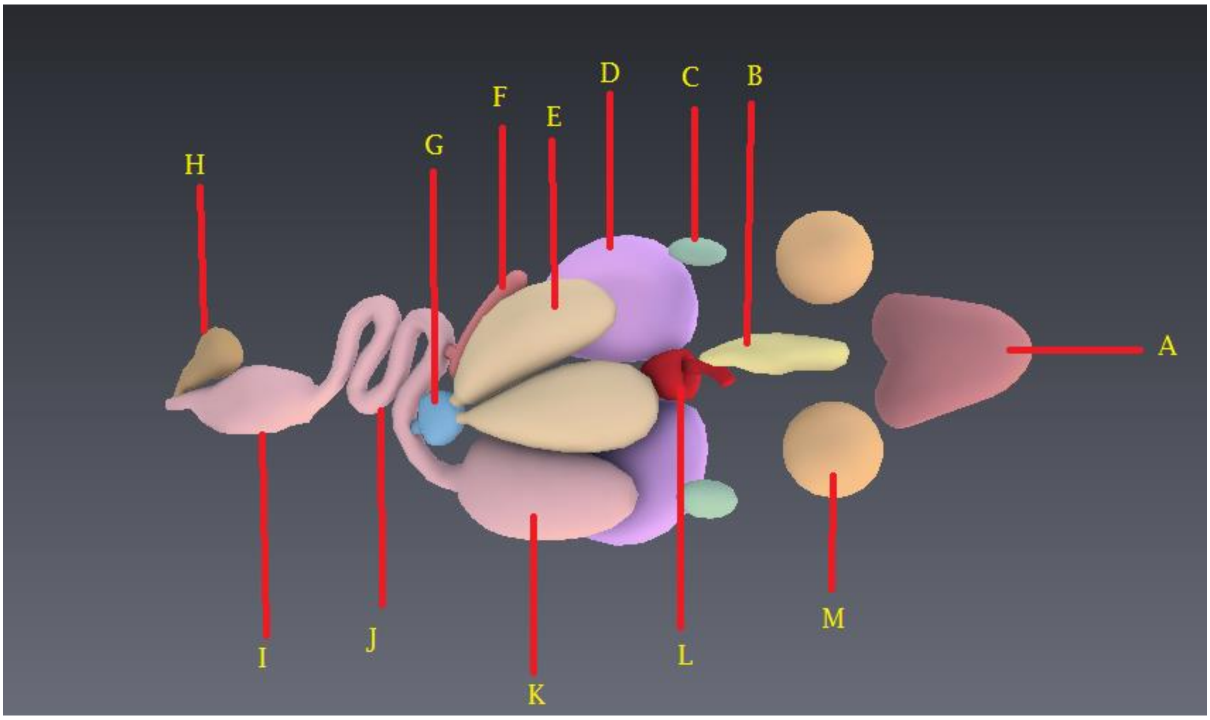
FROG

QUIZ

Q1. Label the following diagram:



Q2. Label the following diagram



A ______________________________

B ______________________________

C ______________________________

D ______________________________

E ______________________________

F ______________________________

G ______________________________

H ______________________________

I ______________________________

J ______________________________

K ______________________________

L ______________________________

M ______________________________

Section B

Q3. How does the male frog attract the female frog?

Q4. What surrounds the frogspawn?

Q5. Up to how many eggs can be contained in the frogspawn?

Q6. How long does it take for the tadpole to wriggle out of the egg?

Q7. What does the tadpole initially use to breath?

Q8. How long until the tadpole develops lungs?

Q9. How long does it take for the tadpole to develop back legs?

Q10. How long does it take for the tadpole to develop into a froglet and the leave the water?

Q11. How long will it take for the froglet to develop into full maturity?

Appendix B – Pre-Post SRQ Questionnaire

Gender ……………………………………………………………………………..

Name ……………………………………………………………………………..

Age ……………………………………………………………………………..

The following items concern your experience with your science lessons. Please answer all items. For each item, please indicate how true the statement is for you, using the following scale as a guide:

1 2 3 4 5

Not at all true somewhat true very true

	Not at all true	Not really true	Somewhat true	True	Very true
	1	2	3	4	5
I feel confident in my ability to learn this material.					
I am capable of learning the material in this lesson.					
I am able to achieve my goals in this lesson.					
I feel able to meet the challenge of performing well in this lesson.					
I do my homework because I want the teacher to think I'm a good student					
I do my homework because I'll get in trouble if I don't.					
I do my homework because it is fun					
I do my homework because I will feel bad about myself if I don't do it.					
I do my homework because I want to understand the subject.					
I do my homework because that's what I'm supposed to do					
I do my homework because I enjoy doing my homework.					
I do my homework because it's important to me to do my homework.					
I work on my classwork so that the teacher won't yell at me.					

	Not at all true	Not really true	Somewhat true	True	Very true
	1	2	3	4	5
I work on my classwork because I want the teacher to think I'm a good student.					
I work on my classwork because I want to learn new things					
I work on my classwork because I'll be ashamed of myself if it didn't get done.					
I work on my classwork because it's fun					
I work on my classwork because that's the rule					
I work on my classwork because I enjoy doing my classwork.					
I work on my classwork because it's important to me to work on my classwork					
I try to answers hard questions in class because I want the other students to think I am smart					
I try to answer hard questions in class because I feel ashamed of myself when I don't try.					
I try to answer hard questions in class because I enjoy answering hard questions					
I try to answer hard questions in class because that's what I'm supposed to do					
I try to answer hard questions in class to find out if I'm right or wrong.					
I try to answer hard questions in class because it's fun to answer hard questions					
I try to answer hard questions in class because it's important to me to try to answer hard questions in class.					
I try to answer hard questions in class because I want the teacher to say nice things about me					
I try to do well in school because that's what I'm supposed to do.					
I try to do well in school so my teachers will think I'm a good student					
I try to do well in school because I enjoy doing my school work well.					
I try to do well in school because I will get in trouble if I don't do well.					
I try to do well in school because I'll feel really bad about myself if I don't do well					
I try to do well in school because it's important to me to try to do well in school.					
I try to do well in school because I will feel really proud of myself if I do well.					
I try to do well in school because I might get a reward if I do well.					

Appendix C – Post Activity Questionnaire

Gender ………………………………………………………………………..

Name ………………………………………………………………………..

Age ………………………………………………………………………..

The following items concern your experience with your science lesson on the *INSERT TOPIC*. Please answer all items. For each item, please indicate how true the statement is for you, using the following scale as a guide:

1 2 3 4 5

Not at all true somewhat true very true

	Not at all true	Not really true	Somewhat true	True	Very true
	1	2	3	4	5
I believe that doing this lesson could be of some value for me.					
I believe I had some choice about doing this lesson.					
I believe that doing this lesson is useful for improved concentration.					
This lesson was fun to do.					
I think this lesson is important for my improvement.					
I enjoyed doing this lesson very much.					
I really did not have a choice about doing this lesson.					
I did this lesson because I wanted to.					
I think this is an important lesson.					
I thought this was a very boring lesson.					
This lesson could improve my studying habits.					
I thought this was a very interesting lesson.					

	Not at all true	Not really true	Somewhat true	True	Very true
I am willing to do this lesson again because I think it is somewhat useful.					
I believe doing this lesson could be somewhat beneficial for me.					
I did this lesson because I had to.					
I believe doing this lesson could help me do better in school.					
While doing this lesson I felt like I had a choice.					
I felt like it was not my own choice to do this lesson.					

Appendix D – Parental Consent – 3D

Introductory letter to Parents

Dear Parent/ Guardian

We are writing to inform you about a research project been conducted by Bangor University, looking at the effectiveness of STEM (Science Technology, Engineering and Mathematics) lessons on students motivation towards STEM. We are interested in looking at the effects of 3D learning. We hope that by doing this research we will be able to see the effectiveness of 3D virtual worlds to aid learning, understanding and motivation in STEM subjects.

Please find enclosed an information sheet that gives you some detailed information about the research and why it is being carried out and what it will involve. Once you have read the information, if you are still unclear about any aspect of the study or have any queries, please do not hesitate to contact Stacey Hunter by email pspf04@bangor.ac.uk or at the address below.

If you are happy for your son/daughter to take part in this research, we would be grateful for your participation in this project.

I look forward to hearing from you.

Yours sincerely

Stacey Hunter
School of Psychology

Information Sheet for Parents

Study title

Increasing motivation in Science with the use of 3D technology

Project team

Stacey Hunter, MSc, Dr Carl Hughes and Dr John Parkinson.

Purpose of the study

There are more employers seeking STEM (Science, Technology, Engineering and Math) professionals, and finding that fewer individuals have the relevant qualification. It is essential that we have people in these professions. Research has shown that students are becoming less motivated in STEM subjects. A number of studies have suggested the use of 3D technology in the classroom can aid learning and help students get a better understanding of the subject matter.

The study aims to compare the effects of 2D verse 3D learning to assess whether it increases students motivation toward STEM subjects

Procedures involved

Schools have been contacted and have provided consent to complete this research at their school. Once parental consent has been gained, prior to your son/daughter taking part in research they will be asked to complete a multiple choice quiz (MCQ) and to complete a questionnaire. They will also be asked to fill out the same MCQ and questionnaire after they have completed their lesson and then again after six weeks of completing the lesson.

What are the benefits of taking part?

This research project aims to identify whether learning in 3D compared to 2D is more motivational for students. By identifying the effects of learning in 3D verse 2D will ensure that future lessons will maximise the potential of conducting a lesson in 3D to ensure that lessons will be delivered in the most effective way, ensuring students receive information in a way that will enhance their motivation to learn. We also hope that this will lead to students taking STEM subjects in higher education allowing them to have the opportunity of a career in a STEM field.

Are there any risks involved?

We do not believe that the students participating in the study are being put in risk in any way. The lesson, MCQ and questionnaire will all take place in the students' school and the lessons will be delivered by their regular teachers. Your son/ daughter's identity will be protected at all times and the completed study will not include their name, or any other identifying information.

Your participation is completely voluntary and you reserve the right to withdraw your son/ daughter from the study at any time without giving any explanations and without this affecting his/her education in any way. If you have any further queries about the study please do not hesitate to contact us, our details are below.

Stacey Hunter Msc

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: pspf04@bangor.ac.uk

Or, you may contact the supervisor directly:

Dr Carl Hughes

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: c.hughes@bangor.ac.uk

Research Consent Form for Parents

Please
Initial box

I confirm that I have read and understand the information sheet for the above study. ☐

I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

I understand that my child's participation is voluntary and that I am free to withdraw him / her any time without giving any reason, without my child's legal rights being affected. ☐

Please complete the following

Signature____

Date____

Your name ____

Your child's name ____

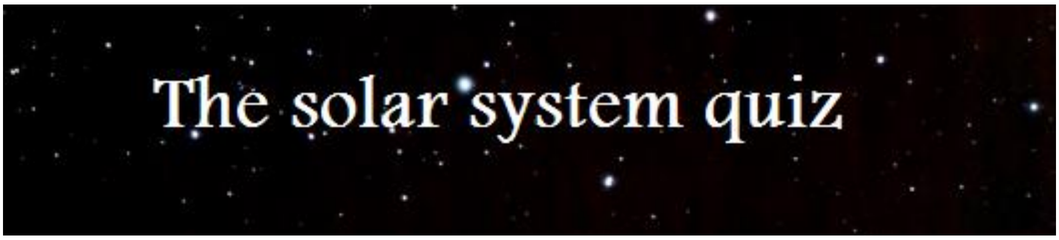
Address____

____

____________________________Postcode_________________________

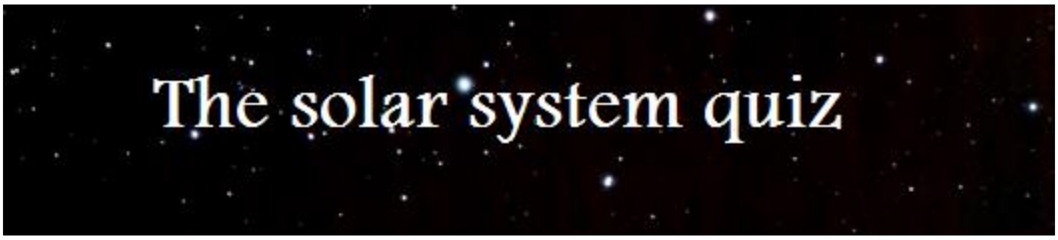
Please return this form, at your earliest convenience, to your child's school via your child's home/school book.

Appendix E – Pre-Post-test Solar System Test A



Q1. Sketch the solar system and add labels to your sketch

Appendix F – Solar System Pre-Post-Test B



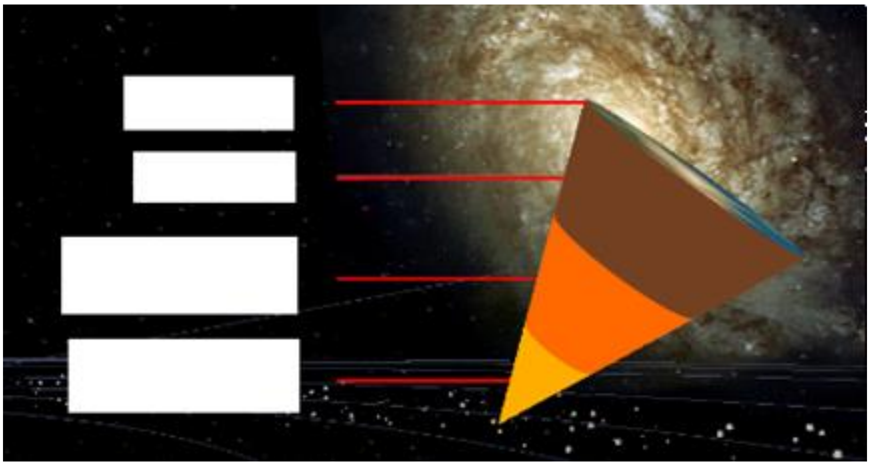
Name:____

Age: ____

Gender: ____

School: ____

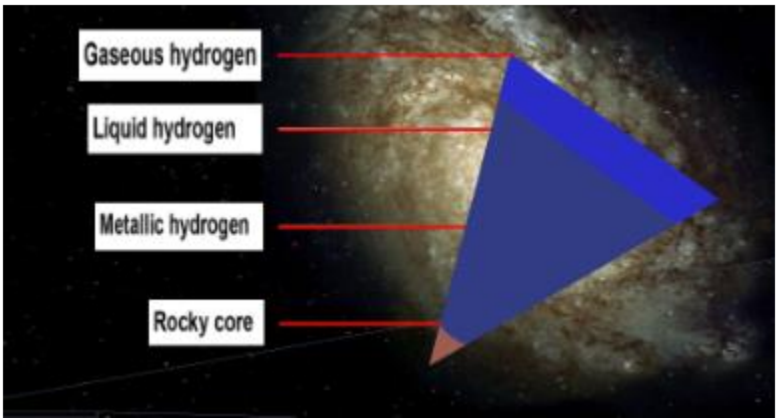
Q1. Fill in the blanks of the cross section of Earth



Q2. Which two planets cross sections contain all of the following: Rocky Crust, Rocky Mantle and Iron/Nickel core?

a) Mercury and Venus
b) Venus and Earth
c) Earth and Mars
d) Jupiter and Venus

Q3. What is the name of the planet of this cross section?



a) Mars
b) Venus
c) Jupiter
d) Uranus

Q4. How many days does it take Earth to orbit the sun?

a) 201.6 days
b) 100.3 days
c) 445 days
d) 365.3 days

Q5. How long does it take Mars to do one rotation?

a) 3 days
b) 7.6 days
c) 17 hours and 26 minutes
d) 24 hours and 37 minutes

Q6. What is the distance of Mercury from the sun?

a) 100 KM
b) 3 Million KM
c) 57 Million KM
d) 3500 KM

Q7. What is in the centre of the solar system?

a) Asteroid belt
b) Sun
c) Earth
d) Pluto

Q8. Which of the following are the inner planets?

a) Mercury, Venus, Earth, and Mars
b) Mercury, Earth, Neptune, and Uranus
c) Earth, Neptune, Mercury, and Mars
d) Earth, Venus, Neptune, and Saturn

Q9. Which planet is the densest?

a) Earth
b) Mercury
c) Venus
d) Mars

Q10. Which planet has the longest day?

a) Earth
b) Venus
c) Mars
d) Neptune

Q11. Which planet has the strongest gravitational field?

a) Earth
b) Mars
c) Venus
d) Jupiter

Q12. Which planet has the most prominent rings?

a) Mars
b) Saturn
c) Earth
d) Neptune

Q13. Does Jupiter have any orbiting rings?

a) Yes
b) No

Q14. Which is the hottest planet?

a) Earth
b) Mars
c) Venus
d) Mercury

Q15. What is the sun?

a) Planet
b) Star
c) Asteroid
d) Galaxy

Q16. Which is the fastest moving planet?

a) Mars
b) Mercury
c) Neptune
d) Venus

Q17. What is a solar flare?

____

____

____

Q18. What is a sun spot?

____

____

____

Q19. What causes a sun spot?

a) Intense Magnetic activity
b) When a planet gets too close
c) It happens once a year
d) It happens when the sun completes a full orbit

Q20. What does a sun spot look like?

a) Appears to be dark
b) Cannot see it
c) Appears to be brighter
d) Appears to be red

Q21. Can a solar flare disrupt the communication systems on Earth?

a) Yes
b) No

Q22. Put the planets and dwarf planet in order starting from the planet closest to the sun.

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____

Appendix G – Workshop Consent form

Introductory letter to Parents / Guardians

Dear Parent/ Guardian

We are writing to inform you about a research project which is being conducted by Bangor University, looking at the effectiveness of STEM (Science Technology, Engineering and Mathematics) workshops on students' motivation towards STEM subjects. We are interested in assessing workshops that are already in place that schools attend. We hope that by doing this research we will be able to see what makes an effective workshop in enthusing and engaging students in STEM subjects.

Please find enclosed an information sheet that gives you some detailed information about the research, why it is being carried out and what it will involve. Once you have read the information, if you are still unclear about any aspect of the study or have any queries, please do not hesitate to contact Stacey Hunter by email pspf04@bangor.ac.uk or at the address below.

If you are happy for your son/daughter to take part in this research, we would be grateful for your participation in this project.

I look forward to hearing from you.

Yours sincerely

Stacey Hunter

School of Psychology

Information Sheet for Parents

Study title

Looking into the effects of STEM workshops on students motivation and attitudes toward STEM subjects.

Project team

Stacey Hunter, MSc, Dr Carl Hughes and Dr John Parkinson.

Purpose of the study

There are more employers seeking STEM (Science, Technology, Engineering and Math) professionals, and finding that fewer individuals have the relevant qualifications. It is essential that we encourage children to take-up these subjects. Research has shown that students are becoming less motivated in STEM subjects. A number of studies have suggested that to enthuse and engage students into STEM subjects the following aspects must be met: Hands on learning, Projects having real-life context, Opportunities for collaborative work, Parental involvement, and providing career information.

The study aims to establish whether or not STEM workshops taking place are increases students motivation toward STEM subjects.

Procedures involved

We will identify the workshops that schools are taking part in and we will then contact the schools to ask their permission to complete the research at the school. Prior to your son/daughter taking part in the workshop they will be asked to fill out a questionnaire. They will also be asked to fill out the same questionnaire after they have completed the workshop.

What are the benefits of taking part?

This research project aims to identify what aspects make a workshop motivating for students. By identifying the key aspects for a successful workshop will ensure that future workshops will be delivered in the most effective way, ensuring students receive information in a way that will enhance their motivation to learn. We also hope that this will lead to students taking STEM subjects in higher education allowing them to have the opportunity of a career in a STEM field.

Are there any risks involved?

We do not believe that the students participating in the study are being put in risk in any way. The questionnaire will take place in the students' school and the workshops the students will be attending will have been arranged by the school with Careers Wales or other local businesses. Your son/ daughter's identity will be protected at all times and the completed study will not include their name, or any other identifying information.

Your participation is completely voluntary and you reserve the right to withdraw your son/ daughter from the study at any time without giving any explanations and without this affecting his/her education in any way. If you have any further queries about the study please do not hesitate to contact either Miss Stacey Hunter or Dr Carl Hughes:

Stacey Hunter Msc

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Or, you may contact the supervisor directly:

Dr Carl Hughes

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: c.hughes@bangor.ac.uk

Research Consent Form for Parents

Please
Initial box

I confirm that I have read and understood the information sheet for the above study. ☐

I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

I understand that my child's participation is voluntary and that I am free to withdraw him / her any time without giving any reason, without my child's legal rights being affected. ☐

Please complete the following

Signature____

Date____

Your name ____

Your child's name ____

Address____

____

_______________________Postcode____________________________

Please return this form, at your earliest convenience, to your child's school via your child's home/school book.

Appendix H – Workshop Opt out form

Introductory letter to Parents / Guardians

Dear Parent/ Guardian

We are writing to inform you about a research project which is being conducted by Bangor University, looking at the effectiveness of STEM (Science Technology, Engineering and Mathematics) workshops on students' motivation towards STEM subjects. We are interested in assessing workshops that are already in place that schools will be attending. We hope that by doing this research we will be able to see what makes an effective workshop by enthusing and engaging students in STEM subjects.

Please find enclosed an information sheet that gives you some detailed information about the research, why it is being carried out and what it will involve. Once you have read the information, if you are still unclear about any aspect of the study or have any queries, please do not hesitate to contact Stacey Hunter by email pspf04@bangor.ac.uk or at the address below.

If you are happy for your son/daughter to take part in this research, we would be grateful for your participation in this project.

I look forward to hearing from you.

Yours sincerely

Stacey Hunter

School of Psychology

Information Sheet for Parents

Study title

Looking into the effects of STEM workshops on students motivation and attitudes toward STEM subjects.

Project team

Stacey Hunter, MSc, Dr Carl Hughes and Dr John Parkinson.

Purpose of the study

There are more employers seeking STEM (Science, Technology, Engineering and Math) professionals, and finding that fewer individuals have the relevant qualifications. It is essential that we encourage children to take-up these subjects. Research has shown that students are becoming less motivated in STEM subjects. A number of studies have suggested that to enthuse and engage students into STEM subjects the following aspects must be met: Hands on learning, Projects having real-life context, Opportunities for collaborative work, Parental involvement, and providing career information.

The study aims to establish whether or not STEM workshops taking place are increases students motivation toward STEM subjects.

Procedures involved

We will identify the workshops that schools are taking part in and we will then contact the schools to ask their permission to complete the research at the school. Prior to your son/daughter taking part in the workshop they will be asked to fill out a questionnaire. They will also be asked to fill out the same questionnaire after they have completed the workshop.

What are the benefits of taking part?

This research project aims to identify what aspects make a workshop motivating for students. By identifying the key aspects for a successful workshop will ensure that future workshops will be delivered in the most effective way, ensuring students receive information in a way that will enhance their motivation to learn. We also hope that this will lead to students taking STEM subjects in higher education allowing them to have the opportunity of a career in a STEM field.

Are there any risks involved?

We do not believe that the students participating in the study are being put in risk in any way. The questionnaire will take place in the students' school and the workshops the students will be attending will have been arranged by the school with Careers Wales or other local businesses. Your son/ daughter's identity will be protected at all times and the completed study will not include their name, or any other identifying information.

Your participation is completely voluntary and you reserve the right to withdraw your son/ daughter from the study at any time without giving any explanations and without this affecting his/her education in any way. If you have any further queries about the study please do not hesitate to contact either Miss Stacey Hunter or Dr Carl Hughes:

Stacey Hunter Msc

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: pspf04@bangor.ac.uk

Or, you may contact the supervisor directly:

Dr Carl Hughes

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: c.hughes@bangor.ac.uk

If you do not want your child to take part in this research please fill in the following opt out form, this will not affect yours or your child's legal right or education.

Opt out Form for Parents

I do not wish for my child to take part in this research

Please complete the following

Signature____

Date____

Your name ____

Your child's name ____

Please return this form, at your earliest convenience, to your child's school via your child's home/school book.

Appendix I – Workshop Pre-Post Questionnaire

Questionnaire

Gender ……………………………………………………………………….

Name ……………………………………………………………………….

Age ……………………………………………………………………….

School ……………………………………………………………………….

Workshop attended ……………………………………………………………………….

	Strongly Disagree	Disagree	Not Sure	Agree	Strongly Agree
I have a clear idea of what Scientists/ mathematician/engineer/ a person who works in the field of technology does for a job.					
My education will create many future opportunities for me.					
I have had experience of hands-on learning in the field of Science/ mathematics/engineering/ technology					
I have had experience of working in a team in the field of Scientists/ mathematician/engineer/ a person who works in the field of technology					
Going to college / University is important to me.					
Going to college / University is important to my family.					
What I'm learning in my classes will be important to my future.					
My parents think it is important for me to do well in mathematics/science/technology/ Engineering at school.					
My friends think it is important to do well in mathematics/science/technology/ Engineering at school.					
I think it is important to do well in mathematics/science/technology/ Engineering at school.					
I usually do well in mathematics/science/technology/ Engineering.					
I would like to take more mathematics/science/technology/ Engineering in school.					
Mathematics/ science/technology/ Engineering is more difficult for me than for many of my classmates.					
I enjoy learning mathematics/science/technology/ Engineering.					
Mathematics/science/technology/ Engineering is not one of my strengths.					
I learn things quickly in mathematics/science/technology/ Engineering.					

I think learning mathematics/science/technology/ Engineering will help me in my daily life.					
I need mathematics/science/technology/ Engineering to learn other school subjects.					
I need to do well in mathematics/science/technology/ Engineering to get into the university or college of my choice.					
I would like a job that involves using mathematics/science/technology/ Engineering.					
I need to do well in mathematics/science/technology/ Engineering to get the job I want.					
Knowing mathematics/science/technology/ Engineering is important for me to be successful in life.					
In lessons we apply what we are learning about mathematics/science/technology/ Engineering to our daily lives.					
In lessons we talk about the types of jobs and careers that use Mathematics/science/technology/ Engineering.					
A scientist/ mathematician/engineer/ a person who works in the field of technology usually works alone.					
Scientists/ mathematician/engineer/ a person who works in the field of technology are good role-models and mentors for students					
Scientific researchers/ mathematician/engineer/ a person who works in the field of technology are dedicated people who work for the good of humanity.					
Scientists/ mathematician/engineer/ a person who works in the field of technology do not get as much fun out of life as other people do.					
Scientists/ mathematician/engineer/ a person who works in the field of technology are helping to solve challenging problems.					
Scientists/ mathematicians/engineers/ people who work in the field of technology are odd and peculiar people.					
Most scientists/ mathematicians/engineers/ people who work in the field of technology want to work on things that will make life better for the average person.					
Scientists/ mathematicians/engineers/ people who work in the field of technology have few other interests but their work.					
Engineering/ Science/ maths/ working in the field of technology is a very important profession.					
Engineers / Scientists/ mathematicians/ people who work in the field of technology do lots of different and interesting things.					
Being an engineer/ scientists/ mathematicians/working in the field of technology can be exciting.					
Engineering/ Science/ maths/ working in the field of technology is a good career for anyone.					
Engineers / Scientists/ mathematicians/ people who work in the field of technology really enjoy their work.					
Engineers/ Scientists/ mathematicians/ people who work in the field of technology have fun in their jobs.					

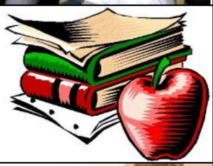
Engineers/ Scientists/ mathematicians/ people who work in the field of technology are very well paid in their jobs.					
Going to an engineering college can be enjoyable and exciting.					
Engineers / Scientists/ mathematicians/people who work in the field of technology get to do many of the things that I like to do.					
Engineering/ Science/ maths/working in the field of technology is something I can be good at.					
I would like to become an engineer/ Scientists/ mathematicians/a person who works in the field of technology.					
I would like to go to an engineering college after high school.					

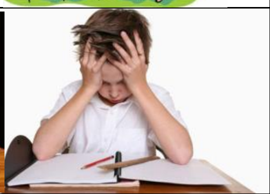
Complete the following sentence 1

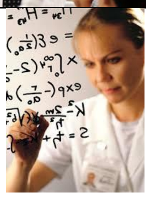
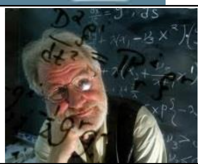
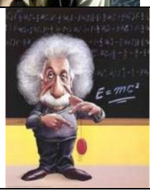
When I am 25 years old I would like to be working as a _________________________

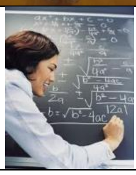
Appendix J – Primary Workshop questionnaire

Gender ……………………………………………………………………………..
Name ……………………………………………………………………………..
Age ……………………………………………………………………………..
School ……………………………………………………………………………..
Workshop attended ……………………………………………………………………………..

			
I know what a Mathematician does. 			
I do practical things in Maths 			
I want to go to college / University when I am older. 			
My family want me to go to college/ university when I am older 			
School work is important 			
My parents think I need to do well in Maths at school.  			

				
My friends think I need to do well in Maths at school.				
I think I need to do well in Maths at school.	 			
I usually do well in Maths				
I like maths.				
Maths is hard	 			
I enjoy learning maths.				
I learn things quickly in maths.	 			
I would like a job where I use maths.				
I need to do well in maths to get a good job.	 = 			

			
In lessons we talk about the types of jobs and careers that use maths. 			
A mathematician usually works alone. 			
Mathematicians are good role-models. 			
Mathematicians do good things 			
Mathematicians are not fun. 			
Mathematicians are odd. 			
Maths is very important. 			
Being a mathematician can be exciting.  			

			
Mathematicians have fun in their jobs. 			
Mathematicians get a lot of money. 			
Mathematicians get to do many of the things that I like to do. 			
Maths is something I can be good at.  			
I would like to become a Mathematician. 			

Complete the following sentence

When I am older I would like to be a ________________________________

Appendix K – Activity perception Questionnaire

Gender ……………………………….. School ………………………………..

Name ………………………………….. Workshop attended …………………..

Age ………………………………..

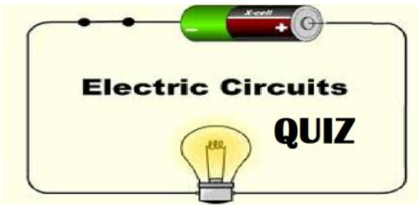
The following items concern your experience with the task. Please answer all items. For each item, please indicate how true the statement is for you, using the following scale as a guide:

1	2	3	4	5
Not at all true		somewhat true		very true

	1	2	3	4	5
I believe that doing this activity could be of some value for me.					
I believe I had some choice about doing this activity.					
While I was doing this activity, I was thinking about how much I enjoyed it.					
I believe that doing this activity is useful for improved concentration.					
This activity was fun to do.					
I think this activity is important for my improvement.					
I enjoyed doing this activity very much.					
I really did not have a choice about doing this activity.					
I did this activity because I wanted to.					
I think this is an important activity.					
I felt like I was enjoying the activity while I was doing it.					
I thought this was a very boring activity.					
It is possible that this activity could improve my studying habits.					
I felt like I had no choice but to do this activity.					

	1	2	3	4	5
I thought this was a very interesting activity.					
I am willing to do this activity again because I think it is somewhat useful.					
I would describe this activity as very enjoyable.					
I felt like I had to do this activity.					
I believe doing this activity could be somewhat beneficial for me.					
I did this activity because I had to.					
I believe doing this activity could help me do better in school.					
While doing this activity I felt like I had a choice.					
I would describe this activity as very fun.					
I felt like it was not my own choice to do this activity.					
I would be willing to do this activity again because it has some value for me.					

Appendix L – Pre-Post-test Electrical circuits



Name:

Circle the correct answers.

Q1. What provides power to make a light bulb glow?

a) Battery

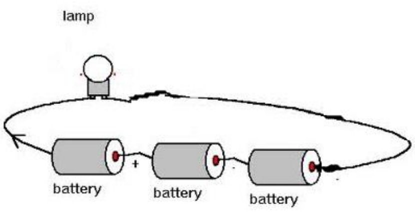
b) Bulb

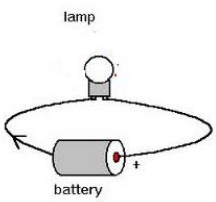
c) Switch

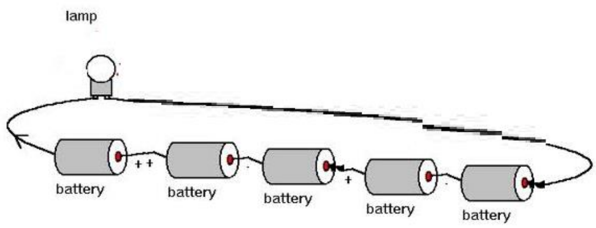
d) Circuit

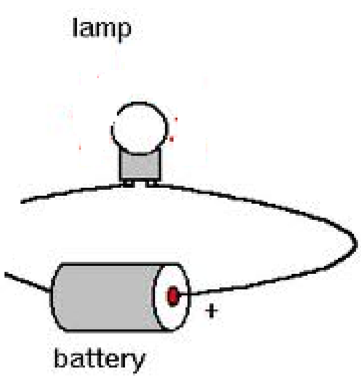
Q2) Which picture has the brightest light?

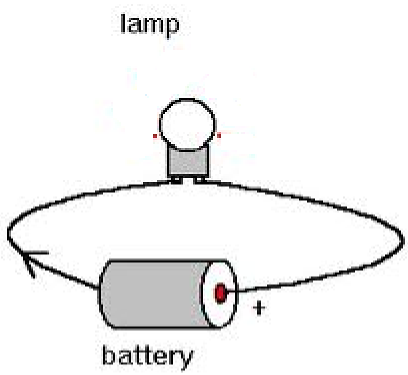
Q3) Which picture will make the bulb light up?







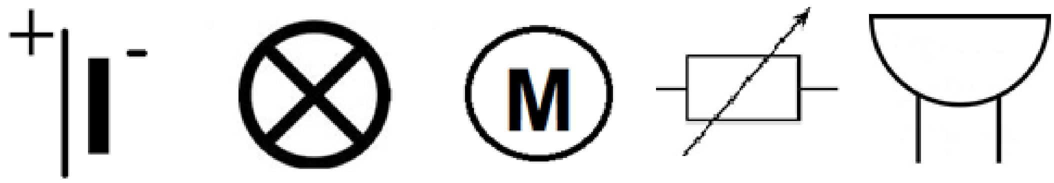




Q4) What is the symbol for a light?

Q5) What is the symbol for a battery?

Q6) What is the symbol for a motor?



Q7) What is the symbol for a variable resistor?

Q8) What is the symbol for a buzzer?

Q9) What symbol shows an open switch?

Q10) What is the symbol for a closed switch?

Q11) What connects a light bulb and a battery?

a) Wires
b) Bulb
c) Battery
d) Motor

Q12) Wires carry the ________

a) Electricity
b) Plastic
c) Metal
d) Batteries

Q13) The path it flows through is called a _______

a) Electricity
b) Circuit
c) Connection
d) Motor

Q14) A ___________ is the metal wires that glows brightly in a bulb?

a) Light
b) Bulb
c) Filament
d) Electricity

Q15) Does metal conduct electricity?

a) Yes b) No

Q16) Will keys conduct electricity?

a) Yes

b) No

Q17) Will a piece of cotton conduct electricity?

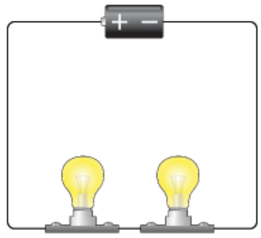
a) Yes

b) No

Q18) Will the light be on in this picture?

a) Yes

b) No



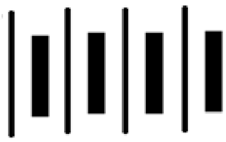
Q19) How many batteries does this symbol show?

a) 1

b) 3

c) 4

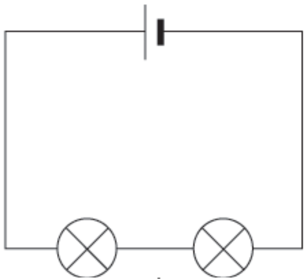
d) 6



Q20) Will the light be on in this picture?

a) Yes

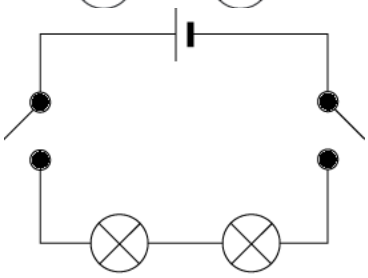
b) No



Q 21) Will the light be on in this picture?

a) Yes

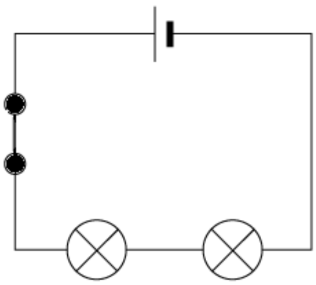
b) No



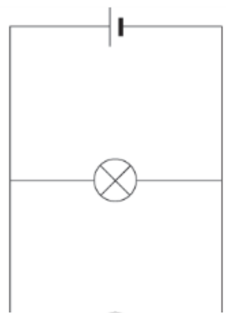
Q22) Will the light be on in this picture?

a) Yes

b) No

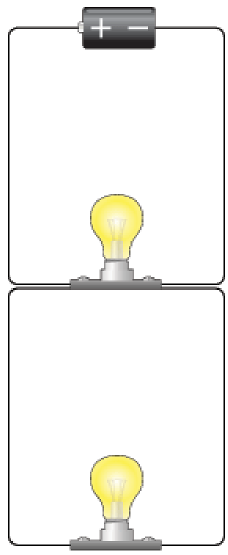


Q23) This is a ___________ Circuit?



a) Broken
b) Open
c) Parallel
d) Circular

Q24) This is a ___________ Circuit?



a) Broken
b) Open
c) Parallel
d) Circular

Appendix M – Pre-Post-Test Forces and movement

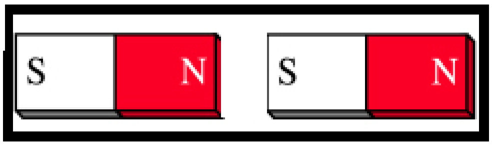
Forces and Movement

Name

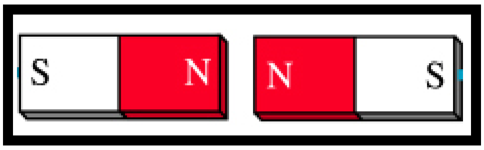
Circle the correct answer

Q1) Which one of these magnets will repel each other?

a)

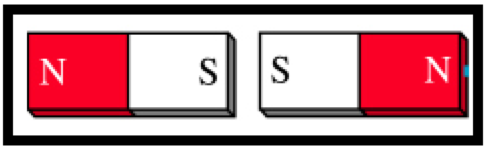


b)

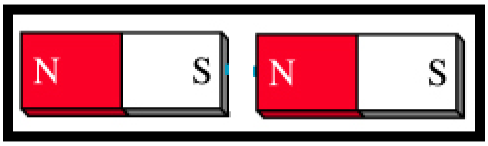


Q2) Which one of these magnets will attract each other?

a)



b)



Q3) Will magnets attract Zinc?

a) Yes

b) No

Q4) Will magnets attract paper?

a) Yes

b) No

Q5) Name a use for an electro-magnet.

Q6) If the forces on a stationary object are **unbalanced** what happens to an object?

a) Starts to move

b) Stays the same

c) Changes direction

Q7) If the forces on a stationary object are **balanced** what happens to an object?

a) Starts to move
b) Stays the same
c) Changes direction

Q8) Friction is a force that slows the motion of two surfaces when they move across each other.

a) True
b) False

Q9) What is the unit for measuring force?

a) Metre
b) Decibel
c) Newton

Q10) Two forces pulling away from each other is called:

a) Tension
b) Weight
c) Newton

Q11) In engineering, deflection is the degree to which a structural element is displaced under a load

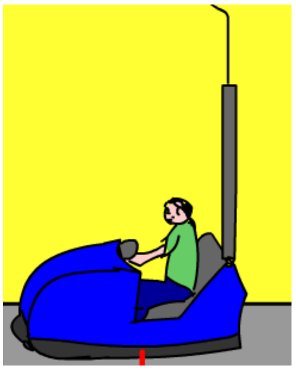
a) True
b) False

Q12) What is the force used to pull objects towards Earth?

a) Gravity
b) Magnets
c) Weight

Q13) This bumper car is not speeding up, slowing down or changing direction are the forces balanced or unbalanced?

a) Balanced
b) Unbalanced



Q14) Two forces pushing towards each other is called:

a) Compression
b) Tension
c) Newton

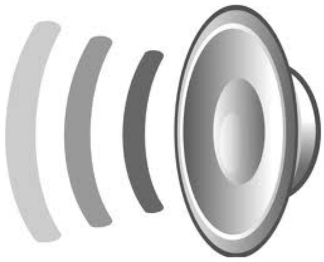
Q15) What is the weight of an average apple in Newton?

a) 2N
b) 3N
c) 1N

Q16) What is the name of the scientist who discovered the laws of forces and motions?

a) Isaac Newton
b) Einstein
c) Stephen Hawking

SOUND QUIZ



Appendix N – Pre-Post-Test Sound

Name:

Circle the correct answer

Q1) How is sound loudness measured?

a) Decibels

b) Ears

c) Meters

Q2) When we soundproof we make sounds _________

a) The same

b) Louder

c) Quieter

Q3) When we amplify we make sounds____________

a) The same

b) Louder

c) Quieter

Q4) Who discovered the effect of travelling sound in 1842?

a) Albert Einstein

b) Issac Newton

c) Christian Doppler

Q5) An echo is a ____________ sound

a) Reflected

b) Wave

c) Silent

Q6) How is sound made?

a) Waves

b) Vibrations

c) Ears

Q7) How does sound travel?

a) In waves

b) In a car

c) In the post

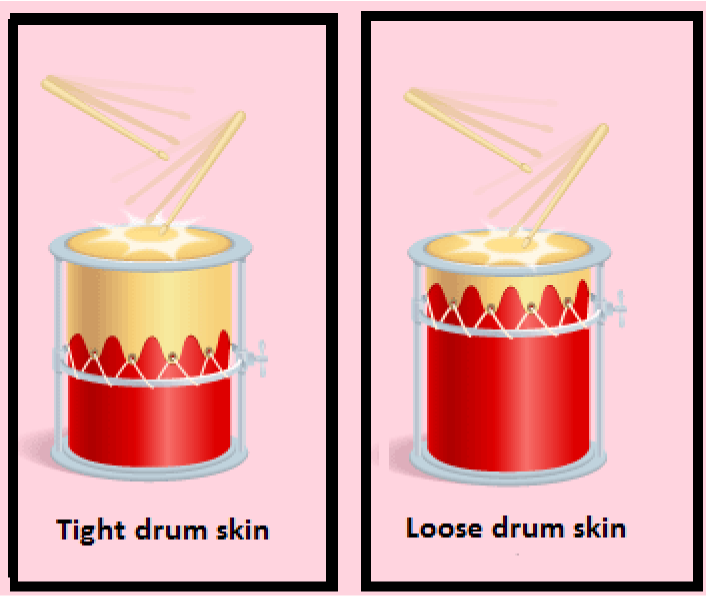
Q8) What can sound travel through?

a) Solid

b) Liquids

c) Solid, liquids and gas

Q9) Which drum will give a higher pitched sound?



Q10) Who invented Morse Code?

a) Albert Einstein

b) Samuel Morse

c) John Bishop

Q11) Does sound travel better through bricks or air?

a) Neither

b) Bricks

c) Air

Q12) The **loudness** of a sound is a measure of the ____________________ of the wave.

a) Amplitude

b) Frequency

c) Decibel

Q13) The greater the amplitude, the ___________ the sound.

a) Quieter

b) Louder

c) Softer

Q14) The **pitch** of a sound is a measure of the _______________ of the wave.

a) Frequency

b) Amplitude

c) Decibel

Q15) The higher the frequency, the _____________ the pitch.

a) Lower

b) Higher

c) Quieter

Appendix O – Technocamps Workshop SAFMEDS opt out form

Introductory letter to Parents/ Guardians

Dear Parent/Guardian

We are writing to inform you about a research project which is being conducted by Bangor University, looking at increasing students' knowledge and motivation towards STEM (Science Technology, Engineering and Mathematics) subjects. We are interested in using SAFMEDS and peer tutoring to aid learning and motivate students. A pilot project has already been conducted to increase students' Technology terminology and gained very positive results. A report has been written up for this study so please contact me if you would like to receive a copy of the report.

Please find enclosed an information sheet that gives you some detailed information about the research, why it is being carried out and what it will involve. Once you have read the information, if you are still unclear about any aspect of the study or have any queries, please do not hesitate to contact Stacey Hunter by email pspf04@bangor.ac.uk or at the address below.

If you are happy for your son/daughter to take part in this research, we would be grateful for your participation in this project.

I look forward to hearing from you.

Yours sincerely

Stacey Hunter

School of Psychology

Information Sheet for Parents/Guardians

Study title

Using SAFMEDS to aid learning and increase motivation towards STEM subjects.

Project team

PhD student: Stacey Hunter, MSc.

Supervised by Dr Carl Hughes and Dr John Parkinson.

Purpose of the study

There are more employers seeking STEM (Science, Technology, Engineering and Math) professionals, and finding that fewer individuals have the relevant qualifications. It is essential that we encourage children to take-up these subjects. Research has shown that students are becoming less motivated in STEM subjects. SAFMEDS (Say All Fast Minute Every Day Shuffled) is a simple procedure to help students learn new facts and increase their fluency of these facts (Graf & Lindsley, 2002). The procedure involves students being given a set a flashcards with a term on the front and a short definition of the term on the back. We also use a peer-tutoring approach (Levin, Glass & Meister, 1987) that involves two students working together - one as the tutor and one as the tutee. The tutor receives training prior to the peer tutoring sessions by someone fluent in the procedure (Topping, 2005). Peer tutoring has not only been shown to be beneficial for the tutee but is also the tutor (Topping, 2005).

The study aims to establish whether or not SAFMEDS aid students learning and motivation towards STEM subjects.

Procedures involved

Students will be asked to complete a quiz and questionnaires before and after the research.

The time needed for this project will be 20 minutes for data collection (10 minutes before the project and 10 minutes at the end of the project). The intervention will be in workshop time and students ideally need to complete the SAFMEDS 9 times a day during the workshop, the SAFMEDS are timed at 1 minute per go. The intervention will last for the length of the workshop. The experimenter will be onsite providing support when needed for teachers and students.

What are the benefits of taking part?

This research project aims to further support the use of SAFMEDS in the educational field and promote techniques for schools to continue after the research. We also hope that this will lead to students taking STEM subjects in higher education allowing them to have the opportunity of a career in a STEM field.

Are there any risks involved?

We do not believe that the students participating in the study are being put in risk in any way. The research will take place in the students' school and the location of the workshop. The student's identity will be protected at all times and the completed study will not include their name, or any other identifying information. Your participation is completely voluntary and you reserve the right to withdraw your child from the study at any time without giving any explanations. If you have any further queries about the study please do not hesitate to contact either

Miss Stacey Hunter or Dr Carl Hughes:

Stacey Hunter Msc

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: pspf04@bangor.ac.uk

Or, you may contact the supervisor directly:

Dr Carl Hughes

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: c.hughes@bangor.ac.uk

Opt out Form for Parents/Guardians

If you **do not** wish for your child to take part in this research please fill in the information below

Please complete the following

Student____

Parent Signature____

Date____

School ____

School Address____

____

___________________________Postcode__________________________________

Please return this form, at your earliest convenience, to your child's worshop.

Appendix P – Internet Boot Camp Pre-Post-test

Gender ……………………………………………………………

Name ……………………………………………………………

Age ………………………………………………………………

School ……………………………………………………………

Workshop attended …………………………………………………..

For the following statements please fill in the blanks, do this as quickly as you can and fill in the time taken to complete at the end of the test. You are not expected to know these terms at the start of the workshop, so if you do not know the answer please put an X by the question, For example:

____X______ are used to cut papers.

1. A portable computer is called _______________
2. A _______________ goes on the end of a network cable
3. A _______________ enables the traffic on one network to move to another
4. _______________ stops attacks from an external network
5. The underlying network system widely used is _______________
6. _______________ is the central point in a star network
7. The generic name for a network hub is _______________
8. Device which allows information to be inputted to a computer __________
9. Device which allows you to control a computer _______________
10. The main memory on a computer _______________

11.Cabling used in most home/ office networks _______________

12.A _______________ stores data in an organised manner

13.A _______________ publishes a website to the internet

14.The number given to a device on a network is an _______________

15.The hardware required to connect to a network is a _______________

16.An alternative name for an email address _______________

17.A unit of computer memory containing 8 bits _______________

18.The _______________ is the area of memory where you copy things to

19.When a computer stops unexpectedly it _______________

20.A _____________is an error in the software that cause it to function incorrectly

21._______________ removes error from the software

22.A _______________ is where you store things in a computer

23._______________is when more than on task is ran simultaneously

24.The software that links the hardware to the end user is a _______________

25.An allotted area of the hard disk is a _______________

26.The base directory where all information is stored _______________

27.The generic name for programs that run on a computer _______________

28._______________ is used to describe the physical computer

29.A battery backup system for the computer power _______________

30.A 9 pin port on a computer for sending and receiving data _____________

31.The universal serial bus _______________

32.The core piece of software at the heart of an operating system _________

33.A piece of software that makes other computer programs ____________

34.A cross platform programming language ______________

35.A machine level programming language ______________

36.A ______________ is a physical link between devices to communicate

37._____________ is the order in which instructions are given to a computer

38.______________ is a server that issues IP leases on a network

39.______________ is a virtual port for connecting computers

40.Two way communication ______________

41.A __________ is a type of wire made of glass that uses light to send data

42.The way information is stored on a hard disk ______________

43.The study of sense and touch when interacting with a computer ________

44.______________ is the language used to make a webpage

45.The local network ______________

46.The external network ______________

47.______________ is a private version of an internet

48.Using multiple hard disks to protect data is called ______________

49.A defined mechanism to communicate ______________

50.______________ is a caching web router that stores previous sites

51.______________ is the plain text version of a computer program

52.______________ is a smaller section of a computer program

53.The name given to humans that login to the computer ______________

54. A program that shows you how the final result will look on the screen

____

55. Part of a firewall that masks the ports and services _______________

56. Some memory that holds a piece of data until required _______________

57. A mechanism used by a virus to disrupt network traffic is

____

58. Controlling engineering machines by computer is _______________

59. A device used to extend the operation reach of a wire _______________

Time taken:________

Appendix Q – Robotics Pre-Post-test

Technocamps Robotics Quiz

Name: ___________ Age: ___________

Q1. ___________ is where you create a sequence of instructions to enable the computer to do something

Q2. ________________ is the design construction operation and application of robots

Q3. _______________ detects an object

Q4. _______ colour model has red green and blue light

Q5. ______________ _____________ is the study of the principles and use of computers

Q6. _______________ is the order in which instructions are given to a computer

Q7. _______________ removes error from the software

Q8. _____________ is something that can vary or change

Q9. A __________________ allows a sequence of instructions to be repeated

Q10. A ________________ is an electrical power mechanism used to effect motion of the robot

Q11. _______________ sensors generates high frequency sound waves

Q12. __________________ is the direction used to specify the robot motion in a linear or rotary mode

Q13.__________________ is the return of information from a sensor to the robot

Q14.___________ _________ can be programmed to make performance choices contingent on sensory inputs

Q15.______________ is the relationship between the motion of the endpoint of a robot and the motion of the joints

Q16.____________ _____________ is a feature to allow a robot to be instructed to perform a sequence of steps

Q17.______________ _____________ ___________ is an interface between a human and a robot, which relates human commands to the robots

Q18. The first well known robot was a mechanical _________

Q19. The first true robot toy was produced in ________ in 1932

Q20. The first LEGO based educational products were launched in ________________

Q21. In 1986 Honda launched a project to build a _________ __________ ___________

Q22. _____ released the first version of AIBO in 1999

Q23. ________________ is a robotic dog with the ability to learn and communicate with its owner

Q24. __________________ are any machine that does work on its own automatically

Q25. ____________ ______________ is the ability of a computer to perform activities that are normally thought to require intelligence

Time taken:_______________________

Appendix R – Wearable Pre-Post-test

Wearable technology Quiz

Name: ________________ Age: _________________

Q1. ______ ______ computing refers to a small computer that can either be worn on the body or placed on clothing.

Q2. E-textiles or electronic textiles are also known as ______ _______

Q3. ___ _____ is the most common conductive material used in wearable technology

Q4. A ______ is designed to test and trial a new design to enhance precision by system analysts and users

Q5. ________ _________ is used to describe designing with hardware and software that respond to the physical world

Q6. ___ ___ is a substitute for wires in many wearable projects

Q7. ___ _____ combines technology, fashion and textiles.

Q8. The first wearable computer was developed in _______

Q9. The first wearable computer was a method for counting cards in a game of ___ _____

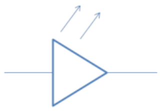
Q10. In _____ Steve Man developed a wearable computer that was worn as a backpack to constantly record everything he saw

Q11. In 1981 ___ _____ developed a wearable computer that was worn as a backpack to constantly record everything he saw

Q12. In 1981 Steve Man developed a wearable _______ that was worn as a backpack to constantly record everything he saw

Q13. _______ is a collective name describing anything to do with fashion and technology

Q14.



______

Q15.

______

Q16.A ___ ____ is used to test a circuit

Q17.The ___ is a semiconductor light source

Q18.______ is a method for telling a computer what to do and how to do it.

Q19.Programming involves 3 processes ___ - process - output

Q20.Programming involves 3 processes input - ______ - output

Q21.Programming involves 3 processes input - process - _____

Q22.The market for wearable devices is reported to have already reached a value of ______ in 2011

Q23.The ______ ________ is a wristband and app that promises to help you live healthier

Q24.

______ ________ designed Rhianna's LED dress

Q25._______ ________ is a wearable computer with an optical head-mounted display

Time Taken: ________________________________

Appendix S – School consent SAFMEDS Introductory letter to School

Dear Head teacher

We are writing to inform you about a research project which is being conducted by Bangor University, looking at increasing students' knowledge and motivation towards STEM (Science Technology, Engineering and Mathematics) subjects. We are interested in using SAFMEDS and peer tutoring to aid learning and motivate students. This method has been already been used in three schools to increase maths skills in students in years 2-9 and received very positive results. A report has been written up for this study so please contact me if you would like to receive a copy of the report.

Please find enclosed an information sheet that gives you some detailed information about the research, why it is being carried out and what it will involve. Once you have read the information, if you are still unclear about any aspect of the study or have any queries, please do not hesitate to contact Stacey Hunter by email stacey.hunter@bangor.ac.uk or at the address below.

If you are happy for your school to take part in this research, we would be grateful for your participation in this project and would like to arrange a meeting to discuss this project further.

I look forward to hearing from you.

Yours sincerely

Stacey Hunter

School of Psychology

Information Sheet for Schools

Study title

Using SAFMEDS to aid learning and increase motivation towards STEM subjects.

Project team

PhD student: Stacey Hunter, MSc.

Supervised by Dr Carl Hughes and Dr John Parkinson.

Purpose of the study

There are more employers seeking STEM (Science, Technology, Engineering and Math) professionals, and finding that fewer individuals have the relevant qualifications. It is essential that we encourage children to take-up these subjects. Research has shown that students are becoming less motivated in STEM subjects. SAFMEDS (Say All Fast Minute Every Day Shuffled) is a simple procedure to help students learn new facts and increase their fluency of these facts (Graf & Lindsley, 2002). The procedure involves students being given a set a flashcards with a term on the front and a short definition of the term on the back. We also use a peer-tutoring approach (Levin, Glass & Meister, 1987) that involves two students working together - one as the tutor and one as the tutee. The tutor receives training prior to the peer tutoring sessions by someone fluent in the procedure (Topping, 2005). Peer tutoring has not only been shown to be beneficial for the tutee but is also the tutor (Topping, 2005). Two main areas of interest currently are Maths and Science. There is also an emphasis on promoting these subjects to female students. We are happy to tailor the project to what you feel as a school would be more beneficial either Maths or Science and the topic area of that subject.

The study aims to establish whether or not SAFMEDS aid students learning and motivation towards STEM subjects.

Procedures involved

Once we have gained interest from schools and gained their permission to complete the research at the school. We will then need to gain parental consent for the students taking part in the research.

Students will be asked to complete a quiz and questionnaires before and after the research. The research can be conducted in three ways:

1. The researchers can complete this procedure with at risk students
2. The researchers can complete this procedure on a class wide basis
3. The procedure can be taught to teachers to implement to their class.

The time needed for this project will be 20 minutes for data collection (10 minutes before the project and 10 minutes at the end of the project). There will be an initial training phase for students/teachers which will be approximately 10 minutes. The intervention will be in class time and students ideally need to complete the SAFMEDS 9 times in their Science/Maths lesson, the SAFMEDS are timed at 1 minute per go. The intervention will last for two weeks. The experimenter will be onsite providing support when needed for teachers and students and will also be observing the students to measure engagement.

What are the benefits of taking part?

This research project aims to further support the use of SAFMEDS in the educational field and promote techniques for schools to continue after the research. We also hope that this will lead to students taking STEM subjects in higher education allowing them to have the opportunity of a career in a STEM field.

Are there any risks involved?

We do not believe that the students participating in the study are being put in risk in any way. The research will take place in the students' school. The student's identity will be protected at all times and the completed study will not include their name, or any other identifying information. Your participation is completely voluntary and you reserve the right to withdraw your school from the study at any time without giving any explanations. If you have any further queries about the study please do not hesitate to contact either Miss Stacey Hunter or Dr Carl Hughes:

Stacey Hunter Msc

School of Psychology

Adeilad Brigantia

Penrallt Road

Or, you may contact the supervisor directly:

Dr Carl Hughes

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: pspf04@bangor.ac.uk

Gwynedd LL57 2AS

Email: c.hughes@bangor.ac.uk

Research Consent Form for Schools

Please Initial box

I confirm that I have read and understood the information sheet for the above study. ☐

I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

I understand that the schools participation is voluntary and that I am free to withdraw from this research at any time without giving any reason, without the school's legal rights being affected. ☐

Please complete the following

Signature____

Date____

School ____

School Address____

____

____________________________Postcode__________________________________

Please return this form, at your earliest convenience, to Stacey Hunter.

Appendix T – Parental consent SAFMEDS Introductory letter to Parents/ Guardians

Dear Parent/Guardian

We are writing to inform you about a research project which is being conducted by Bangor University, looking at increasing students' knowledge and motivation towards STEM (Science Technology, Engineering and Mathematics) subjects. We are interested in using SAFMEDS and peer tutoring to aid learning and motivate students. A pilot project has already been conducted to increase students' Technology terminology and gained very positive results. A report has been written up for this study so please contact me if you would like to receive a copy of the report.

Please find enclosed an information sheet that gives you some detailed information about the research, why it is being carried out and what it will involve. Once you have read the information, if you are still unclear about any aspect of the study or have any queries, please do not hesitate to contact Stacey Hunter by email pspf04@bangor.ac.uk or at the address below.

If you are happy for your son/daughter to take part in this research, we would be grateful for your participation in this project.

I look forward to hearing from you.

Yours sincerely

Stacey Hunter

School of Psychology

Information Sheet for Parents/Guardians

Study title

Using SAFMEDS to aid learning and increase motivation towards STEM subjects.

Project team

PhD student: Stacey Hunter, MSc.

Master students: TBC

Supervised by Dr Carl Hughes and Dr John Parkinson.

Purpose of the study

There are more employers seeking STEM (Science, Technology, Engineering and Math) professionals, and finding that fewer individuals have the relevant qualifications. It is essential that we encourage children to take-up these subjects. Research has shown that students are becoming less motivated in STEM subjects. SAFMEDS (Say All Fast Minute Every Day Shuffled) is a simple procedure to help students learn new facts and increase their fluency of these facts (Graf & Lindsley, 2002). The procedure involves students being given a set a flashcards with a term on the front and a short definition of the term on the back. We also use a peer-tutoring approach (Levin, Glass & Meister, 1987) that involves two students working together - one as the tutor and one as the tutee. The tutor receives training prior to the peer tutoring sessions by someone fluent in the procedure (Topping, 2005). Peer tutoring has not only been shown to be beneficial for the tutee but is also the tutor (Topping, 2005).

The study aims to establish whether or not SAFMEDS aid students learning and motivation towards STEM subjects.

Procedures involved

Once we have gained parental consent for the students taking part in the research. Students will be asked to complete a quiz and questionnaires before and after the research.

The time needed for this project will be 20 minutes for data collection (10 minutes before the project and 10 minutes at the end of the project). There will be an initial training phase for students/teachers which will be approximately one lesson. The intervention will be in class time and students ideally need to complete the SAFMEDS 4 times in their Math lesson, the SAFMEDS are timed at 1 minute per go. The intervention will last for four weeks. The experimenter will be onsite providing support when needed for teachers and students and will also be observing the students to measure engagement.

What are the benefits of taking part?

This research project aims to further support the use of SAFMEDS in the educational field and promote techniques for schools to continue after the research. We also hope that this will lead to students taking STEM subjects in higher education allowing them to have the opportunity of a career in a STEM field.

Are there any risks involved?

We do not believe that the students participating in the study are being put in risk in any way. The research will take place in the students' school. The student's identity will be protected at all times and the completed study will not include their name, or any other identifying information. Your participation is completely voluntary and you reserve the right to withdraw your child from the study at any time without giving any explanations. If you have any further queries about the study please do not hesitate to contact either

Miss Stacey Hunter or Dr Carl Hughes:

Stacey Hunter Msc

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: pspf04@bangor.ac.uk

Or, you may contact the supervisor directly:

Dr Carl Hughes

School of Psychology

Adeilad Brigantia

Penrallt Road

Gwynedd LL57 2AS

Email: c.hughes@bangor.ac.uk

Research Consent Form for Parents/Guardians

	Please Initial box
I confirm that I have read and understood the information sheet for the above study.	☐
I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.	☐
I understand that my son/daughters participation is voluntary and that I am free to withdraw from this research at any time without giving any reason, without my son/daughters legal rights being affected.	☐

Please complete the following

Student____

Parent Signature____

Date____

School ____

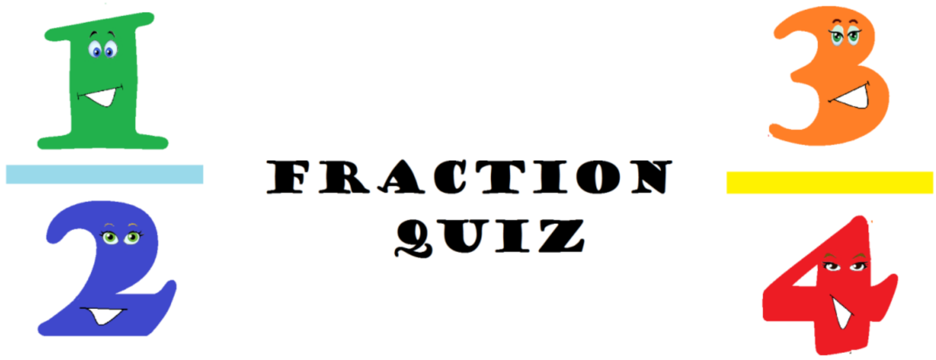
School Address____

____

_____________________________Postcode___________________________________

Please return this form, at your earliest convenience, to your child's school.

Appendix U – Example Pre-Post-test year 2 fractions



Name ……………………………….. School …………………………..

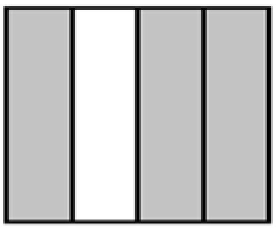
Age ……………………………….. SAFMEDS pack ……….

Fill in the blanks. Complete this as quickly as you can.

Do not worry if you do not know the answer, just try your best. If you do not know the answer please put an X by the question, For example:___X___ are used to cut papers.

For each picture write down what fraction is shaded

Q1.



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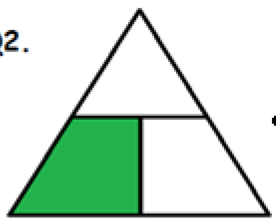
Q2.



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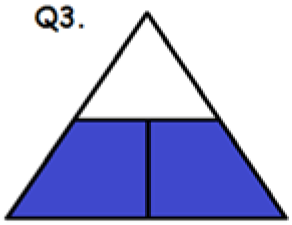
Q3.



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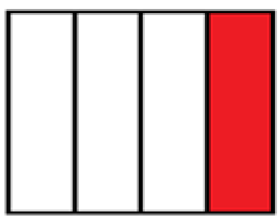
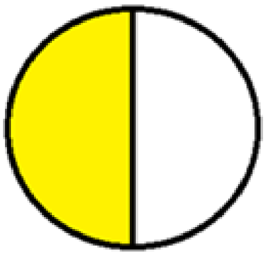
Q4.

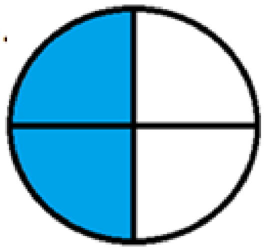


____

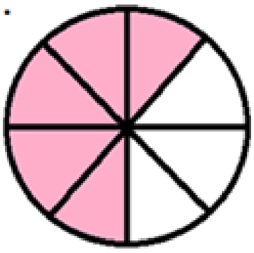
Q5.



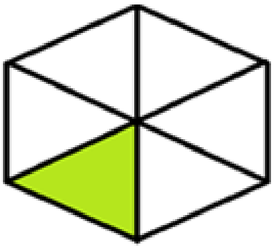
Q6.



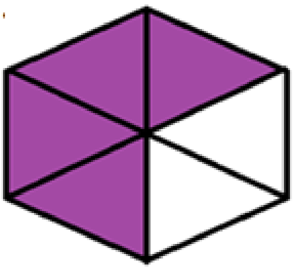
Q7.



Q8.



Q9.



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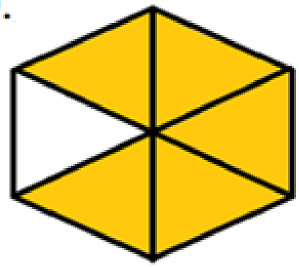

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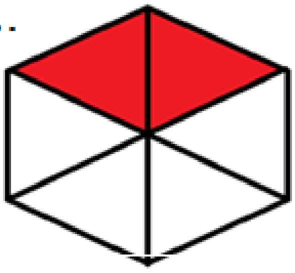

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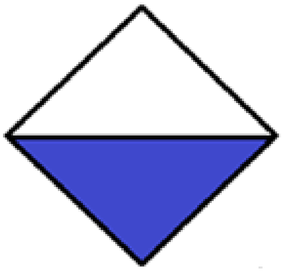

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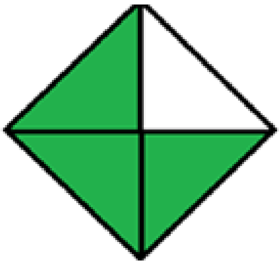

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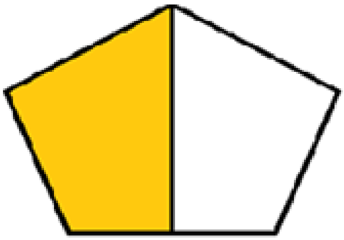

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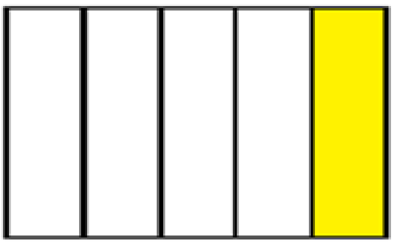

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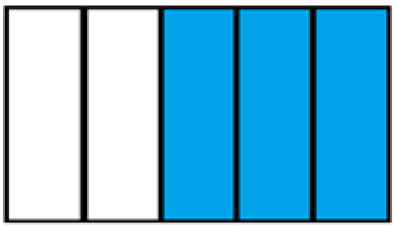

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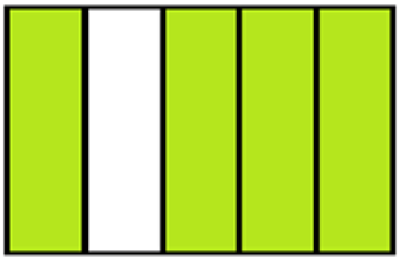

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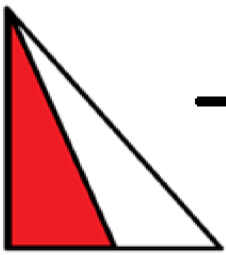

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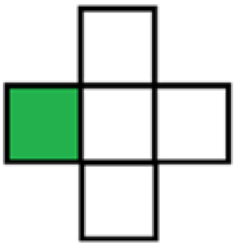

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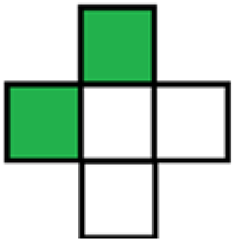

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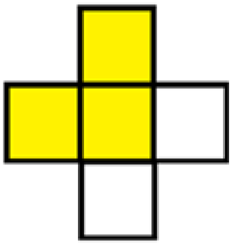

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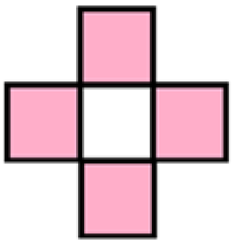

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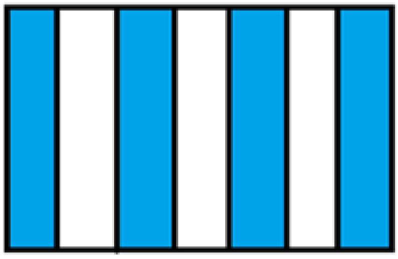

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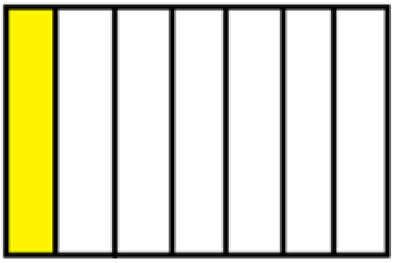

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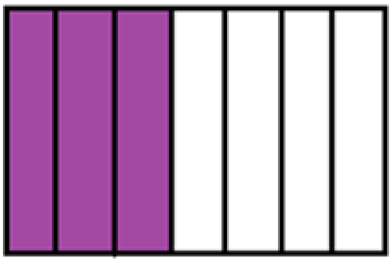

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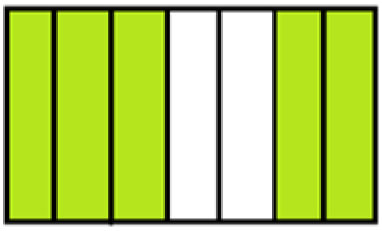

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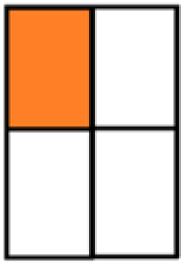

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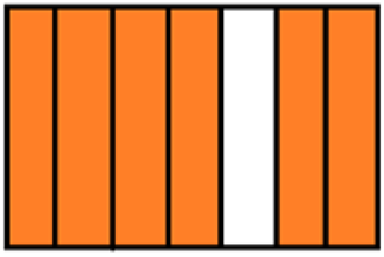

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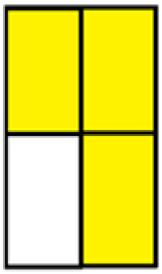

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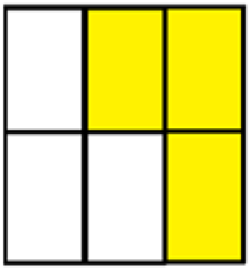

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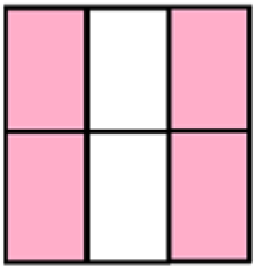

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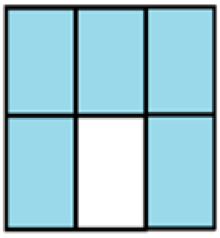

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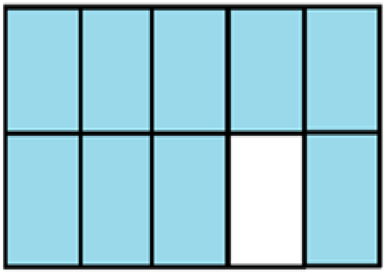

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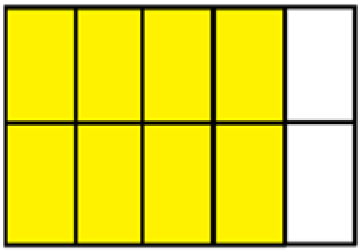

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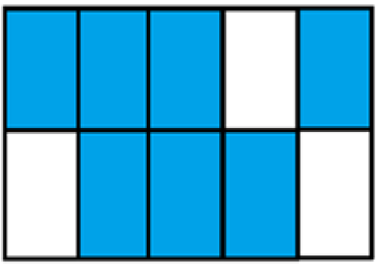

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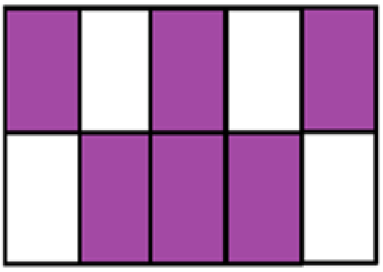

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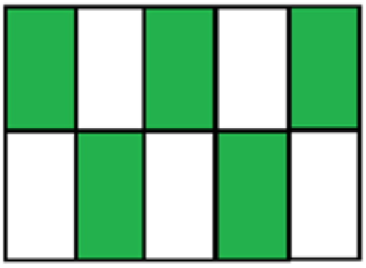

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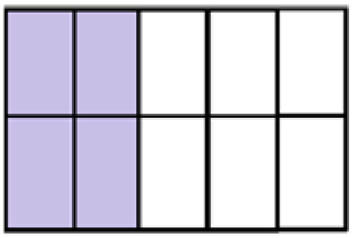

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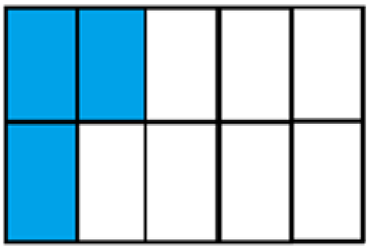
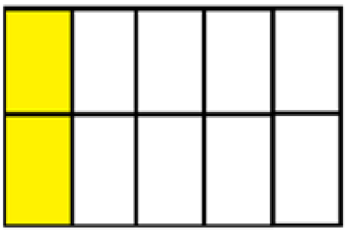


Q40



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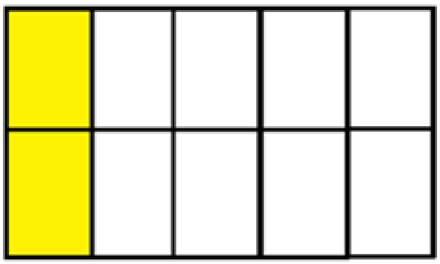
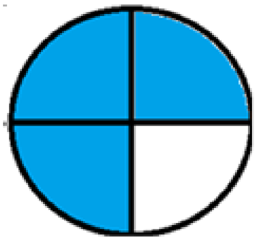
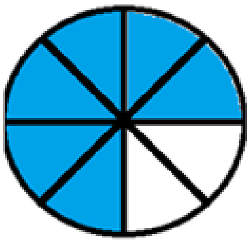


Q42.



Q43.



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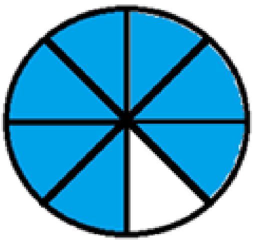

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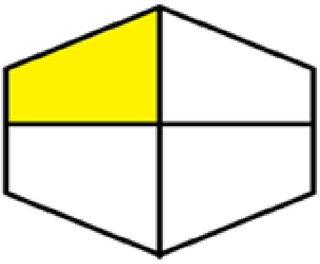

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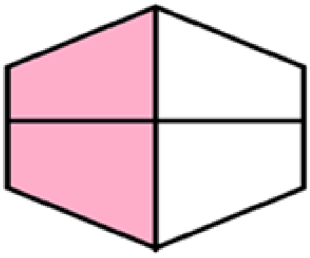
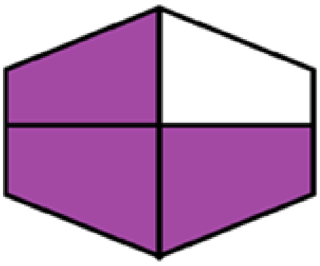
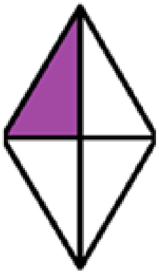


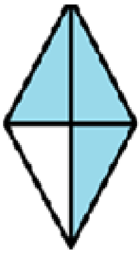
Q47.



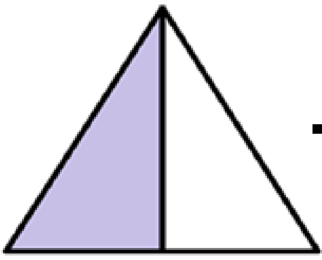
Q48.



Q49.



Q50



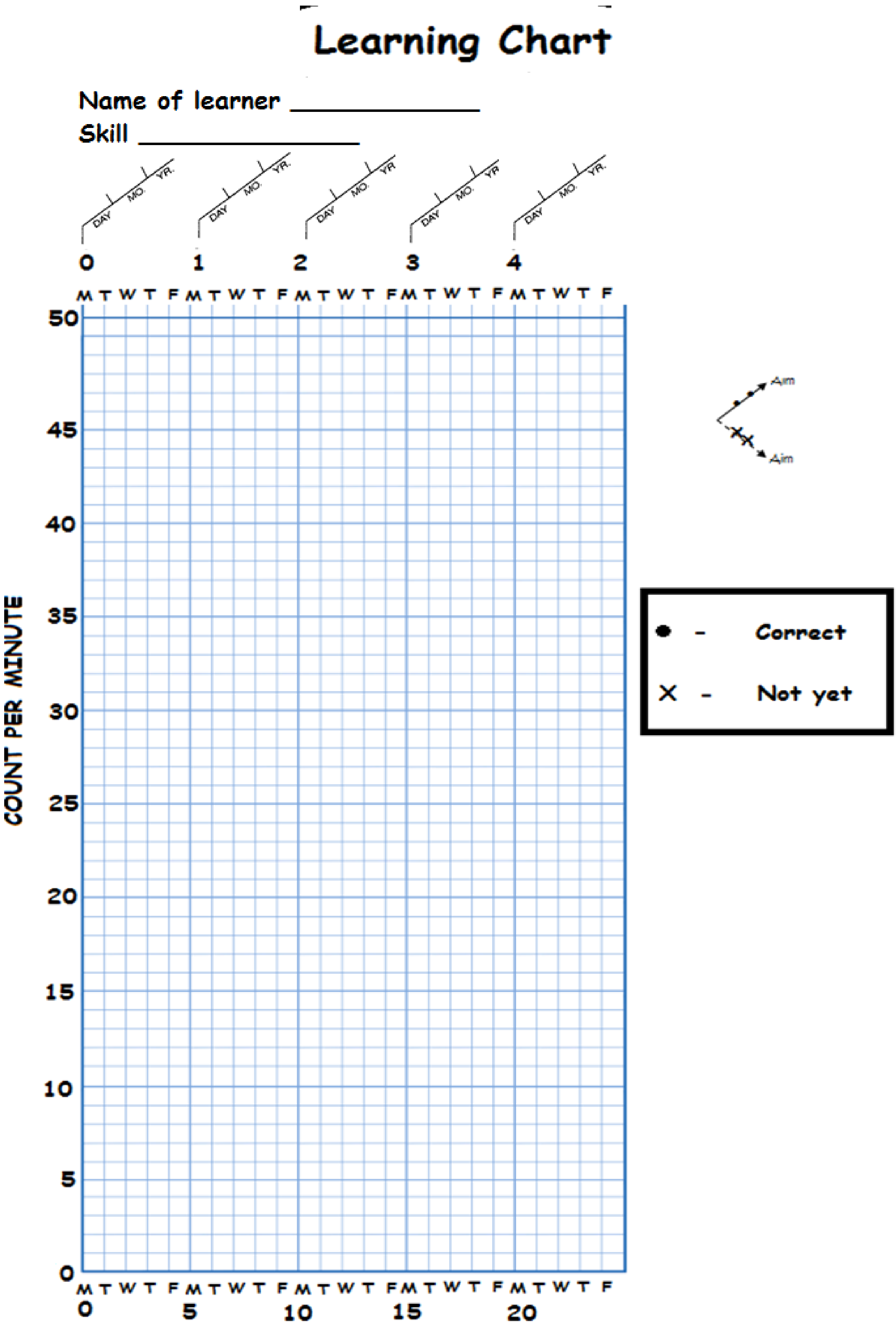
Time: __________

Appendix V – Daily record sheet

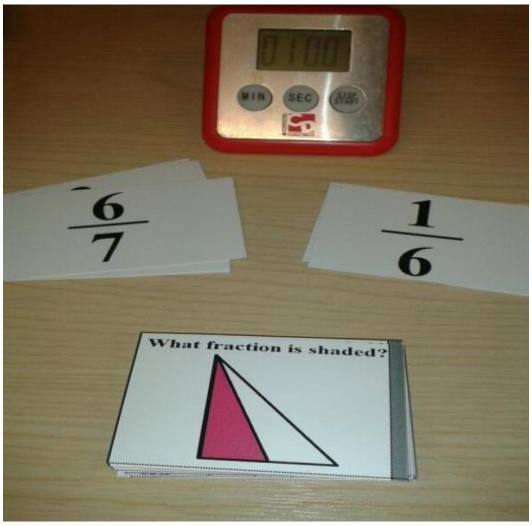
Week Beginning					Student Name	
Aim	√	40-60	X	2-0	Pack	

Day	Try	Score √	Score X	Timing	Checked by
	1				
	2				
	3				
	4				
	1				
	2				
	3				
	4				
	1				
	2				
	3				
	4				

Appendix W – Chart



Appendix X – SAFMEDS and Timer



Appendix Y – Real world scenario quiz year 3 addition

Name: ___________________________

Age: _______________________________

Q1. John has 20 friends and Jill has 24 friends. How many friends do they have all together? _____________

Q2. Jack has 12 apples and Anna has 20 apples. How many apples do they have all together? _______________

Q3. Bob cooked a meal for 20 adults and 21 children. How many people did Bob cook for? _________________

Q4. Hannah has 24 stamps and Claire has 32 stamps they both gave their stamps to Ben. How many stamps does Ben now have? _____________________________

Q5. Lucy has 31 marbles and Rachel has 27 marbles. How many marbles do they have all together? ___________

Q6. Katie bought 20 pizzas for the party and Kyle bought 24 pizzas. How many pizzas do they have for the party? _____________

Q7. Jodie gave Bob 28 lollies. Bob already had 31 lollies. How many lollies does Bob now have? _______________

Q8. Ella has 28 bottles and bought another 25 bottles. How many bottles does Ella have all together? _____________

Q9. Jordan has 31 toy cars. Lewis gave Jordan 32 toy cars. How many toy cars does Jordan now have? ________

Q10. Mrs Jones has 24 boys and 24 girls in her class. How many children are in her class? ________________

Time Taken: ________________