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The Effects of Coding Integration on Student Engagement and Academic Achievement in a 5th Grade Mathematics Class

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Abstract

This action research project investigated the effect coding integration had on student engagement and academic achievement in a fifth-grade mathematics class. Research was conducted on a group of 20 fifth grade students performing on grade level, in a suburban school outside of Philadelphia. Four data collection tools were used: A student survey, teacher observations and reflections, pre and post-test data, and a tally chart. Data was categorized into two domains: student engagement and academic achievement. Coding follow-up works using *Scratch, Wonder Workshop*, and *Turtle Academy* were provided to students over the course of two mathematical topics created by Pearson Education, Inc., in addition to traditional follow-up works such as worksheets and task cards. Qualitative and quantitative data implied that coding integration had a positive effect on student engagement and overall, students' perceptions of math class improved. Quantitative data was unable to determine the effect coding had on academic achievement due to consistent participation in the coding activities offered by all students. The findings suggest that coding integration can be used in fifth grade mathematics classes to cover a range of academic content while increasing student engagement and exposing students to 21st century skills.

Keywords: coding integration, engagement, Scratch, Wonder Workshop, Turtle Academy

Coding. Student engagement. Academic achievement. Three buzz words used in the world of education, but rarely seen together. Coding, the newest of the three buzz words, is the process of writing a set of instructions for a computer to follow. Problem solving, collaboration, logical thinking, digital literacy, sequencing, and critical thinking, are all 21st century skills educational systems aim to teach students before graduation. While coding is not the only way students can learn and practice these skills, coding instruction is considered to be a beneficial tool as "the IT field is set to expand by 12 percent between 2014 and 2024 – faster than most other occupations," (Kajeet, 2017).

Student engagement and academic achievement are terms that have been far more prevalent over the last thirty years. Student engagement refers to the "degree of attention, curiosity, interest, optimism, and passion that students show when they are learning or being taught, which extends to the level of motivation they have to learn and progress in their education" (Great Schools Partnership, 2016). Academic achievement signifies the growth a student has made over a period of time. Research has found a strong correlation between student engagement and academic achievement. As a result, highly qualified teachers aim to plan lessons and activities that are engaging for students, which could in turn, increase students' academic achievement.

Over the course of the past five months, the teacher noticed a lack of student engagement in her 5th grade math class. This was evident based on observable behaviors such as time on task, participation, students' investment in their learning, and students' feelings of enjoyment. The teacher observed this in her classroom as measured in exit tickets, classwork, and topic tests. While the benefits of student engagement and academic achievement have been the cornerstone of education for decades, coding instruction at the elementary level is relatively new. While it is considered to be an essential skill of the 21st century, the means and degree to which students at the elementary level learn to code vary from school to school and country to country, and the academic and social benefits remain largely unstudied. Therefore, the purpose of this action research study was to explore what effect the integration of coding instruction had on student engagement and academic achievement in a 5th grade mathematics class.

Coding follow-up work options were provided to students in addition to traditional follow-up work options such as task cards and worksheets. Coding provided students the opportunity to collaborate with peers, problem solve, showcase their creativity, and create media rather than consume it. Direct instruction was not used to teach students how to code. Instead, students were provided with web addresses or tasks using specific coding programs, and asked to use inquiry-based learning to teach themselves to code in order to accomplish a math related goal.

This action research was conducted in a public-school classroom at an elementary school in a suburban setting. The classroom included 20 children, 11 males and 9 females between the ages of ten and eleven years old. There were two adults in the room, the lead teacher and a paraprofessional who served as a one-on-one aide for a student in need of additional support.

The connectivism theory guided the design of this study. The connectivism theory model of learning emphasizes collaboration and the interconnectedness of people through the use of technology as opposed to older models of learning that focused on individualistic activity. One attribute of connectivism theory is that a teacher's job is not to impart knowledge on students as the knower of all things, but rather to guide students towards learning and sharing what they have learned through inquiry. More specifically, students should learn and make their own connections through technological tools. This action research project investigated if the act of coding and students' ability to make connections to the content through the use of technology, had any impact on student engagement and academic achievement based on the mastery of certain Common Core standards.

Review of Literature

In the world of education, the idea of teaching students to "code" has been widely used by the media, government, and education industry in recent years. Such widespread use of the word "coding" has actually reshaped its definition (Humble, 2018). Prior to 2011, Google search phrases often included "computer programming" or "learn to program" (Humble, 2018). However, after a series of publicity events such as the release of the "Shut down or restart?" report from the Royal Society in the UK, the announcement of the Code.org organization, the launch of the first Raspberry Pi, and the first "Hour of Code" which included a message from President Barack Obama, the terms "program" and "code" became somewhat interchangeable, despite their traditionally different definitions (Humble, 2018).

Many have determined computer coding and programming to be essential skills of the 21st century, although no specific implementation strategy has been established as the most effective. While some countries have decided to create an entirely new subject for coding, others have chosen to integrate it into the subject areas that already exist within the classroom environment (Moreno-Leon, Robles, & Roam-Gonzalez, 2016). The integration of coding is based on the premise that students are not learning to code, but rather coding to learn. Current research analyzes the implementation of coding as an integrated part of literacy, math and technology, and social studies. There is a significant discrepancy regarding the age at which coding instruction should begin. While countries like Ireland and Austria wait to introduce coding until the secondary level, others like Estonia and Israel start to offer it at the primary level

(Moreno-Leon, et al., 2016). Current research studies investigate the effectiveness of coding within various subject areas, for a wide range of academic levels from five-year-olds to high school students.

Coding Integration in Various Subject Areas

Two studies (Hutchison, Nadolny, & Estapa, 2016; Moreno-Leon et al., 2016) examine the effective use of coding apps to support literacy instruction and develop coding literacy. Hutchinson et al. (2016) state that "A critical concern of digital technology as it relates to literacy is the idea that literacy, and what it means to be literate, is ever-changing because of the pace and constancy with which digital technologies emerge" (p. 1). As the world continues to develop and use digital technology in the workplace, educators must work to teach students the skills necessary to make meaning and communicate through the use of such technology. After the careful examination of multiple coding apps, Hutchison et al (2016) chose a small selection, which they believed correlated most closely with the Common Core Language Arts standards. One of those apps, *Scratch Jr*, is an introductory, block based, programming application developed by MIT for children ages 5-7. It allows students to drag and drop a series of commands together to create interactive stories. For instance, through *Scratch Jr*., a student could work on a fourth grade Common Core standard which requires students to describe the overall structure of events, ideas, concepts, or information within a piece of text. Students could use *Scratch Jr*. to do this by creating multiple scenes and programming them to play in chronological order. Depending on the story, students could then verbalize the sequence of events, the problem and solution, or the cause and effect relationship. Another programming app, *Tynker*, allows 4th to 8th grade students to drag and drop commands in order to solve puzzles, build games and stories, and program connected toys to perform specific actions. *Tynker* differs from *Scartch Jr*. in that it allows students to progress from visual blocks to more technical coding languages such as JavaScript, Swift, and Python. Through the use of the *Tynker* app, students can learn to use text features, search tools, and keywords to navigate informational text. The final app chosen by Hutchison et al. (2016) was *My Robot Friend,* a programming app developed by LeapFrog. It allowed students to learn basic coding skills, while simultaneously comparing the traits of two or more characters. While this app was relevant in 2016, it is no longer available in Apple's App Store or on LeapFrog's website.

While Hutchinson et al. (2016) found these apps to be beneficial tools for teaching and reinforcing several Common Core standards, Moreno-Leon, Robles, & Roam-Gonzalez (2016) had less promising results. Moreno-Leon et al. (2016) also investigated the effectiveness of coding integration in language arts using the application, *Scratch*, with a group of 2nd graders. Through the use of a pre-test and post-test, with a control group and experimental group, it was determined that the coding integration for a narrative structure unit did not enhance students' understanding of the topic.

The most widely researched subject with coding integration are the areas of mathematics and technology. Researchers (Fessakis, Gouli, & Mavroudi, 2012; Mozelius & Oberg, 2017; Songy, 2017; Moreno-Leon et al., 2016) in several countries investigated the effective use of coding within a variety of mathematics and technology classes and determined its integration to be an effective tool for increasing student motivation and academic achievement. A case study investigated the use of two Logo-based coding programs with a class of Kindergarteners. Through whole-group instruction, the students had to identify and solve problems by adding or removing tiles. The teacher observed that the students were active and eager, and found the program to be challenging yet achievable (Fessakis et al., 2012).

Sweden adopted a play-based coding model called The Ostersund Model as a part of their mathematics and technology curriculum, using the programs *Scratch* and *Python*. Implementation results varied by class but were promising overall. At the conclusion of the study, Mozelius and Oberg (2017) recommended that coding continue to be a part of the elementary curriculum, but that it remains play-based, with exposure, engagement, enjoyment and future readiness as the primary focus, rather than content or skill driven outcomes. Moreno-Leon et al. (2016) found that students in a 6th-grade math class who received coding instruction as a means of drawing and classifying angles outperformed the control group on their post-test. Similarly, in a research study done by the Harel-Caperton American Educational Research Association, fourth grade students were asked to program a computer game that would teach younger students about fractions. As a result of the study, students gained a deeper understanding of fractions, as well as new coding, programing, and computational thinking skills, in comparison to students who were taught fractions in a more traditional manner (Humble, 2018). In a more direct correlation to the field of technology, Songy (2017) implemented a challenge-based coding unit in her high school level course. As students used coding to create their own websites, Songy worked as a mentor and was amazed by the "student motivation, creativity, resourcefulness, and personalized learning" (Songy, 2017, p.47).

While research regarding the integration of social studies and coding is scarce, the research that does exist shows promising results. In a review of the European Union, 6th-grade students used the *Scratch* program to create question-and-answer video games (Moreno-Leon et al., 2016). Students in the experimental group academically out-performed their peers on the post-test. Gresse von Wangenheim, Alves, Rodrigues, and Hauck (2017) investigated the use of an integrated coding unit in four, 5th and 7th-grade social studies classes. Their study found that the units successfully taught 21st-century computing skills in an efficient, effective, and entertaining way while simultaneously increasing students' interest and motivation (Gresse von Wangenheim et al., 2017).

Overall, the addition of coding to traditional classroom subjects led students to attain a greater understanding of the content, while simultaneously teaching a host of skills such as coding, computational thinking, and 21st century skills. Even when academic achievement measured using academic success tests (Gençtürk & Korucu, 2017), test scores in mathematics and reading (Rondinelli & Owens, 2017), and pre-test and post-test data with a control group and experimental group (Moreno-Leon, et. al., 2016), did not increase, researchers found that the exposure to coding led students to improve upon skills such as collaboration, communication, critical thinking, and problem solving, suggesting that it remain a part of the classroom curriculum to "build a new generation that will be better prepared for the new tasks and professions that will be a fundamental part of the ongoing and inevitable digitization," (Mozelius & Oberg, 2017, p. 381).

21st Century Skills and Academic Achievement

Through coding integration, students learn a wide range of 21st-century skills including collaboration, creativity, critical thinking, and problem-solving. When educators teach computational thinking skills, they are teaching individuals to identify problems and take command of the problem-solving process (Oluk & Korkmaz, 2016). "At each grade level, computational thinking is aligned vertically and grows progressively deeper and more complex through a series of graduated and interrelated projects, creating deeper learning experiences moving from block-based to text-based code" (Rondinelli & Owens, 2017, p. 2). Initial coding experiences for the youngest coders does not even require a computer. Fessakis et al. (2012)

observed Kindergarten students utilize one of two problem-solving strategies as they played Ladybug leaf and Ladybug maze, which are available as Java applets, from the National Library of Virtual Manipulatives. Ladybug leaf and Ladybug maze are problem solving games in which students need to plan the route the ladybug should take to hide under the leaf or make it through a maze. Students can use a series of buttons such as forwards, backwards, 45 degrees right or left, and 90 degrees right or left, to move the ladybug to the desired location. After determining and analyzing the problem, more than half of the students were observed planning their solution, often programming 2-3 commands at a time. The remainder of the students employed a trial and error technique. The children who applied the trial and error technique were described as less confident, often seeking approval from their teacher or peers. Likewise, Gresse von Wangenheim et al. (2017) noted that through coding integration, students learned the basic steps in algorithmic problem solving and gained an understanding that software is a set of directions being followed by a computer. Students naturally followed a problem-solving cycle of identifying a problem, designing a solution, programming the solution and testing it.

At all levels of study, researchers have emphasized the use of collaboration by creating open-ended, project-based assignments, which utilize pairs or small groups. Gresse von Wangenheim et al. (2017) described the execution of paired programming to be one of the greatest strengths of the integrated social studies unit. Students divided tasks and worked collaboratively to create a game based on their knowledge of cultural subjects. It was stated that "the possibility to freely choose both the game genre and the game design stimulated a discussion and contribution of ideas of almost all students within their groups" (Gresse von Wangenheim et al., 2017, p. 8). In a large group setting, Fessakis et al. (2012) allowed students to collaborate by sharing better alternative solutions to previously solved problems. As a result, students' communication skills improved, and they were able to widen their thought processes based on their own experiences and the experiences of their peers.

According to Rondinelli & Owens (2017) and Moreno-Leon et al (2016), academic achievement has been proven to be a positive aspect of coding integration, in some cases. When an entire school district revamped its instructional delivery around problem solving and creative design, students' standardized test scores in reading and mathematics improved consistently over the course of five years (Rondinelli & Owens, 2017). Similarly, when Moreno-Leon et al. (2016) investigated where coding belonged in the K-12 curriculum, they noticed that when embedded in the middle school math and social studies curriculum, students academically outperformed their non-coding peers. However, there was no statistical difference in academic achievement between 2nd graders coding in a language arts class.

Motivation and Student Engagement

Humans are born with a sense of intrinsic motivation led by our natural curiosity. However, this motivation is often temporarily diminished for a variety of reasons. Jensen (1998) explains three primary reasons for temporary demotivation in students. The first reason for temporary demotivation is associations from the past. When students have a negative experience, it is stored in the amygdala, which is located in the middle of the brain. When this part of the brain is triggered, it may feel to the student, as if the same event is happening again. A second reason is the environment. Students can feel temporarily unmotivated when "in the face of unsuitable learning styles, a lack of resources, language barriers, cultural taboos, fear of embarrassment, a lack of feedback" (Jensen, 1998, p. 64) along with a wide range of other possibilities. The final reason for temporary demotivation is the student's relationship with the future. Does the child understand what the goal of a lesson or assignment is, and do they see its purpose for the future?

It is suggested that students are led to feel intrinsically motivated when the process of projects and problem-solving activities are more valuable than the product. As a teacher, one can help children by goal-setting with student's choices in mind, promoting a positive classroom environment, and giving feedback. Jensen (1998) states, "a computer does this perfectly" (p.68). Mozelius and Oberg (2017) and Songy (2018) observed evidence of increased student motivation and engagement through the use of coding instruction. Mozelius and Oberg (2017) state that "around 10 per cent of the students get an instant understanding and an intrinsic motivation for further exploration" (p.380). Songy (2018) states that an "Open-ended challenge brought out internal motivation and non-complacent drive in all students to strive for excellence and make their websites even better" (p. 49). Coding programs such as *Scratch* offer students the opportunity for open-ended exploration in which they can set independent goals and are given immediate feedback as they work to code individualized projects.

Based on the review of literature, the integration of coding into a 5th grade mathematics class has the ability to allow students to learn a host of 21st century skills, increase student engagement, and improve academic achievement. While no two studies followed the exact same methodology, each emphasized collaboration by placing students into pairs or small groups and allowed for discussion throughout the process. The majority of the studies also highlighted the use of open-ended, challenge-based, and project-based learning. Finally, the research reviewed made it evident that a wide-range of applications have been developed to teach students the act of coding and programing, and that the specific program teachers choose to introduce their students to depends on the academic content being covered.

Methodology

This study used an experimental design that utilized both qualitative and quantitative data collection tools. In addition to classroom observations, pre and post-assessment data was collected through topic tests created by Pearson Education, Inc. and questionnaires which included a series of open-ended and multiple choices questions were used to gather data on students' interest in the area of mathematics.

The population for this action research study was a group of fifth grade students enrolled at an elementary school in Pennsylvania. The sample was of 20 fifth graders enrolled in a year-long mathematics course that utilized the Envision Mathematics curriculum published by Pearson Education, Inc. The sample featured 11 males and 9 females. The course being studied was a required class and the sample group was a part of the elementary school population.

Pre and post-intervention surveys were used at the beginning and end of the research study (Appendix A). The questionnaire created using Google Forms was provided to students electronically through their school G-mail accounts. The survey included a series of open-ended and multiple-choice questions regarding students' personal opinions about mathematics class. More specifically, students were asked what they liked and disliked about math follow-up works and what their favorite math follow-up work assignments were. Students also took a pretest and posttest at the beginning and end of each unit. The pretests and posttests were identical tests, created by Pearson Education, Inc. as a part of the 2012, 5th Grade, Envision Math, Common Core curriculum (Appendix B and Appendix C). These tests provided quantitative data regarding the growth of students test scores before and after the coding intervention had been implemented. Both the questionnaire and the pre-assessments for each unit, served as baseline data.

When the intervention began, students were presented with a mini-lesson each day, which is regular practice in a 5th grade mathematics. Mini-lessons were typically 15-20 minutes long and included a combination of teacher directed lecture in a whole group setting and guided practice using digital presentations, demonstrations on the white board, and work with manipulatives. After each lesson, students were assigned follow-up work. Follow-up work refers to the work students were asked to do after a lesson to practice the concept they had just been taught. Traditional follow-up work included worksheets, task cards, games, or a combination of the three. For this intervention, coding activities were added as alternatives to traditional follow-up work.

Based on the literature reviewed, the teacher chose to utilize a variety of coding platforms. Researchers emphasized that the coding languages used today will not likely be the same languages used when today's students enter the workforce. However, the skills acquired through today's coding platforms teach students valuable skills which can be transferred to new coding languages. The literature reviewed highlighted the functionality of a wide range of coding platforms, calling attention to each platform's strengths, weaknesses, and ways in which each could be integrated across different content areas. Hutchison et. al. (2016) states that "well designed games create problem-solving spaces with feedback and clear outcomes that lead to real, deep, and consequential learning" (pp. 494-495). For that reason, three platforms were utilized over the course of this action research study. The platforms used were *Scratch*, *Logo* language through turtleacademy.com, and *Wonder Workshop*.

While studying Topic 8, Order of Operations, students visited scratch.mit.edu to play PEMDAS created by prittykitty. Prior to their work with *Scratch*, students used their school G-mail addresses to create accounts. Students utilized the Chromebooks, individually or in pairs, to access *Scratch*. After viewing the PEMDAS game created by prittykitty, students coded their own game to teach others about the order of operations or modified the existing game to meet their personal interests. Students that had time remaining in class were asked to take a video of their game and add a voice recording or written reflection to post to their Seesaw accounts.

A second activity students participated in during Topic 8 was to create a multistep word problem and then code Dash the robot to act out the problem. Students started by writing their own multi-step word problem, which could be expressed as one equation. They utilized their knowledge of the order of operations to write and solve the equation. Once the problem had been created and solved, students drafted an outline of what they planned to have Dash do. Finally, students used Blockly to create a scene in which Dash acted out the word problem. Once students had successfully programmed Dash to act out the word problem, they were asked to take a video of their work, upload it to Seesaw, and post it to their journal with the word problem typed in the comment section.

As a part of Topic 15, Classifying Plane Figures, students used Logo language to create the seven triangles of reality. Students were given approximately 30 minutes to explore this platform by using a Chromebook to visit turtleacademy.com. Students were then instructed to click, “Start learning code,” and then to click lesson one, “Logo’s turtle.” Students began working through the steps on the left-hand side of the screen to become acquainted with the program. Students moved through the lessons at their own pace for approximately 30-minutes. At the end of the 30-minutes, students were instructed to move to Lesson 7, “Polygons.” The first activity in this set of lessons is for students to create triangles. Based on what they had learned about the seven triangles of reality and their newly acquired Logo skills, students were challenged to code the seven triangles of reality. At the end of the class, students were asked to take a picture of their work, upload it to Seesaw, label the triangles they coded, and post. Students who finished early were asked to add a voice recording or written reflection to their Seesaw post.

After each lesson the teacher completed a reflection and follow-up work observation form (Appendix D). The form was used to evaluate the strengths and weaknesses of the students and the follow-up work assignments. It was also used to track unprompted student comments and concerns and allow for future planning. This form allowed the teacher to gain insight into the students understanding of the academic content, the strengths and weaknesses of each assignment, and any additional gains made with the introduction of coding activities. When coding options were provided, a tally sheet was used to track which students choose the coding follow-up work and which choose more traditional follow-up work options. At the end of the study the researcher compared the data from the tally chart with the pre and post assessment data to determine if students who chose coding made greater academic gains than those who did not.

At the conclusion of the study, the teacher calculated the academic difference the students made during the intervention by taking the post-test score for each topic and subtracting it from the pre-test score from that topic. The teacher then looked at the calculated difference, in relationship to the number of coding activities each student attempted, to determine if there was an identifiable relationship between the two.

Next, the teacher compiled the raw pre and post-survey, multiple choice question data, into individual Google spread sheets. That information was then transferred into tables and graphs by question. The teacher evaluated how students' responses had or had not, changed over the course of the study. The teacher read through the open-ended survey question responses and began to determine reoccurring themes. The teacher used the computers highlight feature to color-code common thoughts and ideas that appeared. Once all open-ended responses had been read and color-coded, the teacher counted the number of students who shared similar ideas and created graphs based on the findings. Finally, the teacher evaluated the student reflections on Seesaw, as well as their own lesson observation and reflection forms to determine the strengths and weaknesses of each coding activity. The teacher utilized peer-debriefing to discuss the study with a colleague to make sure that their interpretations were accurate.

Analysis of Data

The purpose of this action research study was to investigate the effect coding integration had on student motivation and academic achievement in a 5th grade mathematics class. The research design was experimental and utilized a variety of data sources such as pre and post-tests, teacher observation and reflection forms, student reflections on Seesaw, tally sheets, and pre and post intervention surveys. Surveys, teacher reflection forms, and semi-structured student reflections on Seesaw were used to gather data about students' levels of engagement in the area of mathematics. The pre-test and post-test data and tally chart were used to determine the impact coding integration had on academic achievement.

Pre and Post Test Data

Topic tests developed by Pearson Education, Inc. as a part of the 5th grade Envision Math Curriculum were used at the beginning and end of each unit (Appendix B and Appendix C). To analyze the pre and post-test data, tests were scored using the answer keys provided by Pearson Education, Inc. and each test was given a total score based on the number of questions answered correctly. Each student received two scores per topic, one for their pre-test and one for their post-test. Academic gains were calculated using the expression, Post-test – Pre-test= Academic Gain. Numeric comparisons between the students' pre- and post-test scores were used to help answer the research question, how does coding integration in the area of mathematics effect academic achievement.

The majority of students test scores increased from the Topic 8 pretest to posttest (Table 1). For the purpose of consistent data analysis, all raw scores and median scores have been rounded to the nearest whole number. Students' had a median Topic 8 pretest score of 8 out of 18 (or 44%). All students choose to complete at least two coding follow-up activities. The student who completed two coding activities had a posttest score of 11 out of 18 (or 61%). This student's score decreased by one point from the pre-test to post-test. Students who completed three coding activities had a median posttest score of 13 out of 18 (or 72%).

Table 1. Students' Gain Scores-Topic 8

Student	Number of Coding Tasks Attempted	Pre-test Score	Post-test Score	Gain Score
Student 3	2	12/18 (67%)	11/18 (61%)	-1
Student 12	3	14/18 (78%)	13/18 (72%)	-1
Student 6	3	8/18 (44%)	9/18 (50%)	1
Student 9	3	12/18 (67%)	15/18 (83%)	3
Student 19	3	10/18 (56%)	13/18 (72%)	3
Student 4	3	7/18 (39%)	11/18 (61%)	4
Student 7	3	6/18 (33%)	10/18 (56%)	4
Student 10	3	12/18 (67%)	16/18 (89%)	4
Student 5	3	9/18 (50%)	14/18 (78%)	5
Student 14	3	8/18 (44%)	13/18 (72%)	5
Student 16	3	9/18 (50%)	14/18 (78%)	5
Student 11	3	10/18 (56%)	16/18 (89%)	6
Student 17	3	6/18 (33%)	12/18 (67%)	6
Student 1	3	5/18 (28%)	12/18 (67%)	7
Student 2	3	5/18 (28%)	12/18 (67%)	7
Student 8	3	7/18 (39%)	15/18 (83%)	8
Student 13	3	5/18 (28%)	14/18 (78%)	9
Student 15	3	4/18 (22%)	13/18 (72%)	9

Most students test scores increased from the Topic 15 pretest to posttest (Table 2). Students' had a median Topic 15 pretest score of 7 out of 14 (or 50%). All students completed the Turtle Academy coding activities when offered. The average posttest score was 10 out of 14 (or 71%).

Table 2. Students' Gain Scores- Topic 15

Student	Coding	Pre-Test	Post-Test	Gain Scores
Student 11	3	6/14 (43%)	13/14 (93%)	7
Student 2	3	4/14 (28%)	10/14 (71%)	6
Student 18	3	7/14 (50%)	12/14 (86%)	5
Student 3	3	5/14 (36%)	9/14 (64%)	4
Student 4	3	5/14 (36%)	9/14 (64%)	4
Student 6	3	4/14 (28%)	8/14 (57%)	4
Student 9	3	7/14 (50%)	11/14 (79%)	4
Student 13	3	8/14 (57%)	12/14 (86%)	4
Student 15	3	9/14 (64%)	13/14 (93%)	4
Student 20	3	4/14 (28%)	8/14 (57%)	4
Student 8	3	8/14 (57%)	11/14 (79%)	3
Student 17	3	9/14 (64%)	11/14 (79%)	3
Student 1	3	10/14 (71%)	12/14 (86%)	2
Student 10	3	11/14 (79%)	13/14 (93%)	2
Student 19	3	7/14 (50%)	9/14 (64%)	2
Student 7	3	6/14 (43%)	7/14 (50%)	1
Student 16	3	8/14 (57%)	9/14 (64%)	1
Student 5	3	8/14 (57%)	8/14 (57%)	0

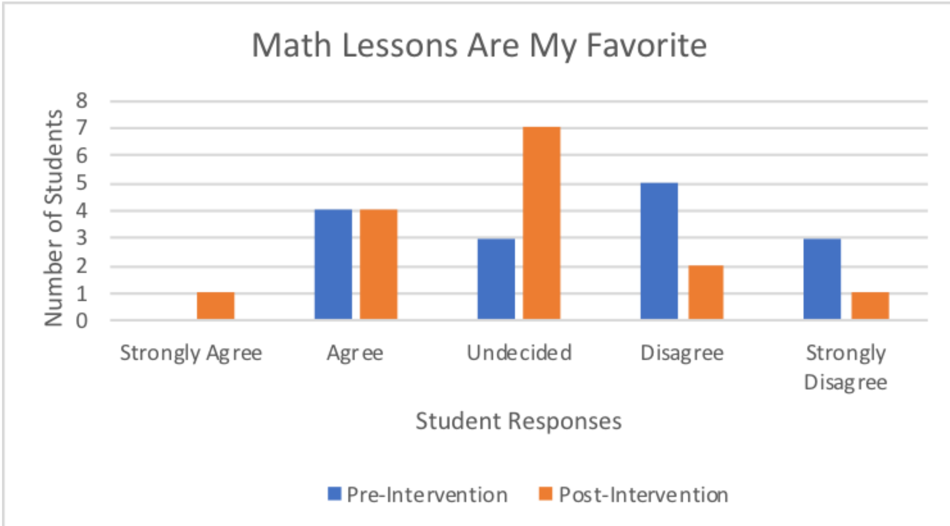
It was difficult to determine the effect coding integration had on the academic achievement of 5th grade students in the area of mathematics based on the pre and post test score data and tally chart because the majority of students opted to complete every coding activity offered. Only one student chose to complete a more traditional follow-up work on the first day coding was offered. Overall, most student test scores increased by an average of 4 points when they completed three or more coding activities per unit.

Student Survey

Student survey data was collected through the use of Google Forms at the beginning and end of the research study (Appendix A). The purpose of collecting this data was to determine how coding affected student's perception of mathematics and mathematics follow-up work. Due to student absences, not every student was able to complete the pre-intervention or post-intervention survey. For the purpose of equal comparison, only students who completed both the pre and post-intervention survey have been included in this section.

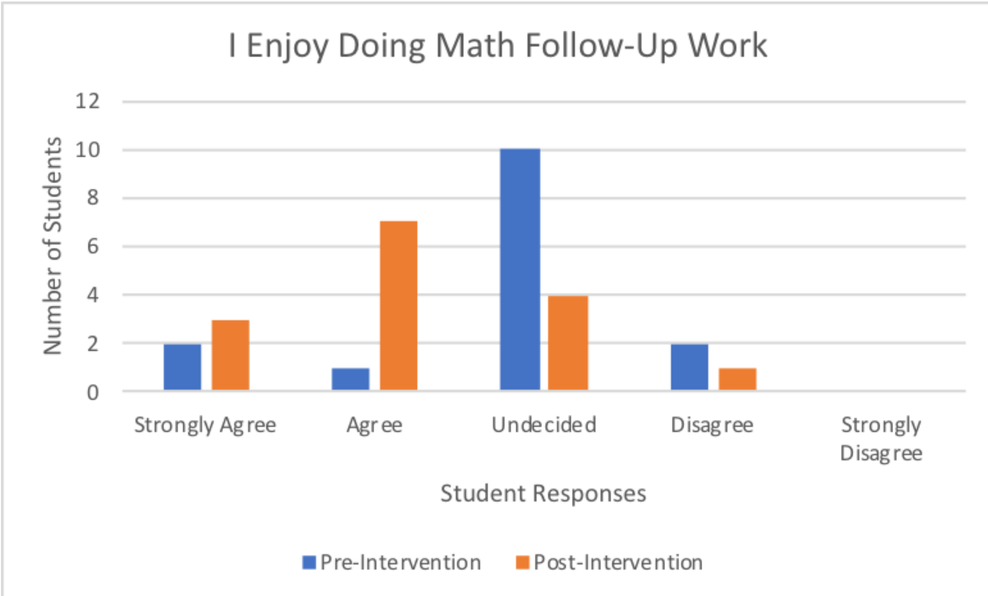
The data received from the initial survey of fifteen participants indicated that four (4) out of fifteen (15) students agreed or strongly agreed that math was their favorite subject (Figure 1). Eight (8) out of fifteen (15) students disagreed or strongly disagreed that math was their favorite subject. The remaining three (3) out of fifteen (15) students were undecided (Figure 1). After the intervention five (5) out of fifteen (15) students agreed or strongly agreed, three (3) out of fifteen (15) students disagreed or strongly disagreed, and seven (7) out of fifteen (15) students were undecided (Figure 1). Overall, students' feelings about math lessons shifted over the course of the 6-week study with the integration of coding. The number of students who disagreed or strongly disagreed decreased from eight (8) students' pre-intervention to three (3) students' post-intervention. The number of students who were undecided, agreed, or strongly agreed increased from seven (7) students' pre-intervention to twelve (12) students' post-intervention.

Figure 1. Math Lessons Are My Favorite



When posed with the statement, "I enjoy doing math follow-up work," three (3) out of fifteen (15) students agreed or strongly agreed (Figure 2). Two (2) out of fifteen (15) students disagreed or strongly disagreed, and the remaining ten (10) out of fifteen (15) students were undecided at the beginning of the study (Figure 2). After the intervention, ten (10) out of fifteen (15) students agreed or strongly agreed, one (1) out of fifteen (15) students disagreed or strongly disagreed, and four (4) out of fifteen (15) students were undecided (Figure 2). Students' opinions regarding math follow-up work changed over the course of the 6-week study. The number of students who agreed or strongly agreed increased from three (3) students at the beginning of the intervention to ten (10) students at the end of the intervention. The number of students who were undecided, disagreed, or strongly disagreed decreased from twelve (12) students at the beginning of the study to five (5) students at the end of the study.

Figure 2. I Enjoy Doing Math Follow-Up Work



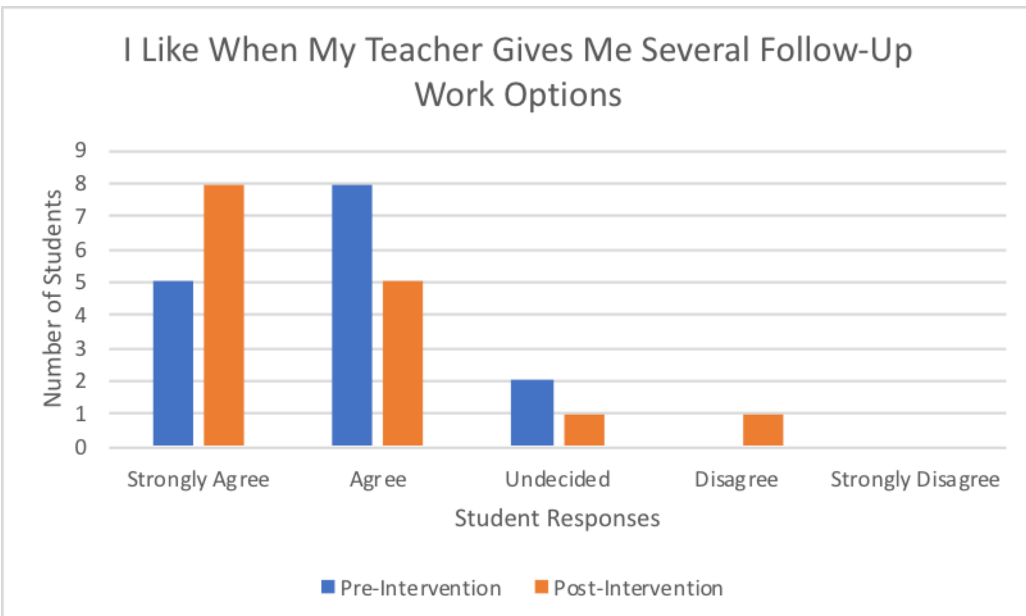
When asked to elaborate on their feelings about follow-up work prior to the inclusion of coding, students gave various answers. Five (5) students reported that they liked the ability to work with self-chosen partners when completing their math follow-up. Two (2) students liked that they had several follow-up work options, five (5) students described the follow-up work options as fun, and three (3) students liked that they could start their homework after they completed their follow-up works.

When it came to students' dislike of math follow-up work, prior to the start of the intervention, four (4) students reported that they disliked having to complete unfinished follow-up work for homework. Five (5) students disliked the number of questions on some of the math worksheets, two (2) students disliked the common core worksheets, and two (2) mentioned that the follow-up works could be hard and frustrating at times. One (1) student stated that there were not enough follow-up work options provided. Six (6) students named games as their favorite follow-up work, seven (7) listed technology related activities and math applications such as

Sumdog, five (5) students listed the reteach and practice pages, and four (4) said that homework was their favorite follow-up work.

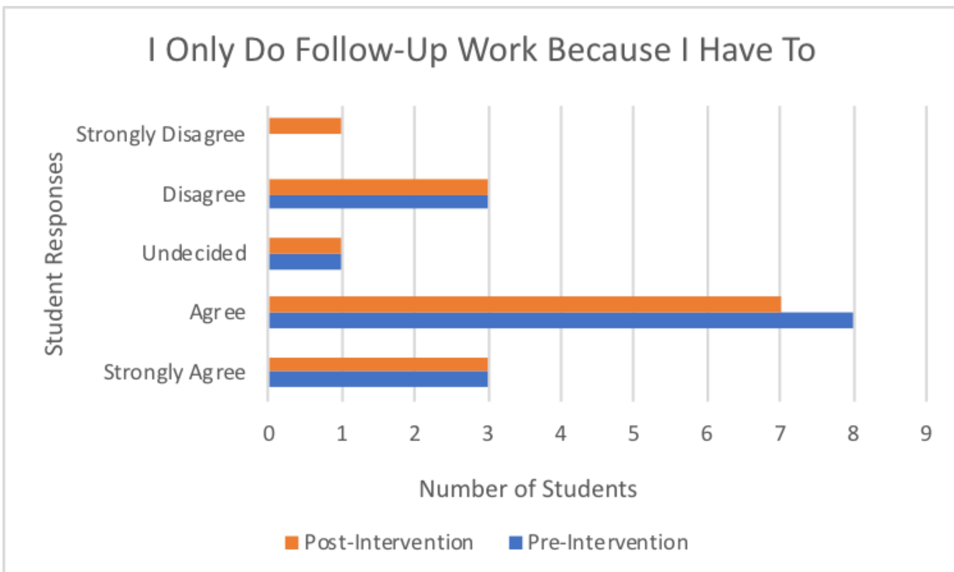
When given the statement, “I like when my teacher gives me several options for follow-up work,” on the initial survey, thirteen (13) out of fifteen (15) students agreed or strongly agreed (Figure 3). No students disagreed or strongly disagreed and the remaining two (2) out of fifteen (15) students were undecided (Figure 3). After the intervention thirteen (13) out of fifteen (15) students agreed or strongly, one (1) out of fifteen (15) students disagreed or strongly disagreed, and one (1) out of fifteen (15) students were undecided (Figure 3). The majority of the 5th grade mathematics students liked that the teacher provided several follow-up work options.

Figure 3. I Like When My Teacher Gives Me Several Follow-Up Work Options



When given the statement, “I only do my math follow-up work because it is assigned to me,” on the initial survey, eleven (11) out of fifteen (15) students agreed or strongly agreed (Figure 4). Three (3) out of fifteen (15) students disagreed or strongly disagreed and the remaining one (1) out of fifteen (15) students were undecided (Figure 4). After the intervention ten (10) out of fifteen (15) students agreed or strongly, four (4) out of fifteen (15) students disagreed or strongly disagreed, and one (1) out of fifteen (15) students were undecided (Figure 4). Overall, students' opinions on completing math follow-up work remained almost the same. More than two-thirds of the class stated that they only did math follow-up work because they had to prior to the intervention. After the intervention, exactly two-thirds of the class stated that they only did math follow-up work because they had. One notable change is that one student who originally agreed that they only did math follow-up work because they had at the beginning of the intervention, changed their response to strongly disagree at the end of the intervention.

Figure 4. I Only Do Follow-Up Work Because I Have To



At the end of the intervention, five (5) out of seventeen (17) students said that they enjoyed math follow-up work because they could work with a partner or small group. Four (4) out of fifteen (15) students stated that they enjoyed the ability to start homework if they finished their follow-up work and four (4) students said they thought math follow-up work was fun. One (1) student stated they liked having choice, one (1) enjoyed math games, and one (1) mentioned how they liked the option of coding.

When students were asked what they disliked about math follow-up work, five (5) out of fifteen (15) students said the follow-up work was too hard. Two (2) students stated that the quantity of work felt rushed for the time given, three (3) disliked the Common Core worksheets, and two (2) students said they didn't always like the options provided. One student stated that they did not like that coding was not an option 99% of the time.

Teacher Observation and Reflection Forms

Teacher observation and reflection forms were used during every lesson that included coding follow-up work. The purpose of these forms was to collect data about the strengths and weaknesses of each lesson and the follow-up work options offered. The teacher observation and reflection forms were also used to gather unprompted feedback regarding each activity from students as they worked.

Scratch was the most engaging for students, but from a teaching perspective, lacked the academic content the teacher was hoping it would reinforce. The majority of students became quickly intrigued by the voice recording and sound functions of *Scratch* and spent the majority of their time exploring those features. However, students that moved past the audio aspect of the program engaged in problem and solution-oriented conversations. Working in small groups, the teacher observed students use trial and error to reprogram the PEMDAS game by prittykitty. Two students were observed asking each other questions such as, "How can I make the cat bigger?" The other student tinkered with several buttons, entering a variety of numbers, until she discovered how to make the cat larger and smaller. She then showed the student who originally asked. In addition to the problem and solution-oriented conversations, students showed a clear excitement for the work they were producing. One student asked the question, "Who wants to see my things?" and several students went running over to his work area to see what he had created.

Using the Dash robots in conjunction with the *Blockly* app created by *Wonder Workshop*, students were able to use drag and drop software to program Dash to act out the multistep word problems they created. Depending on the word problem created, some students found it easier to program *Dash* to act out their problem than others. For instance, students who wrote a word problem involving speed were able to program *Dash* to move slowly over a certain distance, speed up for a distance, and then slow down again before coming to a stop. Others, who wrote about a person who went shopping and bought things had a more difficult time programing Dash to act out the word problem as it involved a more creative thought process. Time constraints made it difficult for all students to program *Dash* to the degree they would have liked to. For that reason, I would suggest that teachers wishing to complete this activity allow for at least two, one-hour blocks of time, or if available, I would suggest that students program using the *Blockly* app prior to working with the robots.

The final program used, *Turtle Academy*, proved to challenge students' mathematical thinking skills the most out of the three programs. Prior to receiving their assignment related to the seven triangles of reality, students were able to move through the lessons quickly and independently. When it came to programing the seven triangles of reality, students easily created the equilateral triangle, as they were able to follow the step by step directions provided by Turtle Academy. One student wrote in their Seesaw post, "This is my equilateral triangle and I think this one is the easiest." When left with the more open-ended challenge of creating the other six triangles, students struggled. One of the main challenges was that students had to have a greater understanding of angles than the teacher originally thought. In order to create the smaller, interior angles of their triangles, students had to enter a larger number. For instance, if a student wanted the interior angle to be 45 degrees, they would have to move the turtle 135 degrees. The second challenge came when students tried to attach the three lines together. It took several trial and error attempts or the entering of very small movements, for students to come close to connecting the three lines. One student wrote in their Seesaw post, "Easy looking at it hard making it," and another wrote, "This is my obtuse scalene angle and this (is) pretty difficult." Additionally, some students found this program frustrating because there was no back button available if they made a mistake. The student would have to clear the screen and begin again.

Action Plan

The goal of this action research project was to determine what effect coding integration had on student engagement and academic achievement in a 5th grade mathematics class. The research question posed was: What effect will the integration of coding have on student engagement and academic achievement in a 5th grade, mathematics class? Based on the analysis of the data, several conclusions can be drawn in regard to the research question.

Based on the pre and post-intervention survey, as well as teacher observations and reflection, it can be concluded that student engagement increased and students' overall feelings about math class improved through the implementation of coding integration. All three coding platforms increased student engagement in mathematics class. The *Blockly* app in conjunction with *Dash* the robot and *Scratch* were the most engaging. The students enjoyed these user-friendly platforms that allowed for customization and the ability to easily change aspects of their program that they did not like. While both platforms used drag and drop software, *Scratch* prompted more conversation among students as they had to use trial and error to navigate the programs features. *Turtle Academy* which used LOGO language rather than drag and drop software also kept students engaged. They found the step by step lessons provided on the website easy to follow, but were more challenged academically and technically when it came to drawing the seven triangles of reality. Students found it frustrating that there was no back button when they made errors. Instead they had to start again.

Determining the effect coding integration had on academic success was unsuccessful. Each 5th grade math student except for one chose to complete every coding follow-up work option provided, which left the teacher without ample data to compare pre-test and post-test data against. The one student who did not complete every coding follow-up work option provided, scored less on the Topic 8 post-test than he did on the pre-test. The teacher believes it is less likely that the student lost academic content knowledge due to coding integration and more likely that social and emotional issues affected the students test taking performance. Should research on this topic be done in the future, I would suggest that the researcher have a control group to compare academic data against. In addition, coding integration in 5th grade mathematics should be investigated in all areas of study, not just order of operations and geometric plane figures. This will allow future teachers to determine the best units to integrate coding in order to maximize academic achievement.

The student surveys provided additional information, unrelated to coding, that will help guide the teacher's future instruction. The open-ended questions that asked students what they liked and disliked about math follow-up work provided the most insight. Based on this feedback, the teacher will continue to allow students to choose whether they work individually, with a partner, or in small groups. The teacher will also continue to offer multiple options for follow-up work. Based on the student's responses to their dislikes, the teacher will work with students to find a balance between the amount of work and the class time given. One possible solution is to create larger, project-based assignments that can be completed over an extended period of time rather than the expectation be that assignments are completed and turned in daily. Several students mentioned that they felt the follow-up work was too hard. For this, the teacher intends to create learning partnerships, provide links for students to watch other educators teach the same content in a different manner, and provide students with an opportunity to set-up conferences with the teacher to work on areas of growth.

In accordance with the findings, the teacher will continue to offer and assess the effectiveness of a variety of coding follow-up works in the area of mathematics. Allowing coding as a follow-up work option will continue to give students exposure to tasks that require the use of 21st century and computational thinking skills.

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Appendix A
Pre and Post-Intervention Student Survey

3/17/2019 Effects of Coding on Student Motivation

Effects of Coding on Student Motivation

* Required

1. **Participant Number** *

2. **Math lessons are my favorite.** *
Mark only one oval.
- Strongly Agree
- Agree
- Undecided
- Disagree
- Strongly Disagree

3. **I enjoy doing math follow-up work.** *
Mark only one oval.
- Strongly Agree
- Agree
- Undecided
- Disagree
- Strongly Disagree

4. **I like when my teachers gives me several options for follow-up work.** *
Mark only one oval.
- Strongly Agree
- Agree
- Undecided
- Disagree
- Strongly Disagree

5. **I only do my math follow-up work because it is assigned to me.** *
Mark only one oval.
- Strongly Agree
- Agree
- Undecided
- Disagree
- Strongly Disagree

6. **What do you like about math follow-up works?**

7. **What do you dislike about math follow-up works?**

8. **What are your favorite follow-up work assignments?**

https://docs.google.com/forms/d/1ZGWfx_ndoPCCTk7BP1XLOiSVklAhlv_Zhk8ATac-8Ko/edit 1/2

Appendix B
Topic 8 Test Created by Pearson Education, Inc.

Name ________________________________

Topic 8
Test

1. Which expression can be used to represent the phrase "five times the amount of pebbles"? (8-1)

   A $5 \div p$

   B $5 - p$

   C $5 + p$

   D $5 \times p$

2. If Torie makes an average of 36 paper swans per hour for 4 hours, she will make 4×36 paper swans. Which of the following is equal to 4×36? (8-2)

   A $(4 \times 30) + (4 \times 6)$

   B $(4 + 30) \times (4 + 6)$

   C $(4 + 30) + (4 + 6)$

   D $(4 \times 30) - (4 \times 6)$

3. Ty had 48 more hits during the baseball season than Sean, who had 24. Evaluate the expression $x + 48$ for $x = 24$. (8-4)

   A 24 **C** 72

   B 2 **D** 76

4. Brianna must put a $5 deposit down to buy a necklace. If p represents the full price of the necklace, which expression tells how much Brianna owes, before tax, after she has paid the deposit? (8-8)

   A $p \div 5$ **C** $p - 5$

   B $5 - p$ **D** $p + 5$

5. The expression $j - 5$ represents the number of years Julio has taken painting classes when Keri has taken sculpting classes for j years. How many years of classes will Julio have when Keri has 12 years? (8-5)

   A 60

   B 17

   C 7

   D 5

6. What is the first step in evaluating the expression shown below? (8-2)

   $8 + (15 - 4) \times 11 - 10 \div 5$

   A Subtract 10 from 11.

   B Divide 10 by 5.

   C Add 8 and 15.

   D Subtract 4 from 15.

7. What value of n makes the equation true? (8-2)

   $24 \times 480 = (24 \times 400) + (24 \times n)$

   A 2 **C** 456

   B 80 **D** 480

8. The price of n tickets to a play is $9n + 6$ dollars. What is the cost for 8 tickets to the play? (8-6)

   A $23 **C** $78

   B $57 **D** $132

Appendix B (Continued)
Topic 8 Test Created by Pearson Education, Inc.

Name ______________________________

9. New Jersey, Tennessee, and Ohio have a total of 40 representatives in the U.S. House of Representatives. New Jersey has 13 representatives and Ohio has 2 times as many as Tennessee. Write an expression showing how many representatives Ohio has. (8-6)

____

____

____

10. Write an expression that represents 2 more than 4 times a number. (8-1)

____

11. What is the value of $15 - 2x + 2$ when $x = 6$? (8-3)

____

____

12. Tom starts with $12 and saves $20 each week. Ruth starts with $15 and saves $20 each week. Copy and complete the chart to show how much money each has saved at the end of each week. What is the relationship between how much money each has at the end of each week? (8-7)

	Tom's Savings	Ruth's Savings
Start	$12	$15
1st week		
2nd week		
3rd week		
4th week		

____

____

13. Jake cleaned up his room. He organized his toys into boxes. He put 7 toys in each of 3 bins. If *t* represents the total number of toys, write an expression that shows how many toys he put away. (8-1)

____

Appendix B (Continued)
Topic 8 Test Created by Pearson Education, Inc.

Name ______________________________

14. Darren is watching a circus act. He notices that there is a relationship between the number of horses and the number of dogs in the act. He makes the table below to collect his observations. (8-7)

	Row 1	Row 2	Row 3	Row 4	Row 5
Horses	2	4	6	8	10
Dogs	8	16	24	32	40

What is the relationship between the number of horses and the number of dogs in each row?

____

____

____

____

15. Which expression has a value equal to 3? Explain how you got your answer. (8-4)

$(8 + 4 \div 2) - 1 \times 3$
$(8 + 4) \div 2 - 1 \times 3$

____

____

____

16. The table shows the cost for Kim to rent a bicycle. Explain how you would write an expression that shows the cost to rent the bicycle for *d* days? (8-9)

Number of Days	Total Cost
3	$42
4	$56
5	$70

____

____

____

Use the following expression to answer **17** and **18**.

$8 \times (36 \div 12) \times y$

17. Which operation do you perform first in simplifying this expression? (8-2)

____

18. Write the simplified form of the expression. (8-3)

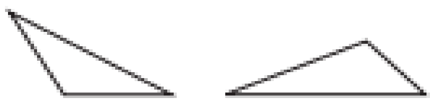
____

Appendix C
Topic 15 Test Created by Pearson Education, Inc.

Name ____________________________

Topic 15
Test

1. Which of the following correctly describes the triangles shown? (15-2)

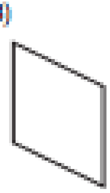


A Both triangles have one right angle.
B Both triangles have two obtuse angles.
C Both triangles have two acute angles.
D Both triangles have three acute angles.

2. A triangle has angles that measure 55°, 35°, and 90°. Classify this triangle by its angles. (15-2)

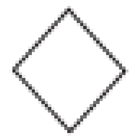
A Equilateral triangle
B Obtuse triangle
C Acute triangle
D Right triangle

3. Which of the following can be used to describe the shape below? (15-3)



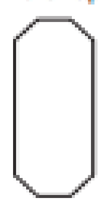
A Opposite sides are parallel.
B All angles are obtuse.
C Adjacent sides are parallel.
D All angles are 90°

4. This quadrilateral has 4 equal sides. What is it? (15-4)



A Square
B Trapezoid
C Rhombus
D Rectangle

5. Kristi has a piece of jewelry that is the shape shown in the picture below. Which of the following describes the shape? (15-1)

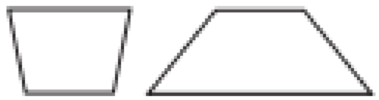


A Opposite sides parallel
B Regular polygon
C Pentagon
D Hexagon

Appendix C (Continued)
Topic 15 Test Created by Pearson Education, Inc.

Name ______________________________

6. The figures below are trapezoids. Which generalization is correct based on these figures? (15-6)



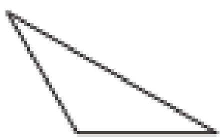
A A rectangle can be a trapezoid.

B A trapezoid can be a square.

C A trapezoid can be a parallelogram.

D A trapezoid has one set of parallel sides.

7. The triangle shown below has two sides of equal length. What two terms apply to this triangle? (15-2)



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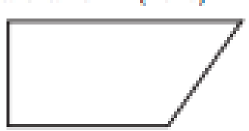
8. The top and bottom of this figure are parallel. What type of quadrilateral is it? (15-3)



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9. Compare and contrast an isosceles triangle and an acute triangle. (15-2)

____

____

____

____

10. Which quadrilaterals have four right angles? (15-3)

____

____

Appendix C (Continued)
Topic 15 Test Created by Pearson Education, Inc.

Name ______________________________

11. Compare and contrast a square and parallelogram. Which is the special case of the other? (15-4)

____

____

____

____

12. Jerri says that a square is a rhombus because it has 4 equal sides. Brianna says that a square is a parallelogram because it has two pairs of parallel sides. Who is correct? Explain. (15-5)

____

____

____

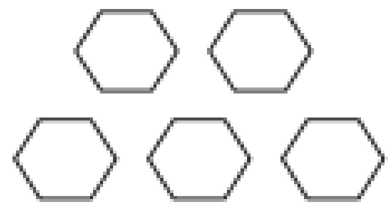
____

13. Compare the total number of sides in each set of shapes below. Which has more sides, **Set A** or **Set B?** Write an equation to support your answer. (15-1)

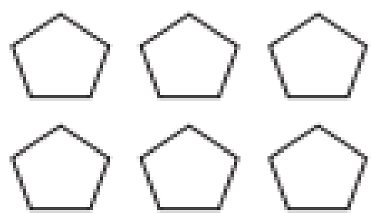
____

____

Set A



Set B



14. Amelie says that every square is a regular quadrilateral. Do you think Amelie's generalization is true? Explain. (15-6)

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____

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Appendix D

Teacher Observation and Reflection Form

Lesson Reflection and Follow-Up Work Observations

Date and Grade:
Planned Lesson:
Reflection of Lesson:

Student/ Application Strengths:
Student/ Application Weaknesses:

Unprompted Student Comments/Concerns:
Future Planning:

Follow-Up Works Completed: _______ Coding _______ Traditional