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Technology Integration and the Effect on Mathematics Fact Fluency in the Middle East

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This quantitative, quasi-experimental study investigated the effect of the Mathletics.com technology on basic multiplication fact fluency in fourth grade students in the Middle East. The treatment group received three weeks of scheduled time using Mathletics.com, while the control group practiced multiplication facts using only traditional methods. To determine the effectiveness of the intervention, a nonequivalent control group design was used, and to evaluate multiple dependent variables a MANOVA was performed. Post hoc tests were applied as needed. Using a multivariate approach with speed and accuracy for the construct of fluency, the results indicated that both groups made gains in the accuracy of their answers ($F(2, 25) = 3.40$, $p < .05$; Wilks' $\lambda = .79$; partial $\eta^2 = .21$). While both groups improved with the speed of response on the posttest, the control group improved significantly more than the treatment group ($t(13) = 3.60$, $p < .025$). The results did not indicate that technology significantly improved the learning of the treatment group.
Keywords: Elementary mathematics, fact fluency, technology, teaching methodology, automaticity

Introduction

Elementary educators generally believe that children should memorize basic number combinations, often called mathematic facts or basic mathematic facts (Baroody, Bajwa, & Eiland, 2009; Van de Walle, Karp & Bay-Williams, 2013). These mathematic facts may include addition, subtraction, multiplication, or division. Quick recall of this information is essential as students advance to higher levels of mathematics learning (Baroody et al., 2009). Past research revealed that when students cannot retrieve mathematic facts from memory quickly, they become inhibited in obtaining a correct answer in more complex problems (Hudson, Kaden, Lavin, & Vasquez, 2010; Willingham, 2010). In essence, “memorization frees up brain power, which can allow most of the students’ attention to focus on the more complex task at hand” (Hudson et al., 2010, p. 22).

The importance of fact automaticity has been noted by researchers who claim that students are more likely to retain the information and apply it to future tasks when automaticity is achieved (Sharp, & Kenyon, 2012; VanDerHeyden & Burns, 2008). Students who need to use substantial cognitive energy to compute basic mathematic facts may struggle to “dedicate their resources to more advanced applications within the problem” (Burns et al., 2012). Because of this, elementary teachers plan mathematics lessons to help students develop automaticity of math facts, yet the way in which students achieve automaticity remains debated. Some believe that traditional drill and practice is more effective and repetition of mathematic facts enables students to recall them more easily (Burns et al., 2012). Others argue that advancements in technology have introduced new approaches for the teaching and learning of mathematics, which can better serve today’s students (Nejem & Muhanna, 2013; Pannese & Carlesi, 2007). Because of the prevalence of technology in the lives of this unique generation, researchers believe they have learning preferences that are different from previous generations (Proserpio & Goia, 2007). As such, the infusion of technology to promote automaticity may be more motivating and have positive outcomes.

Although Caron (2007) stated that most educators believe the best strategy for students to achieve automaticity of basic facts is through traditional teaching involving drill and practice, there is evidence to suggest otherwise. Bay-Williams and Kling (2014) have challenged this position and claimed that students can master basic facts without rote memory drills and timed tests. As teachers today strive to engage a generation saturated in technology to master basic mathematic facts in more engaging ways, it is necessary to determine if technology tools can provide an alternative effective method for increasing multiplication fact fluency and therefore improve overall automaticity.

The purpose of this quantitative, quasi-experimental study was to investigate the effect of the Mathletics.com technology on basic multiplication fact fluency in the fourth grade. This study investigated the primary research question: What effect does the Mathletics.com technology have on basic multiplication fact fluency in the fourth grade? The construct of fact fluency is measured by both time and accuracy, and basic multiplication facts included those from 0-12.

Literature & Theoretical Perspectives

Procedural versus Conceptual Learning

In the 19th century, Warren Colburn, educator and mathematician from Massachusetts, adamantly defended the need for teaching mathematics in a way that promoted understanding, not rote memorization -- a preferred method in mathematics classrooms since the 17th century (Sztajn, 1995). For many years since, a debate ensued about the most effective methods classroom teachers should use to teach students mathematics. In some recent literature, the preferred position is for the students to understand why specific mathematical procedures are utilized in problem solving, leaving the repeated rehearsal until mathematical concepts are secure (Galen & Reitsma, 2010; NCTM, 2000; Van de Walle et al., 2013). The idea of understanding “why” is the foundation of conceptual understanding, which is defined by Hiebert and Lefevre (1986) as:

> Knowledge that is rich in relationships. It can be thought of as a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information. Relationships pervade the individual facts and propositions so that all pieces of information are linked to some network (pp. 3–4).

Procedural knowledge, in contrast to conceptual knowledge, was defined by Hiebert and Lefevre (1986) as ‘‘a familiarity with the individual symbols of the system and with the syntactic conventions for acceptable configuration of symbols … [or] consist[ing] of rules or procedures for solving mathematical problems’’ (p. 7–8). This type of knowledge is frequently supported by direct teaching, drill, practice, and rote types of learning, especially with regard to learning multiplication facts (Van de Walle et al., 2013)

In 1975, researchers such as MacDonald persistently argued for the rightful position of rote practice and memorization in the teaching of mathematics. Diametrically opposing views on this topic have persisted for decades and at distinct points in time, one particular view has prevailed over the other. This ongoing debate has been an impetus for a general shift in the pedagogical paradigm for mathematics teaching today. In response to the prevalence of rote practice and traditional direct teaching methods, Dubrova (2014) insisted this model of teaching is in direct contradiction with the ways in which society needs students to understand and be able to use mathematics. Dubrova (2014) further criticized the traditional approach to teaching as being an inefficient process that merely transfers specified knowledge and skills.

The position of educators today increasingly aligns with the idea that rote memorization is a dated method of teaching (Hudson et. al., 2010) and children should learn mathematics conceptually, including the learning and memorization of multiplication facts (Van de Walle, Karp, Bay-Williams, 2013). Although discussions in the literature are ongoing, the most current research contends that a combination of generating procedural and conceptual knowledge is the most effective way to teach children mathematics (Baroody, Feil, & Johnson, 2007; Rittle- Johnson et al. 2011; Van de Walleet al., 2013). Generally, agreement exists that a one-way approach to teaching mathematics is not in the best interest of students' future learning and problem solving capabilities. Rather, an iterative process between conceptual and procedural experiences is most effective and the relationships between these two types of knowledge are proving to be crucial for student learning (Riddle-Johnson, Schneider, & Star, 2011; Rittle- Johnson, Siegler, & Alibali, 2001)

Fluency and Automaticity

The concepts of automaticity and fluency are closely related in the context of learning mathematics; at times the terms are used interchangeably. Fluency in terms of basic mathematic facts can be described as "the efficient, appropriate, and flexible application of single digit calculation skills" (Baroody, 2006, p. 22). When students can answer basic mathematic facts questions both quickly and accurately, it represents one form of mathematical fluency. Regardless of the precise definition, a student's fluency and ability to answer basic fact questions are essential elements of mathematical proficiency.

There is a dissimilarity that researchers have identified when defining the two terms in the context of mathematics basic facts. The terms fluency and automaticity share the characteristics of students successfully solving math facts quickly and accurately. The defining difference between the two terms though is that students who are automatic are also able to do so with "minimal effort or (use of) cognitive resources" (Parkhurst et. al., 2010, p. 111). Grabe and Grabe (1998) defined automaticity as "the process by which well-learned skills are executed with minimal mental effort" (p. 427). Students that are fluent with basic facts still utilize "cognitive processes" that require effort whereas those that are automatic with basic mathematical facts are said to be "increasingly rapid and automatized" (Cummings & Elkins, 1999, p. 153). Some researchers use time to determine whether a student is automatic with basic facts. For instance, Bay-Williams and Kling (2014) believed that students should answer a basic fact problem within
3 seconds of being questioned, but others argue that students should be successful in answering questions within 1-2 seconds (Vos, 2009).

Fluency and Number Sense

When children conceptually understand number and operation (addition, subtraction, multiplication and division), they are said to have developed number sense (Witzel, Ferguson, Mink, 2012). The National Mathematics Advisory Panel (NMAP) described number sense as "an ability to immediately identify the numerical value associated with small quantities, a facility with basic computing skills, and a proficiency in approximating the magnitudes of small numbers of objects and simple numerical operations" (Witzelet al., 2012, p. 89). Feikes, Schwingendorf, and Gregg (2009) suggested that number sense provides the foundation for all higher level mathematics and is essential to develop concurrently when learning multiplication facts. Boaler (2015) also believed that establishing number sense is not only essential for the future learning of algebra but for the memorization process of mathematics facts. Boaler (2015) claimed, "When students focus on memorizing times tables they often memorize facts without number sense, which means they are very limited in what they can do and are prone to making errors" (p. 2). Essentially, when teachers overemphasize rote learning and the memorization of math facts, students are less prone to think about numbers and make sense of the learning, thereby inhibiting mathematical development (Boaler, 2015).

Fluency is a key term related to number sense and is a construct commonly defined by speed and accuracy. Educators argue that fluency is one of the most important common goals among all teachers in grades 3-5 (Kling & Bay-Williams, 2015). Achieving fluency is highlighted explicitly as a goal in the Common Core Standards for Mathematics (CCSM) and implicitly in the International Baccalaureate (IB) Primary Years Programme (PYP). The International Baccalaureate (IB) and the Common Core Standards are two prominent curriculum frameworks implemented worldwide, and each of these curricular frameworks includes the expectation that students will develop some form of automatic recall of basic mathematic facts as they progress through elementary years.

Baroody (2006) explained that in order to attain fluency of basic mathematic facts, students must progress through three stages: (1) modelling and/or counting; (2) deriving answers using reasoning strategies; (3) achieving mastery by efficiently producing answers. When mathematic facts are taught in a traditional, rote manner such as drill and timed testing, it forces students to attempt to move from stage 1 directly to stage 3 (Kling & Bay-Williams, 2015). This is problematic because research indicates that students will not retain the information with this approach because a critical component for retention is the "explicit development of reasoning strategies, which helps students master the facts and gives them a way to regenerate a fact if they have forgotten it" (Cook & Dossey, 1982; Kling & Bay-Williams, 2015, p. 551; NRC, 2001; Thornton, 1978).

Methodology

The design for this research was quasi-experimental consisting of nonequivalent comparison groups (Shadish, Cook, & Campbell, 2002). The participants of each respective group, control and treatment alike, had already been placed into their group setting (classroom), and random assignment was not possible. This study included a treatment to one group, specifically the use of the Mathletics.com site, and compared the dependent variables for both the control and treatment groups before and after this treatment. The control group was held constant by using only traditional paper/pencil forms of basic multiplication fact reinforcement in similar intervals throughout the week.

Setting and Sample

The setting for this study was two, fourth grade classes located in two different private international schools in the Middle East – one for the treatment site and one for the control site. Both schools implement the International Baccalaureate Primary Years Programme (IBPYP) curriculum. Purposive sampling was used for this study to ensure that participants in the treatment group had access to Mathletics.com website, and all participants, in both the treatment and control groups, had access to an iPad to complete the pre and posttests on the *Math Fact Master* application. The groups consisted of 14 students in the control group and 14 students in the treatment group.

Treatment

The control and treatment group participants were administered an individual pretest and posttest of randomly generated basic multiplication facts using the *Math Fact Master* application on the iPad. Figure 1 below provides an example of the application problems and the report provided to the teacher.

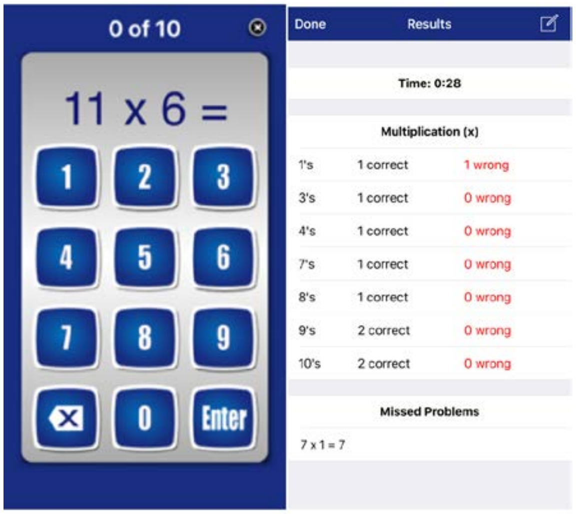

Figure 1. Example of *Math Fact Master* problem and reported score.

This application was utilized to measure speed and accuracy for both groups. The pre- and posttest for each group consisted of 30 multiplication basic fact problems generated randomly with factors between 0-12, inclusive. To prevent the potential for anxiety, the clock keeping the time was not visible to the student while completing the multiplication problems.

After pretesting, the treatment group received three weeks of mathematics practice utilizing the website Mathletics.com, three times a week each for 15 minutes. The Mathletics.com site offers students an integrated, personalized learning space with grade level curriculum and a variety of problem solving experiences. These problems incorporate the need to recall mathematics facts, but not explicitly in a repetitious format. As students played games online at the Mathletics website, their success was monitored allowing them to move on to more difficult concepts as they mastered concepts. They also competed online in real time against other students. The Mathletics.com system matches students that are working within similar levels to compete worldwide. The intent of this treatment was to have students practicing and applying math facts in creative, game-like, and contextualized ways, rather than the intentional mathematic fact practice taking place in a traditional rote manner. The game playing and problem solving on the Mathletics.com site exposed students to experiences that reinforced multiplication facts through problem solving and integrated practice in the online environment, rather than isolated drill using traditional paper and pencil. The students did not engage in any other intentional mathematic fact practice during the three weeks.

The control group, conversely, reinforced multiplication facts also for three weeks, three times a week, for 15 minutes each time using only traditional practice and drill methods with paper and pencil. This was the only intentional exposure for the purpose of practicing mathematic facts, nor did this group engage with any technology during the three weeks. The researchers provided the classroom teachers implementation protocols for both the control and treatment group to guide lessons for consistency during the treatment period.

Data Analysis

The data collected were the results of a pretest and posttest each of which contained 30 questions and represented the dependent variables of completion time and accuracy. Because this study involved more than one dependent variable, multivariate statistical procedures were applied. For this study, the MANOVA, repeated measures MANOVA and necessary post hoc ANOVA or *t*-test analyses were used. During post hoc analysis to counteract the potential of an inflated error rate, the Bonferroni adjustment was used to "set a more stringent alpha level for the test of each DV so that the alpha for the set of DVs does not exceed some critical value" (Tabahnick & Fidell, 2007, p. 122). Where a main effect was found significant, effect size was calculated using partial eta squared to obtain an indication of the magnitude of the treatment.

Findings

The descriptive statistics for the dependent variables in this study are presented in Table 1 and contain the 28 participants (control n = 14; treatment n = 14). As indicated, the pretest scores for the treatment group (M = 27.29, SD = 2.89) were higher than that for the control group (M = 25.50, SD = 4.13). An indication of fluency would be noted by a higher score on the test with a maximum of 30 and a lower completion time, demonstrating a more rapid pace of work. Consistent with this difference in performance, the control group completion time (*M* = 410.79, *SD* = 126.47) was higher than the treatment group (*M* = 209.14, *SD* = 76.03) indicating that the control group scored lower for accuracy while taking more time to complete the 30 problems. The posttest scores and time were similar in that the treatment group outperformed the control group with higher scores and lesser time to complete the test (treatment posttest scores: *M* = 29.36, *SD* = 0.63; control posttest scores: *M* = 27.57, *SD* = 2.14; treatment posttest time: *M* = 183.93, *SD* = 107.45; control posttest time: *M* = 280.50, *SD* = 134.20). Table 1 summarizes this information below.

Cook and Campbell's (1979) growth model analysis was used to examine the potential for differences in posttest scores. Cook and Campbell (1979) explained the concern for selection differences in nonequivalent groups and the pre-existing differences most endemic to this design. Because these differences were confirmed in a significant pretest multivariate analysis, this threat to internal validity can influence posttest results between groups by producing posttest differences even in the absence of the treatment effect. To obtain a reasonable estimate of the treatment effect, Cook and Campbell (1979) offered four alternative posttest analyses to properly manage these differences and separate the effect of the treatment from the effect of selection differences. For this study, the gain score analysis proved to be the most appropriate procedure to examine posttest differences since the pretests and posttests were operationally identical measures (Cook & Campbell, 1979). Examining the pattern of growth through this analysis allows for the prediction of the amount of growth that would have occurred under null conditions when compared with the growth that was actually obtained. Table 2 below provides the summary of descriptive statistics for the gain scores calculated for the control and treatment group posttests.

As indicated in Table 2, the control group and treatment groups grew slightly in their posttest gain scores and both groups also reduced their completion time (treatment posttest gain scores: *M* = 2.07, *SD* = 2.76; control posttest gain scores: *M* = 3.07, *SD* = 3.36; treatment posttest time gain score: *M* = -25.21, *SD* = 62.87; control posttest time gain score: *M* = -130.29, *SD* =135.33). The control and treatment groups on average raised their scores by approximately 3 and 2 points, respectively. On the other hand, the control group on average reduced their completion time by 130 seconds, with the treatment group also working more quickly and reducing their completion time on average by about 25 seconds.

Question 1. To what extent did the control and experimental groups statistically differ in fact fluency as measured by time and accuracy on the posttest?

Using gain scores to detect significant differences in the between group posttest dependent variables, the MANOVA results revealed significant differences among the groups on the combined dependent variables ($F(2, 25) = 3.40$, $p < .05$; Wilks' $\lambda = .79$; partial $\eta2 = .21$). As follow up to MANOVA, ANOVA was conducted to determine differences between each dependent variable using a Bonferroni adjusted alpha level of .025. In this analysis, the only difference to reach statistical significance again was completion time (F (1, 26) = 6.94, $p < .025$, partial $\eta2 = .21$). An inspection of the mean scores for the gain analysis indicated that the control group (*M* = -130.29, *SD* = 135.33) exhibited significant growth in completion time, whereas the treatment group showed only modest gains in speed when completing the posttest (*M* = -25.21, *SD* = 62.87). The posttest scores, however, were not significantly different (F (1,26) = .74, $p > .025$).

Table 1

Summary Descriptive Statistics for Control and Treatment Groups

						95% Confidence Interval for Mean			
				Std. Deviation	Std. Error	Lower Bound	Upper Bound		
Pretest Scores	Control	14	24.50	4.13	1.10	22.12	26.88	16.00	30.00
	Treatment	14	27.29	2.89	.77	25.61	28.96	22.00	30.00
	Total	28	25.89	3.77	.71	24.43	27.36	16.00	30.00
Pretest Time	Control	14	410.79	126.47	33.80	337.76	483.81	218.00	672.00
	Treatment	14	209.14	76.03	20.32	165.24	253.04	103.00	357.00
	Total	28	309.96	145.00	27.40	253.74	366.19	103.00	672.00
Posttest Scores	Control	14	27.57	2.14	.57	26.34	28.81	23.00	30.00
	Treatment	14	29.36	.63	.17	28.99	29.72	28.00	30.00
	Total	28	28.46	1.79	.34	27.77	29.16	23.00	30.00
Posttest Time	Control	14	280.50	134.20	35.87	203.01	357.99	94.00	566.00
	Treatment	14	183.93	107.45	28.72	121.89	245.97	83.00	485.00
	Total	28	232.21	129.03	24.38	182.18	282.25	83.00	566.00

Table 2

Posttest Descriptive Statistics for Control and Treatment Groups' Gain Scores

Group	Mean	Std. Deviation	N
Score_Diff Control Group	3.07	3.36	14
Treatment Group	2.07	2.76	14
Total	2.57	3.06	28
Time_Diff Control Group	-130.29	135.33	14
Treatment Group	-25.21	62.87	14
Total	-77.75	116.55	28

Question 2. To what extent did the pretest and posttest scores statistically differ in fact fluency as measured by time and accuracy within the control group and the experimental group?

To determine if there was a within subject difference in control and treatment groups on the linear combination of the dependent variables of time and score a repeated measures MANOVA was performed. Using pre- and posttest measures to detect within group differences on the dependent variables, the repeated measures MANOVA results revealed significant differences within the groups on the combined dependent variables of time and scores from pretest to posttest. ($F(2, 25) = 6.99$, $p < .05$; Wilks' $\lambda = .79$; partial $\eta 2 = .21$). As follow up to MANOVA, paired sample *t*-test using a Bonferroni adjusted alpha level of .025 was conducted to determine differences between each dependent variable from pretest to posttest within the groups. In this analysis, the control group reached statistical significance on pre- and posttest scores ($t(13) = -3.41$, $p < .025$) and also was significant on pre- and posttest time ($t(13) = 3.60$, $p < .025$). Similarly, the treatment group improved significantly on pre- and posttest scores ($t(13) = -2.81$, $p < .025$), however, a significant change in completion time was not evident for the treatment group ($t(13) = 1.50$, $p > .025$).

Figures 1 and 2 below provide the boxplots representing the pre- and posttest performance on both time and accuracy for the control and treatment groups in this study, which display the performance changes from pre- to posttesting for both groups.

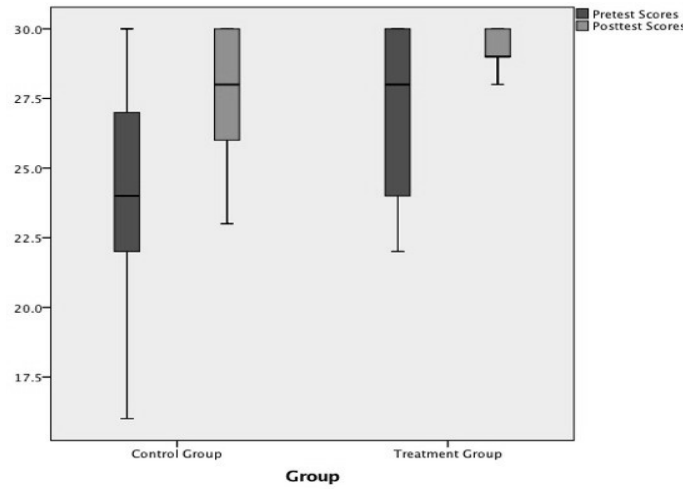

Figure 1. Boxplots for control and treatment groups on scores for pre- and posttests.

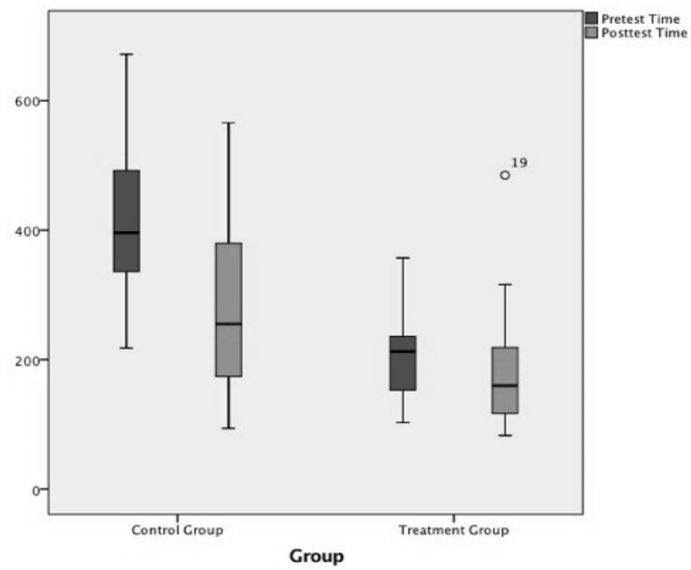

Figure 2. Boxplots for control and treatment groups on time for pre- and posttests.

Limitations

The limitation of a small sample size impacted the generalizability of this study's results. Although the use of nonequivalent group designs without controlled selection are most common in practice, the analysis of this design is "generally more difficult and less salutary than the analysis of designs with controlled selection" (Cook & Campbell, 1979, p. 147). As such, the design of the study also posed distinct limitations. Selection maturation interaction also is a limitation to this research. While the only intentional practice of multiplication facts was during the three week treatment period, it is not possible to assume that students were not exposed to relevant mathematic facts during other lessons for mathematics class or throughout the day. Such incidental exposure is also a limitation of this study.

Results and Implications

The results of this study challenge a growing perspective on the application of classroom technology as it relates to its use to support fact fluency. Although the control and treatment groups improved in speed and accuracy between the pre and the posttests, the control group, using only paper and pencil practice, showed substantially greater improvement of speed after refraining from using technology for three weeks. The results further indicated that the inability to use technology did not have an adverse effect on the control group's posttest scores or ability to improve, nor a significant ability to improve the results of the treatment group.

Prensky (2010) defined digital natives as those born between the years of 1980 and 1994. This generation, since birth, has been inundated with technology such as the Internet, computers, video games and cellular phones. Because of this distinguishing characteristic, theorists and educators believe that today's student learns differently than students in the past and teachers today often do not use strategies that enable the digital natives to learn best. As such, researchers are calling for radical reform in how schools educate students (Arredondo, 2011). This research causes pause for educators when making instructional decisions about the purposeful use of technology in mathematics classrooms to support fact fluency.

The results of this study indicate that consistent reinforcement of basic facts is important in developing mathematical fluency. As both the control and the treatment groups improved in time and accuracy, it seems as though interacting with basic facts in any capacity is sufficient for improving basic multiplication fact fluency. The interaction with the basic facts could be through the use of technology or utilizing traditional methods of instruction such as paper/pencil activities and worksheets. These results are not unlike other studies that have had a focus on the use of technology to improve student learning. Longnecker (2013) found in his research utilizing the website IXL that the use of the website "did not have much of a significant effect on the mathematics achievement scores and math grades of the students" (p.57). Longnecker's (2013) research also indicated that where IXL did produce an effect, "it was often negative and, in fact, hindered the students and cost them points on each of the measurements used" (p.57). In this study, because each group practiced basic facts – one group with technology in an integrated manner and one group with traditional paper and pencil only methods -- the within group growth provided insight into the mere use of intentional practice, regardless of the method, with regard to improving student scores on time and accuracy of mathematics facts from 0-12.

Interesting to these results is that the control group, using only traditional methods for multiplication fact rehearsal and practice, significantly improved during the time of the study on both dependent variables of time and accuracy. The treatment group, however, using the Mathletics.com technology significantly improved their accuracy, but not the time to complete the fact problems. The treatment group, however, began the study with a much higher completion time mean score (M = 209.14) as compared to the control group (M = 410.79), so while the treatment group did not work quicker throughout the duration of the study, the participants using the Mathletics.com technology did improve their accuracy scores. At the time of pretest measures, the treatment group was completing the math fact assessment about 3 minutes quicker than the control group. Upon posttest, however, the time difference between the control and treatment groups was less, with the treatment group completing the assessment only about a minute and a half quicker than the treatment group. This finding suggests that the improvement of time and accuracy of mathematic facts may be achieved in different ways, challenging teachers to consider what may be more important to long-term student success.

Technology is one tool that educators use to motivate today's students, but in what content and for what academic purpose remains a question for further exploration. Arnone and Small (1999) identified various factors for educational websites that benefit student motivation. These factors include, engagement, usefulness, interest, ease of use, allowance for exploration, and some element of fun. Nansen et al. (2012) noted that the website in the study was appealing to children allowing them to have fun while learning providing motivation. The premise for this study was that the use of technology would have appealed to students and may have motivated them to perform better and more readily retain and reproduce mathematics facts. Additionally, the practice provided through the use of the technology was more conceptual and applied in its approach from the Mathletics.com site, rather than merely rote or repetitious. Given the debate between the purpose of conceptual and procedural learning of facts in mathematics class, this explorations was worthwhile in an attempt to parse out the precise ways that fact fluency may be influenced.

An important implication from this study is for educators to deeply examine the value and use of technology in the teaching and learning of mathematics. There are researchers calling for a critical review of how today's teachers are educating digital natives, but perhaps a radical change in the rehearsing of mathematics facts is not an improved approach. Instead, a combination of teaching and learning experiences and consistency over time would be most beneficial for students when learning basic multiplication facts. This study highlights for practitioners that intentional practice with basic mathematics facts may offer benefits, regardless of the method used to rehearse. This challenges current research suggesting that conceptual approaches, even to securing fact fluency, may have better outcomes. In this study, results have indicated a "both…and" approach, rather than an "either…or" perspective.

Another important consideration from this research is for educators to reconsider the value of speed when completing basic math facts. As Hudson et al. (2010) noted, when students have successfully memorized their basic facts, they are able to attend to the more difficult aspects of an algorithm. This would imply that the speed in which solving basic facts does have implications on children experiencing success in mathematics. However, there is evidence that when students focus on completing mathematics problems under timed conditions, they are at risk at developing anxiety towards the subject. Burns (2000) wrote that when student success is measured against time, children can "become fearful and negative toward math learning" (p.157). In mathematics, where the connection between explicit timing and increased anxiety is strongly correlated, the practice of keeping time should be examined further. In this research, although time was recorded for the students, they were unaware of this measure and yet, both groups improved in their time scores. The progress in this research occurred without the potential stress imposed by intentionally and explicitly timing students' work or having them race against a clock.

Conclusions

In this study, the researchers hypothesized that with the use of online technology and a more conceptual approach to obtaining fact fluency, in this case through Mathletics.com, would enhance the learning of basic multiplication facts for students in the 4th grade. Many of today's students have abundant access to technology and have had that access since birth. Because of this, children are drawn to technology for many reasons including that technology is fun, meaningful to them on a personal level, and can be collaborative in nature. By implementing technology in the context of education, researchers suspected students would feel more motivated to retain basic multiplication facts, thereby improving fact fluency. This research did not find a significant difference in basic fact fluency when using technology that applied a more conceptual and integrated approach to the learning. While technology can bring motivation to the learning process, it may not provide the best method for improving basic fact fluency.

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