The effectiveness of supplemental instructional activities on eighth-grade students' understanding of the system of equations unit in pre-algebra

by
Elizabeth Pursell

B.A., Western Governors University, 2018
M.S., Western Governors University, 2021

AN ABSTRACT OF A DISSERTATION

Submitted in partial fulfillment of the requirements for the degree

DOCTOR OF EDUCATION

Curriculum and Instruction
College of Education

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Manhattan, Kansas

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Abstract

Cognitive development of eighth-grade students, as identified by Jean Piaget, occurs during a time when many of them are transitioning between concrete operations and formal operations where the ability to think in abstract concepts becomes possible. Because of this period of transition, many eighth-grade students find difficulty in demonstrating their understanding of the abstract concepts presented in the systems of equations unit of pre-algebra. The purpose of this study was to investigate the effectiveness of supplemental instructional activities on eighth-grade students' understanding of the systems of equation unit of pre-algebra. One hundred-ten middle school pre-algebra students in a rural Midwestern area of the United States provided data for a pretest-posttest control-group design. All participants received similar instruction on the systems of equations using an 11-day unit design. Students in the control group (*n= 23*) received no supplemental instructional activities, whereas students in the *Experimental Group A* (*n= 45*) received the same instruction, paired with supplemental instructional activities that utilized pencil and paper. A second experimental group, *Experimental Group B* (*n= 42*) experienced supplemental instructional activities that utilized technology.

Using pre-test and post-test scores, results of an analysis of covariance (ANCOVA) revealed that a significant difference existed (P = 0.17) between students who received no supplemental instructional activities (Control Group) and students who experienced supplemental instructional activities (Experimental Group A & B). The researcher also wished to explore if a significant difference existed between the modality of the supplemental instructional activities. It was found that no significant difference existed (P = 0.813) between the students who experienced supplemental instructional activities involving pencil and paper and those who utilized technology. These results strongly advocate the need to provide supplemental

instructional activities to eighth-grade students to aid the comprehension of the abstract nature that exists in the systems of equations unit of pre-algebra, and that the modality of these supplemental instructional activities may not be a factor in student comprehension and outcomes.

Keywords: supplemental instructional activities, pre-algebra, systems of equations, Piaget, concrete operations, formal operations

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Approved by:

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Dr. Michael Lawson

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Chapter 1 - Introduction

Young students often have difficulty with abstract concepts typically present in the study of pre-algebra (Chen, 2014; Susac et al., 2014). Learning the systems of equations unit requires student understanding of combining many mathematical concepts (e.g., solving multi-step equations, graphing) into larger more complex concepts, such as substituting a solution to equations into another equation to find intersections or to identify systems of equations with no solution. Improving comprehension and performance in this unit of study is important to the student's success in subsequent lessons and future mathematics courses (Susac et al, 2014). For example, students are often taught concepts such as combining like terms and solving one-step equations early in pre-algebra. Students will then move through units where they experience solving multi-step equations and using tables and graphs to solve equations using multiple variables. This content leads to students learning about systems of equations during pre-algebra, where they combine each of these individual concepts and skills into one larger concept where students will solve for multiple variables and solve two equations to find a common solution. Using collaborative instructional activities, student understanding of systems of equations during an eighth-grade pre-algebra unit may be greatly enhanced. Student success with this unit may also be enhanced by using technology-based collaborative activities.

Successful student experiences in abstract thinking might promote a greater understanding and development of overall higher-order thinking skills and provide students with additional confidence, which heightens motivation toward learning in the classroom (Raymond & Leinenbach, 2000). Further, in building towards these successful student experiences with abstract thinking in pre-algebra, students benefit the most from active learning where they can reinforce their understanding of concepts and become engaged in the learning process as a

stakeholder in their learning trajectory (Ting et al., 2019). Active learning can be defined as "classroom practices that engage students in activities, such as reading, writing, discussion or problem-solving, that promote higher-level thinking" (Braun et al., 2018). Since the teaching of pre-algebra comes at a critical time in students' cognitive development (Chen, 2014), students may benefit from collaboration with their peers (Durandt & Lautenbach, 2020). This partnership may create an environment of cooperation and motivation differently from teacher-led assistance during periods of time when students work alone (Trajkovik et al., 2018). Students learning the complex ideas included in the unit of systems of equations may be able to benefit from collaborative instruction with their peers. In this setting, the students can support each other through the learning process as well as work together in groups to complete the more complex tasks.

Technology devices have become a staple in many classrooms. Their affordability and availability allow teachers the option to incorporate their use in the classroom to enhance student understanding (Choi, et al, 2013). The incorporation of technology, particularly mobile and portable technology, has created a positive effect on motivating students towards mathematics (Taleb, et al, 2015). According to Choi and colleagues (2013), the use of technology and technology-based activities may enhance student learning by "...stimulat[ing] learners' various abilities, such as creativity, problem solving, logical thinking and the like, that build a positive attitude toward mathematics" (p. 3). With technology being more readily accessible in the learning environment, incorporating activities that utilize technology may increase understanding of mathematical concepts due to an enriched attitude that reinforces targeted concepts. (Choi, et al, 2013)

Statement of the Problem

The abstract concepts presented in pre-algebra often prohibit student comprehension due to the immature development of cognitive abilities (Chen, 2014). Students at this age often struggle with abstract concepts presented in pre-algebra as they are unable to comprehend the replacement of numbers with variables to indicate certain input and output data. These students may lack a convincing ability to manipulate equations to solve for the unknown data and successfully insert the new knowledge into the other equations to form a complete solution. Often, these students may not know how to process the information gained from the solution set to create the corresponding graph of the system of equations.

Eighth-grade students often struggle with abstract concepts presented in pre-algebra and are not given practical ways to demonstrate their knowledge (Chen, 2014). Up to this point, the district curriculum has not included practical applications or instructional activities to allow students to demonstrate their acquired knowledge. Students have primarily been taught a skill in rote memorization or method where the teacher instructs the class in a new concept and then completes assignments that test the students' knowledge and accuracy. This is repeated over and over until the student can proficiently complete an assignment with little or no help.

Rote memorization methods, commonly referred to as "drill and kill" (Nobel, 2017), prove to only be effective when learning simple skills such as times tables and addition and subtraction (Helwig, 2018). This method is inefficient with regards to student mastery and retention of complex and abstract mathematical concepts, such as what is used in the unit of pre-algebra known as systems of equations. While repetitive practice of concepts may positively aid in student understanding and comprehension, the method and timing in which the repetition takes place may be key (Helwig, 2018). Visual models are often used for students so that they can

make a more practical connection between the concept being taught and the uses for it. Based on the idea of visual models (Nobel, 2017) and properly timed repetition (Helwig, 2018), it may be surmised that supplemental instructional activities may assist students in the retention of their newly acquired knowledge and skills. Because of the stimulating nature and interactive platform that technology may provide, student understanding of mathematical concepts may be greatly improved.

Purpose of the Study

This quantitative method study aimed to examine the impact and influence of the use of collaborative instructional activities with and without technology on the problem-solving skills of eighth-grade pre-algebra students in the systems of equations unit. The collaborative environment created by grouping students together who actively participate in activities relevant to the topic and who utilize platforms which engage the student may improve understanding and retention of mathematical concepts. The rationale for the different modalities of the instructional activities came from the increase in the introduction of one-to-one technology within schools, where every student and every faculty member has their own electronic device to use within the instructional setting. The study aimed to find if a significant difference in student outcomes based on the modality of participating in instructional activities exists. As the researcher has previously been a classroom teacher within this selected age group and grade, it was the aim to discover if the use of instructional activities as a whole, create a significant impact on student comprehension. As the systems of equations unit is the first unit that presents such complex and abstract ideas to students, it was the aim of the study to discover if instructional activities, whether used with or without technology, showed any significant difference in student comprehension.

Theoretical Framework

The theoretical framework derived from the Swiss psychologist, Jean Piaget and his theory of cognitive development. Developed in 1936, Piaget's theory explains how children construct new understanding through experience and combining new information with prior knowledge. Because middle school-aged students are typically beginning to develop cognitive abilities necessary to understand abstract concepts presented in the systems of equations unit in algebra (Chen, 2014; Susac et al., 2014), utilizing supplemental instructional activities that allow students to be active and engaged in the learning process may assist these young students in understanding the subject material (Braun et al., 2018).

While utilizing paper and pencil or technology-based activities is thought to enhance student understanding of these abstract concepts, a collaborative environment that engages students in these concepts may demonstrate a significant difference in understanding and performance in the systems of equation unit when compared to students who do not engage in supplemental activities whatsoever (Durandt & Lautenbach, 2020; Trajkovik et al., 2018). This may be due to students developing the ability to construct their own understanding and knowledge of the abstract concepts in the system of equations unit from their personal engagement with their peers during collaborative supplemental activities (Allensworth et al., 2021).

The current study also sought to maximize the benefits of student collaboration through the incorporation of the theoretical framework of Russian psychologist and social constructivist, Lev Vygotsky and his Zone of Proximal Development. Developed during the final years of his life in the 1920s and the early 1930s, the Zone of Proximal Development (ZPD) refers to the difference between what a learner can do without help and what he or she is able to achieve with

guidance and encouragement from a skilled partner, or a more knowledgeable other. Vygotsky defined this further by stating the ZPD was, “the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance, or in collaboration with more capable peers” (Vygotsky, 1978, p. 86).

One of the variables tested in this study was if the use of instructional activities during certain class periods throughout the unit’s instruction enhances student comprehension. The other variable tested through the course of this study was the modality of the supplemental instructional activities delivered to students, via pencil and paper or the use of technology. Because collaboration and technology can allow students to construct and manipulate ideas to create personal meaning, the incorporation of this modality of instruction may greatly benefit student understanding when compared to paper and pencil methods (Sharma, 2023).

Research Questions

The intent was to determine whether or not the implementation of supplemental instructional activities and the use of technology will have a significant impact on post-test scores. The researcher intended to answer the following questions in the course of their research:

RQ_1 Do students in the control and both experimental groups show significant learning gains about systems of equations, as measured by the pre- and post-assessments?

RQ_2 For the two experimental groups, is there a significant difference in student learning that is tied to the modality of instruction (i.e., pencil-paper or technology enhanced activities), as measured by pre- and post-assessments?

Implications of the Study

This study may be pivotal for classroom teachers and the way they teach mathematics to middle school-aged students. The implications of this study may show positive student learning outcomes through active, supplemental instructional activities on the systems of equation unit in pre-algebra. Demonstrating a positive learning outcome when the unit requires understanding of abstract concepts by students who are transitioning between concrete and formal operations, according to Piaget, may be of great use to teachers of mathematics. Active learning during this study may show that students who are provided opportunities to actively engage in their learning may demonstrate a positive impact on their comprehension and retention of the materials addressed in the teacher-led portion of instruction. Mathematics teachers may then be able to work closely with their students to find the instructional activities that will help improve comprehension, and therefore the student's motivation to learn. With the considerable advantages technology may provide towards student comprehension in the mathematics classroom, its employment in these activities may be worth the investment of school administrators and classroom teachers alike. This study also sought to show how teachers might incorporate the pairing of students in groups in order to maximize peer collaboration.

Limitations

As with any study involving young students who are between stages of cognitive development, factors related to the subjects may not be present in other communities. Students in the current study came from a wide variety of diverse backgrounds. Due to the proximity to a major military installation, several students are from military families. Chandra and London (2013) note that there are severe gaps in the data collected from military families and children's cognitive development and how military service may affect this development. In many cases, the

rigors of military service and the impact it has on families may mean that, "…potentially important sources of variation remain hidden" (p. 197). "As more and more scholars seek to understand military children and families - their strengths and vulnerabilities, their ability to show resilience, and the systems that support them - the gaps in the data raise the question of how we can bolster the data infrastructure to support research with this population" (p. 189).

Another limitation to this study was a lack of consistency in curriculum in the lower grades. This district where this study occurred did not have one set curriculum for the teaching of mathematics in the early years. There are two elementary schools that "feed" into this middle school. Both elementary schools, until this upcoming school year, allowed the teachers to choose what they will teach during the year as far as mathematics is concerned. Beginning with the 2023-2024 school year, the elementary schools within the district taught from the same curriculum with a prescribed amount of time per week that mathematics was taught within the classrooms. Fifth grade in the district moved to dedicated content matter teachers rather than one teacher for all subjects.

Delimitations

The number of sections used for the study was decided on so that the researcher-instructor could limit the amount of differing teaching styles among teachers. By deciding to use their own classrooms, the source of instruction and delivery of the instructional information could be controlled to the extent that only one teacher was involved. Also, by choosing to only use the researcher's classes, it allowed control over the supplemental or additional instruction provided during each prescribed lesson or activity. The researcher was able to control their own involvement in or the lack thereof in the student's collaboration processes.

By choosing to use their own students, the researcher was able to account for any delays in teaching a lesson or delivery of an activity. For example, if a day of school was missed due to a school closure, the researcher would only work with their own students and lesson plans to meet the instructional needs of the study. This keeps all students on the prescribed path for the study and eliminates the possibility of one group of students getting differing amounts of instruction over another.

With these delimitations chosen, the study would be more consistently adhered to and eliminating any potential outside influences on the teaching methods' process. Another reason for using the researcher's own students was due to the timeframe in the school year and there was already a relationship between the researcher and the students established. The researcher was able to better prepare for and understand the students and any collaborative learning groupings that should or should not be employed in each of the settings.

Definitions

System of Equations: "In algebra, two or more equations to be solved together (i.e, the solution must satisfy all the equations in the system). For a system to have a unique solution, the number of equations must equal the number of unknowns. (Britannica, 2023)

Rote memorization or "drill and kill": introducing a skill and then using repetitive activities to cause memorization of the skill rather than the purpose of the skill. (Nobel, 2017)

Technology: any means of delivering instructional activities using a screen and/or the internet in individual and group instructional settings. A technical definition for "technology" is "a manner of accomplishing a task especially using technical processes, methods, or knowledge" (Merriam-Webster, n.d.) For the purposes of this study the use of a Smart Board by the researcher in the delivery of instruction, and the use of calculators to aid students in their

calculations, were the only exceptions to the use of technology in the non-technology group. This study used web-based and digital technologies for all activities for the technology enhanced experimental group.

Supplemental Instructional Activities: any activities used outside the confines of the initial introduction and teaching of a concept within the systems of equations pre-algebra unit. Researcher: the individual conducting the research also served as the individual that delivered the instruction and administering all activities and assessments. (Pickering, 2021)

Students: the subjects of the study are regular participants within the researcher's daily classroom; no subjects outside of the researcher's grading and teaching purview were utilized.

Summary

A quantitative method research design analyzing assessment data was used to examine each student's performance before and after the implementation of instructor-created group activities. This intervention (Appendix A) provided understanding and strategies to help students with their mastery of the systems of equations unit in pre-algebra. Systems of equations is an important skill for students to master as it is their first experience in creating a visualization of their solutions. Having a mastery of the complex concepts introduced in this pre-algebra unit may better prepare the students for the next unit that requires them to understand the transformations of graphs. The quantitative data from the pretest-posttest data provided information to answer the research questions by indicating how students respond to the intervention. The significance and justification for the study showed insight on how to provide an instructional intervention that may help struggling students expand their understanding of more complex ideas and concepts within their mathematical education. These concepts may be

necessary as students progress through the remainder of the pre-algebra course and mathematics courses into the future.

Chapter 2 - Literature Review

The benefits of collaborative instructional activities on student understanding, demonstration, and retention of mathematical concepts are important for educators to understand when planning lessons. Students in the eighth-grade, pre-algebra class typically range from 12 to 14 years of age. According to Jean Piaget's theory of cognitive development (1936), it is during these years that students move from concrete to formal operations where their understanding of abstract concepts, similar to those found in the systems of equations unit of pre-algebra, are likely to develop. Ojose (2008) suggests that children learn abstract mathematical concepts and relationships best when they have experiences that allow them to practice with concrete materials rather than through lengthy lectures and explanations. This approach to teaching mathematics appeals to different learning styles and provides opportunities for learning abstract concepts through sensory experiences. It also facilitates the transition between concrete and abstract thinking that may allow students to attain a deeper level of understanding, especially when students are developing this confidence. Teachers who are able to provide a variety of representations of the abstract mathematical concepts found in the system of equations unit of pre-algebra may better acknowledge the multitude of ways students process and understand these abstract concepts. Having the ability to teach during a pivotal period between the concrete and formal operational stages of student development, multiple representations and modalities of these abstract concepts may become more imperative for student understanding.

The purpose of this chapter is to review literature related to Jean Piaget's 1936 theory of cognitive development and the acquisition of knowledge by constructing new understanding through experience and combining new information with prior knowledge as it relates to the systems of equations unit in pre-algebra through supplemental instructional activities. Pre-

algebra uses concepts that are typically abstract in nature (Susac, et al, 2014). Since eighth-grade students are transitioning from concrete reasoning to the ability to think and function in abstract settings, many of them may have logical reasons for their incorrect responses based on their rationale of truths not yet fully developed (Rhine, 2019). Through the use of collaborative instructional activities, including the incorporation of games, student understanding of and attitudes towards learning the advanced and abstract concepts in the systems of equations unit may be greatly enhanced (Ojose, 2008). This understanding may be heightened through the use of technology-based games and activities where student engagement in the process may be elevated, especially for auditory and visual learners (Sharma, 2023). This chapter also provides a foundation in prior research for the current study to explore the benefits of instructional activities to improve problem-solving skills in the systems of equations unit in pre-algebra, utilizing technology during these supplemental instructional activities, and the benefits of peer-collaboration versus individual work.

Student Transition from Concrete to Formal Operations in Mathematics

Jean Piaget's theory of cognitive development (1936) suggests that children transition through four different stages of learning throughout their lives: sensorimotor stage (birth to two years old), preoperational stage (ages two to seven), concrete operational stage (ages seven to eleven), and formal operational stage (ages twelve and older) (Piaget, 1983). Piaget suspected that children transition from one stage to another by taking an active role in the learning process and adding new knowledge by building upon existing knowledge and adapting previously held ideas to accommodate new information. Because the current study employs students in middle school pre-algebra (ages twelve to fourteen), only the concrete and formal operational stages will be explored.

Students in the concrete operational stage of development are typically in grades two to six. While the study of pre-algebra typically occurs in grade eight, the transition between stages may take place over time and with a collection of experiences, rather than an instantaneous change. During the concrete operational stages of cognitive development, students typically form understanding and mastery of the ability to think logically about concrete events. Their thinking becomes more logical and organized but it is still very physical and based on absolutes. When students are literal in their thinking, they become more proficient at using reasoning that is assessed according to strict principles of validity (Piaget, 1983).

Students transitioning to the formal operations of cognitive ability typically begin to develop the capacity to think abstractly and reason about hypothetical problems. During this time, it is possible to apply deductive logic to more specific items based on a general principle. A key characteristic of the formal operational stage of cognitive development is the ability to analyze abstract situations and ideas. Throughout these four stages, Piaget suggested children gradually develop a qualitative change in their thinking. As children progress from the beginning of the concrete operational stage to the beginning of the formal operational stage, they do not simply have more information. Rather, according to Piaget, the way they think about the world is fundamentally changing and their capacity to understand and function with abstract concepts has begun to develop through the use of several factors that influence how children learn and grow (Piaget, 1983).

The first factor that influences a child’s learning is through an outline, or model of a plan or theory known as a schema. In order to comprehend and know, mental and physical actions must take place. In Piaget's view, a schema includes both a category of knowledge and the process of obtaining that knowledge. As experiences are accumulated, this new information is

used to modify, add to, or change previously existing schemas. In mathematics, an example of a schema may include word problems, where the problem stated can be represented through some sort of visual means.

The next factor that influences a child's learning and growth is assimilation. This is the process of taking in new information into our already existing schemas. The process is somewhat subjective because we tend to modify experiences and information slightly to fit in with our preexisting beliefs (Piaget, 1983). As students progress to the systems of equations unit in the current study, the visual representation of equations may be depicted through a series of graphs, as there are two or more equations that share the same variables. The objective with the system of equations unit is to find the point where these two equations intersect. Developing an understanding of how graphs work and interpreting their meaning may be considered one schema, and the assimilation of multiple variables develops this understanding further.

The next factor, accommodation, is the ability to change existing schemas due to the acquisition of new information. During this process, new schemas may be developed that allow the child the ability to think more efficiently and in greater detail for heightened understanding. Finally, as children progress through the stages of cognitive development, it is important to maintain a balance between applying previous knowledge (assimilation) and changing behavior to account for new knowledge (accommodation). Piaget believed that all children try to strike a balance between assimilation and accommodation using a mechanism he called equilibration.

This final factor, equilibration, helps explain how children can move from one stage of thought to the next. Regarding the systems of equations unit in the current study, students may eventually understand the graphic representations of these equations and be able to construct the problem in reverse. Because these graphic representations illustrate a more concrete depiction of

the abstract values in the equation, student understanding of both concepts would demonstrate a heightened sense of understanding of the unit. Since this level of understanding may be considered pinnacle in a student's comprehension of these abstract concepts, the development for students to have this level of thinking may be enhanced through supplemental instructional activities supporting the transition through these factors (Piaget, 1983).

Benefits of Instructional Activities to Improve Problem-Solving Skills in Mathematics

Students benefit from active learning that promotes higher thinking when the activities employed are problem-, inquiry- or discovery-based (Ting, et al, 2019). In its simplest form, active learning requires the student to reinforce the higher-order thinking skills and instructional techniques from the learning process. According to Ting and colleagues (2019), an essential element of engaging students in active learning is to, "...cultivate their ability to create new knowledge and apply the acquired knowledge and skills by demonstrating well-developed judgment and responsibility" (p. 2). Through proper manipulation and execution, active learning may motivate the student to be more engaged in the classroom (Raymond & Leinenbach, 2000). This may ultimately promote student initiative and ownership of their own learning.

In one of its simplest forms of collaboration, having students discuss the solution to a math problem presents very few challenges for the instructor to set up and execute. Booth and colleagues (2015) found that students (n = 51) who were given examples of both correctly- and incorrectly solved math solutions in a linear equations module performed significantly better than students who did not have the examples provided. A replication study by the same researchers on a much larger scale (n = 425) provided similar results where the use of correct and incorrect demonstrations was beneficial, however, the results were not statistically

significant when compared to the control group (Booth et al, 2015). The results from both studies suggest that the use of correct and incorrect teacher-provided prompts may not be the most effective use of supplemental instructional material.

Locke and Tailby (2016) sought to observe if the use of oral and written language would assist in the development and understanding of algebra in ninth-grade students from New Zealand. The theory behind the use of language was that "they would facilitate algebraic understanding and knowledge retention and further, would motivate students to engage with this aspect of mathematics" (p. 149). All of the students participated in the experimental design and were taught to simplify and manipulate algebraic expressions using language. In one activity (titled *snowballing*), students collaborated and discussed their individually developed expression of the mathematical problem in groups with other students. The group responses were then shared with the class and with the entire population developing a consensus on the best response to the given problem. Another task (titled *concept circles*) involved the teacher providing a circle on the board drawn into quadrants. Each quadrant had a mathematical concept included and the students were to come up with sentences that paired the concepts and discuss their relationship. Similar to the *snowballing* activity, the students worked individually, then in pairs, and then as an entire class. Posttest results showed that while the students performed significantly better after the experimental treatment, they did not find great value in the activities. According to the data, the students found greater merit in the discussions when working collaboratively in pairs (Locke & Tailby, 2016).

Moving beyond the use of correct and incorrect problem-solving examples (Booth, et.al., 2015) and the use of oral and written language (Locke & Tailby, 2016), Demirel and Yilmaz (2018) found that the use of mind games in math and grammar classes as supplemental

instructional activities may provide a positive significant difference in student understanding. While the use of integrating gameplay into the learning process has been found to increase student performance on test scores (Demirel & Yilmaz, 2018), it has also found to have a positive effect on interpersonal skills, especially among introverted students (Trajkovik, Malinovski, Valileva-Stojanovska, & Vasileva, 2018).

Noreen and Rana (2019) believed that activity-based instruction methods could be beneficial in geometry. According to the researchers, "Learning by doing is very important in successful knowledge because it is proved that the more the senses are inspired, the more a person learns and the longer he/she retains. Activities bring activeness and smartness among the learners" (2019, p. 150). Students in geometry who used a variety of activities to enhance the unit instruction, such as drawing on whiteboards, creating shapes from various materials, and using shadows from light sources performed significantly better than those who did not participate in these activities. Additionally, the researchers found that the students who utilized these activities retained the lessons longer than those who performed well on assessments but did not participate in the activity-based environment (Noreen & Rana, 2019). The student's value of these activities was found to be "joyful, interesting, and fruitful" (p. 157). It is likely that participation in activity-based learning where the students value the activity may yield similar results in other fields of study.

Similarly, Allensworth, Cashdollar, and Gwynne (2021) found that students in Chicago who were engaged in professional learning environments where the teacher incorporated real-world activities and strategies in math instruction showed promising improvement in student achievement with common core state standards. While the results from this study were not consistent between schools with different standards related to professional learning, most

demonstrated growth in student understanding and achievement with students who demonstrated less achievement in the past benefitting the most from these professional learning experiences.

Utilizing Technology to Enhance Student Understanding During Instructional Activities

The use of technology in the classroom to positively aid in student understanding is unquestionable. Sharma (2023) states, "students engage deeply in class when tech tools encourage them to construct ideas, collaborate with peers, and create unique work." All students within the current study were able to use calculators, and the instructor used a SmartBoard for the projection of the notes for whole class lectures. While students may still value the use of learning through lectures and group activities, the use of technology can enhance the learning environment exponentially (Perry, et al, 2012).

In a study of 644 middle school math students in the same school in Indiana, McClain and North (2021) found that the association between student improvement, as measured by the Measures of Academic Progress (MAP) growth, and the integration of technology during instruction was significant. In a survey of 139 undergraduate and graduate student responses from the Communication Sciences and Disorders program at Illinois State University, 87% of the students showed a great interest in their teachers using technology to aid in the learning process and 97% mentioned that they would use technology to supplement their understanding of the lesson (Perry et al., 2012). The use of technology inside and outside the classroom to aid in understanding appears to be valued by a large number of students of all ages.

While technology may be a tremendous benefit to student learning, Neiterman and Zaza (2019) also found that students' perception of its incorporation has provided many challenges. Four hundred seventy-eight undergraduate student surveys and 36 instructor surveys were

collected and analyzed regarding how the learning environment has been impacted by the increased use of technology. Both student and instructor perspectives of the impact of technology on the learning environment were overwhelmingly positive, however, there were a number of responses that warned of distractions during off-task moments. The distractions, as noted by students, include the clicking noises of typing on keyboards and viewing non-course-related items on other students' screens (Neiterman & Zaza, 2019). This data might suggest that the use of technology to facilitate supplemental instructional activities be included but limited and monitored.

In a mixed-methods Canadian study of 320 middle school students, Labonté and Smith (2022) found that students' self-directed learning using technology was significantly related to the instructional quality in their classroom. When learning with technology, students reported less engagement in collaborative activities with their peers. To assist in fostering a positive effect of utilizing technology and maximizing student engagement during collaborative learning, students must be aware of the benefits and receive support to engage collaboratively with their peers. They also concluded that teachers may benefit from professional development in learning how to incorporate best practices for guiding student cooperation and participation with technology. McClain and North (2021) found similar results where investment in professional development training of older and more seasoned teachers to improve the quality of instructional activities with technology may benefit student engagement and understanding.

One technological platform that has received great attention in education is the free online platform Kahoot. Founded in 2012, Kahoot allows educators to use the online platform to "create, share, and play learning games or trivia quizzes in minutes" (Kahoot, 2020). The online platform allows students to work individually and also collaboratively in teams as they compete

to answer questions. Regardless of the number of participants per team, students may value the competitive nature of Kahoot while providing an entertaining platform. The proper use of Kahoot allows the instructor to reinforce the lessons being taught and assessed. It also allows the students to demonstrate their understanding of the lesson in a positive and encouraging environment (Noreen & Rana, 2019).

The effective use of Kahoot in the classroom has been documented in a number of studies in mathematics, biology, geology, physics, and chemistry (Prieto, et al, 2019; Karam, et al, 2016). Students overwhelmingly favored the use of the online gaming platform and felt it helped their understanding. Of particular interest in mathematics is that a large number of students felt that they were able to self-evaluate their own learning (74.3%) and that they had fun using the platform (82.8%) (Prieto et al., 2019). The results in science were positive but were not as overwhelming as the mathematics results. In the same two categories, 72.8% of students felt they were able to self-evaluate their learning. While not that different from mathematics, the Likert scale showed that only 15.2% gave the most favorable rating, *in total agreement*, for science versus 51.4% in mathematics (Prieto et al., 2019). In regards to having fun using the platform, only 57.6% of the students demonstrated a positive attitude toward the science portion. Similar to the phenomenon related to self-evaluation, only 9.1% of the students responded with the most positive rating, that they were in total agreement of having fun with the science portion, compared to 57.1% in the math section. The researchers addressed this phenomenon in their conclusions by stating, "...mathematical concepts do not require such rote learning as scientific concepts, so students could feel more motivated when answering the content questionnaire after the experience, as they could get better results" (Prieto et al., 2019, p. 10).

Gningue and colleagues (2014) observed that the use of other virtual manipulatives also improved remedial college students' attitudes, confidence, and understanding of pre-algebra and algebra concepts. While the students in their study may be older than those that will be studied in the current study, "...urban community college remedial students lack fundamental basic arithmetic and algebra skills similar to middle school students" (2014, p. 159). While the use of technology has shown to significantly improve student performance, student attitudes towards and confidence in mathematics were also improved through the use of virtual manipulatives (Gningue et al., 2014).

The use of a blended curriculum involving hands-on activities and technology-based manipulatives to improve student performance in algebra was the focus of a very large experimental study involving 74 middle school and 73 high school campuses from 51 districts in seven states (Karam et al., 2016). The blended curriculum required students to spend about 60% of their instructional time in classroom activities and the remaining 40% of their time using computer-based instruction. Schools in the experimental group were offered a prepackaged, "blended mathematics curriculum designed to promote student understanding of algebraic concepts and principles, to develop students' problem-solving skills, and to enable them to master higher-order mathematical concepts" (2016, p. 400). Instructors overwhelmingly supported the use of the prepackaged blended activities system and student performance was significantly improved during the first year of implementation. Results from the second year were not positive as a number of instructors abandoned the study citing that the prepackaged system offered very little flexibility and was often too restrictive in how the instructor could interact with the students (Karam et al., 2016).

Benefits of Peer-Collaboration Versus Individual Work

Improving student understanding and performance in pre-algebra may be paramount to their success in future mathematics courses. Because the teaching of pre-algebra typically comes at a pivotal time in a person's cognitive development (Chen, 2014), students may benefit from the collective input and experience of their peers (Durandt & Lautenbach, 2020). This collaboration may stimulate cognition and an environment of cooperation and motivation differently from teacher-led assistance during periods of individual work (O'Donnell, 2006; Trajkovik et al., 2018). While the benefits of peer collaboration are demonstrated, careful consideration by the instructor should be exercised for the most effective pairings of student groups.

In the 1930s, Russian psychologist Lev Vygotsky developed a theory that would explain the space between what a learner is capable of doing on their own and what they were capable of doing with the assistance of person who possessed greater knowledge of the subject matter, a more knowledgeable other (Vygotsky, 1978). The distance between what the student can do on their own and what the student cannot do without assistance is known as the Zone of Proximal Development, or ZPD.

The theory developed by Vygotsky was to further develop Jean Piaget's theory of children being autonomous learners. While Piaget was a proponent of independent thinking but was critical of teacher-led instruction, Vygotsky believed there was merit with social interactions that may provide a nurturing environment between the student and someone who had more knowledge in the same group setting (Vygotsky, 1978). The rationale developed was that student understanding should not be based on what they know, rather students should be examined on their ability to solve problems independently and their ability to solve problems with the help of

a more knowledgeable other. While this theory evolved near the end of Vygotsky's life, it was further developed years later to study children's mental development as it relates to the educational setting (Hausfather, 1996).

Using Vygotsky's theory of the Zone of Proximal Development, it may seem logical for a teacher to first consider the creation of student groupings based on academic development (Walshaw, 2017). Having the student of greater achievement paired with a student who is less competent in the subject matter can serve the group well. The student of greater achievement can serve as the mentor, or the more knowledgeable other, to the student with the lower ability level (Fernández, et al, 2015). To achieve student success in the classroom, it is vital that a teacher consider these academic abilities when pairing students during collaborative work environments.

The use of students of similar and different ability levels has been the subject of several studies, each offering different results. Johnson (2017) observed the pairings of seventh-grade band students who had like abilities (symmetrical pairings) and those who had contrasting abilities (asymmetrical pairings). Students worked in pairs for four weeks and would take turns being the leader of their group as they worked on sight-reading of new music and music theory exercises. While the study of music and mathematics may seem unrelated, the use of fractions to divide time in the performance of rhythm, and the understanding of music theory, which is rooted in basic mathematics, makes for an ideal study in regards to the application of a student's understanding of the fundamental mathematics. Johnson found that while both groups improved during the four-week period, neither group showed a significant difference over the other. This data contradicts the thought process of Vygotsky's theory and may allow teachers more flexibility in their pairings of student groups.

While the pairing of students in Johnson (2017) did not show a significant correlation in regard to ability levels, a similar study in mathematics and language (Vega & Hederich, 2015) offers mixed results. Data collected suggested that the cooperative learning techniques employed showed a significant difference in student improvement in mathematics, but not in language. Further analysis of the data suggests that while the experimental treatment provided a significant difference in posttest performance in mathematics, students of differing ability levels showed a greater significant difference than the pairing of likeability groups (Vega & Hederich, 2015). These results may suggest that cooperative learning helps students assimilate knowledge in the best way possible for the group and for the individual understanding of concepts. In regard to the pairing of students of different levels of ability, it was found that students with a higher level of understanding were able to help promote understanding to students with lower levels of comprehension.

An increase in student engagement during the learning process may enhance understanding of the subject matter (Hooker, 2011). The use of a collaborative environment may stimulate individual thought from the social exchange of ideas from others (Ting et al., 2019). This melding of ideas may develop a deeper understanding and command of the subject being studied. In many ways, this is a preferred method over the passive learning environment typically experienced through a lecture-formatted class that does not utilize peer collaboration (Hooker, 2011; Trajkovik et al., 2018). Group work can be more effective than lecturing in some settings because students may work harder and understand concepts in greater detail due to their contributions and investment in the task (Costley & Lange, 2018).

Hooker (2011) sought to measure student perceptions and attitudes to see why a correlation might exist between the use of peer collaboration groups and student achievement. At

the completion of the pre-algebra and algebra courses that utilized peer collaborative groupings, student reactions were obtained through journal entries, questionnaires, and interviews. Several students remarked that they were able to learn the material when their group leader was able to give relevant examples to the group's real-life situations and when the leader was able to explain concepts in terms the students felt they could relate to and were more comfortable (Hooker, 2011). Students taught using the group methodology expressed that they felt they spent more time studying and learning the material, that it was a more enjoyable classroom experience, and that working together in the group setting helped them to achieve higher grades. Overall, students felt that when the lesson was corroborated with their peers, they were more comfortable with their personal contributions (Hooker, 2011).

While the effectiveness of collaborative group work at the collegiate level has shown to be a useful tool (Ting, et.al., 2019) that is valued by the student participants (Hooker, 2011), the pairing of students who are continuing to develop in their cognitive abilities into collaborative groups may require additional attention. Other factors, such as personality differences, motivation, and record of academic achievement may affect the working environment of young student groups. Understanding how these factors may affect the productivity of group work is of utmost importance for the instructor and the students themselves.

While the pairing of students of like ability and dissimilar-ability levels offers mixed results, Sears and Reagin (2013) suggest that the benefits of group work may depend more on the participants' ability level in relation to the complexity of the task. The results of their study showed that accelerated students performed significantly better on complex tasks when they worked alone. Contrary to this, the students who were classified as 'at-risk' performed better on more complex tasks when paired with a peer. These results suggest that accelerated students who

are able to perform the task successfully on their own might find collaboration, "...more of a hindrance than a benefit…" (2013, p. 1167). The results of this replicated study (Sears & Reagin, 2013) are identical to earlier studies performed by Cooper and Kagel (2005), and Schwartz (1995).

The use of collaborative groups and activities among students may increase active involvement in learning and give students a deeper understanding of their personal contribution to the group and towards their own learning (Trajkovik et al., 2018). The effective pairing of students may create an environment where the success of the group is dependent on the collaboration and cooperation of each participant. The pairing of students based on ability level alone may not yield the best result from collaborative work, as the data from research offers mixed results. These results suggest that other factors may affect student understanding during group activity work and that a number of student arrangements should be considered by the instructor (Johnson, 2017).

Students who are not typically intrinsically motivated in the subject matter may not contribute positively to the group. If the less-motivated student does not participate equally with other members, the less-motivated student may not have the opportunity to construct their own knowledge (Lange, et al, 2016). This lack of opportunity may limit their understanding of the subject matter and also prohibit the other students in the group from benefiting from all group member viewpoints and contributions (Lange et al., 2016). A member of the group who decides to not fully participate is potentially forcing other members to perform tasks that go beyond the scope of the lesson or their own comfort level. When other members of the group have to take on these additional responsibilities, it may make the student who initially lacked motivation feel that

they are no longer welcomed to participate in the group, thus creating a cycle that may fail the unmotivated student altogether (Kagan, 1989).

Rienties, et al (2009) showed that individuals who are motivated in the topic are likely to contribute positively to the group setting. Students who are highly motivated in the topic contribute more to planning within a group setting than those that are less motivated. In a case where the observation of positive group interaction took place (Hooker, 2011), student reactions indicated that the classroom experience was enjoyable and that working in groups motivated them to study and devote more time outside of class to prepare for their work in the next class. An increase in interaction in follow-up classes by all members may lead to greater understanding by everyone in the group (Zhu, 2012). Students who were assigned to collaborative group environments where the outcome of the collaboration was significantly positive also found that their retention of the subject material assisted them in subsequent math classes (Hooker, 2011). This may be an important discovery for continued student learning altogether.

While the use of student collaborative groups may heighten student engagement and understanding of the subject matter, the effectiveness and success of the group may be dependent on the motivation of each participant (Trajkovik et al., 2018). Each member of a small group may bring a different understanding or motivation to the task, and individual goals must give way to group goals (Costley & Lange, 2018). Understanding student motivation of the subject beforehand might assist the instructor in creating a highly effective group learning environment, thus creating a more positive experience for all members (Costley & Lange, 2018). Since the use of peer collaboration may motivate student learning in ways that teacher-led assistance does not do as effectively (Hooker, 2011; Trajkovik et al., 2018), it is very important to find ways to make group work a positive experience for all.

Conclusion

The use of peer collaboration and supplemental instructional activities has shown to be positive in the mathematics setting. Results from Ting et al., (2019); Hooker (2011); Sears and Reagin (2013); Johnson (2017); Vega and Hederich (2015); Trajkovik et al., (2018) support this. Additionally, students acknowledge that the use of peer collaboration is also beneficial (Hooker, 2011). While this is the case, there are factors that the instructor should consider maximizing the effective use of peer collaboration.

As identified by Sears and Reagin (2013) and Vega and Hederich (2015), the confidence level of a student in the subject may greatly impact the effectiveness of the group. Other factors such as personality and motivation (Trajkovik et al., 2018) may help guide the educator in effective pairings during collaborative work. Furthermore, the use of supplemental instructional activities, from technology to hands-on manipulatives, has shown positive results in student achievement in mathematics. While the use of technology enhances the learning experience greater than simply hands-on manipulatives, student achievement may be reached by keeping the classroom teaching environment exciting and by providing students with immediate feedback (Demirel & Yilmaz, 2018; Gningue et al., 2014). For educators, it is also important that a variety of activities be flexible in order for them to be fully incorporated into the curriculum (Karam et al., 2016). It may be rational to assume that student involvement in the learning process and their value of the activities they participate in may promote better understanding and retention of the concepts being taught by the instructor (Noreen & Rana, 2019).

Chapter 3 - Methodology

This chapter discusses the methods of research for this quantitative method study. These methods include identifying the research design, describing the participants to be used for the study, and the data collection instruments and intervention to be employed to evaluate the independent variables. Appropriate statistical treatment of data and security and confidentiality throughout the process was also identified. Because the pretest and posttest assessments were identical, the researcher addressed the internal validity of the assessment tool.

Research Design

The methodology described in this chapter attempted to answer the following research questions:

RQ_1 Do students in the control and both experimental groups show significant learning gains about systems of equations, as measured by the pre- and post-assessments?

RQ_2 For the two experimental groups, is there a significant difference in student learning that is tied to the modality of instruction (i.e., pencil-paper or technology enhanced activities), as measured by pre- and post-assessments?

To address these questions, this study utilized an experimental design to identify if a causal relationship existed between the use of collaborative instructional activities with and without technology on the problem-solving skills of eighth-grade students in the systems of equations unit of pre-algebra. Further, the researcher attempted to justify and satisfy the purpose of the study through quantitative methods. A quantitative approach was selected for this research as it is useful in establishing “cause and effect” relationships among variables being tested (Verhoef & Casebeer, 1997). As this study aimed to find the effect of the use of instructional activities on

student comprehension and outcomes, as well as if the modality in which those instructional activities are participated in, the quantitative approach is more practical to give a numerical value to the findings of the research.

Setting and Participants

The setting of this study was a middle school in a rural area that provided a convenient location for the research, with grades six through eight represented on the same campus. Core subjects taught at the school include mathematics, reading, English language arts, history, and science. In addition, electives and exploratory classes are offered, including but not limited to band, Project Lead the Way, general music, physical education, and health. There are 52 full-time faculty and 764 students enrolled. The school is split by gender with 50% male-identifying students and 50% female-identifying students with ages ranging from 11 to 14 years of age. The ethnicity makeup of the school contains 81% Caucasian, 4% African American, 5% Hispanic, 2% Asian, 1% Hawaiian, and 7% identified as two or more races. Within this school population, 8% qualify for reduced lunch and 29% qualify for free lunch. A number of families are employed by a major military installation that rests a few miles outside the town (Compare Public Schools, 2021).

The subjects from this middle school campus participating in this study in 2021 were five sections of eighth-grade, pre-algebra classes. These classes were chosen based on the school being a trusted environment for the researcher. The school was in proximity to the researcher and therefore provided a potential for participants. The students ranged from 12 to 14 years of age. A total of 110 students participated in the study with a gender breakdown of 55 female-identifying students and 55 male-identifying students. Participant names and any identifying information

was kept confidential. For reporting purposes, each student was assigned a random identification number. The assignment of the identification numbers is only known by the researcher.

The middle school in which this study was performed works on an alternating day block schedule method. Therefore, assignment of the control group ($n = 23$) and the experimental groups was assigned based on the schedule of the researcher. On one instructional day, the researcher taught three of the five classes; so, this day included the control group and the instructional group that did not use technology (Group A, $n=45$). On the second instructional day, the researcher saw the other two classes who were assigned as the technology enhanced groups (Group B, $n = 42$). By using this method of placement for the classes, it limited the possibility of any mix of instructional delivery modality. Further, each section was of mixed abilities, having no single class at a higher or lower learning level than another.

Data Collection Instruments

Students were administered a pretest assessment (Appendix D) to identify their knowledge of the systems of equations unit prior to any lessons being taught by the instructor. Since many of these students attended school in the same school district, this was the first opportunity for students to experience this topic, thus creating the opportunity for a level playing field for all participants. The pretest used a mixed method of assessing student knowledge and skills. The assessment was broken into sections to test based on the standards that were taught, and each standard has a representation of multiple choice, and open-ended questions which allowed the students to show their work and understanding of how to solve the systems given. There were approximately five questions testing each standard that was taught within the unit, solving by graphing, solving by substitution, solving by inspection and solving by elimination.

The pre-test assessment evaluated student readiness and understanding of the concepts of the systems of equations unit of pre-algebra. Students were prepared for this unit of study through their recent experience with solving multi-step equations. Functions such as combining like terms, collecting variables on one side of an equation, and then isolating a variable to obtain a solution are similar between the two units and must be understood prior to a student being able to demonstrate readiness with the systems of equations unit. The pretest assessment allowed the researcher to establish student understanding prior to the introduction of any intervention related to the unit.

After the pre-test, all students were subjected to an eleven-class intervention (Appendix A). Students in *Experimental Group A*, experienced supplemental group instructional activities that did not employ technology and students in *Experimental Group B* experienced supplemental group activities that used technology. A control group received instruction on the unit and did not receive any supplemental group activities. At the conclusion of the instructional and intervention period, posttest assessment, which was the same as the pretest, was administered. (Appendix D)

The pre- and post-test (Appendix D) assessments included questions for the students to answer that were consistent with the examples provided in the lessons and the intervention activities. The two assessments utilized the same material to limit any potential bias of one assessment over the other. With a four-week period between the administration of the assessments, student retention of the exact materials was unlikely, however, the researcher addressed internal research validity.

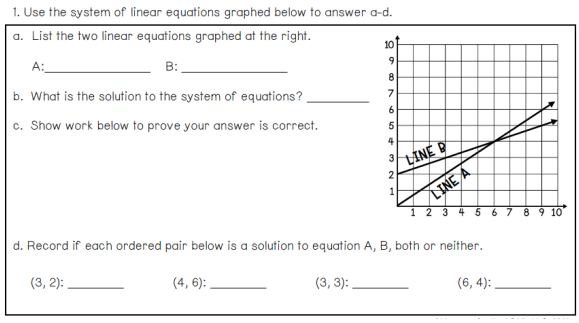
Systems of Equations Unit Design for Intervention and Control Groups

In this study, the Control Group did not receive any additional or supplemental treatment to enhance instruction. Experimental Group A received supplemental instruction that incorporated paper and pencil supplemental instructional activities and Experimental Group B received supplemental instruction that utilized technology-based activities. As each group of students experienced different versions of the same instruction, the information below describes in detail each day of instruction for each group, Control Group, Experimental Group A and Experimental Group B, along with examples of the activities they participated in and the timeline in which it took place.

On the first day of instruction, an introduction to the systems of equations unit was introduced. Since this is the first day of instruction in the unit, all groups experienced the same lesson. All students were given teacher-led instruction, then some guided practice problems and concluded the lesson with individual practice problems (Table 3.1).

Table 3.1 Day 1 of Instruction: Introduction to Systems of Equations for all Participants

Time in Class	Activity
Introduction to the Lesson (approx. 30 mins)	Teacher led instruction with notes, definitions, and guided practice problems.
Guided Practice (approx. 20 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice.


1. Use the system of linear equations graphed below to answer a-d.

a. List the two linear equations graphed at the right.

A:_____ B: _____

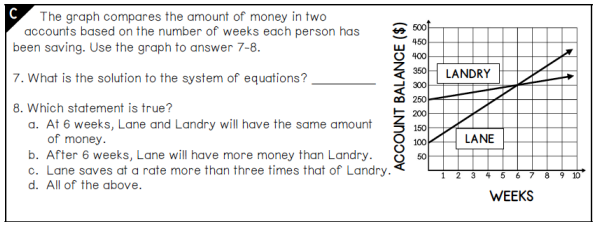
b. What is the solution to the system of equations? _____

c. Show work below to prove your answer is correct.

d. Record if each ordered pair below is a solution to equation A, B, both or neither.

(3, 2): _____ (4, 6): _____ (3, 3): _____ (6, 4): _____

Individual Practice (approx. 30 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.


C The graph compares the amount of money in two accounts based on the number of weeks each person has been saving. Use the graph to answer 7–8.

7. What is the solution to the system of equations? _____

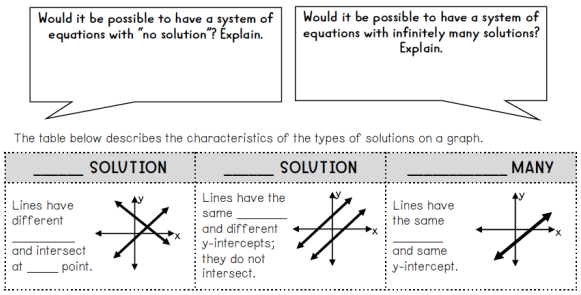
8. Which statement is true?
   a. At 6 weeks, Lane and Landry will have the same amount of money.
   b. After 6 weeks, Lane will have more money than Landry.
   c. Lane saves at a rate more than three times that of Landry.
   d. All of the above.

The intervention began on day two of instruction. The control group began with a verbal review of the previous meeting's lesson. Student's had a chance to ask questions about their independent practice problems. From this they moved into the guided notes and practice as before, this lesson was day one of a two-day lesson (Table 3.2).

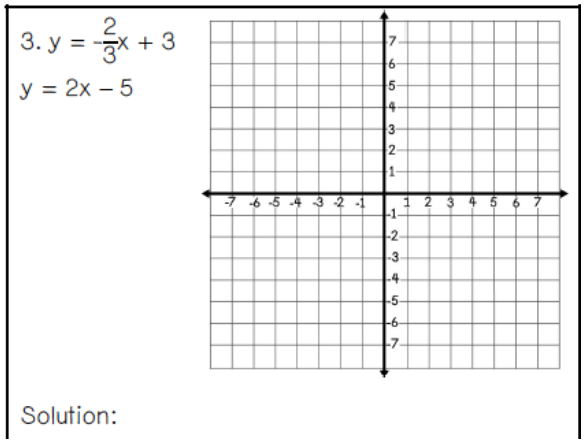
Table 3.2 Day 2 of Instruction: Solving Systems by Graphing, Control Group

Time in Class	Activities
Review of Previous Lesson (approx. 15 mins)	Teacher guided question and answer from previous class meeting
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding

Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice



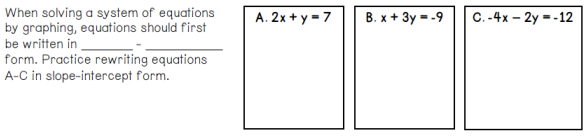
Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.

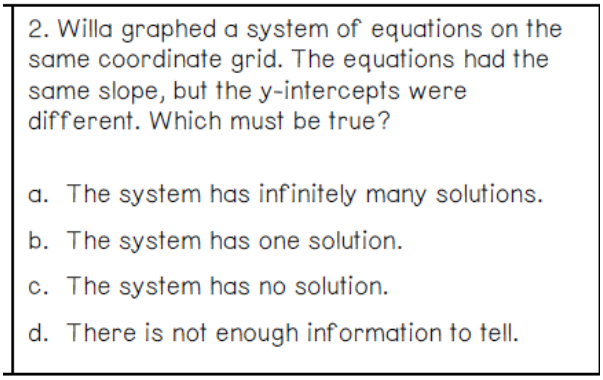


Experimental Group A began class with a team-style quiz with teams of 3-4 students. Each team worked together to solve the problems and race the other teams to see who completed it first. Once all teams completed the quiz, the class moved to the guided notes and practice as before. This was day one of a two-day lesson (Table 3.3).

Table 3.3 Day 2 of Instruction: Solving Systems by Graphing, Experimental Group A

Time in Class	Activities
Review of Previous Lesson (approx. 15 mins)	Team style quiz to review skills from previous class meeting. Teams will work together to solve the problems while racing the other teams in the classroom to see who can finish first!
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice
Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.





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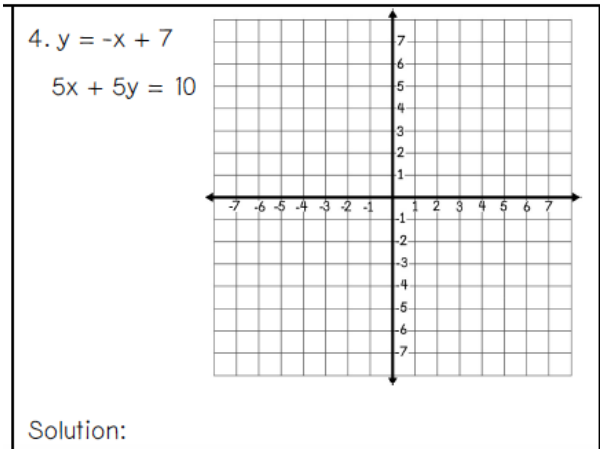
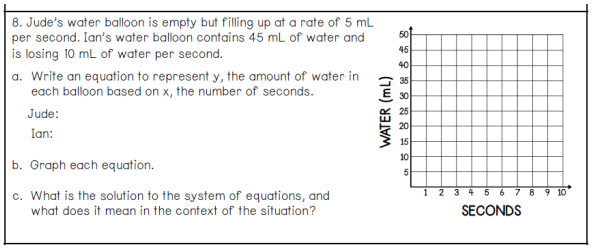
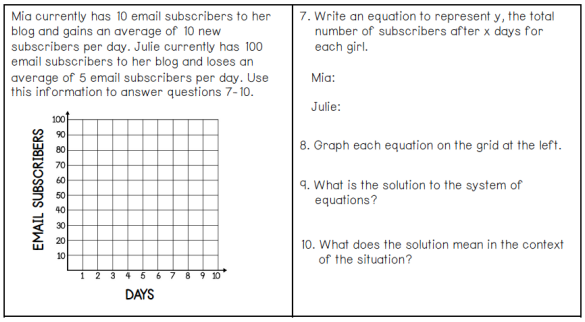


Group B began class with an online activity using a teacher-created Kahoot! quiz. This was a similar strategy to Group A, in that the students raced each other to answer the questions within the Kahoot!. Following the game, the students moved to the guided practice and notes as they did the class before today. This was day one of a two-day lesson (Table 3.4).

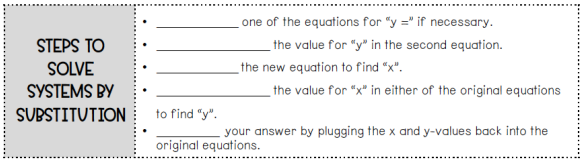
Table 3.4 Day 2 of Instruction: Solving Systems by Graphing, Experimental Group B

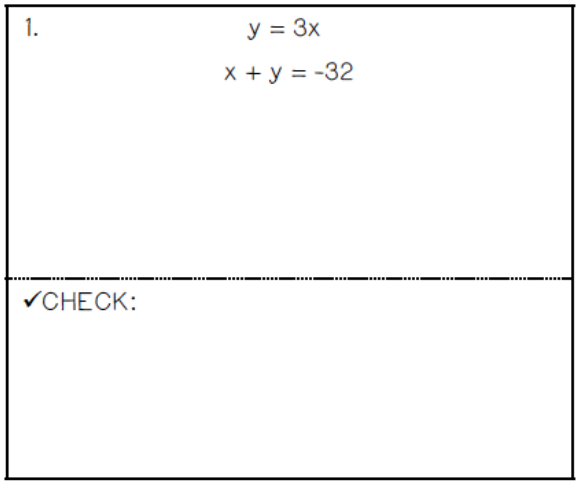
Time in Class	Activities
Review of Previous Lesson (approx. 15 mins)	Students will participate in a teacher-created Kahoot! Activity to review the lesson from the previous class meeting. After each question students will see the correct answer, and then they will also see the leaderboard for who answered correctly the fastest
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice
	
Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.
	

On the third day of instruction, the control group began as they have done before, with a question-and-answer time from the previous session. This helped students prepare to conclude the solving by graphing lessons. Following the question and answer, the students received their guided notes and practice packets to begin the day's lesson. (Table 3.5)

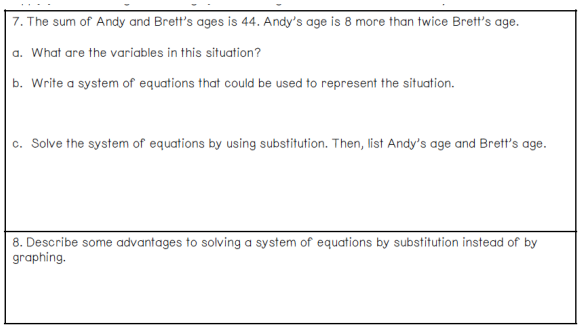
Table 3.5 Day 3 of Instruction: Solving Systems by Graphing, Control Group

Time in Class	Activities
Beginning of Class (approx 15 mins)	Teacher guided question and answer from previous class meeting. This will help students to engage their prior knowledge and prepare to build on it.
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice





Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.


7. The sum of Andy and Brett's ages is 44. Andy's age is 8 more than twice Brett's age.

a. What are the variables in this situation?

b. Write a system of equations that could be used to represent the situation.

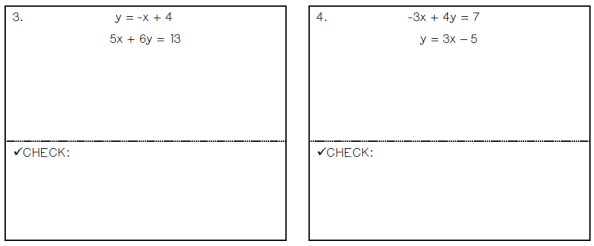
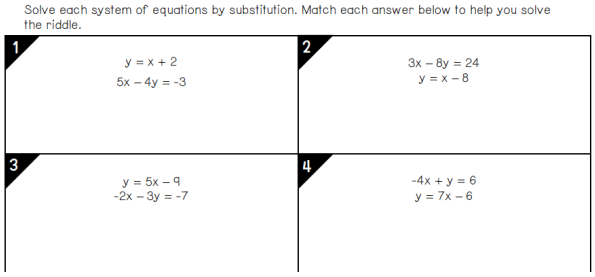
c. Solve the system of equations by using substitution. Then, list Andy's age and Brett's age.

8. Describe some advantages to solving a system of equations by substitution instead of by graphing.

Experimental Group A began day two of instruction by collecting a ruler from the teacher to complete an activity with a partner. The students raced other teams of two to correctly solve and graph two problems. The goal was not only to check comprehension but also enhance their intrinsic motivation "to win the race". Following the activity, students collected their guided notes and practice packets from the previous lesson to conclude the solving by graphing lesson (Table 3.6).

Table 3.6 Day 3 of Instruction: Solving Systems by Graphing, Experimental Group A

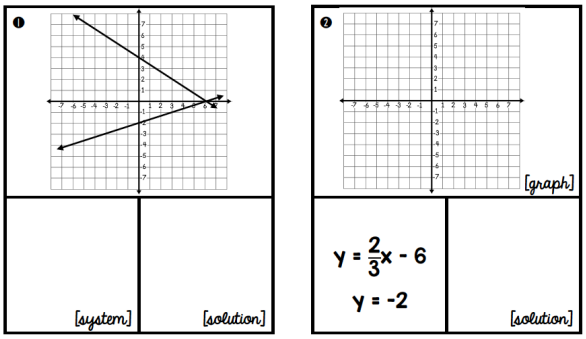
Time in Class	Activities
Beginning of Class (approx. 15 mins)	Partner activity to graph two equations before any other team. This will increase their intrinsic motivation to "win the race" and engage their prior knowledge.
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding.
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice

	
Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.
	

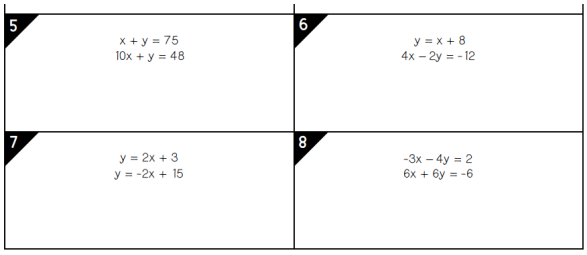
For Experimental Group B, class began with an online computer race of graphing two equations correctly, using an online graphing tool. Similar to Group A, this group enhanced their intrinsic motivation "to win the race" against their classmates. Once everyone submitted their activity, the class continued the previous day's lesson on solving by graphing by collecting their guided notes and practice packets (Table 3.7).

Table 3.7 Day 3 of Instruction: Solving by Graphing, Experimental Group B

Time in Class	Activity
Beginning of Class (approx. 15 mins)	Students will participate in an online graphing race, including a graphing tool on their devices. They will pair with one other student and race the other teams, engaging their intrinsic motivation to solve the problems correctly and quickly. This activity will engage their prior knowledge and prepare them for today's lesson.



Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding.
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice
Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.

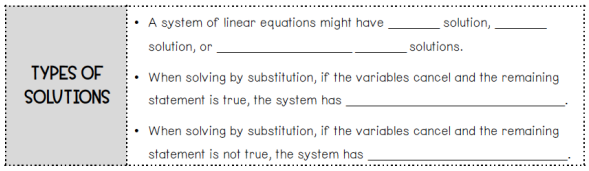


On day four of instruction, students learned to solve by using substitution. The Control Group began as they have all other classes, with a question and answer session to provide clarification on any problems they struggled with in the previous lesson of solving by graphing. They were allowed to ask about any questions from class or their independent practice. They continued with the new lesson with their guided notes and practice packets (Table 3.8).

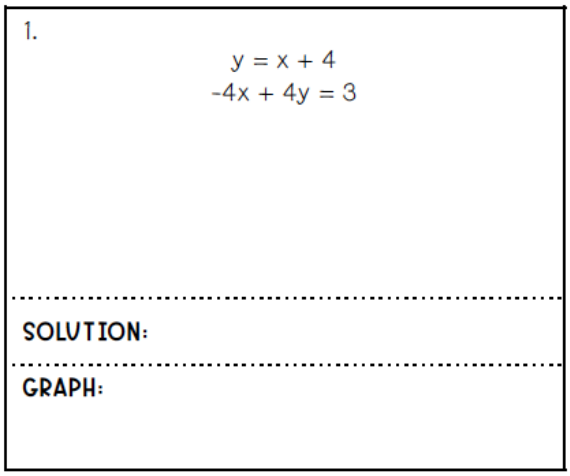
Table 3.8 Day 4 of Instruction: Solving by Substitution Part 1, Control Group

Time in Class	Activities

Beginning of Class (approx. 15 mins)	Teacher guided question and answer from previous class meeting. This will help students to engage their prior knowledge and prepare to build on it.
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding



Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice

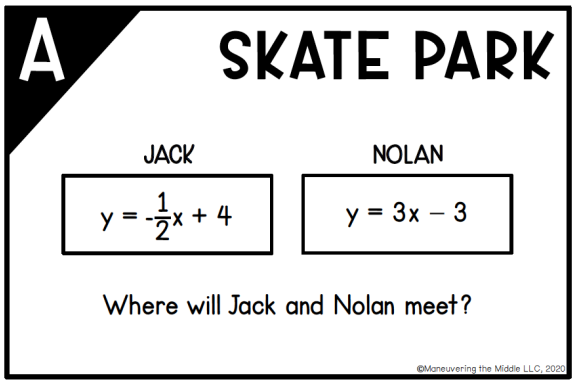
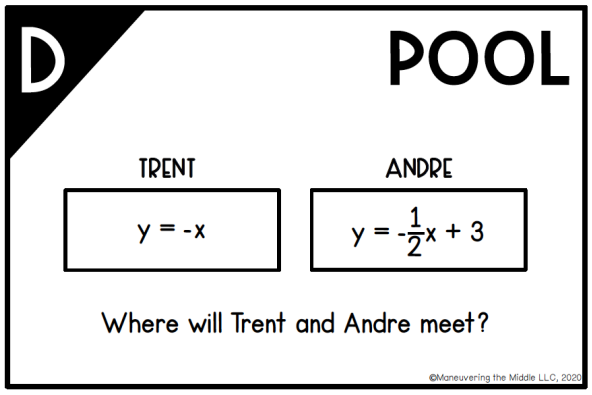


Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.

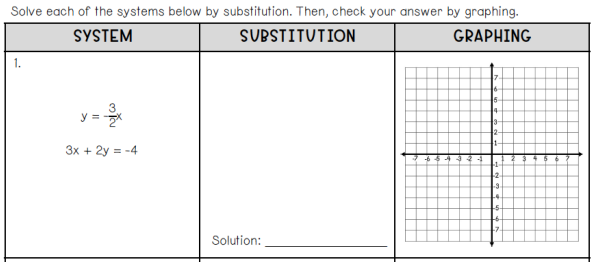
Group A began day four of instruction with a scavenger hunt around the classroom. They worked in teams of no more than four students, with final team size that was dependent on class size that day. Each group had a total of twelve problems to solve. At each card they solved a new clue that moved them to a new card. The activity worked similarly to an escape room where answering clues correctly got them closer to the exit. The goal was to have the twelfth problem solved that then led them to the clue card they began the activity. If, at any time, they returned to

a card that they had already solved, the students knew they had incorrectly solved previous cards. They were to return to the cards to find and correct their mistake. The teams worked cooperatively to complete this task. Following this activity students collected their guided notes and practice packets to begin today's lesson on solving by substitution (Table 3.9).

Table 3.9 Day 4 of Instruction: Solving by Substitution Part 1, Experimental Group A

Time in Class	Activities
Beginning of Class (approx. 15 mins)	Scavenger hunt around the room. They will solve twelve clue cards in an attempt to return to the card they began the activity on.
	
	
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice

Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.


Solve each of the systems below by substitution. Then, check your answer by graphing.

SYSTEM	SUBSTITUTION	GRAPHING
1. $y = -\frac{3}{2}x$ $3x + 2y = -4$	Solution: _____	

Experimental Group B began much like Experimental Group A, however they completed the scavenger hunt online, using their district provided Chromebooks. It worked in the same way that Group A worked; as they solved a clue card, they then choose the next clue card that contains the answer they achieved and work through the twelve problems. Same as with Group A, if they returned to a card they previously solved, then they had to work backwards to find their mistake, correct it and then move forward. Following this activity, the students moved forward as normal by collecting their guided notes and practice packets that begin today's lesson (Table 3.10).

Table 3.10 Day 4 of Instruction: Solving by Substitution Part 1, Experimental Group B

Time in Class	Activities
Beginning of Class (approx. 15 mins)	Scavenger hunt using their Chromebooks. They will solve twelve clue cards in an attempt to return to the card they began the activity on.
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice

Solve each system of equations below for practice. Roll a pair of dice, find the sum of the two numbers showing, and solve that problem.

DICE ROLL	SYSTEM	SOLUTION
2	$y = \frac{1}{2}x + 4$ $y = -x - 2$	
3	$6x + 2y = 1$ $y = -3x + 3$	

SHOW WORK HERE:

Independent Practice (approx. 25 mins)

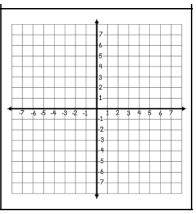
Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.

5.

$y = \frac{1}{2}x + 2$

$y = x + 1$

Solution: _____



On the fifth day of instruction, students in all three groups completed any incomplete work from the previous day, solving by substitution lesson. This allowed for students to ask questions and get clarification of the work they did in the previous class. During the independent practice of solving by substitution the teacher walked through the classroom and assisted students and checked for comprehension of the tasks.

For the control group they completed the previous lesson while asking their questions and getting clarification and making any necessary corrections to their work. They moved to small groups to continue having conversations about their understanding of the lessons up to this point. As a group they worked to solve more sample problems. During this time the teacher stopped by each group to listen to the discussions and clarify any points that as a group they are debating or still needed clarification on (Table 3.11).

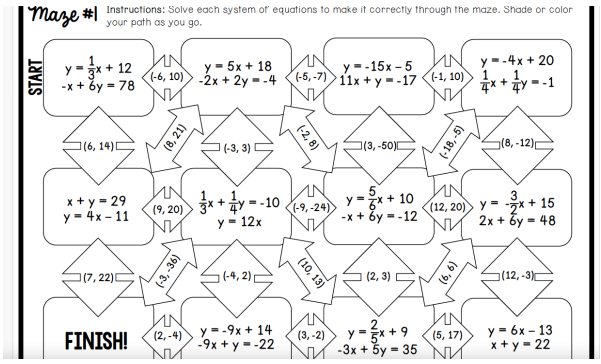
Table 3.11 Day 5 of Instruction: Conclusion of Solving by Substitution, Control Group

Time in Class	Activities
Beginning of Class (approx. 40 mins)	Students will begin by completing the independent practice from the previous day's lesson and ask questions along the way for clarification and guidance on how to solve the problems.
Collaborative Practice (approx. 40 mins)	Students will work in small groups to discuss their practice problems and work to correct mistakes. The teacher will check in with each group to clarify any questions and ensure they are on task and completing their work in a timely manner.

For Group A, the non-technology group, the class moved from the completion of solving by substitution lesson to an activity to reinforce the work they have been doing up to this point in the unit. They worked in pairs to race each other to complete mazes involving solving by substitution. When each partner completed their maze, they traded with their partner to check each other's work. If any problems exist that the students are debating or if any errors were found, they worked to correctly solve the errors (Table 3.12).

Table 3.12 Day 5 of Instruction: Conclusion of Solving by Substitution, Experimental Group A

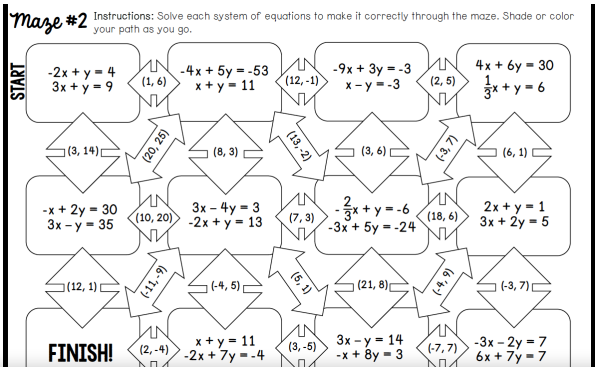
Time in Class	Activities
Beginning of Class (approx. 40 mins)	Students will begin by completing the independent practice from the previous day's lesson and ask questions along the way for clarification and guidance on how to solve the problems.
Collaborative Practice (approx. 40 mins)	Students will collect mazes from the teacher and partner with another student. They will complete their maze and then collaborate with their partner to correct any mistakes, or at any time they reach a "dead end" in the maze.



Group B, the technology-enhanced group, completed the previous class lesson as the other groups have done. From here they moved to logging into their posted Maneuvering the Middle (MTM) curriculum on Canvas, using their Chromebooks, and solving the mazes. They did the same activity virtually that Group A completed, and also participated in the discussions with their partners (Table 3.13).

Table 3.13 Day 5 of Instruction: Conclusion of Solving by Substitution, Experimental Group B

Time in Class	Activities
Beginning of Class (approx. 40 mins)	Students will begin by completing the independent practice from the previous day's lesson and ask questions along the way for clarification and guidance on how to solve the problems.
Collaborative Practice (approx. 40 mins)	Students will log into Canvas to complete mazes posted by the teacher from the MTM curriculum. They will partner with another student and they will complete their maze and then collaborate with their partner to correct any mistakes, or at any time they reach a "dead end" in the maze.



On day six of instruction, all of the groups began with a short formative assessment to allow the teacher to check understanding of the material presented to this point in the unit. The control group worked individually on the assessment until all students have completed their work. The students then spent the remainder of class going over each problem and discussing the solutions and how they were found. This gave the students an opportunity to ask questions about any problem or lesson that they still had trouble with their comprehension (Table 3.14).

Table 3.14 Day 6 of Instruction: Mid-Unit Formative Assessment, Control Group

Time in Class	Activity
Beginning of class (approx. 45 mins)	Students will individually take a mid-unit formative assessment checking for understanding of material presented up to this point in the unit. (Appendix B)
Following completion of assessment (approx. 35 mins)	Following every student completing the assessment the class will discuss each problem and work through those that anyone has questions regarding the solution or the work to get to the correct solution. All students will have all problems completed with correct solutions at the conclusion of class.

Day six of instruction for Group A began with the same formative assessment; however, theirs was a collaborative effort among small groups. Students began the activity with a partner, and worked through two problems, they each turned to someone else and repeated this process

until all the questions were answered. Following the collaborative work, students had an opportunity to review their work and make any necessary corrections. The students came back together as a class in the final twenty minutes to discuss the correct answers and ensure they all understood the reasoning behind the work to find the solutions (Table 3.15).

Table 3.15 Day 6 of Instruction: Mid-Unit Formative Assessment, Experimental Group A

Time in Class	Activity
Beginning of class (approx. 60 mins)	Students will take a mid-unit formative assessment using a pair and share method to complete this assessment. They will work with a total of four students. This will be used for checking understanding of material presented up to this point in the unit. (Appendix B)
Following completion of assessment (approx. 20 mins)	Following the completion of the assessment the class will discuss as a class any problems that they were struggling with and want more clarification on. By the end of class students will all have the correct answers to each of the ten questions on the assessment.

Group B originally completed their work individually on their Chromebooks, then they partnered with another student to discuss and correct the questions they did not answer correctly. They continued to partner and retake the assessment until they reached the score of 100%. Through the partner work, students had the opportunity to speak with the teacher and ask questions to gain more understanding as to what they were not doing correctly to find the solutions (Table 3.16).

Table 3.16 Day 6 of Instruction: Mid-Unit Formative Assessment, Experimental Group B

Time in Class	Activity

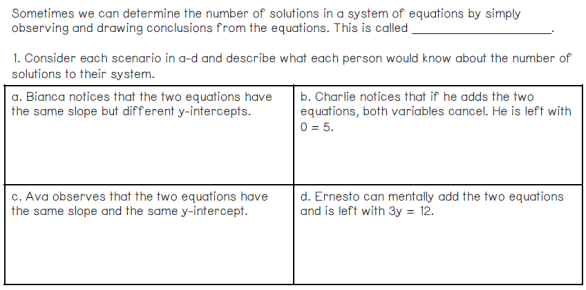
Beginning of class (approx. 60 mins)	Students will individually take a mid-unit formative assessment, on their Chromebooks, using online tools such as graphing software and calculators. The assessment is checking for understanding of material presented up to this point in the unit. Once all students are finished with their work, they will pair with another student to work on any problems they struggled with or did not find the correct solution.(Appendix B)
Following completion of assessment (approx. 20 mins)	Following the students pairing and sharing the class will return to a full class discussion to answer any questions that still remain. All students will have all problems completed with correct solutions at the conclusion of class.

On day seven of instruction in the systems of equations units, all students, regardless of the group they were in, participated in the same instruction for the day. All groups began with a quick review of the mid-unit formative assessment they completed during day six. Students then moved to collect their guided notes and practice packets and began the lesson for the day of solving systems by inspection. This method was a quick review of graphs and substitution so the teacher-led notes and guided-practice ended with a collaborative session of practice. During this time the teacher observed students for their overall engagement in the discussions and practice work. At this time, students should have a solid understanding of the previous lessons and, therefore, all students are expected to be active participants as well as have a strong sense of ownership of their work. (Table 3.17)

Table 3.17 Day 7 of Instruction: Solving by Inspection, All Groups

Time in Class	Activity
Beginning of Class (approx. 15 mins)	All students will participate in a review of questions from the previous sessions mid-unit assessment.
Remainder of Class (approx. 65 mins)	Students will work through the guided notes and the guided practice until the end of class. There is no designated independent practice for

this lesson as it is a combination of the previously learned methods of solving the systems.



Sometimes we can determine the number of solutions in a system of equations by simply observing and drawing conclusions from the equations. This is called _____.

1. Consider each scenario in a-d and describe what each person would know about the number of solutions to their system.

a. Bianca notices that the two equations have the same slope but different y-intercepts.	b. Charlie notices that if he adds the two equations, both variables cancel. He is left with 0 = 5.
c. Ava observes that the two equations have the same slope and the same y-intercept.	d. Ernesto can mentally add the two equations and is left with 3y = 12.

This was day eight of instruction and returned to having different methods of interventions. The Control group began the class by finding, in their notes and practice problems from previous classes, any problem they were still struggling with the solutions for and reworking them before they were allowed to move forward with the day's lesson of solving by elimination (Table 3.18).

Table 3.18 Day 8 of Instruction: Solving by Elimination, Control Group

Time in Class	Activity
Beginning of Class (approx. 15 mins)	Review of previous materials and answer any questions that may still remain from those lessons.
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice

Another method to solve systems of equations is known as elimination. In cases where the variables in two equations have opposite coefficients, we can solve the system with the following steps:

SOLVING BY ELIMINATION

- Line up the like _____ in the equations.
- _____ the equations to _____ one variable and solve for the other.
- _____ your answer into one of the original equations to solve for the other variable.
- Write your variables as an _____ pair and _____ your answer.

Use the method of elimination to solve each of the systems of equations below.

1.	2.
$-2x + 4y = 4$ $3x - 4y = 2$	$6x + 2y = 4$ $-6x - 5y = -28$
✓CHECK:	✓CHECK:

Independent Practice (approx. 25 mins)

Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.

1. McKayla is using elimination to solve the system below and will first add the equations together. $5x - 2y = 42$ $-3x + 2y = -26$ Which of the following shows the result of the two equations added together? A. $8x = 16$ B. $2x = 16$ C. $2x = 68$ D. $8x = 68$	2. Beckett needs to solve the system of equations below using elimination. $-2x + 4y = -2$ $6x - y = 28$ Which correctly describes the first step Beckett should take? A. Multiply each term in the 1st equation by -3 B. Multiply each term in the 1st equation by 3 C. Multiply each term in the 2nd equation by -4 D. Both B and C would work

In 3-7, solve each system using elimination. Use the answer bank to check your solutions. Not all choices will be used.

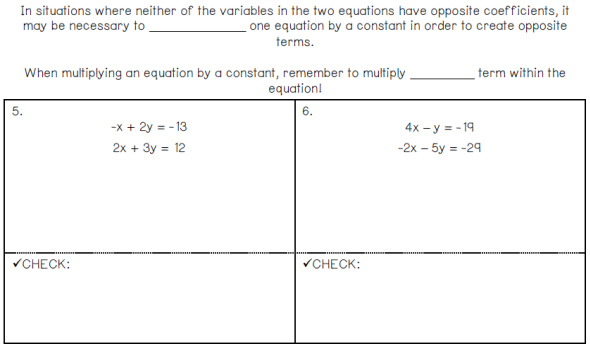
(-5, 6)	(4, 6)	(-6, -4)	(-4, 3)	
(-2, 2)	(1, 5)	(3, -4)	(2, -2)	(1, 6)

3.	4.	5.
$9x - 3y = -42$ $-9x + 8y = 22$	$2x + 4y = 14$ $3x - 4y = -39$	$-5x - y = 8$ $5x - 3y = -16$
_____	_____	_____

Group A began this day of instruction by competing in a team style quiz as they have previously done on Day Two where they raced other teams to complete the two graphing problems. They worked with a small team to complete a series of questions that reviewed solving by graphing, substitution as well as inspection. Following the race, students collected their guided notes and practice packets for today's lesson of solving by substitution (Table 3.19).

Table 3.19 Day 8 of Instruction: Solving by Elimination, Experimental Group A

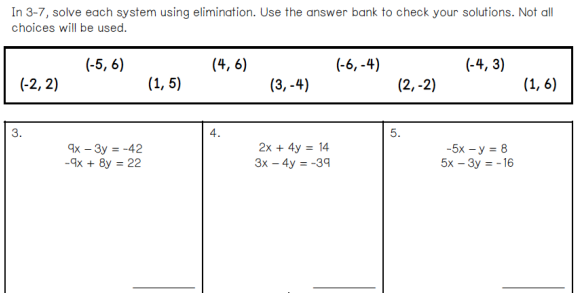
Time in Class	Activities
Beginning of Class (approx. 15 mins)	Partner activity to compete in a race of previous practice problems before any other team. This will increase their intrinsic motivation to "win the race" and engage their prior knowledge.
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding.
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice
Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.



In situations where neither of the variables in the two equations have opposite coefficients, it may be necessary to _____ one equation by a constant in order to create opposite terms.

When multiplying an equation by a constant, remember to multiply _____ term within the equation!

5.	6.
$-x + 2y = -13$ $2x + 3y = 12$	$4x - y = -19$ $-2x - 5y = -29$
✓CHECK:	✓CHECK:



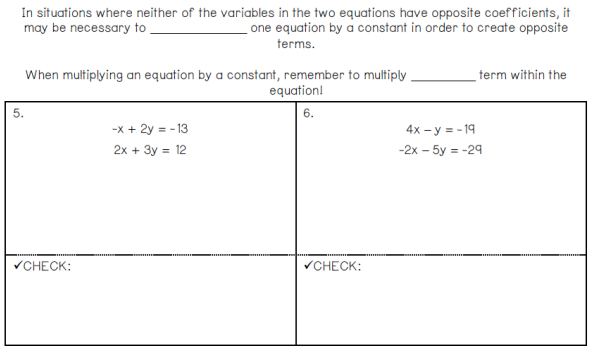
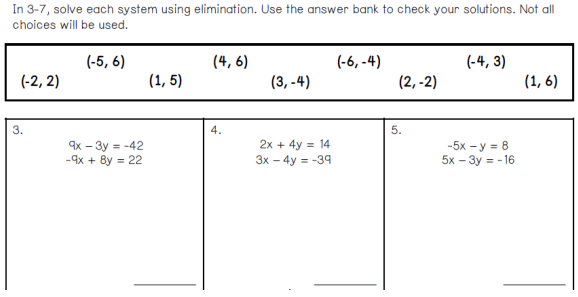
In 3-7, solve each system using elimination. Use the answer bank to check your solutions. Not all choices will be used.

(-5, 6)	(4, 6)	(-6, -4)	(-4, 3)
(-2, 2)	(1, 5)	(3, -4)	(2, -2)	(1, 6)

3.	4.	5.
$9x - 3y = -42$ $-9x + 8y = 22$ _____	$2x + 4y = 14$ $3x - 4y = -39$ _____	$-5x - y = 8$ $5x - 3y = -16$ _____

Group B also began with a quick game-style review by participating in a teacher-created game on the Kahoot! platform on their Chromebooks. This reviewed their previous knowledge of solving systems by graphing, substitution and inspection. Following the game the students collected their guided notes and practice packets for the lesson on solving by elimination (Table 3.20).

Table 3.20 Day 8 of Instruction: Solving by Elimination, Experimental Group B

Time in Class	Activities
Review of Previous Lesson (approx. 15 mins)	Students will participate in a teacher-created Kahoot! Activity to review all of the previous materials. After each question students will see the correct answer, and then they will also see the leaderboard for who answered correctly the fastest
Lesson (approx. 25 mins)	Teacher guided notes, definitions and answering student questions for clarification and understanding
Guided Practice (approx. 15 mins)	Students and teacher will work together to solve sample problems similar to what they will see in the independent practice  In situations where neither of the variables in the two equations have opposite coefficients, it may be necessary to _____ one equation by a constant in order to create opposite terms. When multiplying an equation by a constant, remember to multiply _____ term within the equation! 5. $-x + 2y = -13$, $2x + 3y = 12$ ✓CHECK: 6. $4x - y = -19$, $-2x - 5y = -29$ ✓CHECK:
Independent Practice (approx. 25 mins)	Students will work independently through problems to practice the skills they have just acquired. The teacher will walk around the room to check in with each student for understanding.  In 3-7, solve each system using elimination. Use the answer bank to check your solutions. Not all choices will be used. (-5, 6) (4, 6) (-6, -4) (-4, 3) (-2, 2) (1, 5) (3, -4) (2, -2) (1, 6) 3. $9x - 3y = -42$, $-9x + 8y = 22$ _____ 4. $2x + 4y = 14$, $3x - 4y = -39$ _____ 5. $-5x - y = 8$, $5x - 3y = -16$ _____

Day nine of instruction was a full day of review of the solving by elimination lesson. The control group completed a review of the previous day's lesson with time to rework any of the guided or independent practice problems that students have questions about how to solve them correctly. Students worked independently for the majority of this class, but were able to speak

with the teacher, and the class came back together at the end to discuss any questions that appeared to be questioned by many in the class (Table 3.21).

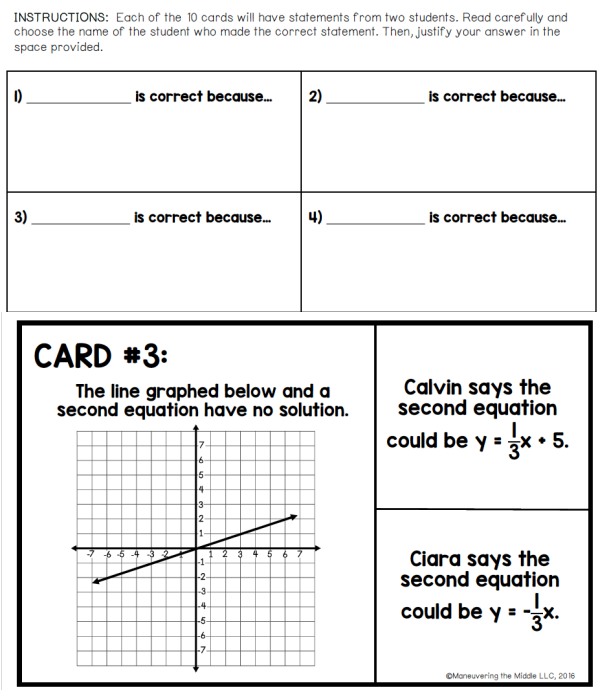
Table 3.21 Day 9 of Instruction: Review of Solving by Elimination, Control Group

Time in Class	Activities
Beginning of Class (approx. 60 mins)	Students will review the lesson from the previous class meeting to gain a further understanding of solving by elimination
Class Discussion (approx. 20 mins)	The class will use the remaining time in class to review together any questions that they are still struggling to understand following the quiet practice. Students will receive their unit study guide as they leave class.

For Group A, day nine consisted of a "He Said/She Said" activity. This activity was completed in a similar way to the scavenger hunt completed on Day Four of instruction. The students worked in groups no larger than three students. Each student worked through the problems to arrive at a solution and discussed this with their partners to move on to the next clue card. Students completed the class with a review and a correction of any problem that they may have solved incorrectly (Table 3.22).

Table 3.22 Day 9 of Instruction: Review of Solving by Elimination, Experimental Group A

Time in Class	Activities
Beginning of Class (approx. 60 mins)	"He Said/She Said" activity around the room. They will solve clue cards and determine which of the two given answers is correct. They should be able to defend their answer to their partners and discuss why they believe they solved it correctly.



INSTRUCTIONS: Each of the 10 cards will have statements from two students. Read carefully and choose the name of the student who made the correct statement. Then, justify your answer in the space provided.

1) _____ is correct because...	2) _____ is correct because...
3) _____ is correct because...	4) _____ is correct because...

CARD #3:

The line graphed below and a second equation have no solution.

Calvin says the second equation could be $y = \frac{1}{3}x + 5$.

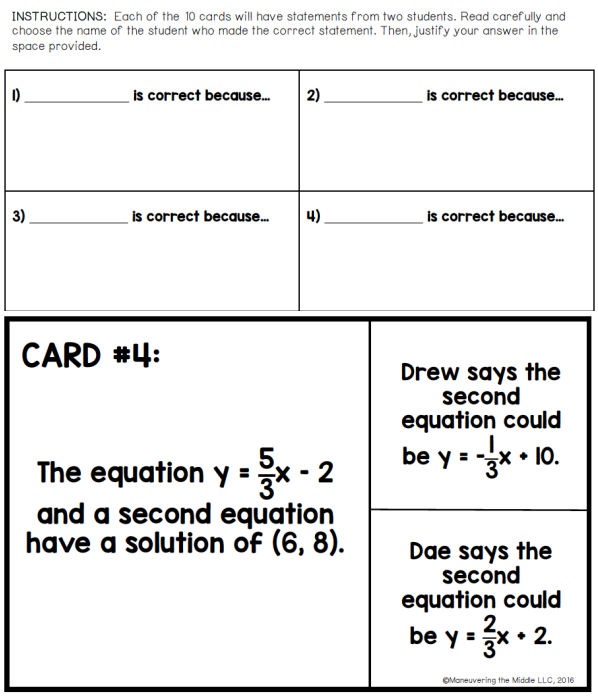
Ciara says the second equation could be $y = -\frac{1}{3}x$.

Class Discussion (approx. 20 mins)	Students will gather back together as a class to discuss which cards were the most difficult and how they were able to work through their troubles and come to an answer. Any incorrect answers will be corrected. Students will receive their unit study guide as they leave class.

As with Group A, Group B completed the "He Said/She Said" activity, however they worked on the digital platform Canvas to complete this activity. Similarly, they completed each card to determine which answer on the card was correct and they were expected to defend their answer and why they believe one answer is correct versus the other. Students completed the class with a review and a correction of any that they may have solved incorrectly (Table 3.23).

Table 3.23 Day 9 of Instruction: Review of Solving by Elimination, Experimental Group B

Time in Class	Activities
Beginning of Class (approx. 15 mins)	"He Said/She Said" activity using their Chromebooks. They will solve clue cards and determine which of the two given answers is correct. They should be able to defend their answer to their partners and discuss why they believe they solved it correctly.



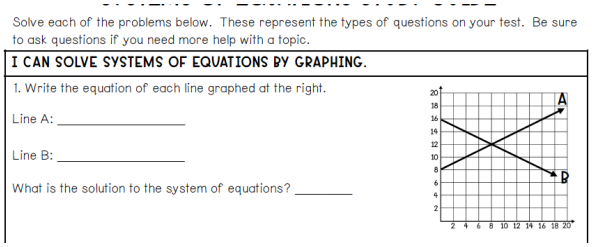
Class Discussion (approx. 20 mins)	Students will gather back together as a class to discuss which cards were the most difficult and how they were able to work through their troubles and come to an answer. Any incorrect answers will be corrected. Students will receive their unit study guide as they leave class. (Appendix C)

Day ten of instruction was the same for all students, regardless of which group they were participants in. All students received their unit study guides as they left class the previous meeting day. They were instructed to work through problems that they felt they could easily solve, showing their work, and to be prepared to discuss those problems with the class. This allowed each student to work to their strengths in this unit. In this day's work, students worked independently for several minutes to complete anything they may have been working on but did not finish. The next several minutes they worked with a partner to try to work through some of the problems that they were unable to complete independently. Following the pair and share time, students created groups of four to discuss and complete as many more problems as possible

on the study guide. The goal here was to try to have them work through their struggles while allowing students to teach each other what they know from the unit. The final portion of class was where all of the students received the correct answer to the study guide; and, as a class, they worked through any problems that remained. By the end of class, all students had every question on the study guide completed with the correct answer and work shown to study for the upcoming summative assessment (Table 3.24).

Table 3.24 Day 10 of Instruction: End of Unit Study Guide, All Groups

Time in Class	Activity
Beginning of Class (15 mins)	Students will work independently to complete as many more problems as they feel they can.
Minutes 15 - 30 of class	Students will work with one other person to discuss what they were able to complete and complete as many more problems together as possible.
Minutes 30 - 45 of class	Student pairs will pair with another set of students to compare their completed work, and if they are not finished with the study guide, the goal is to be complete by the end of this time.



Solve each of the problems below. These represent the types of questions on your test. Be sure to ask questions if you need more help with a topic.

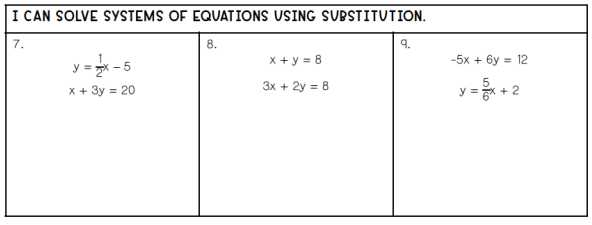
I CAN SOLVE SYSTEMS OF EQUATIONS BY GRAPHING.

1. Write the equation of each line graphed at the right.

Line A: _____

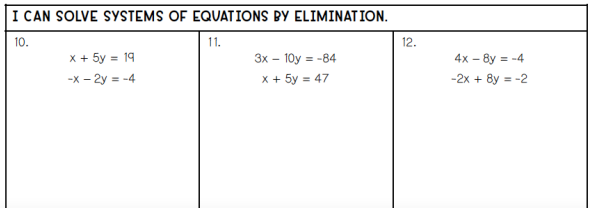
Line B: _____

What is the solution to the system of equations? _____



I CAN SOLVE SYSTEMS OF EQUATIONS USING SUBSTITUTION.

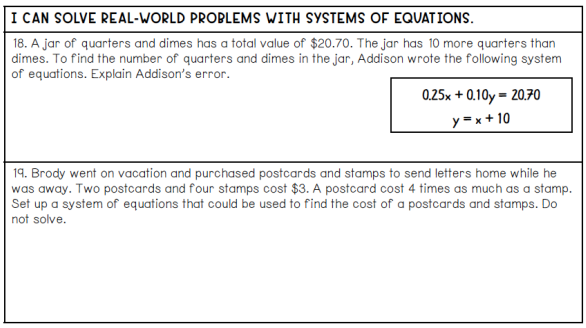
7.	8.	9.
$y = \frac{1}{2}x - 5$ $x + 3y = 20$	$x + y = 8$ $3x + 2y = 8$	$-5x + 6y = 12$ $y = \frac{5}{6}x + 2$



I CAN SOLVE SYSTEMS OF EQUATIONS BY ELIMINATION.

10.	11.	12.
$x + 5y = 19$ $-x - 2y = -4$	$3x - 10y = -84$ $x + 5y = 47$	$4x - 8y = -4$ $-2x + 8y = -2$

Minutes 45 - 80 of class	These final minutes of class will be spent in full class discussion. By the end of class all students will have completed study guides with correct answers and work shown for all questions. Students will participate in the summative assessment during the next class meeting.



I CAN SOLVE REAL-WORLD PROBLEMS WITH SYSTEMS OF EQUATIONS.

18. A jar of quarters and dimes has a total value of $20.70. The jar has 10 more quarters than dimes. To find the number of quarters and dimes in the jar, Addison wrote the following system of equations. Explain Addison's error.

$0.25x + 0.10y = 20.70$

$y = x + 10$

19. Brody went on vacation and purchased postcards and stamps to send letters home while he was away. Two postcards and four stamps cost $3. A postcard cost 4 times as much as a stamp. Set up a system of equations that could be used to find the cost of a postcards and stamps. Do not solve.

This was the eleventh and final day of the systems of equations unit, and all students regardless of group they are participating in, took the same summative assessment. (Appendix D) All students took the assessment on paper and were provided with calculators and rulers. No notes or any other assistive information were allowed. Students were aware of the format of the summative assessment (Appendix D) regardless of supplemental instructional activities or instructional delivery tools. It is the same format in which they took the pretest assessment at the beginning of the unit before any instruction or activities were administered. All students took the assessment and the teacher graded them all at one time.

Data Security and Confidentiality

Participant names and other identifying information was kept confidential and separated from collected data. All students in the researcher's classes were provided an Informed Consent letter and a form for a guardian to provide consent (Appendix E.). All students were given the opportunity to have their data included in the study or decline having their data included. Regardless of consent to have their data included or excluded, all students within a class were given the same instruction and participated in any of the same activities.

A password-protected computer and locked filing drawer was used to store collected data. For reporting purposes, each student, with a signed Informed Consent form (Appendix E) was assigned a random identification number. The assignment of the identification numbers was only known by the researcher and not used in any report. All collected assessments were returned to the student, as this is customary throughout the academic year, and information that identifies the student to their randomly-assigned identification number used in the report was destroyed at the conclusion of the study.

Data Analysis

Pre and posttest data were collected from every participant in each of the three groups: one control group and two experimental groups. The data was subjected to normality and homogeneity of variances tests. The researcher used an Analysis of Covariance (ANCOVA) to determine if there is a significant difference between the control group and both or either of the experimental groups. An ANCOVA allows the researcher to control for the influence of a covariant, which in the case of this study would be the pre-test scores. This also accounts for any initial differences in the groups included in the study. By controlling for the pre-test scores, an ANCOVA provided a more accurate assessment of the treatment effect.

Due to the nature of the classes participating in this study, an ANCOVA was used versus an ANOVA for the analysis data. An ANOVA is very similar to the proposed ANCOVA; however, it does not allow for making each of the classes equal regardless of the pretest outcomes. The groups in this study were not placed due to any known abilities or learning preferences. The groups were created prior to the researcher having any knowledge of these students. Thus, according to the National Center for Biotechnology Information, an ANOVA could be used in this study, as it tests for significant differences using one or two variables, as this study does with

the different methods of supplemental instruction delivery. However, when a researcher wishes to adjust the dependent variable with a covariant, an ANCOVA becomes the appropriate method of statistical analysis. The covariant in this study being the pretest, the researcher can then account for the differences in pretest scores within each group due to the varied student population. (Mishra et.al, 2019)

The process of the research and data collection took place over eleven instructional days with each group of students. Due to the alternating block scheduling of the school, this was approximately a two-and-a-half-week process. The pretest was given prior to any instruction being delivered. All pretests were collected and graded at one time to avoid any grading discrepancies. Once all pretests were graded, the scores of those with signed consent forms were recorded in a password-secured computer file. All participants whose data was included in the study had a number assigned to them to preserve confidentiality of information. Following the pretest, all sections were given the same instructional lessons, and then the two experimental groups had their specific form of instructional activities administered. This followed the instructional outline presented in Appendix A. Following the final day of instruction, the students all took the same post-test, Appendix D, that was given the next class session. The researcher collected all of the post-tests and graded them at one time to eliminate grading discrepancies, as was done with the pretests at the beginning of the data collection period. Once all posttests were graded, the scores of those who gave consent to be included in the study were recorded within the password secured computer file. This kept all of the recorded data in one secure location and continued to protect the confidentiality of the participants and their test scores.

When it is confirmed that all data was collected, the researcher proceeded with the analysis of the data. The researcher used the ANCOVA process to determine if in fact there was a statistical significance in the data between the two experimental groups and the control group. The ANCOVA was also used to determine if there is a statistically significant difference in the modality in which the supplemental instructional activities were delivered to the experimental groups. The use of the ANCOVA process allows for control of the pretest results, which could be considered a covariant.

Internal Research Validity

For this study, identical pre- and post-tests were given to students, which often leads to questions of the validity of the study and the data required. This study used experimental research methods with a control group, a group of students who receive supplemental instructional activities without technology (Group A) and a technology-enhanced instructional treatment experimental group (Group B). The classes that were used for this study contained students with mixed ability levels. The populations of these five pre-algebra classes were randomly assigned by school counselors prior to the first day of the school year. To eliminate selection bias, each class was assigned based on the researcher's schedule due to the school using an alternating day block scheduling method to either the control group or one of the experimental groups. The control group and Experimental Group A were on one day, while Experimental Group B was on the second day of the rotation. This limited the possibility of the incorrect instructional modality being administered.

All students in each class, including those whose data was not included in the scope of the data analysis, were given the pre-test prior to any instruction within the unit of study. The next class meeting, based on which group the class was assigned to, instruction began. For the control

group, no supplemental instructional activities were used, and only traditional teacher-led instruction of curriculum took place. Students in Experimental Group A began with the traditional instruction; however, a supplemental pencil and paper instructional activity was administered at the beginning of the next class meeting. This activity was used to review and enrich the prior class meeting's lesson. In Experimental Group B, students began with traditional instruction followed by a supplemental technology-enhanced instructional activity. This activity was administered at the beginning of each subsequent class and served as a review and enrichment of the prior meeting's lesson. All students in each class participated fully in all instruction and potential activities, including those whose data was not included within the analysis of data for this study.

As this unit was taught to students after the multi-step equations unit in pre-algebra, the only prior knowledge was the concepts that were part of the foundation for the study of the system of equations unit. Because the students all follow the same curriculum, this reduced the effect of any historical aspects influencing the students, their learning or their performance in either the pre- or post-test. Students experienced the systems of equations material for the first time, and within the same timeframe to limit any cross-over from one section to another. Further, to address the issue of maturity of the subjects, this pre-algebra unit lasted no more than one month of physical class-time instruction. While the study participants were of an age that matures at different rates, the relatively short duration of this study should not be affected by issues of maturity of the subjects participating.

Attrition in the validity of the study was a concern for the researcher as the school in which the data was being collected is situated roughly fifteen miles from a major United States military installation. At any given time of the year as active-duty parents or guardians receive orders for

change of duty station, students may come and go from the classroom and as participants in the study. There is typically not a large number of students added to or out at any one time, but any student that entered the room after the pretest was administered, their data was excluded. However, the student received the same instruction and participated in all activities. Any student that withdrew from the classroom after the pretest was administered had their data excluded from the final data analysis.

As previously addressed, selection bias was eliminated by the randomness of how the students were assigned to their pre-algebra classroom prior to the first day of school. It was further addressed by the groups being assigned to one of the two experimental groups or the control group solely based on what day within the alternating block schedule they are seen by the researcher. No prior knowledge of student abilities or achievements were used by the counselors to set the roster of each class. In sum, the researcher worked tirelessly to establish the validity of the study. The instruction of curriculum was the same for all five groups participating in the study with the only differences being the implementation of and modality of the treatment of supplemental instructional activities.

Summary

To adequately measure if the use of collaborative group activities during instruction positively impacts student understanding of the systems of equations unit in pre-algebra, quantitative measurements were taken prior to and immediately after implementation of the intervention (Appendix A). Due to the age and cognitive development of these students (Chen, 2014) and the abstract nature of many topics in pre-algebra (Susac et al, 2014), including the systems of equation unit, it was anticipated that students may benefit from active learning (Ting, Lam, & Shroff, 2019). To further enhance student understanding of the abstract concepts in the pre-

algebra unit, it was anticipated that the use of peer-collaboration may positively impact student understanding of the systems of equation unit being measured in the current study (Durandt & Lautenbach, 2020; Hooker, 2011; Ting et al., 2019) and the use of technology may create a motivating environment to assist in student learning (Choi, Jung & Baek, 2013; Taleb, Ahmadi & Musavi, 2015).

Chapter 4 - Results

This quantitative method study aimed to examine the impact and influence of the use of collaborative instructional activities with and without technology on the problem-solving skills of eighth-grade pre-algebra students in the systems of equations unit. The collaborative environment created by grouping students together who actively participate in activities relevant to the topic and who utilize platforms which engage the student may improve understanding and retention of mathematical concepts. The rationale for the different modalities of the instructional activities came from the increase in the introduction of one-to-one technology within schools, where every student and every faculty member has their own electronic device to use within the instructional setting. The study also aimed to find if there was a significant difference in student outcomes based on the modality of participating in instructional activities. As the researcher has previously been a classroom teacher within this selected age group and grade, it was the aim to discover if the use of instructional activities as a whole, create a significant impact on student comprehension. As the systems of equations unit was the first unit to present such complex and abstract ideas to students, it was the aim of the study to discover if instructional activities, whether used with or without technology, show any significant difference in student comprehension.

The study employed a pretest/posttest design with a control group and two experimental groups. The pretest and posttest were assessed using an answer key. (Appendix F) All data was analyzed using the Analysis of Covariance (ANCOVA) test. The ANCOVA test allowed for determining if a significant difference, $P < 0.05$, was present between the Control Group which did not receive supplemental instructional activities versus Experimental Group A and

Experimental Group B that did receive supplemental instructional activities, while accounting for the difference in pretest scores.

Figure 4.1 shows the initial results from the analysis run on the Control Group versus all of the students in both Experimental Group A and Experimental Group B. This test was performed to address the question posed in Research Question 1.

RQ1 Do students in the control and both experimental groups show significant learning gains about systems of equations, as measured by the pre- and post-assessments?

To determine if there was a significant difference between the two data sets, the P value must be less than .05. When the analysis of the data regarding the Control Group versus all experimental groups was complete it was found that a significant difference of 0.017 was found.

Figure 4.1 Control Group vs Both Experimental Group A and B

Tests of Between-Subjects Effects

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	5241.562[a]	2	2620.781	19.235	<.001	.264
Intercept	56006.248	1	56006.248	411.056	<.001	.793
pretest	2691.434	1	2691.434	19.754	<.001	.156
Group	804.559	1	804.559	5.905	.017	.052
Error	14578.702	107	136.250			
Total	220553.000	110				
Corrected Total	19820.264	109				

a. R Squared = .264 (Adjusted R Squared = .251)

Further analysis was completed, also using an ANCOVA, to answer Research Question 2 regarding the modality of the supplemental instructional activities delivery. Figure 4.2, below, shows the results of the analysis of the data between Experimental Group A which received their instructional activities via the pencil and paper mode of delivery versus Experimental Group B which received their instructional activities via the technology enhanced mode of delivery . This

analysis was completed to determine if there was a significant difference in student outcomes between those that received pencil and paper instructional activities and those that received instructional activities delivered via technology enhanced methods.

RQ$_2$ For the two experimental groups, is there a significant difference in student learning that is tied to the modality of instruction (i.e., pencil-paper or technology enhanced activities), as measured by pre- and post-assessments?

A test of the data was run between the two modalities of instructional activity delivery. This analysis was completed to determine if the modality of delivery, pencil and paper activities or technology enhanced activities showed a significant difference. The results of this analysis are shown in Figure 4.2. Based on this analysis there was no significant difference, P = 0.813, when comparing the two modalities of instructional activities to each other.

Figure 4.2 Experimental Group A vs Experimental Group B

Tests of Between-Subjects Effects

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2212.482[a]	2	1106.241	9.071	<.001	.181
Intercept	45470.485	1	45470.485	372.847	<.001	.820
pretest	2158.458	1	2158.458	17.699	<.001	.178
Group	6.862	1	6.862	.056	.813	.001
Error	10000.295	82	121.955			
Total	186867.000	85				
Corrected Total	12212.776	84				

a. R Squared = .181 (Adjusted R Squared = .161)

Further testing of the data was run analyzing the Control Group's outcomes versus the outcomes of Experimental Group A to determine if there was a significant difference shown in student outcomes between no instructional activities and pencil and paper activities. A significant difference, P = 0.029, was found, those results are shown in Figure 4.3.

Figure 4.3 Control Group vs Experimental Group A

Tests of Between-Subjects Effects

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3557.446[a]	2	1778.723	12.883	<.001	.294
Intercept	35969.930	1	35969.930	260.515	<.001	.808
pretest	1216.643	1	1216.643	8.812	.004	.124
Group	686.532	1	686.532	4.972	.029	.074
Error	8560.492	62	138.072			
Total	123691.000	65				
Corrected Total	12117.938	64				

a. R Squared = .294 (Adjusted R Squared = .271)

Figure 4.4 shows the analysis of the Control Group with no instructional activities versus the Experimental Group B which received their instructional activities through the mode of technology enhancement. This test was used to determine if there was a significant difference present between student outcomes after receiving no instructional activities versus having received technology enhanced instructional activities. No significant difference, P = 0.078, between the Control Group and Experimental Group B.

Figure 4.4 Control Group vs Experimental Group B

Tests of Between-Subjects Effects

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3811.695[a]	2	1905.848	12.118	<.001	.266
Intercept	39036.686	1	39036.686	248.201	<.001	.787
pretest	1958.662	1	1958.662	12.453	<.001	.157
Group	504.772	1	504.772	3.209	.078	.046
Error	10537.676	67	157.279			
Total	130548.000	70				
Corrected Total	14349.371	69				

a. R Squared = .266 (Adjusted R Squared = .244)

To examine if additional factors existed between the Control Group and Experimental Groups A and B, the data was analyzed to determine if there was a significant difference between the time of day the students were exposed to their mathematics lessons and the effect on student outcomes. Kahlaoui (2017) found that student academic performance significantly varied at different times of the day. McElroy and Mosteller (2006) found that classes that were at a student's "optimal-time-of-day" played a significant role in determining grades (p. 612). In Figure 4.5 the relationship between the Control Group and students in either experimental group that were in a morning (before lunch) mathematics class. It was found that there was no significant difference, P = 0.121, between the Control Group and Experimental Groups A and B if they were exposed to their mathematics lesson prior to their lunch break in the school day.

Figure 4.5 Time of Day Control Group vs Experimental Groups – Morning (before lunch)

Tests of Between-Subjects Effects

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3581.060[a]	2	1790.530	11.901	<.001	.262
Intercept	38948.530	1	38948.530	258.876	<.001	.794
pretest	1979.627	1	1979.627	13.158	<.001	.164
Group	370.411	1	370.411	2.462	.121	.035
Error	10080.311	67	150.452			
Total	127106.000	70				
Corrected Total	13661.371	69				

a. R Squared = .262 (Adjusted R Squared = .240)

Figure 4.6 then shows the results of the analysis run on the Control Group versus all experimental group students that were in a mathematics class in the afternoon (post-lunch). This test was used to determine if students exposed to their mathematics lesson after having eaten lunch would show a significant difference between the Control Group with no instructional activities and the experimental group. In this test it was determined to show a significant

difference, P = 0.015, between those students in the Control Group versus those students in either experimental group when exposed to their mathematics lesson after their lunch break during the school day.

Figure 4.6 Time of Day Control Group vs Experimental Groups – Afternoon (post lunch)

Tests of Between-Subjects Effects

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	3833.089[a]	2	1916.545	13.364	<.001	.301
Intercept	36291.551	1	36291.551	253.051	<.001	.803
pretest	1158.562	1	1158.562	8.078	.006	.115
Group	890.415	1	890.415	6.209	.015	.091
Error	8891.773	62	143.416			
Total	127133.000	65				
Corrected Total	12724.862	64				

a. R Squared = .301 (Adjusted R Squared = .279)

Figure 4.7 Morning (before lunch) Experimental Groups vs Afternoon (post lunch) Experimental Groups

Tests of Between-Subjects Effects

Dependent Variable: posttest

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2359.949[a]	2	1179.974	9.820	<.001	.193
Intercept	46099.459	1	46099.459	383.662	<.001	.824
pretest	2142.725	1	2142.725	17.833	<.001	.179
Group	154.329	1	154.329	1.284	.260	.015
Error	9852.828	82	120.156			
Total	186867.000	85				
Corrected Total	12212.776	84				

a. R Squared = .193 (Adjusted R Squared = .174)

A final test of the data was performed to determine if there was a significant difference between the two experimental groups and the time of day that the student was engaging in their mathematics lesson. Figure 4.7 shows the results of this analysis between all of the students in

both Experimental Groups A and B that were in morning versus afternoon classes. It was determined that there was no significant difference found, $P = 0.260$, in the two experimental groups based on when they were exposed to their mathematics lesson during the school day.

Chapter 5 - Discussion

A concern for many teachers of pre-algebra, particularly those who teach the subject to eighth graders, is the student's inability to demonstrate understanding of abstract concepts found in the systems of equations unit (Chen, 2014; Susac et al, 2014). Developing an understanding of the systems of equations unit is important, as many subsequent lessons and future mathematics topics depend on the fundamentals developed with the concepts presented in that unit (Susac et al, 2014). In many respects, the systems of equations unit in pre-algebra may be one of the first opportunities a student will be required to function with abstract concepts in the classroom.

The purpose of this study sought to examine the impact and influence of the use of collaborative instructional activities with and without technology on the problem-solving skills of eighth-grade pre-algebra students in the systems of equations unit. According to Piaget (1936), eighth-grade students often struggle with abstract concepts presented in pre-algebra and are not given practical ways to demonstrate their knowledge (Chen, 2014). Students who are provided experiences that allow them to practice with concrete materials rather than through lectures and explanations are typically better positioned to understand these abstract mathematical concepts and relationships (Ojose, 2008). Because multiple representations and modalities of these abstract concepts may be necessary to enhance student understanding, this study employed two different experimental treatments: supplemental instructional activities with technology and without technology.

Based on the findings of this study, it was concluded that a significant difference in pretest to post-test scores existed when students received supplemental instruction. Because a significant difference in pretest to posttest scores was found when employing supplemental instructional activities, the researcher also wished to identify if a significant difference existed

between the pencil and paper group (Experimental Group A) and the students who utilized technology (Experimental Group B). When the data was used to compare the students between the two experimental groups, it was found that no significant difference existed. This indicated that neither the pencil and paper group, nor the technology group demonstrated a significant difference in their understanding when using the pretest and posttest results.

Discussion

Because this study's primary focus was the use of supplemental instructional activities in the teaching of the systems of equations unit of pre-algebra, the first data that was analyzed involved the Control Group's learning outcomes versus those of all students that participated in Experimental Groups A and B. It was found that a significant difference was found between these groups and is further supported with prior research efforts. Durandt & Lautenbach (2020) found that students benefit from working with their peers during this crucial time in cognitive development. A students' motivation may be enhanced by this cooperative learning environment more so than when teacher-led assistance during individual practice times (O'Donnell, 2006; Trajkovik et al., 2018). Students expressed that a cooperative learning environment was a more enjoyable classroom experience, and that they spent more time learning and practicing the material being taught (Hooker, 2011). The students also expressed that they were able to achieve higher grades when they worked together with other students. Vygotsky (1978) believed that students who worked in groups with others that had more knowledge, or a higher understanding of the material, may experience higher social interactions, which could lead to a more nurturing and productive learning environment.

Another analysis sought to find if there were significant differences between the modality of supplemental instructional activities delivered to the students in the experimental groups. It

was found that the students in the pencil and paper group showed a significant difference when using pre-test and post-test scores, however there was not a significant difference found for those students participating in the group that utilized technology-enhanced activities. While the difference was only slightly above the threshold for a significant difference to exist (P = 0.056) for the technology group, there could be a number of factors that would lead to these results. Students in the technology enhanced activities group may have experienced distractions that would not have been present for the pencil and paper group. Some distractions may include clicking noises of typing, distractions from the screen displays of other groups including the viewing of non-course-related items on other students' screens (Mossman, 2021; Neiterman & Zaza, 2019). Students also reported they had feelings of less engagements in cooperative learning with their peers, even when they knew of the expected outcome of the technology enhanced activity (Neiterman & Zaza, 2019).

Because the time of day might affect a student's academic performance, an analysis of covariance was performed with this variable. It was found when the analysis was run on the data for this study that students that were exposed to their systems of equations lessons after they had eaten lunch showed a significant difference in their learning outcomes versus their counterparts that were in sections of the course that were seen prior to their lunch break in the school day. This data was supported through a collection of prior studies regarding what time of day students participated in their more difficult subjects. Since the experimental groups that participated in this study were seen by the researcher, half before lunch and half after lunch, it was important to determine if the time of day in which a student was exposed to these abstract ideas made a significant difference in student outcomes. It was found in a 2017 study by Kahlaoui that students performed significantly differently depending on the time of day they participated in

their harder subjects. Kahlaoui stated, “In both the short-term memory and problem-solving tests students were able to recall more information and perform better in the afternoon in all age groups as compared to the morning” (p. 8). Results in McElroy & Mosteller’s work (2006) found that classes that are relatively difficult, an individual's optimal time-of-day has a powerful influence on student grades. Since the abstract nature of the systems of equations unit likely makes this a difficult subject for many students, it was important to determine if there was any significant difference with this study’s participants.

Implications

Supporting the research by Ting and colleagues (2019), the results from the current study showed that active learning, through the use of supplemental instructional activities, does have a significant impact on student learning outcomes in the systems of equations unit of pre-algebra. Additionally, it was discovered that students participating in pencil and paper activities, Experimental Group A, showed a significant difference in their outcomes. Research of Noreen and Rana (2019) and Allensworth and colleagues (2021) are in harmony with the findings of the current study’s Experimental Group A, as incorporating active learning through physical activities may engage the student in a positive and meaningful manner. Regarding the participation of active learning activities, Noreen and Rana (2019) , believe that the students’ value of these activities may have been “joyful, interesting, and fruitful” (p. 157).

In contrast, students in Experimental Group B, where technology-based supplemental activities were incorporated, did not experience a significant difference in their outcomes after the 11-class intervention. From the researcher’s informal observations, there were no extenuating factors noticed that may have influenced these results in a less-positive manner when compared to Experimental Group A. One possible explanation of the technology-based group offering less

significant results compared to the paper and pencil group may lie with some of the findings from Neiterman and Zaza (2019) that cited distractions, including clicking noises from the computer keyboards and possibly viewing non-course-related materials on other students' screens, as likely influences. While the technology-based activities may be exciting and stimulating, the physical nature experienced during many of the paper-pencil activities may have a greater connection with students in the early stages of their cognitive development into the formal operations stage (Noreen & Rana, 2019). These are all important findings for the direction of future teaching methods, especially in years where students are developing the ability to function with abstract concepts from the concrete thinking they may be more familiar and comfortable with.

Curriculum-Developers

Curriculum developers should view these findings as a rationale to include instructional-based activities with their educational products. The developers should offer several suggestions on how these activities are to be delivered by the educator so they can best address the needs of the students. A few of these suggestions could be to provide the included instructional activities in both paper and pencil and technology-enhanced modalities. This could allow educators to choose the modality that best fits their student's learning environment. By providing the educator these options, they may be better prepared so that students may be presented with meaningful opportunities to comprehend abstract concepts presented in pre-algebra during the time when student understanding may be developing in the formal operations stage. However, careful consideration of these materials should be observed by curriculum developers. As noted in Karam and colleagues (2016), instructors who feel that pre-packaged systems that offer the classroom teacher little to no flexibility, may ultimately abandon the system especially when

their interaction with the students is negatively impacted. Curriculum developers may wish to invest in obtaining teacher feedback before making final plans to package such activities for the classroom teacher at-large.

Another suggestion could be that the curriculum developers provide teachers with video tutorials on how to best implement their supplemental instructional activities into their classrooms. It may be beneficial for curriculum developers to provide detailed lesson plans to accompany the instructional activities. If these types of support are added to the curriculum it could provide educators with a stronger sense of how to effectively use these new instructional activities.

Educators

Educators may need additional training and resources in the implementations of these newly-implemented instructional activities. Labonté and Smith (2022) found that students' self-directed learning using technology was significantly related to the instructional quality in their classroom. Teachers may benefit from professional development in learning how to incorporate best practices for guiding student cooperation and participation with technology. Further training may be necessary in order to help the classroom educators effectively integrate the activities into their normal teaching environment. If an educator is not well trained in the use of these activities, they could potentially be more of a distraction and hindrance to the student's understanding of abstract concepts, rather than an effective teaching and learning tool. A greater investment in professional development training of older and more seasoned teachers to improve the quality of instructional activities with technology may benefit student engagement and understanding (McClain & North, 2021).

Based on the results of this study, teachers who employ technology-based supplemental instructional activities should receive additional training on how to monitor their students' activities to limit off-task time or other noise distractions associated with the use of the technology itself (Neiterman & Zaza, 2019). By equipping educators with a supportive classroom environment and the necessary tools to deliver supplemental instructional activities, it is possible to enhance student understanding of the abstract concepts they are being exposed to so they are better equipped to think critically. This may make each student better positioned to apply their newly-acquired knowledge in effective and meaningful ways and provide an opportunity to achieve at a higher level.

Research

This study would benefit from further research conducted with the inclusion of a qualitative aspect. Researchers could interview teachers on their opinions, beliefs and experiences on the use of instructional activities in their classrooms and the effects that they observe with their students. It may also be beneficial to include a qualitative approach by asking the students being studied on their opinions on the use of the instructional activities as well as their thoughts and beliefs on the effectiveness of the activity on their learning. Student achievement may be elevated by keeping the classroom teaching environment exciting and by providing students with immediate feedback through activities they feel are meaningful (Demirel & Yilmaz, 2018; Gningue et al., 2014).

This study would also benefit from replication with a larger sample size of students. Having a larger sample size could provide for the control group being larger, which could potentially negate any previous discrepancies that may have been present due to the smaller sample size. With the researcher also being the teacher in this study, it could be beneficial to

replicate this study using outside teachers for implementation of the intervention. It could also be studied if a different population of students would create different outcomes.

More research could be conducted using instructional activities over a longer period of time or even over more units of study. By increasing the aspect of the time spent within the systems of equations unit, the researcher could expand it where on the days of instructional activities, there would be no new instruction. This may allow the instructor to determine if a correlation exists between an increase in the exposure to the instructional activities and improved student outcomes. The other aspect of this would be expanding the study to include more units in pre-algebra. This may determine if instructional activities are beneficial to more concepts than just the newly acquired abstract concepts, or if using the activities in general increases student engagement. If such a correlation exists, this could lead to greater student outcomes in the study of pre-algebra.

Limitations

Through the process of the conducting of this study, several limitations were determined. One of the first limitations that was noted was the strict use of quantitative data collection and analysis. The choice to use only a quantitative approach was made due to limited access to the students participating in the study after the data had been collected. As the unit of instruction being used in this study was taught in the later part of the spring semester of 2021, students were preparing for state standardized testing shortly after the completion of this unit. This limited the student's availability for additional data collection that may have addressed student concerns related to their attitude towards the activities and their perceived worth of these activities.

Another limitation found in this study was the small sample size that was available to the researcher. The researcher was attempting to control the pace of the instruction and intervention

of the study and, therefore, it was determined to only use the classes that were taught by the researcher. This limited the sample size and created a discrepancy in the size of the control group versus the two experimental groups. It is anticipated that a larger sample size may control abnormalities of some result outliers, which could influence if a significant difference exists after the intervention period.

Conclusions

This study was conducted to answer the question of whether or not the use of supplemental instructional activities had a positive impact on student outcomes within the pre-algebra unit of systems of equations. Upon analysis of the data collected in five eighth-grade pre-algebra classes in the spring of 2021 it was determined that supplemental instructional activities did have a significant difference in the student outcomes. With these findings it can be said that when educators in eighth-grade pre-algebra classrooms implement the use of supplemental instructional activities into their normal teaching routines, students may be more engaged in their learning and, therefore, have higher comprehension rates for these more complex and abstract concepts.

This study also sought to answer the question of whether the modality in which these supplemental instructional activities were delivered to the students would show a significant difference in student outcomes. In this study it was determined that students who experienced pencil and paper activities versus those that experienced technology-enhanced activities showed no significant differences in their learning outcomes. It can be said that, based on these findings, students may demonstrate greater learning when supplemental instructional activities are incorporated within the learning environment.

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Appendix A - Intervention/Curriculum/Solution

The proposed solution for this study implemented mixed-method learning strategies in the form of collaborative instructional activities to enhance student comprehension within the systems of equations unit in pre-algebra. The systems of equations unit took place over the course of 11 class sessions, which was nearly four weeks of classes. Each class met every other day due to the block scheduling that took place within this instructional setting (Red Days and White Days). Except for the first session, each class session was 82-minutes long and consisted of teacher-led discussion and examples, some independent practice, and implementation of the intervention.

Prior to the implementation of the intervention, students were administered a pretest assessment for the systems of equations unit. The researcher made observations of student behavior and reactions while they worked on their pretest. As students completed the assessment, they returned their copy to the researcher. These completed assessments were stored in a sealed envelope until all sections of the class were given the pretest. Once fully completed, each student's assessment was assigned a unique identification number and then graded by the researcher. Pretest scores were recorded in a computer program and were only viewable by the researcher.

The 11-class intervention/lesson plan is described in detail below.

Class 1: Introduction to Systems of Equations

All classes will be given the same instruction as it will be the start to the unit. Students were given a packet that included guided notes that they will complete during the teacher-led discussion portion of the instruction. This will be done each time a new concept in the unit is introduced. Rulers will be provided to each student. The lesson will focus on the

graphing of linear equations. The teacher-led discussion will lead to guided-practice examples where the students will work with the teacher to provide the next steps to graphing the given equations. Following the guided practice period, the students will work through several individual practice questions, which will be gone over as a class before the end of this session.

Class 2:

Non-Technology Treatment Group (Group A):

Students begin with a team style quiz where they are teamed up 3-4 students per team, and they work problems out on paper and race the other teams to complete it first. Students will again be given their guided notes packet as well as a ruler. Today's lesson will be the first day of the two-part solving systems by graphing lesson. As with Class 1, the lesson will begin with teacher-led discussion and note-taking, followed by the teacher guided-practice period and ending with individual practice.

Technology Enhanced Treatment Group (Group B):

Students will begin class with an online activity using the Kahoot platform to practice the skills and definitions they learned during the previous session. The questions will engage the students' prior knowledge and get them ready for the new lesson. Students will again be given their guided notes packet as well as a ruler. Today's lesson will be the first day of the two-part solving systems by graphing lesson. As with Class 1, the lesson will begin with teacher-led discussion and note-taking, followed by the teacher guided-practice period and ending with individual practice.

Control group:

Class begins with a verbal review with students over the prior class's lesson. Students will again be given their guided notes packet as well as a ruler. Today's lesson will be the first day of the

two-part solving systems by graphing lesson. As with Class 1, the lesson will begin with teacher-led discussion and note-taking, followed by the teacher guided-practice period and ending with individual practice.

Class 3:

Group A:

Students will be given a ruler upon the start of class to complete a quick starter activity with two questions from the previous session. The students will "race" each other in pairs to complete the examples. This quick cooperative activity will engage the students and prepare them to complete the lesson on solving systems by graphing. They will again be given their guided notes packet to complete part two of this lesson. Students will work through the guided notes packet, teacher-led practice, and finally with individual work as with previous lessons.

Group B:

Students will complete a computer race of questions created by the teacher to review the previous lesson. The race included an on-screen drawing tool for graphing. The students will "race" each other in pairs to complete the examples. This quick cooperative activity will engage the students and prepare them to complete the lesson on solving systems by graphing. They will again be given their guided notes packet to complete part two of this lesson. Students will work through the guided notes packet, teacher-led practice, and finally with individual work as with previous lessons.

Control group:

Again, students will begin with a verbal review of the prior class lesson. They will again be given their guided notes packet to complete part two of this lesson. Students will work through

the guided notes packet, teacher-led practice, and finally with individual work as with previous lessons.

Class 4:

Group A:

Students will retrieve a ruler and a handout from the teacher. During this lesson, the students will complete a scavenger hunt about solving systems by graphing. The students will be working in groupings of no more than four. Final grouping will depend on the individual class size to keep the activity manageable. Each student will be given an answer sheet to complete their own work, however, they will work collectively to complete the activity. During the scavenger hunt, clue cards are hung around the classroom and each group of students chooses which clue station they will begin. The students will work through the system that is displayed at the first station. When the group collectively solves the system, they move to the clue card in the room that displays their answer, which then contains their next clue. Each group will continue working together until the final clue takes them back to the clue where they began. Should the students arrive back at their first clue card prior to solving all of the other cards, the group will have to go back and figure out where they made their mistake and correct it. At the end of the activity, they should have 12 correctly-solved systems. The activity is expected to be completed in 45 minutes. During this time, the researcher will informally visit with the students as they work in their groups, noting interactions between the student participants. Following the completion of the scavenger hunt activity, the students will continue as with previous classes with guided notes, teacher-led examples, and closing with individual practice. Today's lesson will focus on solving systems by substitution.

Group B:

Students will complete a digital scavenger hunt, provided within the Maneuvering the Middle (MTM) curriculum. The students will be working in groupings of no more than four. Final grouping will depend on the individual class size to keep the activity manageable. Each student will complete their own work, however, they will work collectively to complete the activity. During the scavenger hunt, clue cards are placed around the virtual room. The students will work through the system that is displayed at the first station. When the group collectively solves the system, they move to the clue card in the room that displays their answer, which then contains their next clue. Each group will continue working together until the final clue takes them back to the clue where they began. Should the students arrive back at their first clue card prior to solving all of the other cards, the group will have to go back and figure out where they made their mistake and correct it. At the end of the activity, they should have 12 correctly-solved systems. The activity is expected to be completed in 45 minutes. During this time, the researcher will informally visit with the students as they work in their groups, noting interactions between the student participants. Following the completion of the scavenger hunt activity, the students will continue as with previous classes with guided notes, teacher-led examples, and closing with individual practice. Today's lesson will focus on solving systems by substitution.

Control group:

The students will begin by solving a few review problems in a teacher-led discussion. They will then complete the guided notes and individual practice as with other days.

Class 5:

All groups begin the same:

This class begins with the completion of solving systems by substitution. Students will complete the guided notes and individual practice. During the individual practice period, the teacher will check in with students for understanding.

Group A:

Following the individual practice, students will be asked to pair into groups of two for the next activity involving the completion of a set of mazes. Each student in the pair will have a different maze where they will start at one end. In order to exit the maze, they will answer questions. A correctly answered question will give the student the correct path in the direction towards the exit. The student pair will be racing against each other to see who can complete the maze first. To ensure that each student provides the work necessary to complete the maze, their partner will check their work at the end of the task. If an error is found in the work, the pair will work together to correct the error and talk to each other to find the correct solution.

Group B:

Following the individual practice, students will be asked to log into the MTM curriculum to complete virtual mazes. Each student will have a different maze where they will start at one end and work through problems to reach the end. A correctly answered question will give the student the correct path in the direction towards the exit. If they end up at a "dead end" they must go backwards to find their mistake.

Control group:

Students will discuss in small groups some extra example problems. The teacher will meet with the groups to check for understanding.

Class 6:

All groups:

This class begins with a mid-unit formative assessment. Students will collect a ruler and an answer recording sheet.

Group A:

This mid-unit assessment will be cooperative where the students will complete the first two problems on their own, then find a partner and compare work on those two problems. Using different colors to write down any corrections, the partners will then complete the next two problems together. Each partner will then turn to a different partner, make any necessary corrections, and then complete two problems together. This method will continue until all ten questions on the assessment are completed. By the end of the activity, all students will have worked with four other students in the room and discussed all 10 problems. Following the work with partners, students will have the opportunity to look over the work they did individually and cooperatively. With the collaborative problems, each student will circle the answer they consider to be correct as their final answer. During this time the teacher will be walking around the class checking in with students and monitoring progress and understanding. In total this activity should take about an hour. The final 20 minutes of class will be used to review the correct answers. Students will have the opportunity to ask questions and see how answers were determined if they are still unsure.

Group B:

This assessment will be completed online. Students will complete their work on their computers and then be paired with another student to work together to correct the problems they answered incorrectly. This process will continue until each student raises their grade to a 100%. The final

20 minutes of class will be used to review the correct answers. Students will have the opportunity to ask questions and see how answers were determined if they are still unsure.

Control Group:

Students will complete their assessments individually. Once all students have completed the assessment, the class will discuss each problem and work through the solution to each.

Class 7:

All groups will participate in the same instruction.

Students will begin with a quick review of the mid-unit formative assessment and ask any questions that were unanswered from the previous session. Following this review, students will be given their guided packets and begin the lesson on solving systems by inspection. This is a quick review of graphs and substitution so the teacher-led discussion, guided-practice session, and individual student practice will lead to collaborative practice at the end of the session. Students will be observed for their engagement during the various practice times of the lesson and for their overall comprehension of the material.

Class 8:

Group A:

Students begin with a team style quiz where they are teamed up 3-4 students per team, and they work problems out on paper and race the other teams to complete it first. This review will cover all previously learned methods of solving systems of equations such as graphing, substitution, and inspection. This will engage the students and prepare them for the lesson of the day which is solving systems using elimination. Students will work through the guided notes packets similar to previous days.

Group B:

Students will begin with a quick game on the online platform Kahoot. This game will review all previously learned methods of solving systems of equations such as graphing, substitution, and inspection. This will engage the students and prepare them for the lesson of the day which is solving systems using elimination. Students will work through the guided notes packets similar to previous days.

Control Group:

Students will begin with a review of their notes from all previous lessons. They will work quietly to find problems they still have questions about and rework them. This will prepare the students for the lesson of the day which is solving systems using elimination. Students will work through the guided notes packets similar to previous days.

Class 9:

Group A:

Students will begin with a cooperative activity titled “He Said/She Said”. This activity works much like the scavenger hunt activity from Class 4. Students will work in groups of no more than three students. Each student will have an answer recording sheet where they can complete their own work. This activity will serve as an opportunity to review the entire unit before moving on to the unit study guide and the post-test. In the activity, problem cards are placed around the room with two possible solutions. The students will record their work on their recording sheet and then determine which solution suggested on the card is correct and why. This will engage all of the information the students have learned and practiced over the previous eight days of instruction and activity. The activity should take approximately 60 minutes. The final 20 minutes of class will be used to go over any problems students struggled with or were unable to get their

group to come to one agreeable answer. This activity will prepare the students for the study guide to be completed during the next class session.

Group B:

Students will begin with a cooperative activity titled “He Said/She Said”, this is digitally available through the MTM curriculum. This activity works much like the scavenger hunt activity from Class 4. Students will work in groups of no more than three students. Each student will have an answer recording sheet where they can complete their own work. This activity will serve as an opportunity to review the entire unit before moving on to the unit study guide and the post-test. In the activity, problem cards are placed around the room with two possible solutions. The students will record their work on their digital recording sheet and then determine which solution suggested on the card is correct and why. This will engage all of the information the students have learned and practiced over the previous eight days of instruction and activity. The activity should take approximately 60 minutes. The final 20 minutes of class will be used to go over any problems students struggled with or were unable to get their group to come to one agreeable answer. This activity will prepare the students for the study guide to be completed during the next class session.

Control Group:

Students will begin with a class review of previous lessons. It will work much like the previous class. This will engage all of the information the students have learned and practiced over the previous eight days of instruction and activity. The review work should take approximately 60 minutes. The final 20 minutes of class will be used to go over any problems students struggled with or were unable to come up with the correct answer. This exercise will prepare the students for the study guide to be completed during the next class session.

Class 10:

All groups will complete the work in the same manner today.

Students will begin with instructions to retrieve all previous notes, activities, and practice examples in preparation for working through the unit study guide. For the first 15 minutes, students will work individually with the collection of notes and examples to complete as much of the guide as possible. During the next 15 minutes, students will work with one partner to review already completed problems and to complete as many remaining problems as possible. During the next 15 minutes, students will work in groups of four to five to review and complete the study guide. During this time the teacher will walk around the classroom checking in with students to monitor collaboration, comprehension, and overall engagement with the material. The final 40 minutes will allow the class to work together with the teacher to complete the study guide and get any remaining questions regarding the unit answered. Students will be reminded that in the next class session they will be administered their posttest on the systems of equations unit. They are encouraged to use their study hall time on the day between class sessions to work together and ask questions. The teacher is available via email on days that they do not have their math class.

Class 11:

All groups will be administered the posttest assessment for the systems of equations unit.

Students will have access to a ruler, but they will not be able to use any notes or other aids for the assessment. Students will have the full 82 minutes to complete their assessment and return it to the teacher where it will be cataloged with that student's assigned study participant number and the test will be placed inside an envelope for grading once all sections are collected. All

assessments will be scored at one time to ensure consistency and only the study participant numbers will be visible to the graders to avoid bias.

Appendix B - Mid-Unit Formative Assessment

Unit: Systems of Equations
Quiz 1

Name _____

Date _____Pd_____

QUIZ: SYSTEMS OF EQUATIONS

Answer each question, and be sure to show work when necessary.

Answers
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

1. Which of the following is a solution to the equation $y = -\frac{1}{4}x + 8$?

A. (10, -8)
B. (4, 8)
C. (-4, 9)
D. (-8, -10)

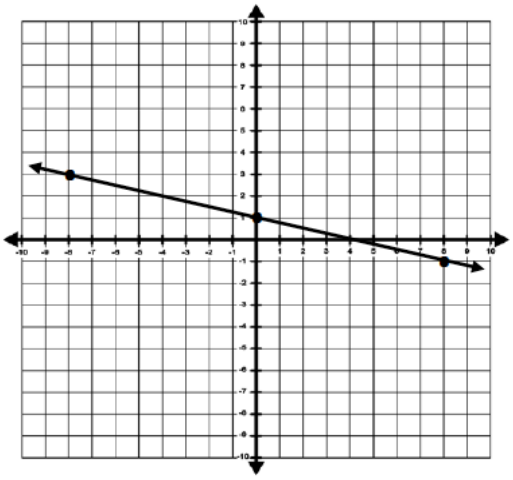
2. Presley graphed a system of equations, and the graph showed two parallel lines. What does this mean?

A. The system of equations has one solution.
B. The system of equations has no solution.
C. The system of equations has infinitely many solutions.
D. Presley made an error in her graphing.

3. What is true about the graph of a system of equations that has infinitely many solutions?

A. The lines will have the same slope but different y-intercepts.
B. The lines will have the same slope and the same y-intercepts.
C. The lines will have different slopes and different y-intercepts.
D. The lines will have different slopes but the same y-intercepts.

4. Write the equation in slope-intercept form of the line graphed below.



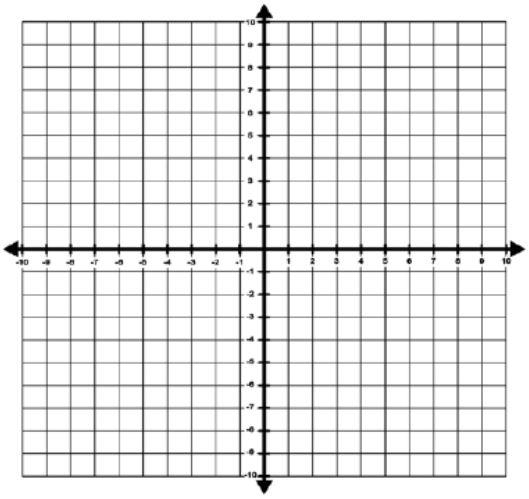
5. Use the graph in #4 to graph the equation $y = -x - 2$. What is the solution to the system of equations on the graph?

A. (-8, 3)
B. (8, -1)
C. (4, 0)
D. (-4, 2)

6. Solve the system of equations by graphing.

$y = -3x + 1$

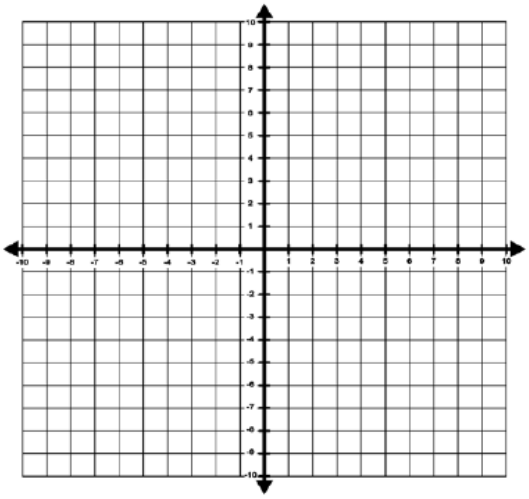
$y = x - 7$



7. Solve the system of equations by graphing.

$y = \frac{3}{2}x - 1$

$-x + y = -3$



8. Solve the system of equations by substitution.

$y = -\frac{1}{4}x$

$x + 2y = 4$

9. Solve the system of equations by substitution.

$y = -x - 2$

$3x + 3y = 6$

10. Solve the system of equations by substitution.

$-8x + 2y = 4$

$y = 4x + 2$

Appendix C - Unit Study Guide

Unit: Systems of Equations Review

Name _____

Date _____ Pd _____

SYSTEMS OF EQUATIONS STUDY GUIDE

Solve each of the problems below. These represent the types of questions on your test. Be sure to ask questions if you need more help with a topic.

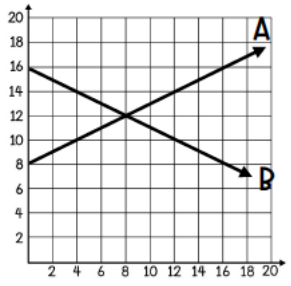
I CAN SOLVE SYSTEMS OF EQUATIONS BY GRAPHING.

1. Write the equation of each line graphed at the right.

Line A: _____

Line B: _____

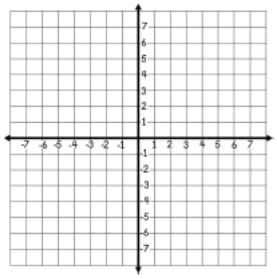
What is the solution to the system of equations? _____



2. Solve the system of equations by graphing.

$y = 6$

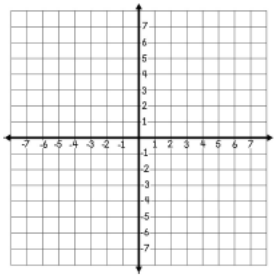
$y = 3x - 3$



3. Solve the system of equations by graphing.

$y = -x + 2$

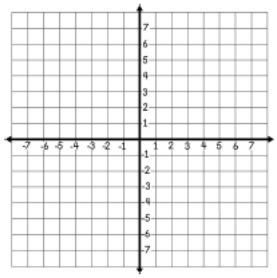
$3x + 3y = 6$



4. Solve the system of equations by graphing.

$y = x - 3$

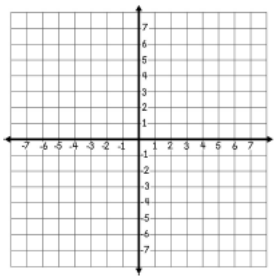
$y = 1.5x - 5$



5. Solve the system of equations by graphing.

$y = \frac{1}{2}x + 3$

$-x + 2y = -6$



I CAN SOLVE SYSTEMS OF EQUATIONS BY GRAPHING.

6. Ralph's t-shirt company sells custom t-shirts for $5.00 each plus a $20 shipping and design fee. Frank's t-shirt company sells t-shirts for $10 each with no additional fees. Let x represent the number of shirts sold and y represent the total cost.

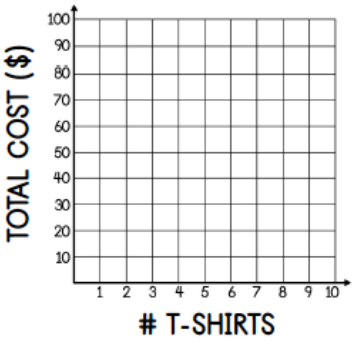
a. Write an equation to represent each t-shirt company.

Ralph's: _____

Frank's: _____

b. Solve the system of equations by using the graph.

c. What does the solution mean in the context of the situation?



I CAN SOLVE SYSTEMS OF EQUATIONS USING SUBSTITUTION.

7. $y = \frac{1}{2}x - 5$

$x + 3y = 20$

8. $x + y = 8$

$3x + 2y = 8$

9. $-5x + 6y = 12$

$y = \frac{5}{6}x + 2$

I CAN SOLVE SYSTEMS OF EQUATIONS BY ELIMINATION.

10. $x + 5y = 19$

$-x - 2y = -4$

11. $3x - 10y = -84$

$x + 5y = 47$

12. $4x - 8y = -4$

$-2x + 8y = -2$

I CAN SOLVE SYSTEMS OF EQUATIONS BY INSPECTION.

13. Aaron and Blake both wrote down equations. Their equations had the same slope, but Aaron's y-intercept was negative, and Blake's y-intercept was positive. How many solutions would their system of equations have? Explain your reasoning.

In 14-17, determine the number of solutions the system of equations will have. Explain your reasoning.

14.

$$6x + y = 8$$
$$y = -6x + 8$$

15.

$$x + y = 7$$
$$x + y = -7$$

16.

$$y = 0.75x - 2$$
$$y = -0.75x + 2$$

17.

$$x + y = 6$$
$$3x + 3y = 18$$

I CAN SOLVE REAL-WORLD PROBLEMS WITH SYSTEMS OF EQUATIONS.

18. A jar of quarters and dimes has a total value of $20.70. The jar has 10 more quarters than dimes. To find the number of quarters and dimes in the jar, Addison wrote the following system of equations. Explain Addison's error.

$$0.25x + 0.10y = 20.70$$
$$y = x + 10$$

19. Brody went on vacation and purchased postcards and stamps to send letters home while he was away. Two postcards and four stamps cost $3. A postcard cost 4 times as much as a stamp. Set up a system of equations that could be used to find the cost of a postcards and stamps. Do not solve.

I CAN SOLVE REAL-WORLD PROBLEMS WITH SYSTEMS OF EQUATIONS.	
For each of the following questions, write a system of equations and then solve.	
20. Selena's snow cone stand sells small snow cones for $2 and large snow cones for $3.50. One summer day, she sold $163 worth of snow cones. If the number of large snow cones sold was 12 more than the number of smalls, how many of each size did she sell? System of equations: Solution:	21. Two angles are supplementary. The larger angle is 15 more than 10 times the smaller angle. Find the measure of each angle. System of equations: Solution:
22. Maci put 200 inches of ribbon along the border of a rectangular bulletin board. If the length of the bulletin board is 4 times the width, then what are the dimensions? System of equations: Solution:	23. The larger of two numbers is 10 more than three times the smaller number. The larger number decreased by the smaller number is 80. What are the two numbers? System of equations: Solution:

Appendix D - Pre- and Post-test Assessment

Unit: Systems of Equations Test

Name _____

Date _____ Pd _____

SYSTEMS OF EQUATIONS UNIT TEST

Solve the problems below. Be sure to show your thinking.

1. Mateo plans to solve the system below using elimination. Which is a reasonable first step Mateo could take?

$$-x + 6y = 9$$
$$3x + 2y = 13$$

A. Multiply the 2nd equation by 3

B. Multiply the 2nd equation by -3

C. Multiply the 1st equation by -3

D. Any of the above

2. Which of the following is true about the solution to the system of equations below?

$$2x + 4y = 9$$
$$2x + 4y = -9$$

A. The system has no solution.

B. The system has infinitely many solutions.

C. The system has one solution.

D. None of the above.

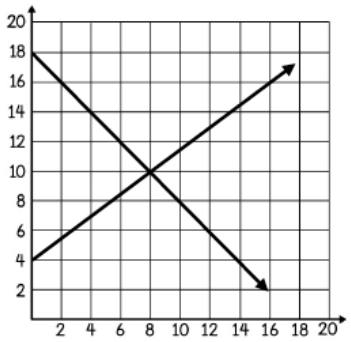
3. What can you conclude from the graph of the equations shown below?

A. The solution to the equations $y = -2x + 18$ and $y = \frac{4}{3}x + 4$ is (8, 10).

B. The solution to the equations $y = -x + 18$ and $y = \frac{4}{3}x + 4$ is (10, 8).

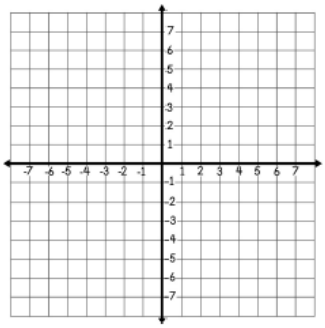
C. The solution to the equations $y = -x + 18$ and $y = \frac{3}{4}x + 4$ is (10, 8).

D. The solution to the equations $y = -x + 18$ and $y = \frac{3}{4}x + 4$ is (8, 10).



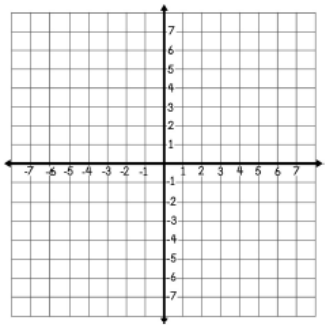
4. Solve the system of equations by graphing.

$$y = \frac{2}{3}x - 2$$
$$y = -4$$



5. Solve the system of equations by graphing.

$$y = 2x$$
$$x + y = -6$$



6. Which is the solution to the system of equations?

$$x + y = -7$$

$$3x + 2y = -17$$

A. (-1, -6)
B. (3, -13)
C. (4, -11)
D. (-3, -4)

7. Which system of equations would have no solution?

A. $x + y = 4$ and $y = -x + 4$
B. $y = 3x + 2$ and $y = -3x - 2$
C. $2x + y = 10$ and $y = -2x + 10$
D. $3x + y = 8$ and $3x + y = 9$

8. Solve the system of equations.

$$y = -\frac{3}{2}x + 9$$

$$2x + 2y = 16$$

_____

9. Solve the system of equations.

$$-3x + 2y = 48$$

$$3x + y = 42$$

_____

10. Which of the following statements is NOT true about the graph of a system of equations with infinitely many solutions?

A. The lines will have the same slope.
B. The lines will have the same y-intercept.
C. The lines will have one positive y-intercept and one negative y-intercept.
D. The lines will share all of the same points.

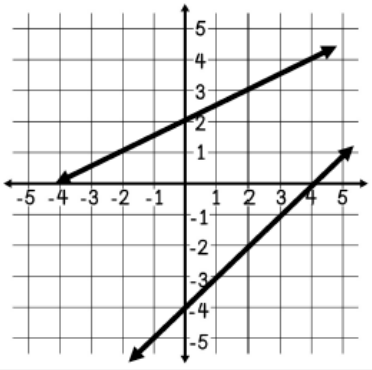
11. Which is a true statement about the system of equations graphed below?

A. The system of equations does not have a solution because the lines do not intersect.

B. The system of equations has one solution, although it is not visible on the graph.

C. The system of equations has an infinite number of solutions.

D. None of the statements above are true.



12. Jane is observing the system of equations below and thinks it will have exactly one solution. Is she correct? Why or why not?

$$y = \frac{5}{6}x + 2$$
$$6y = 5x - 12$$

13. At a concession stand, a pickle and two bags of chips costs a total of $3.25. Three pickles and four bags of chips costs a total of $7.25. To determine the cost of one pickle, Kevin is writing a system of equations. His first equation is shown:

$$x + 2y = 3.25$$

Which of the following could be the second equation in his system of equations?

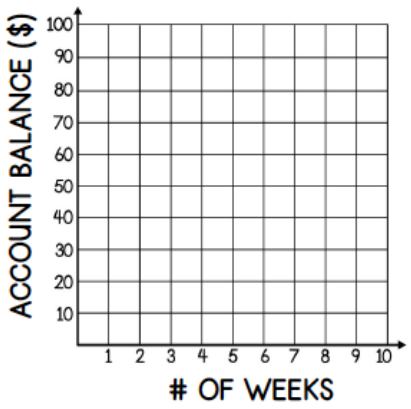
A. $3x + 4y = 7.25$
B. $4x + 3y = 7.25$
C. $3x - 4y = 7.25$
D. $(3 + 4)x = 7.25$

14. Jacobi wants to solve the system of equations below by using elimination. Which of the following describes the next step Jacobi should take?

$$8x - 2y = -6$$
$$-3x + y = 4$$

A. Multiply each term in the 1st equation by -1
B. Multiply each term in the 2nd equation by -2
C. Multiply each term in the 2nd equation by 2
D. Add the two equations together

15. Macy doesn't have any money in her bank account, but begins saving $15 each week. Robby has $20 in his bank account and saves $10 each week. After how many weeks will Macy and Robby have the same amount in their accounts? Use the graph to solve.



Number of weeks: _____

16. At a movie theater, 2 medium drinks and a large popcorn costs $13.85. At the same theater, a family bought 3 medium drinks and 2 large popcorns for a total of $23.90. Which system of equations could be used to find x, the cost of a medium drink and y, the cost of a large popcorn?

A.
$x + 2y = 13.85$
$3x + 2y = 23.9$

B.
$2x + y = 13.85$
$3x + 2y = 23.9$

C.
$3x + 2y = 13.85$
$2x + y = 23.9$

D.
$2x + y = 13.85$
$2x + 3y = 23.9$

17. Christine's rectangular bedroom has a perimeter of 44 feet. The length of her bedroom is 2 feet more than the width. Which of the following is a true statement?

A. The width of Christine's bedroom is 10 feet.
B. The length of Christine's bedroom is 8 feet.
C. Both A and B are true.
D. Neither A nor B is true.

18. Tickets to a concert cost $15 online and $25 at the door. One hundred more people bought their tickets at the door than online. If ticket sales totaled $20,500, write and solve a system to determine the number of people who bought their concert tickets online.

_____

19. Two angles are complementary. The larger angle is 36 more than the smaller angle. What is the measure of the larger angle?

_____

20. Hudson worked two jobs last summer to start saving for a car. He mowed lawns during the day and worked at a pizza place in the evenings. In one month, Hudson earned a total of $1,400. If he earned $360 more at the pizza place than mowing lawns, how much did he earn at each job?

Mowing lawns:_____

Pizza place:_____

Appendix E - Informed Consent

Informed Consent

Student (K–12) Classroom Research

Western Governors University - Teachers College

Master of Science: Curriculum and Instruction

Elizabeth Pursell

The Effects of Collaborative Instructional Activities on Problem Solving Skills in Systems of Equations for Pre-Algebra Students

Introduction

Elizabeth Pursell, a graduate student researcher in the Teachers College of Western Governors University, wishes to conduct a research study for the purpose of determining the effectiveness of using collaborative instructional activities on problem solving skills in the systems of equations for pre-algebra students in her eighth grade mathematics classes. Approval of the Warrensburg R-VI Middle School principal to conduct this study was obtained prior to this announcement. By signing this consent form, parents or legal guardians agree to allow their child to participate in the study. Any data collected will be reported as part of a group; individual student names will not be used.

Description of the Project

Students benefit the most from active learning where they are able to reinforce concepts from the lessons taught in the classroom. Since the teaching of pre-algebra comes at a critical time in a person's cognitive development, students may also benefit from collaboration with their peers. This partnership may create an environment of cooperation and motivation differently from teacher-led assistance during periods of time when students work alone.

The systems of equations unit is scheduled to take place over the course of 11 class sessions. The tasks associated with this study are part of the prescribed curriculum, and no additional requirements on the students or parents is necessary. Students who do not participate or who do not have permission to participate in the study will continue to learn in the environment with those participating in the study, however, these student assessments nor observations will not be reported in the study.

Benefits and Risks of the Study

The results gained from this research will benefit mathematics teachers and researchers alike. Using collaborative instructional activities to enhance and secure problem solving skills at this critical point in a child's development is necessary and may lead to the student demonstrating an increased understanding of the systems of equations unit and other mathematical concepts.

With any research activity, there are risks involved and this study poses a minimal risk to all participants. Some students may feel anxious being part of a research study and may experience test anxiety when completing the pretest and posttest evaluations. While these risks are possible and minimal in nature, the researcher will minimize them to the best of her ability and, in the case of test anxiety, this experience is normal from the everyday classroom experience. Student confidentiality will be assured throughout the entire study.

Confidentiality

Participant names and any identifying information will be kept confidential and separated from collected data. A password-protected computer and locked filing drawer will be used to store collected data. For reporting purposes, each student will be assigned a random identification number. The assignment of the identification numbers will only be known by the researcher and not used in any reports. All collected assessments will be returned to the student, as this is customary throughout the academic year, and information that identifies the student to their randomly assigned identification number used in the report will be destroyed at the conclusion of the study.

Voluntary Participation

The system of equations unit is a routine pre-algebra curriculum expectation; as such, all students are expected to participate fully in the classroom activities. Those students that choose not to participate in the study will not have their assessments nor their observations recorded as part of the study.

Withdrawal

Participants may withdraw at any time from non-regular classroom instruction and will not be penalized for nonparticipation. To withdraw from the study, the parent or participant must notify the researcher. Parental or legal guardian consent as well as school principal or district administrator permission must be granted in order for the student researcher to gather data for the purposes of their research project. Participants or their parents can request that their individual results be excluded from the final report. Grades/enrollment will not be impacted in any way as a result of withdrawing from this study.

Questions, Rights, and Complaints

Participants and their parents/legal guardians have a right to view the results of the study. If you have questions about this study, please contact me by calling 660-747-5612 or email epursel@my.wgu.edu.

If you have questions about your rights, unresolved questions, or complaints pertaining to the study, contact the WGU IRB Chairperson by email: irb@wgu.edu.

Consent Statement

By signing this document, the administrator grants permission for student data collection and all reporting necessary for this study.

By signing this document, the parent/legal guardian grants permission for their child to participate in the study and has the opportunity to have his or her questions answered.

Student participants will be informed of the research purpose and activities and will be asked for their assent to participate upon parental approval.

School Administrator Signature	Parental/Legal Guardian Signature
Title of Administrator	Typed/Printed Name
Typed/Printed Name	Date
Date	Student Signature

Appendix F - Pre- and Post-test Answer Key

Unit: Systems of Equations Test

Name Answer Key

Date _____ Pd _____

SYSTEMS OF EQUATIONS UNIT TEST

Solve the problems below. Be sure to show your thinking.

1. Mateo plans to solve the system below using elimination. Which is a reasonable first step Mateo could take?

$$-x + 6y = 9$$
$$3x + 2y = 13$$

A. Multiply the 2nd equation by 3

B. Multiply the 2nd equation by -3

C. Multiply the 1st equation by -3

D. Any of the above

+1

2. Which of the following is true about the solution to the system of equations below?

$$2x + 4y = 9$$
$$-(2x + 4y = -9)$$
$$0 + 0 = 18$$

A. The system has no solution.

B. The system has infinitely many solutions.

C. The system has one solution.

D. None of the above.

+1

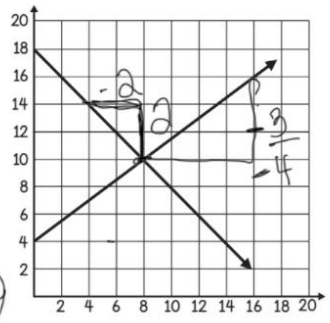
3. What can you conclude from the graph of the equations shown below?

A. The solution to the equations $y = -2x + 18$ and $y = \frac{4}{3}x + 4$ is (8, 10).

B. The solution to the equations $y = -x + 18$ and $y = \frac{4}{3}x + 4$ is (10, 8).

C. The solution to the equations $y = -x + 18$ and $y = \frac{3}{4}x + 4$ is (10, 8).

D. The solution to the equations $y = -x + 18$ and $y = \frac{3}{4}x + 4$ is (8, 10).



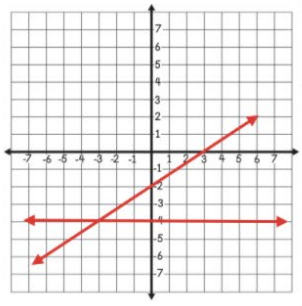
x2

4. Solve the system of equations by graphing.

$$y = \frac{2}{3}x - 2$$
$$y = -4$$

graphs = +2

ans = +1



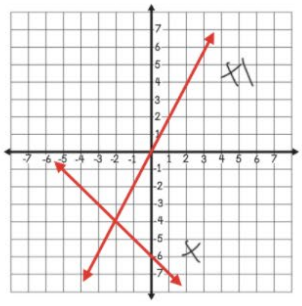
(-3, -4)

5. Solve the system of equations by graphing.

$$y = 2x$$
$$x + y = -6$$

graphs = +2

ans = +1



(-2, -4)

+10

(can be solved by elimination)

6. Which is the solution to the system of equations?

work +2
ans +1

$x + y = -7$

$3x + 2y = -17$

$y = -x - 7$

$3x + 2(-x - 7) = -17$

$3x - 2x - 14 = -17$

$x - 14 = -17$

$+14 \quad +14$

$x = -3$

$y = -(-3) - 7$

$y = 3 - 7$

$y = -4$

A. (-1, -6)
B. (3, -13)
C. (4, -11)
D. (-3, -4)

7. Which system of equations would have no solution?

+2

A. $x + y = 4$ and $y = -x + 4$
B. $y = 3x + 2$ and $y = -3x - 2$
C. $2x + y = 10$ and $y = -2x + 10$
D. $3x + y = 8$ and $3x + y = 9$

8. Solve the system of equations.

work +2
ans +1

$y = -\frac{3}{2}x + 9$

$2x + 2y = 16$

$2x + 2\left(-\frac{3}{2}x + 9\right) = 16$

$2x - 3x + 18 = 16$

$-x + 18 = 16$

$-18 \quad -18$

$\frac{-x}{-1} = \frac{-2}{-1}$

$x = 2$

$y = -\frac{3}{2}(2) + 9$

$y = -3 + 9$

$y = 6$

(2, 6)

9. Solve the system of equations.

work +2
ans +1

$-3x + 2y = 48$

$+ \quad 3x + y = 42$

$3y = 90$

$\frac{3y}{3} = \frac{90}{3}$

$y = 30$

$3x + 30 = 42$

$-30 \quad -30$

$\frac{3x}{3} = \frac{12}{3}$

$x = 4$

(4, 30)

10. Which of the following statements is NOT true about the graph of a system of equations with infinitely many solutions?

A. The lines will have the same slope.
B. The lines will have the same y-intercept.
C. The lines will have one positive y-intercept and one negative y-intercept.
D. The lines will share all of the same points.

+1

11. Which is a true statement about the system of equations graphed below?

$y = \frac{1}{2}x + 2$ $\quad y = x - 4$

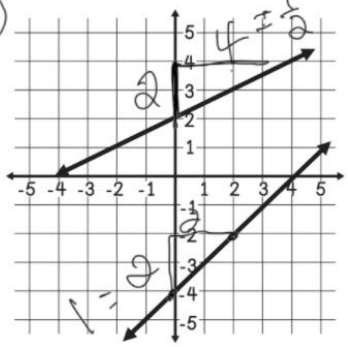
+3

A. The system of equations does not have a solution because the lines do not intersect.

B. The system of equations has one solution, although it is not visible on the graph.

C. The system of equations has an infinite number of solutions.

D. None of the statements above are true.



+15

12. Jane is observing the system of equations below and thinks it will have exactly one solution. Is she correct? Why or why not?

$$y = \frac{5}{6}x + 2$$
$$6y = 5x - 12$$

$y = \frac{5}{6}x - 2$

No; the slopes are the same, but the y-intercepts are different, so there would be no solution to the system of equations.

13. At a concession stand, a pickle and two bags of chips costs a total of $3.25. Three pickles and four bags of chips costs a total of $7.25. To determine the cost of one pickle, Kevin is writing a system of equations. His first equation is shown:

$3x + 4y = 7.25$

$x + 2y = 3.25$

Which of the following could be the second equation in his system of equations?

A. $3x + 4y = 7.25$
B. $4x + 3y = 7.25$
C. $3x - 4y = 7.25$
D. $(3 + 4)x = 7.25$

14. Jacobi wants to solve the system of equations below by using elimination. Which of the following describes the next step Jacobi should take?

$$8x - 2y = -6$$
$$-3x + y = 4$$

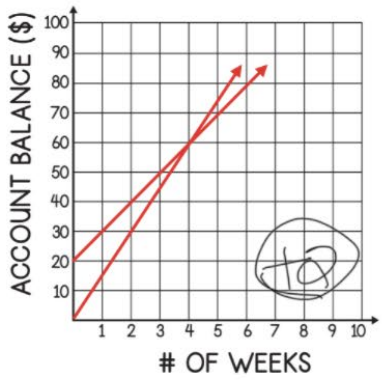
$2(-3x + y = 4)$

$-6x + 2y = 8$

A. Multiply each term in the 1st equation by -1
B. Multiply each term in the 2nd equation by -2
C. Multiply each term in the 2nd equation by 2
D. Add the two equations together

15. Macy doesn't have any money in her bank account, but begins saving $15 each week. Robby has $20 in his bank account and saves $10 each week. After how many weeks will Macy and Robby have the same amount in their accounts? Use the graph to solve.

Macy: $y = 15x$ Robby: $y = 10x + 20$



Number of weeks: 4

16. At a movie theater, 2 medium drinks and a large popcorn costs $13.85. At the same theater, a family bought 3 medium drinks and 2 large popcorns for a total of $23.90. Which system of equations could be used to find x, the cost of a medium drink and y, the cost of a large popcorn?

A.
$x + 2y = 13.85$
$3x + 2y = 23.9$

B.
$2x + y = 13.85$
$3x + 2y = 23.9$

C.
$3x + 2y = 13.85$
$2x + y = 23.9$

D.
$2x + y = 13.85$
$2x + 3y = 23.9$

y = 12

17. Christine's rectangular bedroom has a perimeter of 44 feet. The length of her bedroom is 2 feet more than the width. Which of the following is a true statement?

+4

A. The width of Christine's bedroom is 10 feet.
B. The length of Christine's bedroom is 8 feet.
C. Both A and B are true.
D. Neither A nor B is true.

width = x
length = y
$2x + 2(x+2) = 44$
$2x + 2x + 4 = 44$
$2x + 2y = 44$
$y = x + 2$
$4x + 4 = 44$
$-4 \quad -4$
$4x = 40$
$x = 10$

18. Tickets to a concert cost $15 online and $25 at the door. One hundred more people bought their tickets at the door than online. If ticket sales totaled $20,500, write and solve a system to determine the number of people who bought their concert tickets online.

online = x
door = y
$y = x + 100$
$15x + 25y = 20{,}500$
$15x + 25(x+100) = 20{,}500$
$15x + 25x + 2500 = 20{,}500$
$40x + 2500 = 20{,}500$
$-2500 \quad -2500$
$40x = 18000$
$x = 450$

+3

450 people

19. Two angles are complementary. The larger angle is 36 more than the smaller angle. What is the measure of the larger angle?

$x + y = 90$
$x + (x+36) = 90$
$2x + 36 = 90$
$36 - 36$
$2x = 54$
$2 \quad 2$
$x = 27$
$y = x + 36$
$y = 27 + 36$
$y = 63$

+4

63°

20. Hudson worked two jobs last summer to start saving for a car. He mowed lawns during the day and worked at a pizza place in the evenings. In one month, Hudson earned a total of $1,400. If he earned $360 more at the pizza place than mowing lawns, how much did he earn at each job?

lawn = x
Pizza = y
$x + y = 1400$
$x + (x+360) = 1400$
$2x + 360 = 1400$
$-360 \quad -360$
$2x = 1040$
$2 \quad 2$
$x = 520$
$y = x + 360$
$y = 520 + 360$
$y = 880$

+6

Mowing lawns: $520
Pizza place: $880

+17

Appendix G - Raw Data of Student Scores (pre- and post-test)

Control Group Student Code	Pretest Score/55	Post Test Score/55
44	1	38
45	5	17
46	8	49
47	5	46
48	1	39
49	5	51
50	1	45
51	1	13
52	2	17
53	1	47
54	4	12
55	4	49
56	5	27
57	5	17
58	2	15
59	6	33
60	3	19
61	1	33
62	2	14
63	5	45
64	3	52
35	2	34
66	0	33
67	27	54
68	4	47

Group A Paper & Pencil Group Student Code	Pretest Score/55	Post Test Score/55
92	17	55
93	14	37
94	21	54
95	16	49

96	13	42
97	18	54
98	27	49
99	15	51
100	21	48
101	29	55
102	17	48
103	12	55
104	30	54
105	14	48
106	25	52
107	12	48
108	23	50
109	26	47
110	17	54
111	16	49
112	29	55
25	5	46
26	4	50
27	9	26
28	3	52
29	10	54
30	3	50
31	8	31
32	6	43
33	1	55
34	2	47
35	4	50
36	4	50
37	1	4
38	1	43
39	4	28
40	4	49
41	9	52
42	5	47
43	4	16

Group B Technology Group Student Code	Pretest Score/55	Post Test Score/55
1	1	29
2	4	31
3	4	24
4	7	54
5	7	43
6	4	45
7	1	33
8	4	33
9	6	43
10	7	5
11	4	45
12	4	69
13	0	51
14	1	44
15	4	50
16	2	46
17	3	47
18	6	15
19	5	41
20	3	47
21	6	45
22	0	19
23	3	14
24	3	45
69	13	53
70	22	55
71	21	44
72	22	36
73	16	51
74	18	52
75	14	55
76	12	52
77	37	52

78	26	55
79	15	52
80	11	55
81	18	48
82	19	54
83	24	54
84	20	51
85	16	52
86	20	54
87	18	54
88	16	55
89	15	54