2022

The 6E Instructional Model in the Mathematics Classroom

Danielle K. Deutsch
Bowling Green State University, ddeutsc@bgsu.edu

The 6E Instructional Model in the Mathematics Classroom

Danielle Deutsch

Honors Project

Submitted to the Honors College

at Bowling Green State University in partial fulfillment of

the requirements for graduation with

UNIVERSITY HONORS

April 8, 2022

Emilio Duran, School of Teaching and Learning

Sandra Zirkes, Department of Mathematics and Statistics

The 6E Instructional Model in the Mathematics Classroom

The 5E instructional model is widely known in science classrooms. The model has five phases which are meant to more deeply engage students in science instruction, identify and address misconceptions, and effectively explain and evaluate key concepts. While it is used and taught to pre-service science teachers, the 5E model is rarely mentioned in the mathematics classroom and little research has been done on its place in mathematics teaching. There is even less research on the 6E model in the mathematics classroom, an extension of the 5E model which aims to more effectively differentiate instruction using intentional formative assessment. This action research aims to explore how the 6E model can be used in the mathematics classroom and how it affects student achievement and interest in math. Furthermore, the 6E model and how it facilitates differentiation in the classroom will be explored, as well as how this differentiated instruction affects students' perceptions of the lesson.

The 6E model will be compared to traditional models of instruction, as defined by the creator of the 5E model, BSCS Science Learning, and the National Council of Teachers of Mathematics (NCTM). BSCS Science Learning defines the traditional model of instruction as a "lecture-demonstration" approach where a lecture is followed by a lab or other activity (Bybee et al., 2006, p. 24). Additionally, NCTM defines the traditional model of instruction as one which includes review, demonstration, and practice (NCTM, 2014, p. 9). In other words, the traditional model is a teacher-centered form of instruction in which students are expected to absorb knowledge and then verify their learning through a lab, activity, or practice exercises.

Both the 5E and 6E models offer interactive and inquiry based instructional models that are not taught to preservice mathematics teachers and are not commonly used in mathematics classrooms. However, the phases and principles of both models closely align with NCTM standards, as well as the standards for mathematical content and practice from the Common Core State Standards for Mathematics (CCSSM). Thus, both models, in theory, will promote mathematical thinking, problem solving, and exploration. This action research will explore the 6E model and its effectiveness in the mathematics classroom in order to influence my future teaching and find the best instructional practices in my seventh to twelfth grade classroom.

Literature Review

The 5E Instructional Model

In order to understand the impacts and benefits of the 6E model, it is important to first look at what the original 5E model entails. This instructional model was first developed in the 1980s by what is known today as BSCS Science Learning (Bybee et al., 2006). It includes five instructional phases: engage, explore, explain, elaborate, and evaluate (Bybee et al., 2006). The first phase, engage, starts the lesson with a short, engaging activity that allows students to access prior knowledge and make connections, and makes students curious about the subject matter (Bybee et al, 2006, p. 2). The second, explore, provides students with activities which allow them to explore the new material in the context of what they already know (Bybee et al., 2006, p. 2). In a science classroom, this phase may include a lab activity in which students investigate and hypothesize about a new concept. The third phase is the explain phase. This phase, while called the explain phase, does not automatically include explicit instruction and explanation from the teacher. Instead, students should have the opportunity to explain their learning from earlier phases and teachers can guide and correct misconceptions as necessary (Bybee et al., 2006, p. 2). Teachers may also provide explanations which allow students to go deeper in their understanding of the material (Bybee et al., 2006, p. 2). The next phase is the elaborate phase. In this phase, teachers will challenge and extend the knowledge students have from previous phases, including providing activities that allow students to apply what they have learned (Bybee et al., 2006, p. 2). Finally, the 5E model concludes with the evaluate phase. This phase allows for the teacher to assess student understanding and allows students to assess their own understanding (Bybee et al., 2006, p. 2). The 5E instructional model, in total, includes five phases which are meant to deepen learning and better address misconceptions in the classroom.

The 6E Instructional Model

Numerous extensions and variations of the 5E model have been proposed. This research will focus on the 6E model, created by Duran, Duran, Haney, and Scheuermann in 2011. In their research, the authors found that the 5E model assumed that all learners were learning at the same pace (Duran et al., 2011). They propose the addition of a sixth phase in the model, between the explain and elaborate phases, called the express phase (Duran et al., 2011). This phase inserts a “conscious pause in the learning cycle” so the teacher can assess and ensure that all students have adequately progressed through the earlier phases (Duran et al., 2011, p. 57). The teacher gives active formative assessment during this phase which then informs the instruction given in the next phase. Following the express phase, the teacher can then provide differentiated and tiered instruction in the elaborate phase such that students’ individual needs are met and all students have met the learning objectives before a final assessment is given (Duran et al., 2011). This extension of the 5E model, the 6E model, attempts to address the assumption in the 5E model that all students have the same needs and learn at the same pace by adding an additional phase, which easily allows the teacher to differentiate instruction through a tiered approach.

Connecting the 5E and 6E Models and Mathematics

As previously discussed, the 5E and 6E models are not commonly used in the mathematics classroom and are more widely known in science education. However, clear connections exist between the rationales for the 5E and 6E models and the mathematical standards from CCSSM and NCTM. Due to these connections, the 5E and 6E models can and should have a place in the mathematics classroom. NCTM outlines five process standards for learning mathematics: problem solving, reasoning and proof, communication, connections, and representations (Bossé et al., 2010, p. 263-264). In the study done by Bossé, Lee, Swinson, and Faulconer in 2010, the researchers analyzed descriptors for both the NCTM process standards and the 5E model and found that of the fifty-one descriptors used, "41 (80%) were shared among learning processes in both subject areas" (p. 268). In other words, there was a strong connection between the learning processes used in both science and mathematics, suggesting that either learning process could be easily modified to fit either subject area.

Furthermore, NCTM outlines effective mathematics teaching standards in their 2014 publication, *Principles to Actions*. Here, NCTM describes mathematics learning as an "active learning process" (p. 9). The 5E model is derived from the theory that "learning is an active process" in which students are constantly building on previous knowledge (Cheyne, Glasgow, & Yerrick, 2010, p. 25). There is a clear connection between effective mathematics teaching and effective science teaching, as the learning and teaching of both subjects should be seen as active learning processes. Furthermore, NCTM describes effective mathematics teaching as having opportunities for learners to connect new learning with what they already know, as well as address preconceptions and misconceptions (2014, p. 9). The first two phases of the 5E and 6E models, engage and explore, are designed to provide learners with opportunities such as these, in which they can connect new knowledge with previous knowledge (Bybee et al., 2006). These opportunities are essential to the 5E and 6E instructional models, as explained by Cheyne, Glasgow, and Yerrick (2010, p. 25). Finally, the use of phased lessons in mathematics has been seen to support “mathematical investigation and problem solving” (Bill & Jamar, 2010, p. 78). The phases of the 5E and 6E instructional models, as a result, would likely also support this type of mathematical thinking and investigation that has been seen with other phased lessons. The phases of the 5E and 6E models also closely align with the Standards for Mathematical Practice (SMP) from the Common Core State Standards for Mathematics. For example, the first SMP asks students to “make sense of problems and persevere in solving them” (Council of Chief State School Officers, 2010). The extend phase of the 5E and 6E models is already designed to include problem solving and application of knowledge, as described in the first SMP. Additionally, the extend phase could be designed to include some type of mathematical modeling, which aligns with the fourth SMP (Council of Chief State School Officers, 2010). Finally, there is a clear connection between the 5E and 6E models and both SMP 7 and 8. The seventh and eighth Standards for Mathematical Practice both ask students to connect and recognize patterns and structure. This requires the connection between what students already know and what students are learning, which is an essential part of the 5E and 6E models, especially in the engage and explore phase. Overall, there are many clear connections between the principles of the 5E and 6E instructional models and the standards for mathematics teaching and learning outlined by NCTM and CCSSM, which suggest that the 5E and 6E models can easily be implemented in the mathematics classroom.

Benefits of the 5E and 6E Instructional Models

Subject Mastery

One of the greatest benefits of using the 5E or 6E models in the classroom is their positive effect on students’ mastery of the content being taught. This increase in mastery when using these models has been shown in both science and mathematics classrooms. In general, BSCS has found that students who were taught using the 5E model experienced "learning gains that were nearly double" that of the students whose teachers used another instructional model (Bybee et al., 2006, p. 29). This increased subject mastery makes sense considering the design of the instructional model. The 5E and 6E models take students through an exploration process of the concepts being taught, and as a result, they are able to access a deeper understanding of these concepts (Unwir, Herman, & Dahlan, 2016). As explained by Milton Huling and Jackie Speake Dwyer in their book on designing STEM lessons that are meaningful, students have the opportunity to correct their misconceptions on their own as they work through the five or six phases of the model, which leads to more meaningful learning and a deeper understanding (2018, p. 18). The 5E model also affected the permanence of students' knowledge. One study looked at the effect of the 5E model in a tenth-grade trigonometry classroom. Results from this research showed that students had higher achievement after learning through the 5E cycle, as well as a greater permanence of knowledge than students who learned through a traditional model (Tuna & Kaçar, 2013). This makes sense, as "students discover the concepts and principles and develop their own understanding of them," leading to greater retention (LaFave, 2012, p. 61). Mastery and knowledge permanence should be important goals for students in any classroom, and the 5E model clearly has a significant positive effect on both.

Prior research on the 5E model in the mathematics classroom specifically has revealed not only a deeper understanding of mathematical content, but also increased mathematical creativity and mathematical communication. Mathematical creativity is the ability of a student to solve mathematical problems in new ways, and is deeply connected to the problem solving ability of a student (Unwir, Herman, & Dahlan, 2016). Mathematical creativity is also important as it gives students the ability to solve problems without explicit instruction or simply plugging numbers into a formula (Unwir, Herman, & Dahlan, 2016). In a study done by Runisah Unwir, Tatang Herman, and Jarnawi Dahlan, three classes of eighth grade math students were taught the same content. One class received instruction through the 5E learning cycle, another through the 5E learning cycle with the addition of metacognitive techniques, and the third through a conventional or traditional instructional model (Unwir, Herman, & Dahlan, 2016). After instruction, students were given a creative thinking skills posttest which assessed students' mathematical creativity; results from the posttests revealed that students who received 5E or 5E and metacognitive techniques scored significantly higher than students who received traditional instruction (Unwir, Herman, & Dahlan, 2016). Mathematical creativity is not the first thing that comes to mind when thinking about the teaching and learning of mathematics; however, it is still important for students to be able to think about problems in many ways, and this can be achieved with the 5E model.

One of the key aspects of effective mathematics teaching and learning is the facilitation of mathematical discussion and discourse. The third SMP states that students should be able to construct mathematical arguments, as well as critique the arguments of others (Council of Chief State School Officers, 2010). Further, NCTM explains that effective mathematics teaching facilitates this discourse and allows students to build their mathematics knowledge through discussion and discourse (2014, p. 10). The 5E model facilitates this communication and discourse between students, and mathematical communication was found to be improved in eleventh grade classrooms due to the use of the 5E model (Aini et al., 2019). Mathematical communication, as defined by the authors of this study, includes expressing mathematical ideas visually, orally, and in written form, as well as appropriately using mathematical symbols and terms (Aini et al., 2019). Overall, the 5E model has been shown to increase students' achievement in many aspects of science and mathematics, from mastery to communication.

Attitude and Interest

According to NCTM, it is important for students to be given the resources and support to reach high levels of mathematical success and interest (2014, p. 64). In other words, it is important for teachers of mathematics to foster a positive attitude and high levels of interest in mathematics in their students, and the 5E model has been shown to improve students' interest and attitudes towards both math and science. In a report prepared to show the origins and effectiveness of the 5E model, BSCS highlights the effect of the 5E model on students' interest and attitudes towards science (2006). This report states that the instructional model has had positive effects on attitudes towards science across grade and subject bands, including elementary students, middle and high school physical science and chemistry students, and entry-level college biology students (Bybee et al., 2006, p. 29). Similar findings have been reported in mathematics classroom; a study done with seventh-grade students in Indonesia found that there was a greater increase in mathematical disposition, or "the students' attitude and perception towards mathematics" (Nopasari, Ikhsan, & Johar, 2020, p. 2), for students who learned with the 5E model than those who did not. As NCTM described, it is important for teachers to create opportunities which foster their students' interest in mathematics. The 5E model increases interest and positive attitudes towards both math and science.

Differentiation

Another important aspect of mathematics teaching and learning is differentiating learning so that all students have the opportunity to succeed. NCTM develops this idea further, stating that teachers must provide differentiated learning opportunities so that all students can develop deep understanding of mathematics (2014, p. 72). One method of differentiation is a tiered approach. A tiered lesson allows students to branch off at some point during the lesson and take various pathways at different levels while still learning the same content (Laud, 2011, p. 49). This tiered approach can be designed in many ways; teachers can create tiers based on readiness, interest, content, or processes (Laud, 2011). As Laud explains, tiering lessons is central to differentiating instruction and offers challenges to all students, regardless of ability or background (2011). The 5E model allows for a tiered approach (Dwyer & Huling, 2018, p. 22), but the 6E model takes it one step further and specifically includes a phase of formative assessment that can guide tiered instruction during the elaborate phase (Duran, Duran, Haney, & Sheuermann, 2011). This redesigned elaborate phase in the 6E model allows teachers to meet each students' individual needs through a three-tiered approach (Duran, Duran, Haney, & Sheuermann, 2011). A study done in a third-grade classroom using the 6E instructional model found that the 6E model helped meet all students' needs by grouping them such that "misconceptions could be cleared up and challenges were low enough to not frustrate the students, but also high enough that the students would learn something new and ultimately be challenged" (Fletcher, 2011). While the 5E model does allow for differentiated instruction with strategic planning by the teacher, the 6E model builds differentiation directly into the lesson framework; this allows for easy implementation of differentiation strategies within instruction and more easily meets the needs of all students in the classroom.

Methodology

Research was conducted in two seventh grade mathematics classes at a school in Holland, Ohio. Both classes are 7^{th} grade math courses, with students performing at an average level in mathematics for their grade. Class I consisted of eleven students, while Class II consisted of twelve students. Research was conducted over two 63-minute class periods on December 7th and 8th, 2021. Before beginning the research, students completed a combined pre-survey and pre-test (see Appendix A). On the pre-test, students were asked a variety of questions that asked them to find patterns and write equations or rules for non-proportional relationships. The pre-survey included items about students' attitudes towards mathematics.

Students then began learning about non-proportional relationships and writing equations to match these relationships. Class I received instruction that followed the 6E instructional model. For the first part of the lesson, Engage, students connected what they knew about proportional relationships from previous units to non-proportional relationships using popcorn prices. Students filled in the table below (see Figure 1) with prices for popcorn if the relationship were both proportional and non-proportional.

A movie theater sells popcorn in bags of different sizes. The table shows the volume of popcorn and the price of the bag.

Complete one column of the table with prices where popcorn is priced at a constant rate. That is, the amount of popcorn is proportional to the price of the bag. Then complete the other column with realistic example prices where the amount of popcorn and price of the bag are not in proportion.

volume of popcorn (ounces)	price of bag, proportional ($)	price of bag, not proportional ($)
10	6	6
20		
35		
48		

Figure 1

Then, for the Explore phase, students used pattern blocks to create non-proportional relationships and write rules for them. Instructions for this phase can be found in Appendix B. The explore phase was followed by a class discussion in the Explain phase, where the class discussed whether or not all relationships are proportional. The final phase that was completed on the first day was the Express phase, where students completed an exit ticket to assess their understanding from the day (see Appendix C). The results from this formative assessment were used to determine which tier each student would fall into the following day in the Elaborate phase. Students who were placed into Tier I were unable to identify that the given relationship was not proportional. Students in Tier II recognized that the relationship was not proportional but could not yet determine the rule or equation represented by the relationship. Finally, students in Tier III stated that the relationship was not proportional and came up with the correct rule.

On the second day of research, students began by working on the tasks for their designated tier. In Class 1, five students were in Tier I, six were in Tier II, and no students were in Tier III. Students in Tier I worked on a What's My Rule? Task (see Appendix D), in which they were asked to (1) determine if the relationship shown was proportional or not and (2) write an equation or a rule for the relationship. Students in Tier II worked with the Pool Border Problem, which was adapted into a Desmos Classroom activity (see Appendix D). They were asked to determine how many tiles would be needed to create a border around various sizes of pools, including a pool of size *n x n*. Finally, research was concluded with students taking the post-test and post-survey, which was identical to the post-test and post-survey in Appendix A.

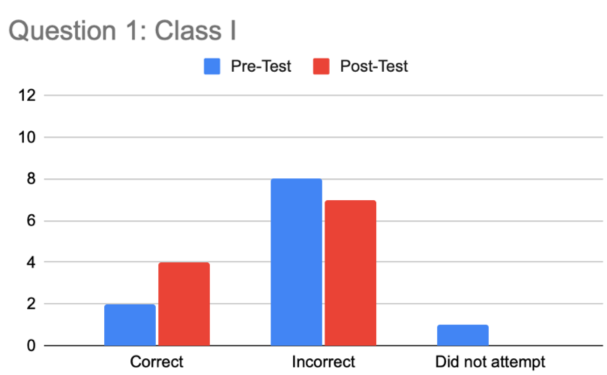
Class II received instruction using the lecture-demonstration approach. The lesson began with the same popcorn prices problem as was used with Class I. Then, the whole class completed the first pattern block train, using the square pattern block, together. Once they understood the first one, students worked individually to create the other pattern block trains and look for rules. On the second day, students were *not* placed into tiered groups. All students, regardless of their understanding, worked on the What's My Rule? Task (see Appendix D). They then completed the post-test and post-survey.

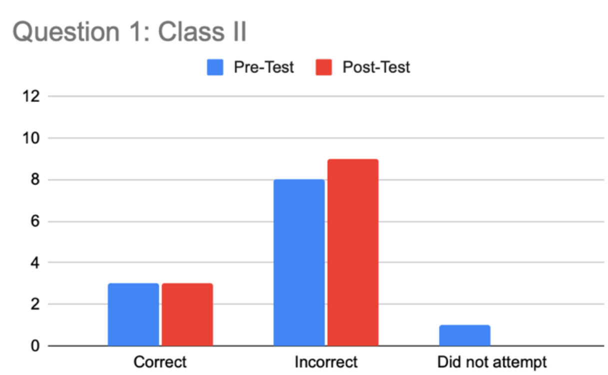
Data Analysis

Both classes took both the pre- and post- tests. In the class that received instruction through the 6E Model, Class I, 11 students completed both tests. In the class that received a more traditional, lecture style instruction, Class II, 12 students completed both tests. The pre- and post-tests consisted of 5 questions related to finding rules or equations for non-proportional relationships. The pre- and post- surveys included two questions in which students provided a written response about their feelings towards mathematics, as well as seven statements about mathematical attitudes which students responded to with "strongly disagree," "disagree," "unsure," "agree," or "strongly agree."

Pre- and Post-Test Data Analysis

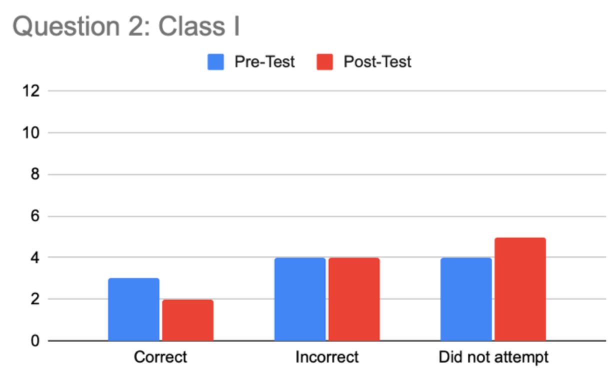
The first question on the assessments is as follows: *Elena must spend $349 on a printing machine and $4.80 per shirt for the blank shirts, ink, and other supplies. Using this rule, determine how much Elena will spend to make 6 shirts.* To receive full credit for this question, students needed to provide a response of $377.80, which is the cost of the printing machine plus $4.80 times 6 total shirts. The charts below show the comparison in pre- and post- test scores for both classes.

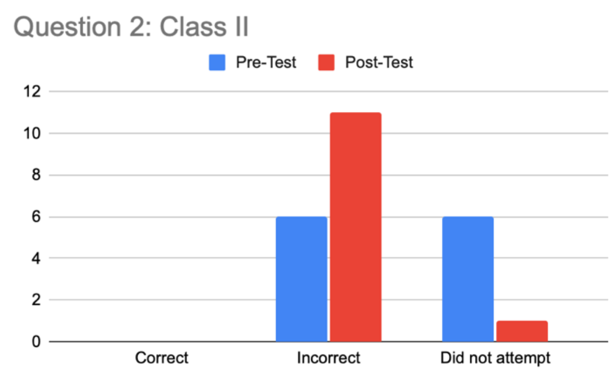




As shown in the charts, the class that received 6E instruction (Class I) improved slightly from the pre-test to the post-test. The number of students providing a correct response doubled. In the non-6E class (Class II), the number of students providing a correct response stayed the same, whereas the number of incorrect responses increased.

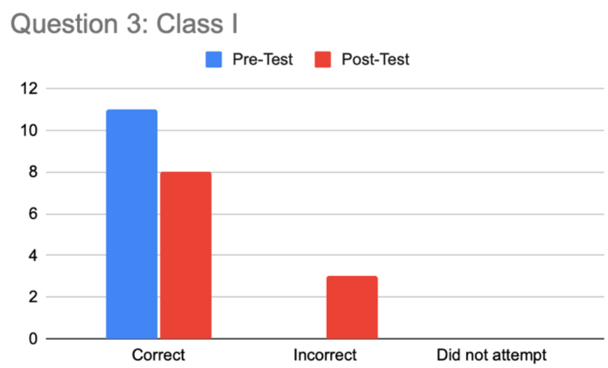
Question 2 asked students: *A sandwich store charges $20 to have 3 subs delivered, $26 for 4 subs, and $32 to deliver 5 subs. What rule does the sandwich store use to determine its delivery costs?* For this question, students received full credit for any response that show that the delivery fee was $2 plus $6 per sub. The charts below show the comparison between pre- and post- test scores for both classes.

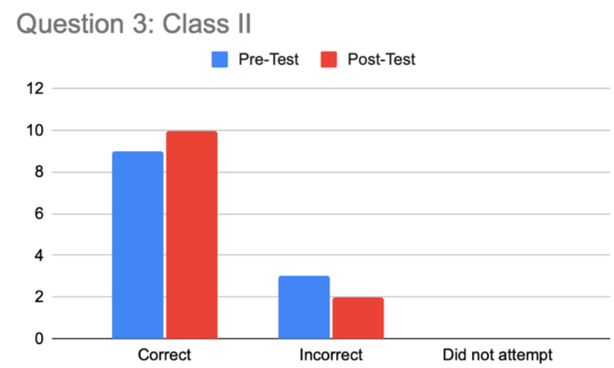


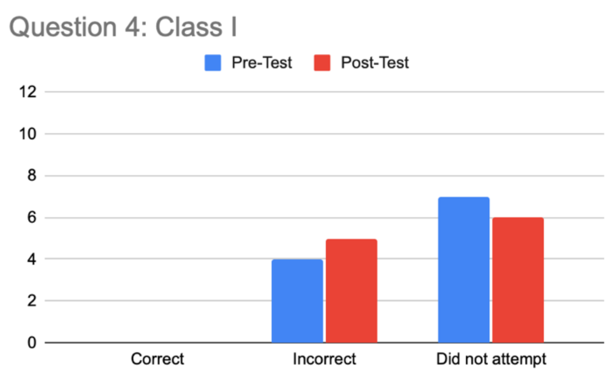


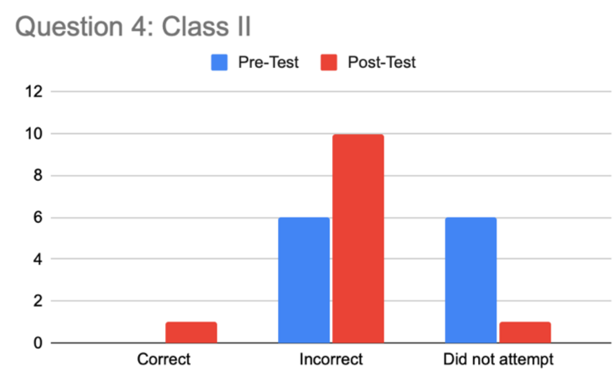
As shown, no students provided correct responses on either test in Class II. On the other hand, in Class I, 3 students answered correctly on the pre-test compared to only 2 on the post-test. This shows that students still struggled with identifying rules given a set of data, such as the sandwich costs in this question, regardless of the type of instruction they received.

For question 3 and 4, students were given a scenario and asked to determine if it was proportional or not. The scenario was as follows: *A student reads 150 pages in 1 day, 350 pages in 3 days, and 550 pages in 5 days.* This relationship is non-proportional since there exists no constant of proportionality and it cannot be written in the form $y = kx$. Then, in question 4, students were asked to either write an equation if they believed this relationship was proportional, or explain the rule being used if they believed the relationship was non-proportional. Since the relationship was not proportional, students needed to identify the rule of 50 pages plus 100 pages per day.



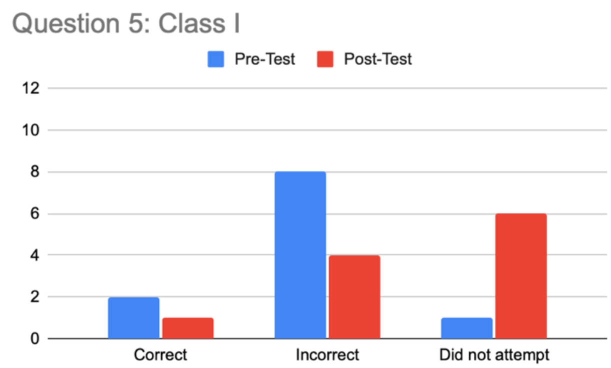


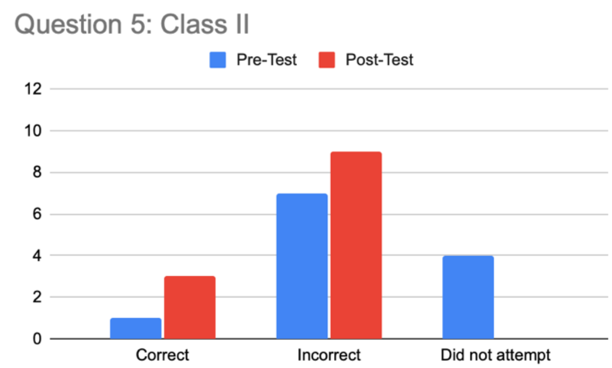




As seen in the charts above, the majority of students in both Class I and Class II correctly identified the relationship as non-proportional. This suggests that they had a strong background knowledge on proportional relationships prior to beginning the research. However, on question 4, only one student in both classes was able to correctly identify the rule being used. Like the data from question 2, this shows that students continued to struggle with identifying the rule or equation used in a scenario, regardless of the type of instruction they received.

The final question on the pre- and post- tests was: *Francisco makes $12 per hour doing part-time work. He spends $4 total on transportation to and from work. Use this information to determine how much money he makes AFTER transportation costs for five (5) hours.* To correctly answer this question, students needed to find how much money Francisco made for five hours of work and subtract the four dollars spent on transportation. The correct answer, which would receive full points, was $56.





This data shows that more students in Class II, who did not receive 6E instruction, were able to provide a correct response after the two lessons. However, it is interesting to note that more students in Class I did not attempt this question on the post-test than on the pre-test. The data shown in these charts above once again suggest that students had a better understanding of how to use and apply a rule, rather than how to identify a rule given a data set. Overall, the scores on the pre-test versus the post-tests revealed some patterns in the content understanding of students in Class I and Class II.

Pre- and Post-Survey Analysis

Students responded first with written responses to two questions. The first was *When you hear the word math, what words pop into your head? Write at least 2 words.* The second was *Do you think you are good at math? Why or why not?* For question 1, it was expected that students would write a combination of vocabulary words related to math and feelings that they associate with math. Many students provided responses with words such as “addition,” “numbers,” “fractions,” and “subtraction.” In Class I, one student’s original response was “calculations and math.” This response changed to “calculations and fun” on the post-test, suggesting that they began to associate math with the word “fun.” In Class II, the opposite shift was seen. One student responded with “anxious, excited” on the pre-test, but changed their response to “anxious, tired” on the post-test.

The second question asked students if they believed that they were good at math and to explain their response. In both classes, the majority of responses stayed the same from the pre-test to the post-test. However, in Class I, which received 6E instruction, a few students’ responses changed from a “no” to a “yes.” Their reasonings for believing that they were good at math are as follows:

- “yes, cause i pay attention most of the time”
- “yes because i can find an answer most of the time”

This showed that some students’ attitudes towards mathematics improved after receiving 6E instruction, whereas the lecture-demonstration approach had little to no effect on students’ attitudes.

For the next section of the pre- and post- survey, students were asked to select the response from a Likert scale that represented their level agreement with a given statement. Students could select from the following: “strongly disagree,” “disagree,” “unsure,” “agree,” or “strongly agree.” The survey included the following seven statements for students to respond to.

1. I like to share my ideas in math.
2. Math is fun.
3. I think I am good at math.
4. My classmates think I am good at math.
5. It is okay if I get an answer wrong when doing math.
6. I’ll need math for the job I want in the future.
7. In the past, I have not enjoyed math class.

Once again, as with the written statements, most of the students' responses stayed the same from the pre-test to the post-test. However, some changes between the pre- and post- tests can be seen. The table below shows the percentage of students responding with each of the five options to each statement in Class I.

	Strongly Disagree		Disagree		Unsure		Agree		Strongly Agree	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
I like to share my ideas in math.	27.3%	27.3%	9.1%	18.2%	36.4%	27.3%	18.2%	27.3%	9.1%	0%
Math is fun.	18.2%	27.3%	18.2%	9.1%	45.5%	45.5%	18.2%	18.2%	0%	0%
I think I am good at math.	27.3%	18.2%	27.3%	18.2%	9.1%	18.2%	18.2%	27.3%	18.2%	18.2%
My classmates think I am good at math.	36.4%	18.2%	18.2%	27.3%	36.4%	45.5%	9.1%	9.1%	0%	0%
It is okay if I get an answer wrong when doing math.	9.1%	18.2%	9.1%	0%	9.1%	0%	63.6%	54.5%	9.1%	27.3%
I'll need math for the job I want in the future.	0%	0%	27.2%	36.4%	36.4%	18.2%	27.2%	36.4%	9.1%	9.1%
In the past, I have not enjoyed math class.	9.1%	9.1%	27.2%	9.1%	9.1%	0%	18.2%	36.4%	36.4%	45.5%

Table 1

The largest change between the pre- and post- test that is shown here is with the statement "It is okay if I get an answer wrong when doing math." The percentage of students responding "strongly agree" jumped from only 9.1% to 27.3%. This suggests that students felt increasingly comfortable sharing their ideas during mathematics instruction, even if their answer or response was not correct. Another change seen here comes with the statement "I think I am good at math."

A decrease in the percentage of both “strongly disagree” and “disagree” responses can be seen. This is accompanied by an increase of 9.1% in “agree” responses, showing that some students felt more confident in their own ability to do mathematics after 6E instruction.

The table below, Table 2, shows the percentage of students responding with each of the five options to each statement in Class II, which did not receive 6E instruction.

	Strongly Disagree		Disagree		Unsure		Agree		Strongly Agree	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
I like to share my ideas in math.	0%	0%	0%	0%	50.0%	41.7%	33.3%	50.0%	16.7%	8.3%
Math is fun.	8.3%	8.3%	8.3%	0%	33.3%	33.3%	41.7%	58.3%	8.3%	0%
I think I am good at math.	8.3%	0%	8.3%	33.3%	33.3%	25.0%	41.7%	33.3%	8.3%	8.3%
My classmates think I am good at math.	8.3%	16.7%	16.7%	16.7%	33.3%	33.3%	33.3%	33.3%	8.3%	0%
It is okay if I get an answer wrong when doing math.	0%	0%	0%	0%	8.3%	8.3%	66.7%	58.3%	25.0%	33.3%
I’ll need math for the job I want in the future.	8.3%	0%	8.3%	8.3%	33.3%	50.0%	33.3%	33.3%	16.7%	8.3%
In the past, I have not enjoyed math class.	8.3%	0%	25.0%	8.3%	16.7%	25.0%	16.7%	25.0%	33.3%	41.7%

Table 2

For Class II, there was a change in the percentage of students responding to “strongly agree” for the statement “I like to share my ideas in math.” The percentage of students dropped from 16.7% to only 8.3%. It is important to note, however that Class II saw increases in responses to “strongly agree” for the statement “It is okay if I get an answer wrong when doing math.” This increase was not as high as the increase from Class I, but still shows that a small number of students felt that it was okay to not always have a correct answer when doing mathematics.

Conclusion, Limitations, and Implications

After analyzing the data from completed tests and surveys, a few patterns emerged between Class I and Class II. First, it was clear that all students, regardless of the type of instruction received, continued to have difficulties creating rules or equations given a set of data. This was shown through their results on Questions 2 and 4 on the post-test. Second, students who received 6E instruction generally performed better when applying rules. For example, with Questions 1 and 5 on the post-test, students were expected to use a given rule to find the price or cost for a new scenario. Class I, in general, performed better on these types of questions. Finally, different shifts in attitudes towards math were seen between Class I and Class II. In Class I, there were significant increases in students who believed that they were good at math and felt that it was okay if they provided a wrong answer when doing math. Further, students in Class I provided written statements suggesting that they had positive connotations for the word math. On the other hand, Class II showed decreases in the number of students who stated that they like and felt comfortable sharing their ideas in math class. This evidence suggests that students receiving 6E instruction showed generally more positive attitudes towards math and slightly out-performed peers receiving lecture-demonstration style instruction. This is consistent with the literature reviewed earlier, such as the 2013 study on the 5E model in the trigonometry classroom by Tuna and Kaçar which showed that the 5E model led to greater content mastery and knowledge permanence for students. Furthermore, the 5E model was built to increase students' positive attitudes towards science (Bybee et al., 2006), which is consistent with the shifts in attitude seen as a result of the use of the 6E model in this research.

While the research showed generally positive results regarding the use of the 6E instructional model in mathematics, there were some limitations. First, research was conducted with a total of 23 students across two seventh grade math classes. Students in these two classes performed at an average achievement level in mathematics. The sample size for this study was small. Additionally, since research was only conducted with average performing students in one grade level, results cannot be generalized to high-performing or low-performing students. Another limitation was the length of the research. Research was conducted over two 63-minute class periods. The results may have been different if students had been receiving 6E instruction for an entire unit or school year, compared to two days. If I were to do this research again, I would plan to use the 6E instructional model for a longer period of time to see long-term effects of this instructional model on students' content mastery and attitudes towards math.

Overall, this research will continue to impact my work as I continue teaching mathematics. I plan to continue incorporating the 6E instructional model into my future mathematics instruction, as it had some effect on students' attitudes towards math. One of my goals as a teacher of mathematics is to help students love math, which I believe can be accomplished by using engaging, discovery-based teaching styles like the 6E model. I hope to incorporate the 6E model, as stated earlier, for a longer period of time to see how my students perform long-term with this style of instruction. From this action research, I learned how to successfully plan and implement the 6E instructional model. Additionally, I improved my ability to use formative assessment to group and differentiate instruction, through the Express and Elaborate phases. This action research has made me a better teacher of mathematics and has given me insights into what types of instruction work best when teaching mathematics.

References

Aini, K., Hobri, Prihandoko, A. C., Yuniar, D., Faozi, A. K., & Asmoni. (2020). The students' mathematical communication skill on caring-community based learning cycle 5E. *Journal of Physics: Conference Series, 1538*.

Bill, V.V., & Jamar, I. (2010). Disciplinary literacy in the mathematics classroom. In S.M. McConachie, & A.R. Petrosky (Eds.), Content matters: A disciplinary literacy approach to improving student learning (pp. 63-85). New York, NY: Teachers College Press.

Bossé, M. J., Lee, T. D., Swinson, M., & J. F. (2010). The NCTM process standards and the five Es of science: Connecting math and science. *School Science and Mathematics, 110*(5), 262-276.

Bybee, R. W., Taylor, J. A., Gardner, A., Scotter, P., Powell, J. C., Westbrook, A., Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness.* Colorado Springs: BSCS.

Council of Chief State School Officers. (2010). *Common Core State Standards: Mathematics*. http://www.corestandards.org/Math/.

Duran, E., Duran, L., Haney, J., & Scheuermann, A. (2011). A learning cycle for all students. *The Science Teacher, 78*(3), 56-60.

Fletcher, S. (2011). *The impact of the 6E model in a third grade science classroom* (Master's thesis, Bowling Green State University).

Glasgow, N. A., Cheyne, M., & Yerrick, R. (2010). Try using the 5E model. In *What successful science teachers do: 75 resesarch-based strategies* (pp. 25-29). Corwin.

Huling, M., & Dwyer, J. S. (2018). Teaching StEMT through inquiry and the 5E instructional model. In *Designing meaningful STEM lessons* (pp. 17-25). Arlington, VA: National Science Teachers Association.

LaFave, N. J. (2012). Yes, Virginia, study habits and learning techniques are key! In *You want me to teach what?: Sure-fire methods for teaching physical science and math*. Arlington, VA: National Science Teachers Association.

Laud, L. (2011). Tiered instruction. In *Using formative assessment to differentiate mathematics instruction, grades 4-10: Seven practices to maximize learning* (pp. 49-61). Corwin.

NCTM. (2014). *Principles to actions: Ensuring mathematical success for all*. Reston, VA: NCTM.

Nopasari, W., Ikhsan, M., & Johar, R. (2020). Improving mathematical understanding and disposition of junior high school students through the 5E learning cycle model. *Journal of Physics: Conference Series, 1460*.

Tuna, A., & Kaçar, A. (2013). The effect of 5E learning cycle model in teaching trigonometry on students' academic achievement and the permanence of their knowledge. *International Journal on New Trends in Education and Their Implications*, *4*(1), 73–87.

Unwir, R., Herman, T., & Dahlan, J. A. (2016). The enhancement of students' creative thinking

Appendix A

Pre-Test, Pre-Survey, Post-Test, and Post-Survey

Unit 6 Pre-Test & Survey

Please complete the following Unit 6 Pre-Test during class today. You may use a handheld calculator to help you complete the pre-test.

Remember that this is a PRE-test and will not be taken for a grade. Do your best, but we're going to be learning this over the next few days, so it is okay if you don't ace this pre-test. :)

(not shared) Switch account

* Required

Name *

Your answer

Period *

○ 1

○ 2

○ 3

○ 4

Pre-Test

Elena must spend $349 on a printing machine and $4.80 per shirt for the blank shirts, ink, and other supplies. Using this rule, determine how much Elena will spend to make 6 shirts. *

Your answer

A sandwich store charges $20 to have 3 subs delivered, $26 for 4 subs, and $32 to deliver 5 subs. What rule does the sandwich store use to determine its delivery costs? *

Your answer

Determine if the following relationship is proportional or not: A student reads 150 pages in 1 day, 350 pages in 3 days, and 550 pages in 5 days. *

- Proportional
- Non-proportional

If you chose "proportional" for the previous question, write an equation that represents the relationship between pages and days. If you chose "non-proportional" for the previous equation, explain the rule that can be used to find the number of pages the student reads each day. *

Your answer

Francisco makes $12 per hour doing part-time work. He spends $4 total on transportation to and from work. Use this information to determine how much money he makes AFTER transportation costs for five (5) hours. *

Your answer

Pre-Survey

When you hear the word math, what words pop into your head? Write at least 2 words. *

Your answer

Do you think you are good at math? Why or why not? *

Your answer

For the next questions, use the dropdown menu to choose the answer that best matches how you feel about the given statement.

I like to share my ideas in math. *

Choose

Math is fun. *

Choose

I think I am good at math. *

Choose

My classmates think I am good at math. *

Choose

It is okay if I get an answer wrong when doing math. *

Choose

I'll need math for the job I want in the future. *

Choose

In the past, I have not enjoyed math class. *

Choose

Appendix B

Pattern Block Trains Instructions

Name:__________________ Date:______ Period:_____

Pattern Block Trains

Use the provided pattern blocks to create pattern block trains. Determine the perimeter for a train made of 1-10 pattern blocks and then determine a rule for the perimeter of any pattern block train. Use your rule to determine the perimeter of a pattern block train with 20 blocks in it. Assume that the length of each side of the pattern blocks is 1.

1. Squares:

Number of Blocks in Train	Perimeter
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Rule for the perimeter of square trains:

Perimeter of a square train made with 20 blocks:

2. Trapezoids:

Number of Blocks in Train	Perimeter
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Rule for the perimeter of trapezoid trains:

Perimeter of a trapezoid train made with 20 blocks:

3. Rhombuses:

Number of Blocks in Train	Perimeter
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Rule for the perimeter of rhombus trains:

Perimeter of a rhombus train made with 20 blocks:

4. Hexagons:

Number of Blocks in Train	Perimeter
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Rule for the perimeter of square trains:

Perimeter of a square train made with 20 blocks:

Appendix C

Express Phase Exit Ticket

Name:____________________ Date:______ Period:______

What's My Rule?

The following table shows the price a family pays at the amusement park based on how many game tickets they purchase.

Number of Game Tickets	Price
1	$22
2	$24
4	$28
10	$40

Determine if this relationship is proportional or not. If it is proportional, write an equation in the form $y=kx$ to represent it. If it is not proportional, explain the rule used to determine the price the family pays.

Appendix D

Tiered Instructional Materials

What's My Rule?:

What's My Rule?

For each question, determine if the relationship shown in the table is proportional or not. If it **is proportional**, write an equation. If it **is not proportional**, determine the rule that is being used. Write the rule using words, numbers, or a drawing.

1. A state park charges an entrance fee based on the number of people in the vehicle. The table shows the entrance fee for three different cars.

Number of People	Entrance Fee ($)
2	14
4	20
8	32

Equation or Rule:

Use your equation or rule to determine what the entrance fee for a bus with 30 people on it would be.

2. A store buys cases of paper towels to sell in its store. The table shows how many paper towel rolls they receive for the number of cases they buy.

Number of Cases	Number of Paper Towel Rolls
1	12
3	36
5	60
10	120

Equation or Rule:

Use your equation or rule to determine what the number of paper towel rolls would be for 25 cases.

3. The table below shows the price a store charges depending on the number of t-shirts bought.

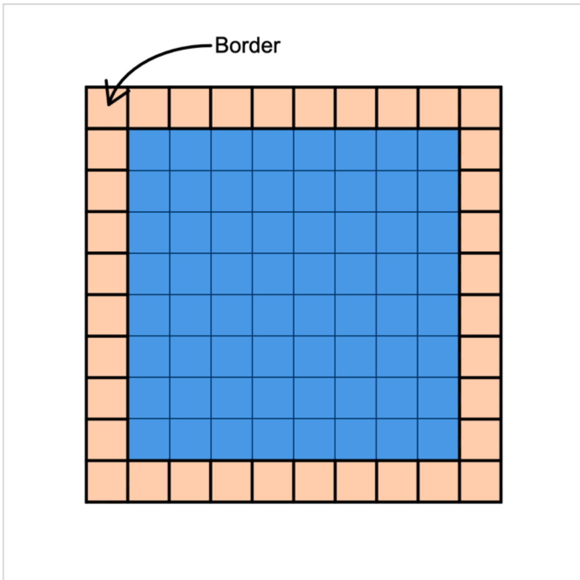
Number of Shirts	Price ($)
1	5
2	9
5	21
15	61

Equation or Rule:

Use your equation or rule to determine what the price for 10 shirts would be.

Desmos Pool Border Problem:

What is your job?



Your job is to buy the right number of tiles for the border of different swimming pools.

Continue to the next screen when you're ready.