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Spatial-Temporal Math and its Effect on Student Achievement

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Abstract

The purpose behind this action research was to determine the effect Spatial-Temporal (ST) Math, a web-based mathematics program, has on student achievement at a second grade level. The ST Math program was given to a small group of second grade students on top of the classroom mathematics curriculum while another group of students strictly used the classroom mathematics curriculum. A pre and post assessment were given to these students over an eight week period. This quantitative data was analyzed to determine the correlation between the students' exposer to ST Math and their achievement on the assessments. After analyzing the data, it shows that students' scores who participated in the ST Math program increased. However, when compared to the students who did not participate in the math program, there was no distinct difference in scores.

Spatial-Temporal Math and its Effect on Student Achievement

A mathematics curriculum can have a great impact on student achievement in the content area. When the curriculum does not meet the needs of every student, educators look elsewhere to add supplemental materials. There are many different supplemental curriculums available to educators. It is important for educators to know which supplemental materials are more beneficial than others. This teacher researcher's classroom was no different. The current classroom mathematics curriculum, Saxton Math, was severely outdated and teachers have been searching for a supplemental curriculum to include in their everyday mathematics instruction. Before jumping into a new curriculum, data needed to be analyzed on the correlation between the program and student achievement. The supplemental mathematics curriculum, Spatial-Temporal (ST) Math was chosen.

ST Math is a web-based program that students participate in individually. There is not any direct teacher instruction. Students are introduced to multiple situations where they are challenged to use their math concept knowledge and problem solving skills to complete each situation. Situations get more and more complex as students complete them correctly. In comparison, situations get easier as students do not complete them correctly. There are hints along the way for students to request if they find themselves stuck.

Literature Review

Computer Assisted Technology

Computer assisted technologies are becoming more and more common throughout classrooms. Teachers are employing new ways to increase student motivation along with student scores. Computer assisted technologies are being used in classrooms as curriculum enhancements and interventions. The West Central Valley School District is no different. When presented with the opportunity to begin using the computer-assisted program, Spatial-Temporal (ST) Math, many teachers jumped at the chance. Rutherford, Farkas, Duncan, Burchinal, Kibrick, Graham, Richland, Tran, Schneider, Duran, and Martinez (2014) state, “These programs are being widely implemented under the belief that they provide a significant educational benefit with relatively small investments of time and money by the schools” (p. 359). There is conflicting research on the topic of computer assisted technologies and very few research has been done on ST Math specifically. While many studies and articles state the educational benefits of using computer-assisted technology, no computer-assisted intervention for elementary schools is listed within the Institute of Education Science’s What Works Clearinghouse (Rutherford et al., 2014). Yet many districts spend millions of dollars each year on these programs. This is a break-down of relevant research done on the different aspects, positive and negative, of computer assisted technologies as well as specifically ST Math.

ST Math Background

ST Math is a computer based supplemental mathematics program. It was developed and researched by the MIND Research Institute. Essentially ST Math “consists of visual representations of math standards, concepts, and procedures, presented to students as ‘puzzles’ of virtual manipulatives” (Guise, 2016, p. 5). On the computer or tablet screen students are presented the task of helping Jiji, an animated penguin, complete different tasks in order to move across the screen. These tasks may include building bridges or moving obstacles in Jiji’s way. They must do this by solving mathematical puzzles. These tasks “blend into the mathematical puzzles such that there is often little distinction between the game and the mathematics- in other words, the game elements *are* mathematics” (Rutherford et al., 2014, p. 360). Students are given two lives at the beginning of each level. The students must finish each level before making two mistakes, using their lives. If they cannot, they must repeat the level. Students must complete the level before they can progress onto the next. Studies have coined the term “developmental progression” to describe this idea of building a foundation before continuing to learn another (Rutherford et al., 2014, p. 363). Developmental progression “describes a typical path children follow in developing understanding and skills about a mathematical concept” (Rutherford et al., 2014, p. 363). Rutherford et al. (2014) states, “Within this progression, new math skills are built on previously mastered skills to form a trajectory of increasingly sophisticated thinking” (p. 363). The MIND Research Institute encourages schools to set aside two 45 minute blocks or 90 minutes a week for students to use ST Math. Their goal is for students to complete 80% of their grade level modules in one academic year. Student educational growth increases when adhering to these. There are nine different modules specifically for second grade; place value up to 1,000, money, time and elapsed time, addition and subtraction (2 digits), geometry and measurement, fractions, intro to multiplication, intro to division, and addition and subtraction (3 digits) (Rutherford et al., 2014). The Mind Research Institute has done studies on the effect ST Math has on student achievement. In one study done across the 2012-2013 and 2014-2015 school years, the Mind Research Institute showed findings that fifth grade students who participated in the ST Math program gained a statistically significant 11.14 points over the fifth grade control group who did not receive ST Math instruction (Guise, 2016).

Virtual Manipulatives

There is quite a bit of research on the specific use of virtual manipulatives. Most of this research is positive. Anderson-Pence (2017) states, “Virtual manipulatives have the potential to make learning more enjoyable and to encourage students to persist in problem solving” (p. 1). They also “allow students to generate their own representations, encourage creativity and novelty, and promote experimentation" (Anderson-Pence, 2017, p. 4). Finally, virtual manipulatives allow students to focus on "particular aspects of mathematical objects- aspects that they otherwise may not have paid attention to" (Anderson-Pence, 2017, p. 4). The virtual manipulatives that ST Math uses presents students with specific problems to solve. These types of problems are important for students because they provide students with a real-world context. Lantz-Andersson, Linderoth, and Saljo (2009) state "it is here that children allegedly learn how to make practical use of their mathematical skills" (p. 326). The real-world contexts and gaming aspect of virtual manipulatives such as ST Math increase the depth to which students comprehend mathematics topics. In many cases, paper and pencil word problems provide students with situations in which they disregard their real-world knowledge. Lantz-Andersson et al. (2009) provides an example of a story problem in which these issues occur; "Kalle goes to school and on average he has seven lessons a day. How many lessons does he have per week?" (p. 327). In this word problem, most of the students overlook the real-world aspect that students only go to school five days a week. Therefore, many will multiply seven times seven instead of seven times five. It is examples like this that show the effect paper and pencil word problems have on students. They struggle with the real-world aspect *not* the math (Lantz-Andersson et al., 2009). Virtual manipulatives provide students with an atmosphere that is more authentic and realistic. Lantz-Andersson et al. (2009) state that by using virtual manipulatives like ST Math "learners will find it easier to understand tasks than in a traditional, purely verbal, context" (p. 327).

Concreteness Fading

While the research on virtual manipulatives shows the positives of using computer assisted programs like ST Math, there is another component of the program that researchers are beginning to look at more closely. This component is called "concreteness fading". There has been much debate about the positives and negatives of using strictly concrete materials versus using strictly abstract materials when teaching mathematics. Concrete materials "connect with learner's prior knowledge, are grounded in perceptual and/or motor experiences, and have identifiable correspondences between their form and referents" (Fyfe, McNeil, Son, & Goldstone, 2014, p. 9). However, there are negatives with teaching solely with concrete materials. Concrete materials include outside details that distracts learners from the important, mathematical, information (Fyfe et al., 2014). Using strictly abstract materials has positives and negatives as well. Abstract materials eliminate the outside details that distract learners as mentioned above. They also "present structure efficiently, and are more arbitrarily linked to their referents" (Fyfe et al., 2014, p. 9). The risk with using strictly abstract materials is that learners may begin to "manipulate meaningless symbols" instead of understanding the basics behind those symbols (Fyfe et al., 2014, p. 10). The concept of concreteness fading takes the positives of each of these separately and attempts to eliminate their negatives. "Concreteness fading refers specifically to a three-step progression by which the concrete, physical instantiation of a concept becomes increasingly abstract over time" (Fyfe et al., 2014, p. 10). This concept begins at a concrete level and then slowly moves toward a more abstract context. It begins to "strip away" any irrelevant information and ends with the abstract form (Fyfe et al., 2014, p. 11). Fyfe et al. (2014) states that it "allows learners to initially benefit from the grounded, concrete context while still encouraging them to generalize beyond it" (p. 10). The first phase of concreteness fading, called the enactive stage, is strictly concrete. The second phase begins to combine those concrete materials with their abstract counterparts. This phase is called the iconic stage. Fyfe et al. (2014) presents the idea that "if the concrete materials precede the abstract materials, the learner can successfully interpret the ambiguous abstract materials in terms of the already understood concrete context. This process may underlie children's improved performance on symbolic equations when they are preceded by equations constructed from concrete manipulatives" (p. 12). The final phase of concreteness fading, called the symbolic stage, is strictly abstract. Fyfe et al. (2014) again state, "Once an understanding of the abstract concept has been achieved learners do not give up their imagery, but rather rely on this stock of representations as a means of relating new problems to those already mastered" (p. 13). Concreteness fading is a component that is very relevant in the ST Math supplemental program. The beginning tasks are very concrete, only after students have mastered the concrete levels are they introduced to the corresponding symbols and procedures (Fyfe et al., 2014). The creators of ST Math developed the program with this specific concept in mind. Guise (2016) states, "The puzzles typically start with concrete representations of the math, without abstract symbols, math vocabulary, or even English words. Gradually, through subsequent levels or games, abstractions are introduced" (p. 5). The absence of words is another element that the creators deliberately determined to eliminate. The hopes being that the program would be a better fit for low performing students and English language learners (ELLs). The absence of words would allow students, who had trouble reading or understanding English, to actively participate and gain mathematics knowledge. There has been different research on this claim which will be discussed next.

Research

There has been very few studies conducted directly on the ST Math program. Much of the research that can be found is done by the MIND Research Institute. While the findings are interesting, it must be noted that the MIND Research Institute created and developed the ST

Math curriculum, so their findings may not be entirely without bias. Overall computer assisted technology has had very positive findings with regard to research. However, one study done by Lantz-Andersson et al. (2009) had the opposite findings. This group observed students using a different computer assisted mathematics program. There were a few problems that the program introduced into the students thinking that worked against their learning environment. Lantz-Andersson et al. (2009), the researchers on that study, stated that "a common claim is that [computer assisted technologies] contribute to the authenticity of the learning environment. Problems are supposed to appear more realistic when presented in a dynamic and interactive digital environment. Our results indicate that the digital tool instead may be constructed as adding a level of complexity that the students have to consider in their activities" (p. 342). Many of these issues will be discussed further on in the literature review, but some of the basic issues included; not understanding how to give an answer, deciding whether the students' answers were wrong or whether it was a glitch in the program, and not knowing why their answer was labeled incorrect. The MIND Research Institute developed an article stating the research findings they had seen across the 2012-2013 and 2014-2015 school years. Their study compared the growth of students receiving ST Math instruction to a set of students who were not receiving ST Math instruction. Their studies showed that the students who were participating in the program where gaining more than their counterparts who were not participating in the program (Guise, 2016). Specifically a fifth grade group using ST Math gained 11.14 points over their counterparts who were not receiving ST Math instruction (Guise, 2016). A school district in the D.C. area allowed schools in their district the option to implement ST Math into their mathematics curriculum. After the 2012-2013 school year, the schools that had fully implemented the ST Math program saw large gains in the number of students scoring proficient or advanced on their standardized tests (Herold, 2015). The number of students scoring proficient or advanced on those tests rose 19 percentage points compared to 5 percentage points of growth by those schools not using ST Math (Herold, 2015). Finally, a group in Southern California linked up with several different districts to conduct research on the effect of ST Math on their students as well as the different effect it may have on struggling learners and ELLs. Their studies showed that the learning gains from using ST Math were "relatively small" although there was some gain (Rutherford et al., 2014, p. 378). That same study also showed "little support for the hypothesis that ST Math has stronger effects for the lowest performers and/or for ELLs" (Rutherford et al., 2014, p. 373). These three different studies show the wide range research is currently showing about the effects of ST Math. When more unbiased research is done, there may be a better opportunity to see the full effects of ST Math. There are also some basic elements that must be implemented in order to create a better atmosphere of growth when it comes to implementing ST Math.

Important Components

While some studies show positive effects of ST Math there are just as many showing negative effects. There are a couple elements of ST Math that need to be implemented by teachers if they are hoping to provide a positive atmosphere for ST Math learning. One important aspect is clearly stated by the creators of ST Math: teachers need to be an integral part of the process. Teachers need to be aware of when students are stuck and be able to provide them with the needed assistance (Rutherford et al., 2014). Without the assistance of teachers, students who become stuck will not be able to progress through the game nor understand the specific mathematics concepts. Teachers need to monitor their students as they participate in the ST Math activities, without them students are not likely to make positive mathematical gains. Another important element in any computer assisted technology is discussion. Teachers need to be taking the time to discuss the ST Math tasks in their daily mathematics lessons. Students need to be provided the opportunity to explain their thinking and ask questions. Teachers need to be solidifying students' understanding of different concepts in the classroom. This is where they will be able to identify whether students have developed an understanding for the different mathematics concepts. Anderson-Pence (2017) discusses the importance of class discussions, it allows students the opportunity to "analyze and evaluate the mathematical thinking and strategies of others and deepen their own mathematical understanding" (p. 3). Although ST Math is not set up for partner work, allowing students to complete ST Math tasks with a partner is a great opportunity for learning and discussion. "Students develop understanding as they interact with other individuals through verbal or nonverbal communications or written words" (Anderson-Pence, 2017, p.2). One last element that needs to be implemented to provide the best atmosphere for ST Math is the amount of time spent on the supplemental curriculum. This element is endorsed by the MIND Research Institute. They believe students should spend two 45 minute sessions or 90 minutes each week using the program. This will allow students to complete close to 80% of the grade-level modules. By completing the majority of the modules, the opportunity for students to succeed is much greater. These elements will help ensure positive growth by students while using the ST Math program, however; there are some elements that articles have deemed as problems with the program.

Difficulties

While there have been many positives regarding the ST Math supplemental program, there have been some negative areas discussed as well. Three areas that have been discussed the most are; determining how to frame the answer, the amount of time needed to implement the program, and the lack of feedback on an incorrect answer. First, determining how to frame the answer is something many computer assisted technologies have had difficulty with. For example, students are not sure whether to use fractions or decimal points when entering their answer. This becomes a larger issue when students become so wrapped up in how to enter their answer they do not understand why their answer may have been incorrect in the first place. Earlier in the literature review, a research study was addressed in which students were observed while they used a computer assisted mathematics program. This program was not ST Math. One observation that researchers discovered was that when students were told their answer was incorrect they instantly determined it was an error in framing their answer. They were so quick to assume this that they did not take into consideration that they may actually have the wrong answer. This inadvertently led to students using a trial-and-error method of entering answers (Lantz-Anderson et al., 2009). The study suggested "it doesn't cost very much in terms of time and effort to enter new digits repeatedly, and the software serves as a patient partner who does not react no matter how many times you write incorrect answers" (Lantz-Andersson et al., 2009, p. 333). Eventually when students cannot determine the right answer, they give up and go onto another task (Lantz-Andersson et al., 2009). This leads us to the next issue; lack of feedback on an incorrect answer. "Studies have shown that valuable visual feedback prompt productive problem-solving student discourse" (Anderson-Pence, 2017, p. 6). In ST Math, the computer "visually animates the puzzle, diagram, or symbols to show why the posed solution correctly solves, or why it does not solve the math problem" (Guise, 2016, p. 5). This is the positive part, when students find it is incorrect the program visually shows them why it cannot be the answer. However, it does not do the same to show them how to find the correct answer. It simply offers them the opportunity to try again. This is where the ideas of finding an issue with the framing of the answer or resorting to trial-and-error come into play. Students may simply begin to guess instead of determining what the correct answer should be. Lantz-Anderson et al. (2009) state why this is, “The lack of feedback of what is the correct answer, which they are accustomed to having access to when working with regular exercise books, causes them to handle the situation in a different manner. When having the correct answer as a resource, they are able to rethink their calculations and answers in the light of this information” (p. 334). The final issue is time. As discussed earlier, the MIND Research Institute suggests students participate in the program for 45 minutes two times a week or 90 minutes each week. When combined with 35 weeks in a school year, students should be able to complete 80% of the grade-level modules. “MIND’s historical analysis have shown that it is necessary to complete at least 50% of the program in order to expect significantly higher performance compared to non-users” (Guise, 2016, p. 6). Research shows that the average student completes about 80% of their grade-level modules (Rutherford et al., 2014). However, the lowest performers on average completed only 47.82% of the modules while the high performers where completing 90.36% (Rutherford et al., 2014). Low performing students where not getting through enough of the program to expect significantly higher performances. The bigger issue is that to make time for 90 minutes a week of ST Math time, teachers are needing to collect that time from somewhere whether that be reading, writing, social studies/science, or their regular math curriculum time. While making time for ST Math, teachers are taking away time for education in some other area. Are those other areas seeing decreased scores because of the time being taken away for ST Math?

Conclusion

There is much research being conducted on computer assisted technology, virtual manipulatives, and concreteness fading. Little research has been done specifically on the supplement mathematics program ST Math outside of the MIND Research Institute. It is important to look at the elements of ST Math that have been researched, some positive and some negative. As more research is conducted, it may become more apparent which direction research will lean, positive or negative. For now it is very mixed.

Methodology

Participants

This action research was conducted in a second grade general education classroom. This classroom was located in rural central Iowa. There are around 180 students in the kindergarten – fifth grade building. There is less than one percent diversity in the elementary building and 60 percent free and reduced lunch.

Six students participated in the research program; two girls and four boys. These students ranged in age from seven to eight. Three students participated in the ST Math program in addition to the regular classroom mathematics curriculum. The other three students participated strictly in the regular classroom mathematics curriculum. The pre-assessment was given to all second grade students. A high, low, and average achieving student was chosen for each research group. Students were comparable in achievement between both groups. These six students were predominately white. One in each study group received free and reduced lunch. None of the students received special education or Title I services for math.

Process

Students were pretested on math skills on week one. Both educators, the general education teacher researcher and Title 1 teacher, where actively involved with strong interest in determining any correlation between students who received the ST Math intervention and those who did not. Support was given from all those involved including the general education teacher-researcher, Title I teacher, and principal. This research was conducted with the hypothesis that students receiving the ST Math intervention would gain more skills than those students who did not receive the ST Math intervention. On week eight students were given a posttest on math skills.

Data Collection

The purpose of this action research was to determine the correlation between the ST Math program and students' achievement. Students were given a pre-assessment screener before they were selected to participate in the study. The screener was an element of the general education classroom Saxton mathematics curriculum. Students were chosen for this study based on their similar score to another student. One high achieving, low achieving, and average achieving student was selected for both the ST Math intervention group and the non-intervention group. Students who were selected to participate in the ST Math intervention, went to a different classroom for 20 minutes five times a week. In this classroom, they were provided a tablet to participate in the ST Math program. The Title I teacher was available as a resource for students to ask questions and to observe the students.

The students who participated in the study were then given a post-assessment screener at the end of eight weeks. This qualitative data was analyzed to determine the relation, if any, between students' achievement and their participation or lack of in the ST Math program.

Findings

Data Analysis

Table 1 shows the students' scores on their pretest, their posttest, and the amount of gain between the pre and posttests.

Table 1

Students' Pre and Posttest Scores

Student received ST Math intervention	Student did not receive ST Math intervention	Pretest Score	Posttest Score	Gain from pre to posttest
Student A		17	18	1
Student B		16	18	2
Student C		20	23	3
	Student X	14	20	6
	Student Y	19	20	1
	Student Z	21	25	4

Students A, B, and C received the ST Math intervention for eight weeks. Those students averaged a 2.0 point gain between pretest and posttest. Students X, Y, and Z did not receive the ST Math intervention. They averaged 3.6 point gain between pretest and posttest. Student B and Student X were both low achieving students. Student X did not receive the ST Math intervention and gained six points while Student B did receive the ST Math intervention and gained two points. Both students C and Z were high achieving students. Student C received the ST Math intervention while student Z did not. Student C gained three points compared to Student Z who gained 4 points. Finally, students A and Y were both average achieving students. Student A received the ST Math intervention and gained one point. Student Y did not receive the ST Math intervention and gained one point.

Discussion

Summary of Major Findings

This study concluded that the students receiving the ST Math intervention program did not make significant gain over the students who strictly received the classroom mathematics instruction without the ST Math intervention. The data shows that the students who did not receive the ST Math intervention averaged a 3.6 point gain while their intervention receiving counterparts averaged only a 2.0 point gain. The students who did not receive the intervention averaged 1.6 points more than those students who did receive the intervention.

The study also showed interesting data when students were broken up into their high, average, and low achieving status. Both high achievers gained similar points from pre to posttest. Student C received the ST Math intervention and gained three points, while student Z did not receive the intervention and gained four points. With a one point difference, the data shows that students gained similar knowledge whether involved in the ST Math program or not. The same can be said for the average achieving students. Student A received the ST Math program and gained one point, while student Y did not receive the intervention and gained one point as well. This data again shows that the intervention or lack thereof did not have an impact on the average achieving students. However, the data showed something different for the low achieving students. Student B received the ST Math intervention and gained two points. Student X did not receive the intervention and gained six points. This is a significant difference. This data shows that the low achieving student, X, actually gained more while not participating in the ST Math intervention than the one participating in the intervention, B. The study found that the ST Math intervention had no impact when comparing high or average achieving students. The study also found that ST Math had a lesser impact on low achieving students than those simply receiving classroom mathematics instruction without an intervention.

Limitations of Study

The limitations of this study included using strictly one computer-based intervention, ST Math. Studies may have different results when comparing other computer-based interventions. This study also included a small number of participants. When a larger group of students is utilized there may be different results. The researcher must also take into account the natural learning styles and learning maturation of the students involved. Computer-based models may not have matched their learning style. As well, their level of learning may not have matured yet in the early part of the school year. The students' motivation to learn may also have played a factor. Students with higher or lower motivation to learn may score differently.

Further Study

The lack of research done on ST Math, outside of the company who created it, suggests that more research about this specific computer-based intervention program should be done. More research needs to be conducted on the potential benefits outside of the researcher's classroom. Also, the amount of time students receive the intervention, longer than eight weeks, should also be studied further. The ST Math intervention program may show benefits after more than eight weeks.

Conclusion

The elements of computer assisted technologies have been researched in different ways. The research on specific elements of computer assisted technologies that are incorporated into the ST Math program have had positive findings such as using virtual manipulatives and the concept of concreteness fading have shown to be beneficial parts of computer assisted technology. However, there has been little research done on the specific program, ST Math, outside of the company that created it, The MIND Research Institute. The few studies that have been done specifically on ST Math have had mixed findings. In order to effectively implement the ST Math program, teachers need to be actively involved while students participate in the program as well as providing discussion opportunities afterward. Teachers should also be allowing students to participate in the program for 90 minutes each week. The specific problems with computer assisted technology and ST Math specifically are setting aside enough time for students to participate, confusion with formatting answers within the program, and lack of feedback on incorrect answers.

Three students in this teacher researcher's classroom where presented with the ST Math intervention five times a week for eight weeks. They were provided with a pre and posttest along with their three counterparts who did not receive the ST Math intervention. The findings from this particular active research suggest that the addition of ST Math does not increase students' achievement any more than strictly receiving the classroom mathematics curriculum. The data shows that students receiving the ST Math intervention did not gain any more points from pre to posttest and in some cases actually gained less than their counterparts who did not receive the intervention.

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