Summer 2021

Math Talks Impact on Students in ST Math

Rachel Coulter
Northwestern College - Orange City

Math Talks Impact on Students in ST Math

Rachel Coulter

Northwestern College

An Action Research Project Presented

In Partial Fulfillment of the Requirements

For the Degree of Master of Education

July 2021

Dr. Theresa Pedersen

Table of Contents

Abstract

The purpose of this action research study was to determine the impact math talks had on student performance in ST Math and how math talks impact students' understanding of mathematical concepts outside of ST Math. This action research study was conducted in two sixth-grade classrooms at an Intermediate School in Central Iowa. Quantitative data was collected via the number of puzzles individual students completed per minute. Quantitative data was also collected in the comparative number of correct responses on a pre and posttest over the mathematical concept students covered in ST Math. The results of the study showed students had significant growth in their understanding of the mathematical concepts covered in ST Math. No significant growth was shown in the number of puzzles individual students completed per minute.

Keywords: ST Math, math talks, number talks, spatial temporal math

Introduction

Ask a student of any age what they are doing during their free time and most of the answers will include playing some sort of video game, whether on a console, computer or phone. In a study conducted by the NPD group, 73 percent of Americans age 2 and up play some sort of video game, with a noticeable increase in gaming engagement yearly for individuals ages 2-17 (Riley, 2019). With gaming becoming an essential part everyday life, it is no surprise the world of education is interested in how game-based learning can impact student achievement.

Research states a lack of engagement and motivation in learning has led to students dropping out of school (Khan et al., 2017). One way to combat this is with game-based learning or gamification. Game-based learning is "learning activities that have a game at their core, either as the main activity or as a stimulus for other related activities, and have learning as a desired or incidental outcome" (Kirriemuir & McFarlane, 2004).

ST Math is a "visual instructional program that leverages the brain's innate spatial-temporal reasoning ability to solve mathematical problems" (ST Math, 2020). Students in a classroom spend 20 minutes a day solving problems on the interactive website, playing mastery-based games to teach mathematical thinking and concepts. One aspect of ST Math is for teachers to lead math talks with the students using the ST Math puzzles. These math talks consist of projecting one of the puzzles for everyone to see and leading a discussion amongst students to answer questions such as "What is the goal of this puzzle?" "What are some ways you can solve this puzzle?" and "How does this puzzle relate to math?"

The purpose of the study was to investigate how math talks impact both the students' performance on the program, as well as their understanding of the mathematical concepts ST Math aims to develop. This action research project focused on the following questions:

- How do math talks impact student performance on ST Math?
- How do math talks impact students' understanding of mathematical concepts outside of ST Math?

The study focused on a quantitative data analysis of student performance within the ST Math platform and on pre and post assessment performance. For the research question, "How do math talks impact student performance on ST Math?," the independent variable is the math talks and the dependent variable is the students' ST Math performance. For the research question "How do math talks impact student's understanding of mathematical concepts outside of ST Math?," the independent variable is the math talks and the dependent variable is the students' understanding of mathematical concepts outside of ST Math. The research studies and articles for this literature review are from peer-reviewed journals. These articles were found from databases in DeWitt Library or Google Scholar.

Literature Review

Math Talks

Math talks, also known as number talks and math talk communities, are teaching tools teachers can use to help their students understand mathematical thinking and discourse. During a math talk, teachers present a problem and allow students time to solve the problem. After sharing their answers, correct or incorrect, the students are presented with the answers. The goal of math talks is for students with incorrect answers to "revise" their thinking and understanding by using a strategy to find the correct answer, and to allow for other students to share their thinking with each other (Parrish. S, 2011). Other strategies include discussing why math talk is important, teaching students how to listen and respond, introducing sentence stems, contrasting explanation versus justification, and giving an example (Wagganer, 2015).

Benefits of Math Talks

Higher test scores and mathematical skills

When students participate in mathematical discussions, they can benefit from higher standardized test scores and more solid mathematical skills and general understanding (Susperreguy & Davis-Kean, 2016; von Spreckelsen, Dove, Coolen, Mills, Dowker, Sylva, Ansari, Merkley, Murphy, & Scerif, 2019). Susperreguy and Davis-Kean (2016) analyzed the relationship between the amount of mathematical input preschool children hear (i.e., math talk) from their mothers in their homes with their early math ability a year later. The researchers worked with forty mother-child pairs during the research. The mothers recorded their natural exchanges with their child in their homes using an audio-recording device. Through their research, Susperreguy and Davis-Kean (2016) found preschool children who were exposed to more conversations about math, such as math talks, tend to score higher on their standardized math tests a year later.

These findings were also mirrored in the research conducted by von Spreckelsen, Dove, Coolen, Mills, Dowker, Sylva, Ansari, Merkley, Murphy, & Scerif (2019). The researchers found when students were able to participate in classroom-based math discussions, the students' understanding of complex mathematical concepts grew. In an examination of educational aspects of preschool math, the researchers investigated the different types of mathematical language used by teachers in a variety of different daily activities. The researchers then assessed the relationship between educators' math talk and math provisions and several key preschool math skills, such as cardinality, verbal counting, and symbolic number knowledge). The researchers found, "in settings with greater practitioners' breadth of math language, children display greater cardinality skills" (Spreckelsen, Dove, Coolen, Mills, Dowker, Sylva, Ansari, Merkley, Murphy,

& Scerif, 2019). The research from both studies provide insight into how math talks and mathematical discussions can have a positive impact on students' standardized test scores and their mathematical understanding.

Active participation and community

Math talks encourage students to actively participate in their learning and provide students the opportunity to learn from each other (Wagganer, 2015; Hufferd-Ackles, Fuson, & Sherin, 2004; Michaels, O'Connor, Hall, & Resnick, 2010). In an article published in *The National Council of Teachers of Mathematic*s, the author describes her observation of 24 fourth-grade students who were involved in creating math talk communities. Instead of students arguing over answers and blurting out responses, students collaboratively work together to problem-solve. "Each student is eagerly participating in mathematical discussions involve multiple strategies to discover solutions. What a dramatic change since the first months of school when the same students sat as quiet as stone statues, hoping their teacher would just tell them how to solve the problem" (Wagganer, 2015). Wagganer's experience with math talks exemplifies how the conversations can open opportunities for students to share their thinking and to actively participate in their learning.

In a study on educational discourse which was conducted over 15 years, Michaels, O'Connor, Hall, & Resnick (2010) found "teachers have been successful at establishing norms and building a discourse culture involving risk-taking and the explicit modeling and practice of particular talk moves. Over time (and it often takes many months of concerted effort), new forms and norms of discourse are developed and students from widely varying backgrounds begin to listen to one another, build on one another's ideas, and participate productively in complex deliberative practices." (Michaels, O'Connor, Hall, & Resnick, 2010).

Similarly, in research conducted by Hufferd-Ackles, Fuson, & Sherin (2004), the researchers found, “compared to the traditional teaching of algorithms, which can leave students with a lack of deep understanding of arithmetic, math talks depend on students' problem solving and reasoning skills which deepen their understanding”. For this study, the researchers observed four teachers implementing Children’s Math Worlds (CMW), a researched-based math curriculum. The teachers were observed throughout the school year. The researchers’ collected observation notes, they created transcripts from the classes, and also collected teacher post observation interviews. The researchers found growth in the following areas: questioning, explaining math thinking, source of mathematical ideas, and responsibility for learning (Hufferd-Ackles, Fuson, & Sherin, 2004). These findings concluded math talks encourage students to be active participants in their learning and to provide the opportunity to learn from each other.

Attitudes and confidence towards math

Math talks help students show a more positive attitude and confidence towards mathematics among pk-12 students as well as adults. (Hufferd-Ackles, Fuson, & Sherin, 2004; von Spreckelsen, Dove, Coolen, Mills, Dowker, Sylva, Ansari, Merkley, Murphy, & Scerif, 2019). In the research described previously by von Spreckelsen, Dove, Coolen, Mills, Dowker, Sylva, Ansari, Merkley, Murphy, & Scerif (2019), the researchers found “when discussing math confidence, two areas began to emerge: the practitioner’s confidence in teaching math in preschool and their own confidence in math.” This research shows both students and teachers can grow from mathematical discourse.

In research conducted by Hufferd-Ackles, Fuson, & Sherin (2004), also previously described, the researchers found both the teachers’ and the students’ confidence in partaking in mathematical discussions grew. “A primary goal of such a community is to understand and extend one's own thinking as well as the thinking of others in the classroom" (Hufferd-Ackles, Fuson, & Sherin, 2004).

Saylor and Walton (2014) found these benefits do not reach only elementary students, but adults as well. Saylor and Walton worked with seven female, early-childhood education, preservice teachers to create math talk communities to grow the preservice teachers' understanding of mathematics and math-talk communities. At the beginning of the semester, the math talk learning community was established. They introduced the math talk learning community approach to students as an evidence-based way to utilize classroom discourse to enhance students' mathematical learning. "After participating in the semester-long math talk learning community, all of the preservice teachers had made strides in their understanding of the math talk learning community as a pedagogical approach and many had experienced 'aha' moments in their own understanding of mathematical concepts" (Saylor and Walton, 2014). The previous study provides insight into how math talks help support positive attitudes and confidence towards mathematics amongst adults as well as students.

Impact on number sense

Number sense is one's "general understanding of numbers and operations along with the ability and inclination to use this understanding in flexible ways to make mathematical judgments and to develop useful and efficient strategies for managing numerical situations" (Tsao, p. 2, 2011). In *Principles and Standards for School Mathematics* by the National Council of Teachers of Mathematics, one of the foundational ideas in mathematics is number sense. Students understand aspects of numbers in ways such as representing numbers, the relationships between numbers, and the number system; they also understand the meanings of operations and how they relate and connect to one another; understand how to compute fluently and how to make reasonable estimates. (NCTM, 2000, p32). While conducting math talks, the teacher elicits answers to a problem, asks students to explain why solutions are reasonable, and has students estimate prior to thinking about strategies; this is helping to build number sense (Parrish, p. 158, 2014). Math talks help students "develop number sense focused on making sense of quantity and mathematical relationships, understand there can be many ways to solve a mathematical problem, and learn to trust their own reading which helps build intellectual autonomy" (Sun, K., Baldinger, E., & Humphreys, C., 2018).

In a research study set out to examine the implementation process and impact of a six-week number talk intervention with sixth-grade middle school students in a large urban school district, Okamoto (2015) found number sense had a great impact on students' understanding of number sense. The researcher conducted number talks twice weekly for six weeks, giving her students a pre-test and post-test in order to measure the effects of the intervention on students' number sense development. "Results of the quantitative analysis showed there were statistically significant increases in the overall mean score on the number sense assessment and the mean score on the equivalent expressions subtest of the assessment which was closely aligned to the content of the intervention" (Okamoto, 2015). These research findings show number talks and math talks have a positive impact on students' understanding of number sense which is a fundamental part of students' learning.

ST Math

ST Math, created by MIND Research Institute (MIND), is an online program designed to teach mathematical reasoning through spatial temporal representations. Key fundamental concepts are taught visually and then the program connects the ideas to "the symbols, language, and robust discourse." (STMath, 2020).

Rutherford, Farkas, Duncan, Burchinal, Kibrick, Graham, Richland, Tran, Schneider, Duran, & Martinez (2014) conducted an independent research trial of ST Math in fifty-two low performing schools in Orange County with second-grade through fifth-grade students. The schools were provided access to ST Math and the students' performance on the California Standard Tests were observed for two years. The researchers found, “1 year of ST Math produced very modest, marginally significant gains in mathematics… Estimates of 2-year effects were larger but not statistically significant” (Rutherford, Farkas, Duncan, Burchinal, Kibrick, Graham, Richland, Tran, Schneider, Duran, & Martinez, 2014).

These findings are mirrored in the article, “Techno-Mathematical Discourse: A Conceptual Framework for Analyzing Classroom Discussions” published in *Education Science*. The author states “Virtual manipulatives have the potential to make learning more enjoyable and to encourage students to persist in problem solving” (Anderson-Pence, p. 1, 2017). She also states virtual manipulatives and gaming applications, like ST Math, have “the potential to significantly influence the depth to which students understand important mathematics concepts” (Anderson-Pence, p. 1, 2017).

Benefits of Game-Based Learning

Increased Engagement, performance and Motivation

Game-based learning has a positive effect on students’ engagement in class, work motivation, and overall performance (Khan, Farzana, & Malik, 2017; Woo, 2014; Cheng and Su, 2012; Plass, Homer, and Kinzer, 2015).

Khan, Farzana, and Malik (2017) conducted research with the goal to identify the impact of game-based learning on student engagement in an 8th grade classroom. The researchers worked with 72 students split into two different groups. The first group, a control group, received traditional science instruction and a teacher-centered teaching approach involving rote learning, while the other group, the experimental group, received game-based learning instruction. The researchers found a significant difference in the body language, attention, confidence, and repetitive measures of fun and excitement of students who received the game-based learning instruction. The game-based learning students “were significantly focused and paid attention to their instruction, on average as compared to the participants who received conventional science instruction” (Khan, Farzana, & Malik, 2017). The game-based learning students also scored significantly better on post-tests than their performance on the pre-test.

During the student interviews, the students in the game-based learning group admitted the instruction kept them engaged, both emotionally and behaviorally. The students also added the game-based learning presentation attracted their attention thus keeping them more interested throughout the entire learning process. “They were more involved in this learning experience, and they had more fun while learning, in contrast to their previous teacher-centered learning approach” (Khan, Farzana, & Malik, 2017).

Woo (2014) investigated the effects game-based learning had on student’s cognitive load, motivation, and performance. Woo conducted his research with 63 university students. The students learned by using “Operating a Small Factory in Computer-Aided Manufacturing”, an online game, for 8 weeks. Data was then collected using a cognitive load scale, performance scales, and an instructional materials motivation survey. Through his work, Woo found the online program stimulated students’ learning motivation in the areas of attention, relevance, confidence, and satisfaction and increased germane cognitive loads (Woo, 2014).

In another research study conducted by Cheng and Su (2012), researchers explored the difference between game-based learning and traditional, teacher-centered learning to see what impact the two different strategies had on learning achievement and motivation of students. The researchers divided students into two groups, a control group who received a traditional face to face learning environment and an experimental group who received game-based learning. Both groups of students had the same instructor, the same amount of class time, and the same pre- and post- tests. The experimental group met in a computer classroom while the control group met in a regular classroom. The pre- and post-tests of all students were analyzed to see if there was a significant difference between the experimental and control groups' learning achievements. Cheng and Su (2012) found "the results [showed] the learning motivations of students [had a] significant impact on the learning achievement, and the learning achievements of students with game-based learning are better than those who [used] the traditional face-to-face teaching".

These findings support the argument presented in the article "Foundations of Game-Based Learning" published in *Educational Psychologists*. The authors stated "The argument is games for entertainment have been shown to be able to motivate learners to stay engaged over long periods through a series of game features are of a motivational nature. These features include incentive structures, such as stars, points, leaderboards, badges, and trophies, as well as game mechanics and activities learners enjoy or find interesting" (Plass, Homer, and Kinzer, 2015).

Test Anxiety

Yang, Lin, and Chen (2018) conducted research into how high- or low- anxiety affected students' learning performance and gaming performance when participating in a game-based English learning system. The researcher worked with 43 fourth graders, 21 high-anxiety students and 22 low-anxiety students, twice a week for 3 weeks. The learning goal was for students to build an understanding of how to describe numbers and time in English in terms of speaking, listening and word/sentence match. The researchers used a traditional English proficiency test, which is anxiety-provoking, in order to assess the learning performance. To measure the gaming performance, the researchers used the frequencies of making practice and the number of rewards students received.

Overall, the researchers found students with high anxiety performed worse than those with low anxiety on the learning performances, but both high- and low-anxiety students performed at a similar level on their gaming performance (Yang, Lin, and Chen, 2018). This research is important because, while we see anxiety influenced the learning performance of students, it did not impact their gaming performance. This shows high anxiety learners' gaming performance can be improved through game-based learning.

Support learning of 21st century skills

In the article "Gamification: questing to integrate content knowledge, literacy, and 21st-century learning" published in the *Journal of Adolescent & Adult Literacy,* the authors describe a case study of a 5th/6th grade intermediate school in the Midwest where a teacher uses gamification, an aspect game-based learning, in his classroom. The study was conducted over four weeks in which data was collected through classroom observations, an analysis of the gamified learning environment, semi-structured interviews with the teacher, and a survey of students. The teacher "gamified his classroom through 3D GameLab, a quest- based learning platform where students earn XPs, badges, and awards competing against themselves to progress through hierarchical tasks" (Kingsley & Grabner-Hagen, 2015). Through the student surveys, they found students were motivated and excited for their work, believed the work was easier, and felt they learned better through the gamification. There was also support of the 21st century skills through online communication tools, encouraging creativity, engaging in critical thinking, as well as collaboration and communication to a larger audience (Kingsley & Grabner-Hagen, 2015).

Methodology

Research Questions

The purpose of the study was to investigate how math talks impact both the students' performance on the program as well as their understanding of the mathematical concepts ST Math is trying to teach. This action research project focused on the following questions: How do math talks impact student performance on ST Math and how do math talks impact student's understanding of mathematical concepts outside of ST Math. From this action research, the researcher will be able to conclude if math talks should be implemented in the classroom during their ST Math time.

Research Design

The researcher implemented the research over the course of four weeks. Students were given 20 minutes a day to work on ST Math. Students also had access to ST Math at home, but were not required to work on it outside of school hours. Once a week, the researcher took 10 minutes of these ST Math minutes to facilitate a math talk in the experimental group. The researcher used a specific set of questions which included "What is the goal of this puzzle?", "How do you think we could solve this problem?", "How can we use this information in our math class?".

Quantitative data was collected each week over the students' performance in the form of puzzles per minute in ST Math. The researcher compared the students' average puzzles per minute from the program prior to the math talks to their average puzzles per minute during the research window to see if their average puzzles completed increased, decreased, or stayed the same during the research time.

Quantitative data was collected in the form of pre-test and post-test on the mathematical concept. The students received seven questions on the concept, worked on the concept through their ST Math work and math talks, and then completed the same seven questions at the end of the four weeks. These pre/post tests were created by MIND Institute and were specifically created for ST Math. This allowed the researcher to see if the students were able to translate their ST Math learning of the concept into understanding of the concept outside of ST Math.

Variables

The study will be focusing on finding the correlation between the variables. For the research question, "How do math talks impact student performance on ST Math?", the independent variable is the math talks and the dependent variable is the students' ST Math performance. For the research question, "How do math talks impact students' understanding of mathematical concepts outside of ST Math?", the independent variable is the math talks and the dependent variable is the students' understanding of mathematical concepts outside of ST Math.

Setting and Participants

The research for this study was conducted at an Intermediate School in Marshalltown, Iowa. The community is a mixture of both rural and urban. The researcher conducted the research in two classes, one being a control group and one being the experimental group. The experimental group consisted of 27 students: 13 males and 14 females. Seven of these students received English Language Learning services and five students received Special Education services. Thirteen of these students identified as Hispanic/Latin X, eight identify as White, two identified as Asian, one identified as American Indian or Alaska Native, and one identified as mixed race.

The control group also consisted of 27 students: 11 males and 16 females. Eight of these students received English Language Learning services and six students received Special Education services. Fourteen of these students identified as Hispanic/Latino, six identified as Asian, four identified as White, two identified as African American/Black, and one identified as mixed race.

Data Collection Plan

At the end of each week, data was collected from the ST Math website over the students' puzzles per minute for each class and stored in an Excel Spreadsheet. The students' average puzzles per minute for the year was also collected as a baseline. Students were also administered a pre and post-test through the ST Math website over the mathematical concept. This was administered prior to the intervention and then at the end of the intervention.

Data Analysis Plan

The data analysis process included conducting a dependent samples t-test over the students pre and post tests to determine if there was a significant change in the students' understanding of mathematical concepts outside of ST Math. A second dependent sample t-test was also conducted over the students' average puzzles per minute during the instructional time to be compared to the baseline of their average puzzles per minute for the year. Both tests were to be performed in data analysis tools in the software app Microsoft Excel.

IRB

IRB exemption was granted from Northwestern College's IRB board prior to data collection. The board approved exemption because Students pose minimal risk, will be conducted at our school, and the researcher was using normal educational practices and diagnostic tests.

Data Analysis

Pre/Post Tests

A dependent sample t-test was conducted to determine whether there was a significant change in the students' understanding of mathematical concepts outside of ST Math after the math talks intervention using the data analysis tools in the software app Microsoft Excel. A baseline pre-assessment revealed students in the experimental group were able to solve an average of 2.55 out of 7 questions correctly (M = 2.55, SD =1.82). Students in the control group were able to solve an average 1.85 out of 7 questions correctly (M = 1.85, SD =1.18).

The students in the experimental group participated in a four-week intervention where they engaged in math talks facilitated by the teacher over different ST Math levels, followed by a second assessment of their understanding of mathematical concepts outside of ST Math. Students in the experimental group were able to solve an average of 3.3 out of 7 questions correctly (M = 3.30, SD = 1.59). Students in the control group were able to solve an average of 2.16 out of 7 questions correctly (M = 2.16, SD = 1.23).

Table 1

t-Test: Paired Two Sample for Means run on the data for the control group

	Pre-test	*Post-test*
Mean	2.35	3.3
Variance	2.239474	2.536842
Observations	20	20
Pearson Correlation	0.792722	
Hypothesized Mean Difference	0	
df	19	
t Stat	-4.25413	
P(T<=t) one-tail	0.000214	

t Critical one-tail	1.729133	
P(T<=t) two-tail	0.000429	
t Critical two-tail	2.093024	

While looking at the data from the experimental group, results of the dependent samples two-tailed t-test reveal a significant difference between the baseline and final assessment, t(19) = - 2.88, p = 0.009. While looking at the data from the control group, results of the dependent samples two-tailed t-test reveal a significant difference between the baseline and final assessment, t(19) = - 1.10, p = 0.28. The intervention of math talks and ST Math content did improve the students' knowledge of mathematical concepts outside of ST Math.

Table 2

t-Test: Paired Two Sample for Means on the data for the experimental group

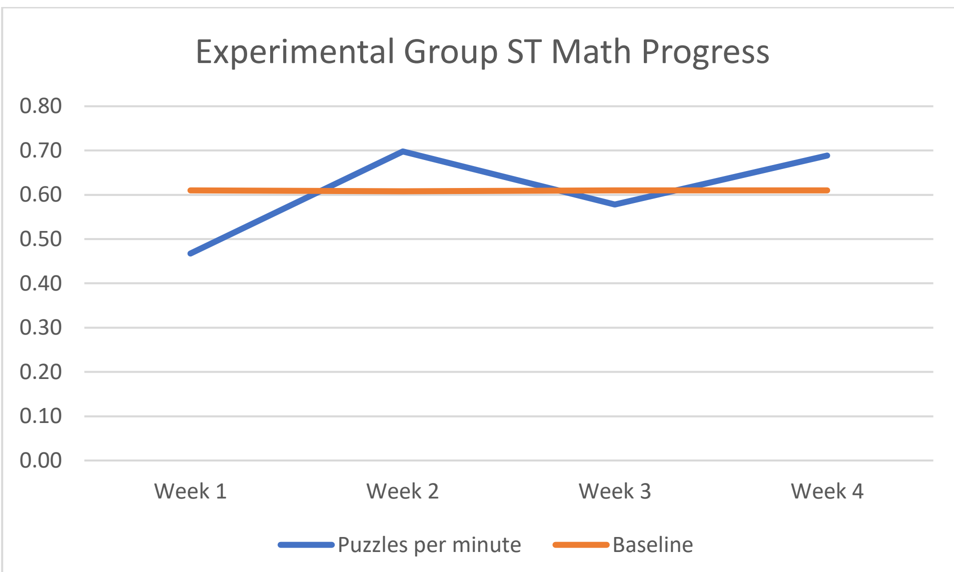
	Pre-test	*Post-test*
Mean	1.85	2.15
Variance	1.397368	1.502632
Observations	20	20
Pearson Correlation	0.488525	
Hypothesized Mean Difference	0	
df	19	
t Stat	-1.10126	
P(T<=t) one-tail	0.142271	
t Critical one-tail	1.729133	
P(T<=t) two-tail	0.284541	
t Critical two-tail	2.093024	

Performance on ST Math

To determine whether there was a significant change in the students' performance on ST Math after the math talks, the researcher compared the baseline data to the students' puzzles per minute during the intervention. A baseline puzzle per minute revealed students in the experimental group were averaging 0.61 puzzles per minute for the school year. Students in the control group 0.53 puzzlers per minute for the school year.

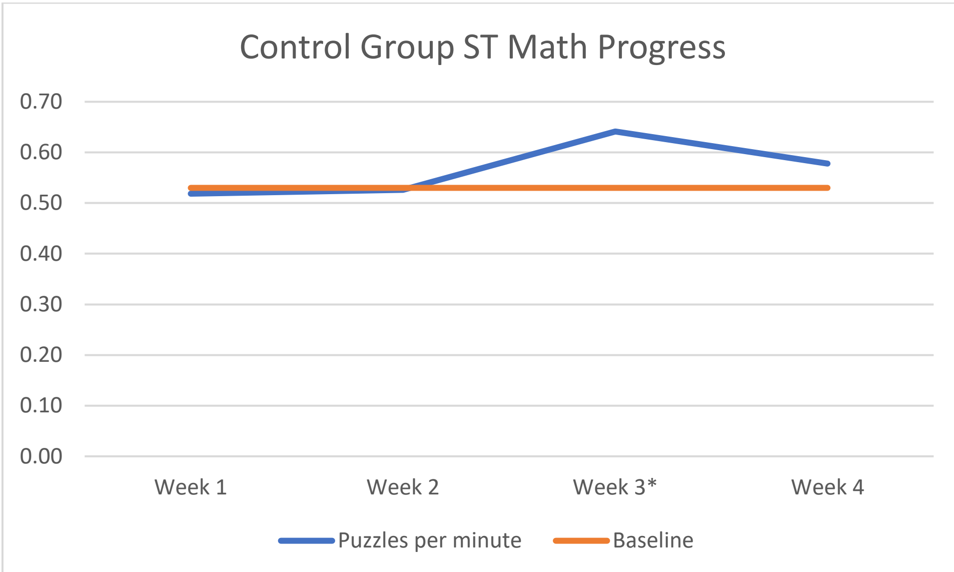
During the four-week intervention window, students in the experimental group averaged 0.47 puzzles per minute the first week, 0.70 puzzles per minute the second week, 0.58 puzzles per minute the third week, and 0.69 puzzles the fourth week. This averaged out to 0.61 puzzles per minute for the entire four-week intervention window. As shown in Figure 1, there was not a significant increase or decrease in the experimental group students' progress versus their baseline during the intervention window.

Figure 1



During the four-week intervention window, students in the control group averaged 0.52 puzzles per minute the first week, 0.53 puzzles per minute the second week, 0.64 puzzles per minute the third week, and 0.58 puzzles the fourth week. This averaged out to 0.53 puzzles per minute for the entire four-week intervention window. As shown in Figure 2, there was not a significant increase or decrease in the control group students' progress versus their baseline during the intervention window.

Figure 2



Since neither group had a significant increase nor decrease, this study concluded the math talk interventions had no significant impact on the students' performance on ST Math.

Discussion

This study has demonstrated there was a significant change in the students' understanding of mathematical concepts outside of ST Math after the math talks. From the data collected and analyzed from this study, it can be concluded students who engage in these activities will be able to apply their learning to tasks outside of these two settings. The results from this study reflect some of the benefits described in the literature review. After participating in the math talks, students demonstrated higher test scores and mathematical thinking, one of the benefits identified previously. The students in the experimental group showed significant improvement on their post-test compared to control group post-tests.

This study has demonstrated there was not a change in the students' ST Math performance because of math talks. It can be concluded math talks do not have any impact on the students' ability to solve puzzles more efficiently during their time on the program.

Both the experimental and control groups showed growth on their post-tests which supported the findings of Rutherford, Farkas, Duncan, Burchinal, Kibrick, Graham, Richland, Tran, Schneider, Duran, & Martinez (2014). In their research study they saw improvement of mathematical skills after 1 year of ST Math. Both groups demonstrated improvement of mathematical skills after the four week intervention window.

Further Research

Based upon the findings from this study it can be suggested further research is needed to test the validity and reliability of these results. Since this student was only conducted once, during a short period of time, it is necessary to conduct the study multiple times in order to prove validity of the results.

It is recommended this research be conducted with different groups of students and different mathematical concepts. To identify the growth in students' post-tests was because of the math talks and not because of the specific group of students, it is important to run the same study on several different groups of students. Similarly, changing the mathematical concepts with the same group of students would identify if certain concepts were more impacted by math talks than others. This would help identify whether the math talks were impactful on the performance or not.

It is also recommended this research be conducted longer than 4 weeks. Since this study was conducted over a short period of time, running the study again over a longer period of time would allow more insight into how math talks impact the students' performance and understanding of mathematical concepts. Students only participated in four math talks related to the ST Math concepts, it could be argued they did not partake in enough to have a significant impact on their ST Math performance. Running the study over a longer period of time would allow more insight into this aspect.

Conclusion

Math talks and game-based learning such as ST Math can bring many benefits to students in a classroom. With previous research being conducted on each strategy separately, this this action research study, the research was able to examine the impact of these two strategies being brought together. The research questions “how do math talks impact student performance on ST Math?” and “how do math talks impact students’ understanding of mathematical concepts outside of ST Math?” were both answered.

The results of this action research study suggest math talks have a significant impact on students' understanding of mathematical concepts outside of ST Math, but not on students’ ST Math performance. The results of this study implied there were some benefits to combining these two strategies together.

References

Anderson-Pence, K. (2017). Techno-Mathematical Discourse: A Conceptual Framework for Analyzing Classroom Discussions. *Education Sciences*, *7*(1), 40. https://doi.org/10.3390/educsci7010040

Cheng, C.-H., & Su, C.-H. (2012). A Game-based learning system for improving student's learning effectiveness in system analysis course. *Procedia - Social and Behavioral Sciences*, *31*, 669–675. https://doi.org/10.1016/j.sbspro.2011.12.122

Guise, J. (2016). *Iowa math outcomes analysis 2014/15.* MIND Research Institute

Hufferd-Ackles, K., Fuson, K. C., & Sherin, M. G. (2004). Describing Levels and Components of a Math-Talk Learning Community. *Journal for Research in Mathematics Education*, *35*(2), 81. https://doi.org/10.2307/30034933

Khan, A., Ahmad, F. H., & Malik, M. M. (2017). Use of digital game based learning and gamification in secondary school science: The effect on student engagement, learning and gender difference. *Education and Information Technologies*, *22*(6), 2767–2804. https://doi.org/10.1007/s10639-017-9622-1

Kingsley, T. L., & Grabner-Hagen, M. M. (2015). Gamification. *Journal of Adolescent & Adult Literacy*, *59*(1), 51–61. https://doi.org/10.1002/jaal.426

Kirriemuir, J., & McFarlane, A. (2004). *Literature review in games and learning.* Futurelab. Retrieved from http://www.futurelab.org.uk/ resources/documents/lit_reviews/Games_Review.pdf.

Michaels, S., O'Connor, C., & Resnick, L. B. (2007). Deliberative Discourse Idealized and Realized: Accountable Talk in the Classroom and in Civic Life. *Studies in Philosophy and Education*, *27*(4), 283–297. https://doi.org/10.1007/s11217-007-9071-1

National Council of Teachers of Mathematics. (2008). *Principles and standards for school mathematics*.

Okamoto, Y. (2015) *The Implementation Process and Impact of a Six-Week Number Talk Intervention with Sixth-Grade Middle School Students in a Large Urban School District.* University of California. Retrieved from https://escholarship.org/content/qt28x558qx/qt28x558qx.pdf

Parrish, S. D. (2011). Number Talks Build Numerical Reasoning. *Teaching Children Mathematics*, *18*(3), 198–206. https://doi.org/10.5951/teacchilmath.18.3.0198

Plass, J. L., Homer, B. D., & Kinzer, C. K. (2015). Foundations of Game-Based Learning. *Educational Psychologist*, *50*(4), 258–283. https://doi.org/10.1080/00461520.2015.1122533

Riley, D. (2019). *According to The NPD Group, 73 Percent of U.S. Consumers Play Video Games.* Accessed 6/13/2021 from https://www.npd.com/wps/portal/npd/us/news/press-releases/2019/according-to-the-npd-group--73-percent-of-u-s--consumers-play-video-games/

Rutherford, T., Farkas, G., Duncan, G., Burchinal, M., Kibrick, M., Graham, J., Richland, L., Tran, N., Schneider, S., Duran, L., & Martinez, M. E. (2014). A Randomized Trial of an

Elementary School Mathematics Software Intervention: Spatial-Temporal Math. *Journal of Research on Educational Effectiveness*, *7*(4), 358–383. https://doi.org/10.1080/19345747.2013.856978

Saylor, L. L., & Walton, J. B. (2018). Creating a math-talk learning community with preservice teachers. *School Science and Mathematics*, *118*(8), 348–357. https://doi.org/10.1111/ssm.12302

Spreckelsen, M., Dove, E., Coolen, I., Mills, A., Dowker, A., Sylva, K., Ansari, D., Merkley, R., Murphy, V., & Scerif, G. (2019). Let's Talk About Maths: The Role of Observed “Maths-Talk” and Maths Provisions in Preschoolers' Numeracy. *Mind, Brain, and Education*, *13*(4), 326–340. https://doi.org/10.1111/mbe.12221

Sun, K. L., Baldinger, E. E., & Humphreys, C. (2018). Number Talks: Gateway to Sense Making. *The Mathematics Teacher, 112*(1), 48–54. https://doi.org/10.5951/mathteacher.112.1.0048

Susperreguy, M. I., & Davis-Kean, P. E. (2016). Maternal Math Talk in the Home and Math Skills in Preschool Children. *Early Education and Development*, *27*(6), 841–857. https://doi.org/10.1080/10409289.2016.1148480

Tsao, Y. (2011). *The study of number sense and teaching practice.* Journal of Case Studies in Education, 2, 1-14.

Wagganer, E. L. (2015). Creating Math Talk Communities. *Teaching Children Mathematics*, *22*(4), 248–254. https://doi.org/10.5951/teacchilmath.22.4.0248

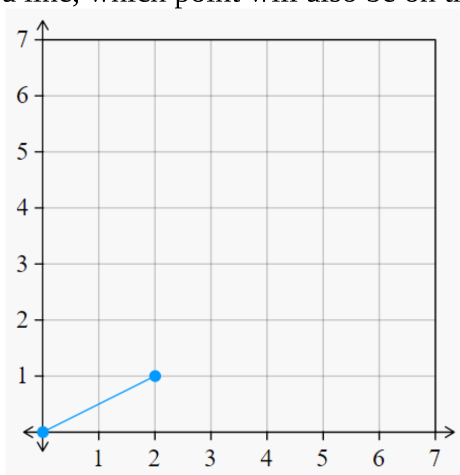
Woo, J.-C. (2014). Digital Game-Based Learning Supports Student Motivation, Cognitive Success, and Performance Outcomes. Educational Technology & Society, 17 (3), 291–307.

Yang, J. C., Lin, M. Y., & Chen, S. Y. (2018). Effects of anxiety levels on learning performance and gaming performance in digital game-based learning. *Journal of Computer Assisted Learning*, *34*(3), 324–334. https://doi.org/10.1111/jcal.12245

Appendix A

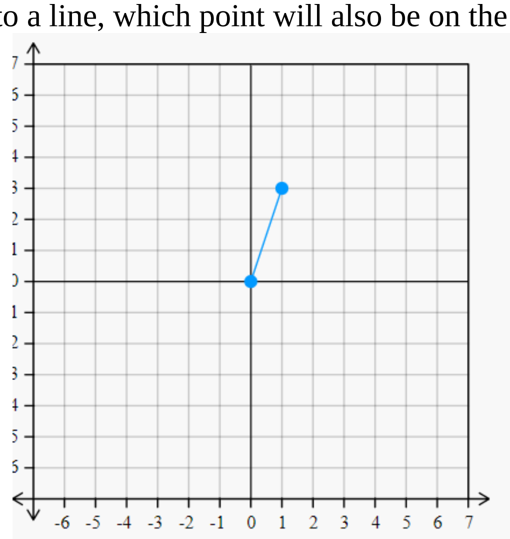
ST Math Pre-Test

1. The points with coordinates (0,0) and (2,1) are connected by a line segment. If this line segment is extended into a line, which point will also be on the line?



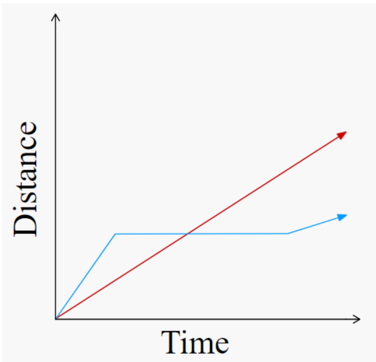
- (1,2)
- (3,2)
- (3,3)
- (4,2)

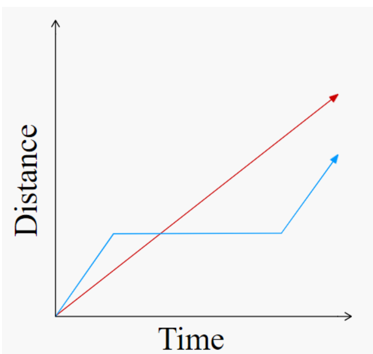
2. The points with coordinates (0,0) and (1,3) are connected by a line segment. If this line segment is extended into a line, which point will also be on the line?

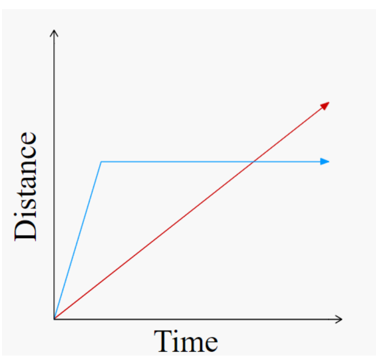


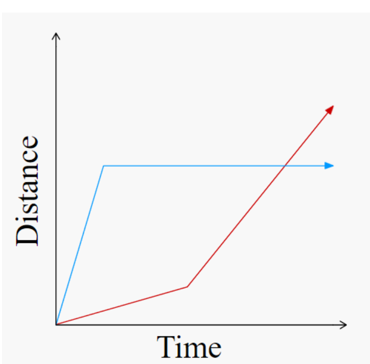
- (-2,-2)
- (-2,-6)
- (3,1)
- (-6,-2)

3. A tortoise walks slow and steady. A hare runs quickly, then stops and takes a nap, and then wakes up and runs quickly again. Which of the graphs best represents this story?

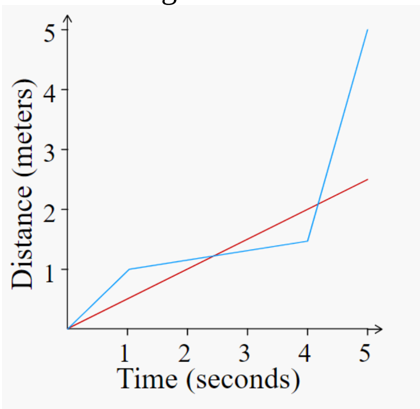






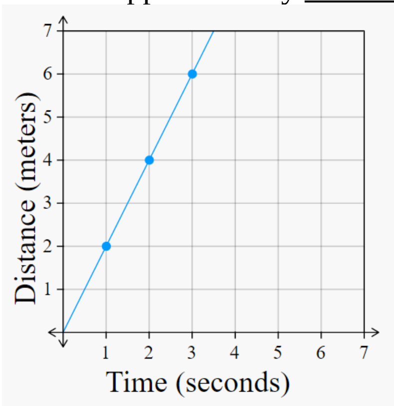


4. The graph shows two cars' positions along a straight track at each point in time after a race begins. At which of the following times is the red car going faster than the blue car?



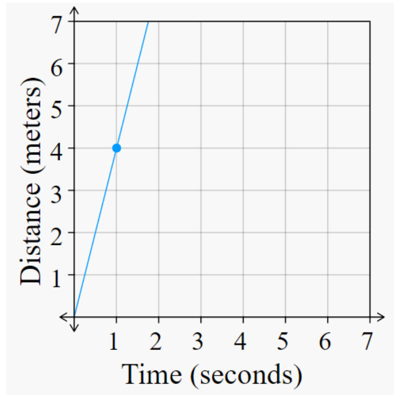
- 2 seconds
- 0.25 seconds
- 0.75 seconds
- 4.25 seconds

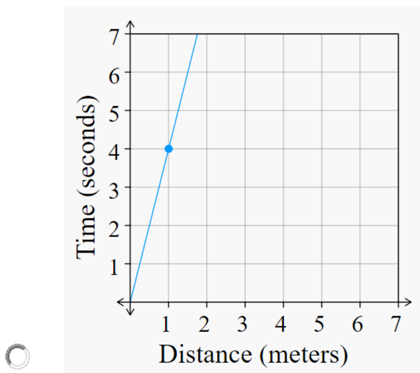
5. The speed represented by this line is approximately ____________.

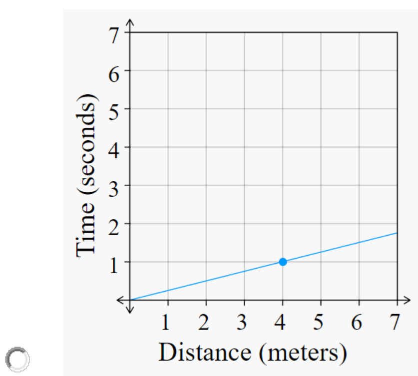


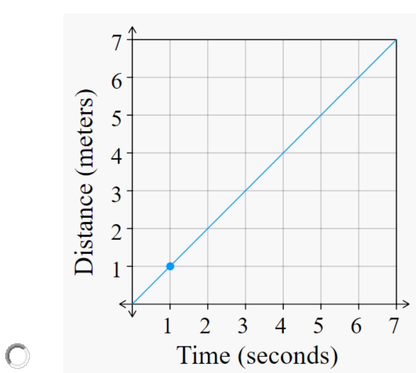
- 0 meters per second
- 1 meter per second
- 2 meters per second
- 0.5 meters per seconds

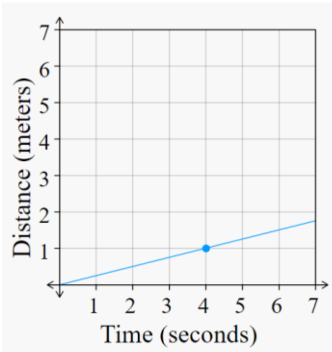
6. Which graph best represents the same time and distance relationship as this graph?


Distance (meters)
Time (seconds)
1 2 3 4 5 6 7

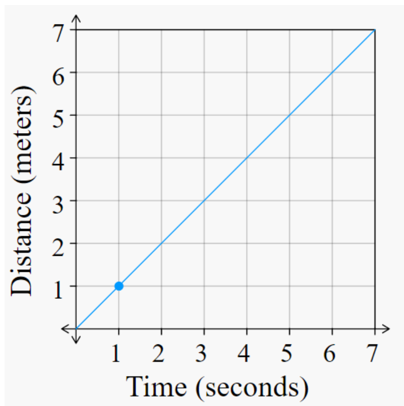

Time (seconds)
Distance (meters)
1 2 3 4 5 6 7

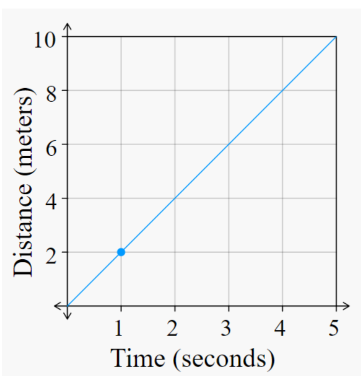

Time (seconds)
Distance (meters)
1 2 3 4 5 6 7

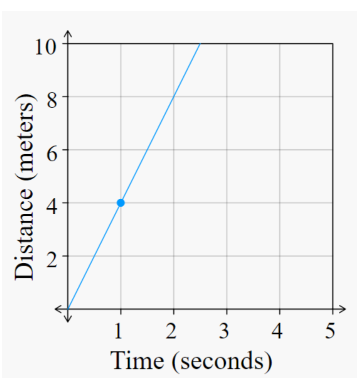

Distance (meters)
Time (seconds)
1 2 3 4 5 6 7

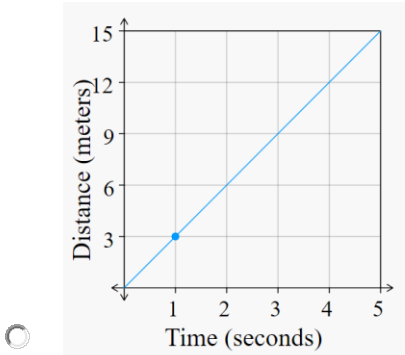


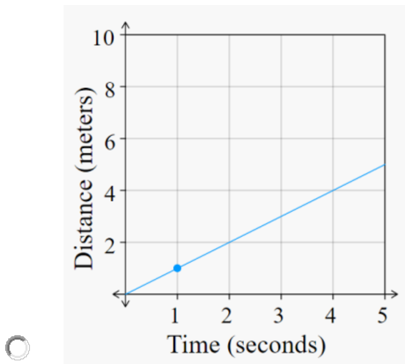
7. Which graph best represents the same time and distance relationship as this graph?







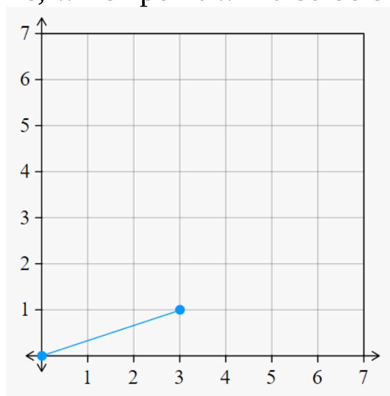

15
12
9
6
3
Distance (meters)
1
2
3
4
5
Time (seconds)


10
8
6
4
2
Distance (meters)
1
2
3
4
5
Time (seconds)

Appendix B

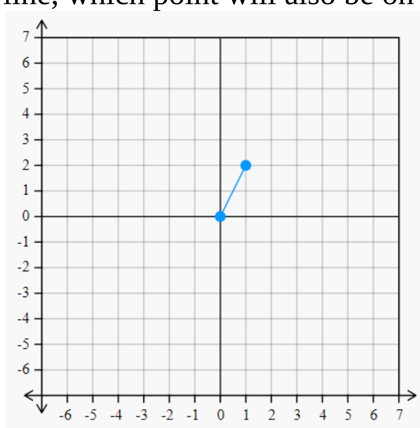
ST Math Post-Test

1. The points with coordinates (0,0) and (3,1) are connected by a line segment. If this line segment is extended into a line, which point will also be on the line?



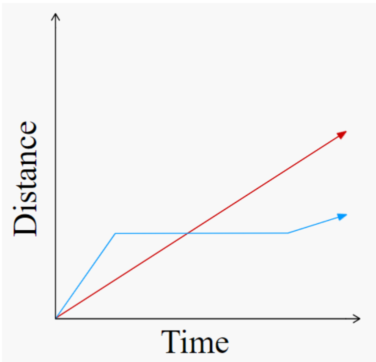
- (1,2)
- (5,2)
- (5,3)
- (6,2)

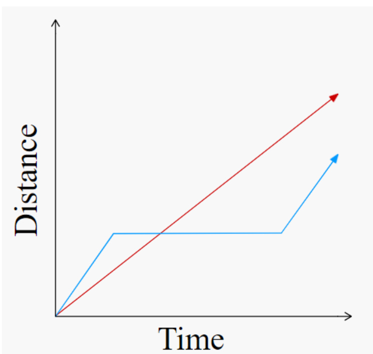
2. The points with coordinates (0,0) and (1,2) are connected by a line segment. If this line segment is extended into a line, which point will also be on the line?

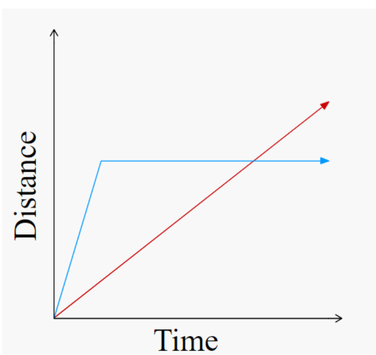


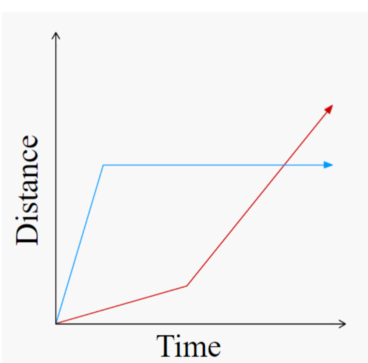
- ($^-2$,$^-2$)
- ($^-2$,$^-4$)
- (2,1)
- ($^-4$,$^-2$)

3. A tortoise walks slow and steady. A hare runs quickly, then stops and takes a nap, and then wakes up and runs quickly again. Which of the graphs best represents this story?

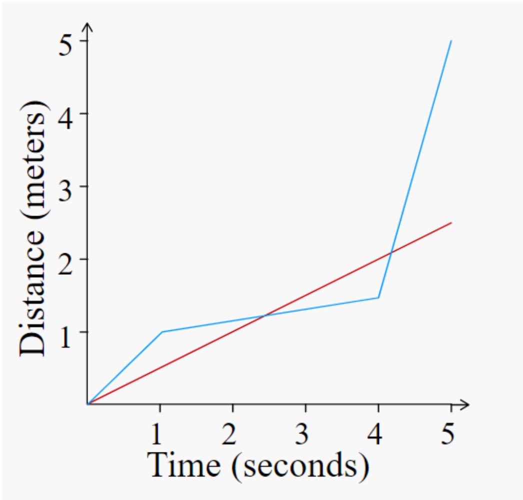






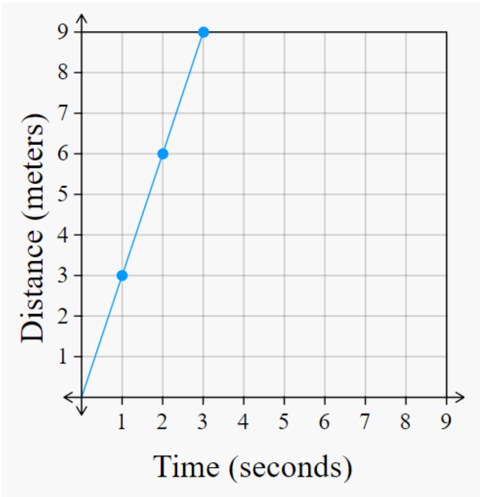


4. The graph shows two cars' positions along a straight track at each point in time after a race begins. At which of the following times is the blue car going faster than the red car?



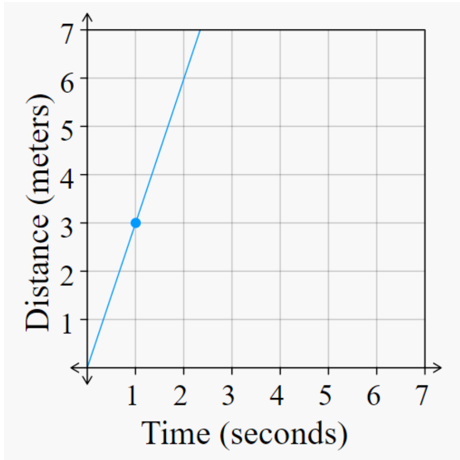
- 3 seconds
- 1.75 seconds
- 2.25 seconds
- 4.25 seconds

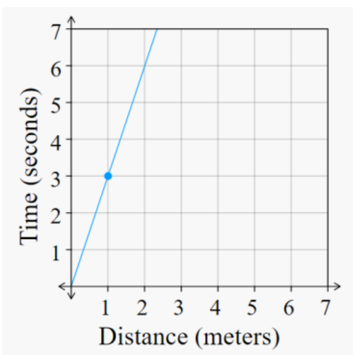
5. The speed represented by this line is approximately ____________.

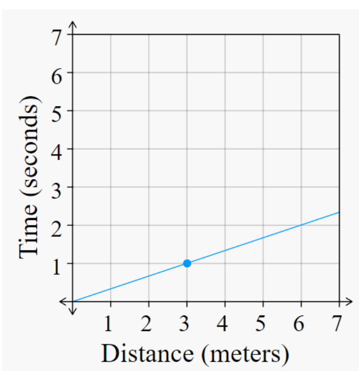


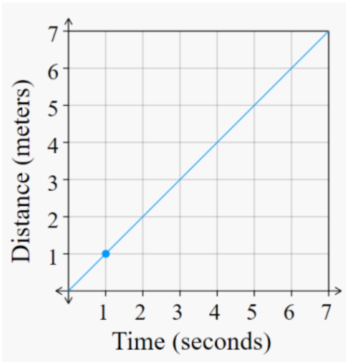
- 0 meters per second
- 1 meter per second
- 3 meters per second
- 0.35 meters per second

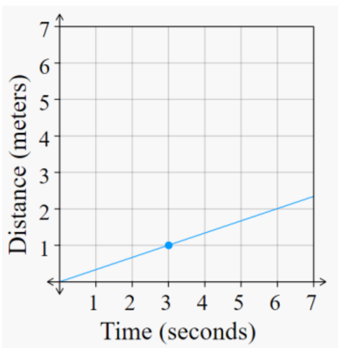
6. Which graph best represents the same time and distance relationship as this graph?



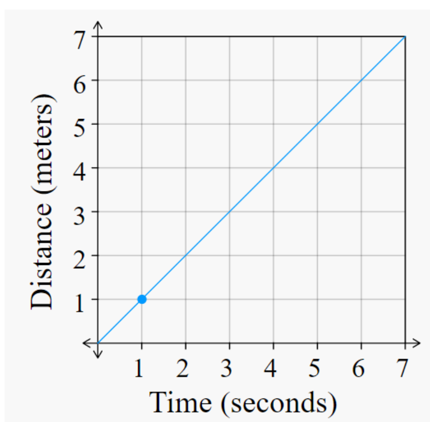


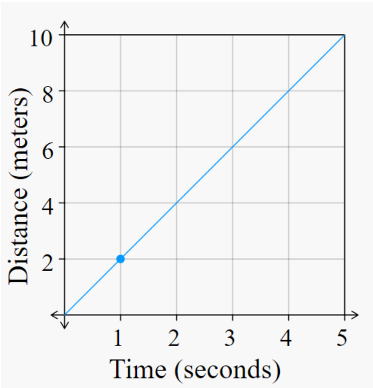


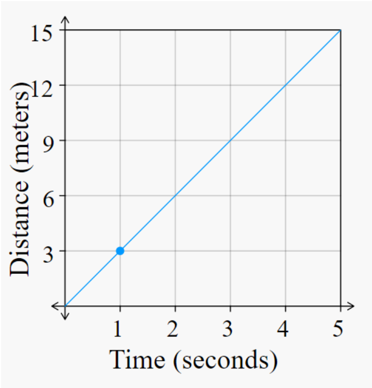


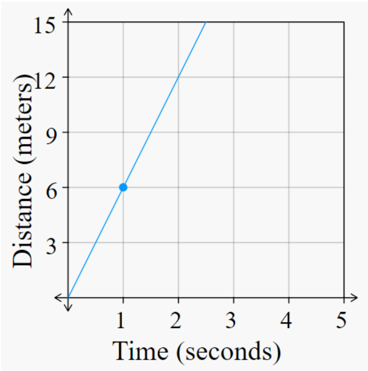


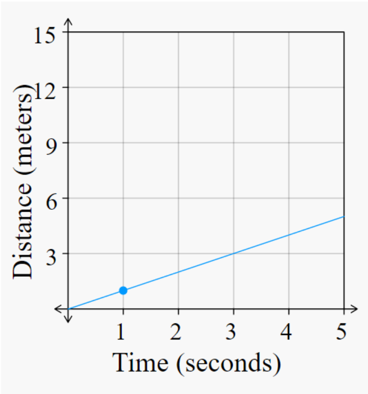
Which graph best represents the same time and distance relationship as this graph?




10
8
6
4
2
Distance (meters)
1 2 3 4 5
Time (seconds)


15
12
9
6
3
Distance (meters)
1 2 3 4 5
Time (seconds)


15
12
9
6
3
Distance (meters)
1 2 3 4 5
Time (seconds)


15
12
9
6
3
Distance (meters)
1 2 3 4 5
Time (seconds)

Appendix C

IRB Exemption from Northwestern College

Institutional Review Board (IRB) Research Proposal Application for Educational Practice Exemption at Northwestern College (Orange City, IA)

*This blank template is provided as an overview of the information needed for new educational research proposals that may be subject to **educational exemption** and therefore would **not** need to undergo the full/normal IRB review process (e.g., that normally would include informed consent forms, specific/detailed research protocols, survey questions, debriefing forms, and/or additional documentation, etc.). The Northwestern IRB committee must review and determine if the proposed research meets the Educational Practice Exemption from full IRB review.*

Upon completion of this form, please submit it as an email attachment to the following Northwestern College IRB committee chair: Karissa Carlson (kcarlson@nwciowa.edu)

Review of the application for educational exemption typically occurs within 1-2 weeks of submission, so plan ahead. You may **not** undertake your proposed research until your application for educational exemption has been approved by the Northwestern College IRB.

Northwestern IRB Submission Summary for this Educational Practice Exemption Request

Project Title: Do Math Talks Impact Students Performance on ST Math?

Student Researcher(s) carrying out the research (name, email, phone number):
Rachel Coulter, rmtallman@gmail.com, 515-422-4071

Principal Faculty Sponsor/Supervisor/Thesis Advisor (name, email, phone number):
Gary Richardson / **gary.richardson@nwciowa.edu** / 712-395-1317

Educational Program/Degree Sought: Master of Education

Other Northwestern College faculty associated with the research: None

Other investigator(s) associated with the research (but not associated with Northwestern College; names, emails, phone numbers):

Sponsoring Agency and/or Funding Source (if any):

Describe the common educational setting/site for your project (e.g., specific course/class/curriculum, site of project). Include the name of the institution(s), city and state where the research will be carried out.

I plan on implementing my research at my school, Lenihan Intermediate School, in Marshalltown, Iowa. Our community is a mixture of both rural and urban. I will conduct my research in one of my 6th grade math classes. This group will consist of 26 students. I will be observing scores from the students' work on the online program ST Math.

Briefly describe the normal educational practice to be evaluated.
Students work independently for 20 minutes a day on the online program ST Math. Students practice math concepts through games and visual learning. When students are stuck on levels, we do a math talk as a class to work through strategies that might be helpful to solve the levels.

Indicate whether the normal education practice to be evaluated is being implemented as part of the research or is separate from your research.
These are normal practices that are already being implemented in my classroom. I will just be increasing the frequency of the math talks.

Will your research involve obtaining and analyzing data from secondary sources including, but not limited to, online educational sources; student records; local, state, or federal datasets?
Yes, I will be using the data collected from the online program, ST Math.

Do you have or will you have permission to use the data from secondary sources before the completion of your research?
Yes

What permissions need to be obtained to carry out your research ethically (you may not undertake research without appropriate permissions, e.g., onsite teachers, principals, etc.)? Include the name, title, phone number and email contact information for the administrator who has granted access to the research site(s).
Principal Kyle Young, 641-754-1160, kyoung@marshalltown.k12.ia.us

Family Educational Rights and Privacy Act (FERPA): Does research data to be collected or obtained include any identifiable study records (e.g., grades, test scores, class assignments, class evaluations) beyond standard directory type data and how will you abide by FERPA requirements?
No, it looks at the student's progress as a whole class, not as individuals. No student names will be used or published in the results.
If you were the parent, guardian, classroom teacher or other responsible adult concerned for research participants in your study, would you have any ethical concerns regarding the study you propose to conduct? If "yes," what are those concerns and how will you address them?
No, there are no ethical concerns with this work.
Anticipated research start date: April 12th, 2021 **Anticipated research completion date:** May 17th, 2021
****

<u>Exempt Review</u>

At a minimum, the procedures of your research must incur no more than "minimal risk" to your research participants, i.e., your research may **not** place participants in situations of foreseeable risk/harm beyond that encountered in everyday life.

Educational Practice Exemption Criteria (see Clarification of Terms below)

All three of the following conditions must be met in order to qualify for the Educational Practice Exemption.

1. The research will be conducted in established or commonly accepted educational settings and will involve normal educational practices (e.g., research on regular and special education instructional strategies, research on instructional techniques, curricula, or classroom management methods).

2. The research is unlikely to adversely impact student learning.

3. The research is unlikely to adversely impact teacher assessment.

****

Clarification of Terms used in the Educational Practice Exemption Criteria

Educational setting: The consistent interpretation of this term is that commonly accepted educational settings can be almost anywhere, as long as the setting is one where specific educational offerings normally take place or a setting where one would go in order to have an educational experience. Examples include: K-12 schools and college classrooms, after-school programs, preschools, vocational schools, an alternative education programs; professional development seminar for school district personnel; soccer practice field; Boy/Girl Scouts meeting; Medical school; Religious education settings; Training simulators (e.g., medical simulators, flight simulators, etc.).

Normal educational practices: Normal educational practices are those activities that are routinely used in similar educational settings and/or are considered proven educational practices with the population under study. For example, these could include regular course evaluations or student assessment.

Adversely impact students' opportunity to learn: Consider whether the proposed activity requires students to deviate from a curriculum that is aligned with any national or state-level indicators of student achievement (e.g., state end of grade testing) or if the activity will take instructional time away from students.

Adversely impact assessment of educators: Will participation, or the refusal to participate, in the research be a factor in the assessment of educators? Will the outcomes of the research be a factor in the assessment of participating instructors?

****

The signatures below are our commitment as researchers that the proposed research will be conducted ethically to the best of our abilities and in accordance with the Educational Practice Exemption Criteria listed above.

Signatures (Typed or electronic signatures are acceptable)

Signature of student researcher(s): Rachel Coulter Date 3/24/2021

.

Signature of Faculty Sponsor/Supervisor: Gary Richardson Date 3-24-21

.

****************** DO NOT FILL IN THE INFORMATION BELOW **************************

NWC IRB Assessment – The IRB Committee will fill in this portion following review

Your application for the Educational Practice Exemption has been reviewed and approved. You may proceed with your research:

After review, your application for the Educational Practice Exemption has **not** been approved for the following reason(s):

Appendix D

Student pre-test and post-test scores

Some students did not partake in the pre and post quizzes due to the being on an alternative ST Math path (most commonly due to receiving Special Education services), low attendance, or quarantine.

Experimental group

	Quizzes	
Student	Pre-Quiz	Post Quiz
Student 1	3	3
Student 2		
Student 3		
Student 4	1	3
Student 5	2	3
Student 6	2	3
Student 7	5	5
Student 8	3	5
Student 9		
Student 10	3	4
Student 11	3	5
Student 12		
Student 13		
Student 14	2	4
Student 15	2	2
Student 16	1	3
Student 17	2	2
Student 18	1	1
Student 19	2	4
Student 20	1	1
Student 21	3	3
Student 22	7	7
Student 23		
Student 24	1	1
Student 25	1	2
Student 26	2	5
Student 27		

Control Group

	Quizzes	
Student	Pre-Quiz	Post Quiz
Student 1	2	2
Student 2	1	1
Student 3		
Student 4	3	3
Student 5	1	2
Student 6		
Student 7	2	2
Student 8	2	2
Student 9	2	2
Student 10	1	1
Student 11		
Student 12	2	3
Student 13		
Student 14		
Student 15	3	1
Student 16		
Student 17		
Student 18	5	4
Student 19	2	6
Student 20	0	1
Student 21	1	1
Student 22	3	3
Student 23	2	2
Student 24	1	2
Student 25	1	1
Student 26	0	2
Student 27	3	2