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Testing the Effects of Professional Development on Elementary Pre-Service Teachers' Beliefs about Mathematics Inquiry Instruction

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TESTING THE EFFECTS OF PROFESSIONAL DEVELOPMENT ON ELEMENTARY PRE-SERVICE TEACHERS' BELIEFS ABOUT MATHEMATICS INQUIRY INSTRUCTION

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By

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ABSTRACT

In this study, a professional development (PD) seminar was designed and implemented with elementary pre-service teachers (*n*=20) enrolled in a mathematics content course at a small Midwestern university. The central focus of the PD was on bringing inquiry, specifically the 5E model, into mathematics instruction at the elementary level. The structure of the PD followed the 5E model format and participants learned about inquiry through inquiry. The study utilized a pre-post-test design and measured participants' knowledge about the 5E model and beliefs about using inquiry in elementary mathematics instruction. Statistically significant growth from pre-test to post-test appears in the four variables tested: 5E content knowledge, beliefs about using inquiry in mathematics, self-efficacy to implement inquiry, and intentions to use inquiry.

Keywords: Professional development, Pre-service teachers, Beliefs, Inquiry mathematics education

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CHAPTER ONE

INTRODUCTION

As the number of science, technology, engineering, and mathematics (STEM) career options continue to increase, there becomes a greater need to maximize student potential and encourage the pursuit of studying in the STEM disciplines (PCAST, 2012). The increase in STEM career options has led to a paradigm shift in teacher pedagogy, especially in the field of mathematics (PCAST, 2012). In fact, current reform efforts suggest the use of inquiry-oriented instruction (NCTM, 1991) or the use of student-centered pedagogy that increases student learning through investigation and context of real-world problems (Supovitz, Mayer & Kahle, 2000). One specific research-based instructional model with these important characteristics is the 5E. The 5E model of inquiry includes strategies for active learning, student engagement, and specific instructional focus through 5 distinct stages: Engagement, Exploration, Explanation, Elaboration, and Evaluation (Bybee et al., 2006; Bybee, 2014).

In order to propel the reform movement in mathematics, the Common Core State Standards (CCSS) were created to stress conceptual understanding of ideas with emphasis on a return to organizing principles. However, this pedagogical emphasis is a stark shift away from how mathematics has been historically taught which has been through direct instruction, using standards that mainly required recalling formulas or basic arithmetic facts without having to show understanding of the concept ("Old Standards v. Common Core," n.d.). Now educators – both in-service and pre-service – are expected to create instructional opportunities within mathematics that meet the CCSS and challenge students to develop mathematical thinking skills that prepare them for college, career, and life beyond K-12 school. Two key components necessary to facilitate this pedagogical shift are teachers' beliefs about how mathematics should be taught and their knowledge of creating inquiry-based mathematics lessons.

Teachers' beliefs - "an individual's judgment of the truth or falsity of a proposition" - are influenced by the specific individual's experiences (Pajares, 1992, p. 316). Beliefs serve as a basis for subsequent action (Pajares, 1992) and "are a crucial component of teachers' pedagogical content knowledge" (Forbes & Zint, 2010, p.31). Pre-service teachers' beliefs about how mathematics should be taught and their perception of their own capabilities to teach math (i.e., self-efficacy) are shaped from their experiences as students during K-12 school (Pajares, 1992) then further developed during teacher preparation (Lortie, 1975). As a result of mathematics often being taught in an authoritarian manner at both the K-12 and post-secondary levels, many elementary pre-service teachers believe that mathematics means applying formulas without providing authentic classroom experiences as one would find in an inquiry-based classroom (see Szydlik, Szydlik & Benson, 2003). Furthermore, research suggests that pre-service elementary teachers experience high levels of mathematics anxiety (Bursal & Paznokas, 2006; Gresham, 2007) have negative views of mathematics (Cady & Rearden, 2007), feel ill-prepared to teach mathematics due to deficiencies in their mathematical content knowledge (MCK) and pedagogical content knowledge (PCK; Vinson, 2001), and have low self-efficacies to teach mathematics (Beswick, 2006; Bursal & Panznokas, 2006; Swars, Daane, & Giesen, 2006). Therefore, in order to change how mathematics instruction is implemented in the elementary classroom (i.e., through inquiry-based pedagogies), pre-service teachers' beliefs, knowledge, and skills for implementing inquiry must change.

While teacher education programs train pre-service teachers to use more constructivist approaches to education, pre-service teachers need additional training to help them become proficient in meeting this pedagogical shift. One method of training is through Professional Development (PD) seminars. In fact, many recent efforts to improve mathematics instruction have focused on professional development (McCaffrey, Hamilton, Stecher, Klein, Bugliari, & Robyn, 2001) and show that teachers' knowledge, beliefs, and instructional strategies can be transformed through effective PD opportunities (Boston & Smith, 2009; McMeeking, Orsi, & Cobb, 2012). Unfortunately, an effective PD can have many different characteristics depending upon the audience. By utilizing the ideas found in current reform efforts for the classroom, a PD can be made more effective by providing active and engaging opportunities for teachers to deepen knowledge (Garet, Porter, Desimone, Birman, & Yoon, 2001; Heck, Banilower, Weiss, & Rosenburg 2008). The 5E model of inquiry instruction (Bybee, 2014; Bybee et al., 2006) might serve as a viable format to organize a PD about the 5E model as it should engage participants in learning the content and enhance their beliefs about teaching mathematics through inquiry.

Therefore, the present study had two aims: (1) to design and implement an effective PD seminar that would train elementary pre-service teachers on the 5E model of inquiry instruction (Bybee, 2014; Bybee et al., 2006) for teaching mathematics and (2) to test the effectiveness of the PD on participants' beliefs towards inquiry-based instruction within mathematics. Specifically, we wanted to determine if the one-day PD about designing inquiry-based lessons for mathematics would affect elementary pre-service teachers' knowledge of the 5E instructional model and their beliefs about, perceived capacities, and intentions to use inquiry for mathematics teaching.

CHAPTER TWO

LITERATURE REVIEW

Mathematical and Pedagogical Content Knowledge

Pre-service teachers enter teacher education programs with at least 13 years of experience as students. During those 13 years, pre-service teachers develop knowledge of different content areas – germane to this study, mathematics. In what Lortie (1975) has termed apprenticeship observation, pre-service teachers form knowledge– both mathematical content knowledge (MCK) and pedagogical content knowledge (PCK) (Shulman 1986; Thames, & Phelps, 2008). MCK refers to both the conceptual knowledge – i.e., knowing the concepts (e.g. understanding the use of zeros with place value problems) and the procedural knowledge, which is knowing how to do the math (e.g. step-by-step instructions for solving two-step linear equations) (Newton, Evans, Leonard, & Eastburn, 2012). Research suggests that pre-service elementary mathematics teachers lack MCK – that is, a deep conceptual understanding of the mathematics content knowledge needed to teach (Ball, Hill, & Bass, 2005; Newton, Evans, Leonard, & Eastburn, 2012). Due to the lack of knowledge and understanding, many pre-service elementary teachers have high levels of mathematics anxiety (Bursal & Paznokas, 2006; Gresham, 2007), so they perceive they are less competent than those with lower mathematics anxiety (Ashcraft & Moore, 2009).

PCK refers to the knowledge that teachers should possess in order to be able to teach (Shulman, 1986) and includes knowing how to encourage student responses and how to respond to correct and incorrect answers, how to make the subject more understandable to students, and how to identify misconceptions (Archambault & Crippen, 2009). PCK influences the instructional strategies that a teacher will choose to use in their classroom (Clark, et al., 2014; Phillip, et al., 2007). PCK can be influenced by content knowledge as it often takes a deeper understanding of the subject in order to figure out appropriate methods to use to help novices learn the material -- especially in an inquiry-based classroom (Clark, et al., 2014). PCK can be a strong predictor of student learning, as teachers with stronger PCK tend to challenge and assess their students with more cognitively demanding activities as opposed to those teachers with weaker PCK's who tend to focus on activities and assessments that measure basic arithmetic facts (Baumert, et al., 2010). Therefore, developing adequate MCK and PCK is important for effective instruction and a major plight for teacher education programs. In fact, teacher education and Professional Development should address both MCK and PCK in ways that advance mathematics content knowledge while fostering effective pedagogical practices (Georges, Borman, & Lee, 2010). In order to advance MCK, mathematical content should be challenging to pre-service elementary teachers. As such, pre-service elementary mathematics teachers should learn mathematics above the level that they will be teaching so they have a deep, conceptual understanding of the mathematics.

Pre-service Teacher Beliefs

As apprentices in the classroom, pre-service teachers also develop beliefs about how mathematics should be taught as well as their perceptions of their own abilities to teach – i.e., self-efficacy (Bandura, 1997; Lortie, 1975; Pajares, 1992). Beliefs about teaching, as well as, self-efficacy beliefs are influenced by mastery experiences (i.e. personal success or failure), vicarious experience (i.e. observations of others), verbal persuasion (i.e. motivation or praise), and affective states (i.e. stress and emotions) (Bandura, 1997; Pajares, 1992). Beliefs serve as a lens through which new information is viewed and evaluated prior to internalization and action. In other words, beliefs mediate the relationship between knowledge and practice (Pajares, 1992; Wilkins, 2008). For example, pre-service teachers having high self-efficacy beliefs for learning and teaching the mathematics content are more likely to seek out challenges, persist during times of difficulty, utilize creative problem-solving strategies (Pajares, 1996) and have lower mathematics anxiety (Hoffman, 2010; Jain & Dawson, 2009). Therefore, beliefs influence future actions, which for teachers, includes the pedagogical choices that they make in the classroom. (Pajares, 1992; Richardson, 1996; Thompson, 1992; Forbes & Zint, 2010).

Once beliefs become well established, they are more difficult to change (Bandura, 1997; Pajares, 1992). Luckily, pre-service teachers' beliefs are quite malleable during teacher preparation. For example, research suggests that pre-service teachers' self-efficacy beliefs for teaching mathematics increase during their methods courses, but decline during student teaching (Newton, Evans, Leonard, & Eastburn, 2010, p. 290). The decrease during student teaching is likely the result of decreased support during a very demanding time. Thus, addressing pre-service teachers' beliefs about the teaching of mathematics is more advantageous during teacher preparation because pre-service teachers' beliefs are more susceptible to change during that time period (Decker, Rimm-Kaufman, 2008).

Role of Teacher Education

The purpose of teacher education is to challenge what pre-service teachers have learned about different ways of teaching from their years as students, teach pre-service teachers to put what they learn into action, and show that teaching is complex (Darling-Hammond & Bransford, 2007). Unfortunately, as a result of forming knowledge and beliefs while acting as students, many pre-service teachers enter teacher education programs with false mental models (i.e. misconceptions) of what and how to teach mathematics. For example, most pre-service mathematics teachers enter teacher education programs with the idea that it is their job to dispense formulas, rules, and procedures to their students because most pre-service mathematics teachers learned mathematics in this way (Phillip et al., 2007; Stipek et al., 2001). In order for pre-service teachers' conceptions to change, their current beliefs about teaching must be challenged and found dissatisfying, and the new belief must be intelligible, plausible, and appear fruitful (Pintrich, Marx, & Boyle, 1993; Posner, Strike, Hewson, & Gertzog, 1982).

In response to the reform movements in mathematics, advocated by NCTM and the CCSS, teacher education programs are now encouraging prospective teachers to adopt constructivist pedagogies which stray pre-service teachers away from solely dispensing knowledge to eliciting student responses and helping students construct their own understanding of the mathematical content (Grossman, Hammerness, & McDonald, 2009;

Holt-Reynolds, 2000; MacPhail, Tannehill, & Karp, 2013). One such pedagogy that meets the aforementioned constructivist goals is inquiry. "Inquiry is a process of learning that is driven by questioning, thoughtful investigating, making sense of new information, and developing new understandings" (as cited in Diggs, 2009, p. 31). Inquiry-based mathematics is different from traditional mathematics in that students work in small groups and utilize whole-class discussion to construct their own mathematical understandings that they will explain to their peers (Chapko & Buchko, 2004). When implementing inquiry in the classroom, the student is viewed as an active learner in the classroom by discovering and constructing mathematical relationships while the teacher is the facilitator (Herrera & Owens, 2001).

Although teacher education programs strive to change pre-service teacher's beliefs, the programs – on their own -- are usually not enough. During teacher education, pre-service teachers may add new beliefs to their prior beliefs; however, when challenged, pre-service teachers will often revert back to their firmly established beliefs -- e.g., didactic instruction rather than constructivist (Patrick & Pintrich, 2001). PDs offer another venue to reinforce new views that are learned in teacher education and potentially help to clear misconceptions that may have formed. Self-efficacy beliefs can also be challenged and improved during PDs as a result of participants using the opportunity to practice newly learned skills.

Professional Development and the 5E Model of Inquiry

One specific model of inquiry that will meet the shifting pedagogical needs is the 5E model of instruction. During the 5E each student will go through 5 distinct stages:

engagement, exploration, explanation, elaboration, and evaluation, with the teacher as the facilitator.

Engagement, the first stage in the 5E model of instruction, engages the students in the topic. The teacher may present the students with a problem, situation, or event to challenge thinking and spark student interest. The engagement should make connections to past experiences and disrupt students' equilibrium (i.e. provide opposition to already formed opinions) (Bybee, et al., 2006: Bybee, 2014). For example, when teaching the concept of two- and three-dimensional shapes, a potential engagement would be: The teacher will tell the students that she is building a house and the architect wants them to review the blueprint or plan for accuracy. The teacher asks the students if they know what an architect is and what they do. Then she shows them the blueprint and presents the challenge: To figure out what types of two-dimensional shapes are in the plan for the house and to figure out how to make those two-dimensional shapes three-dimensional.

The lesson would then transition into the Exploration. The exploration phase of the model would require student engagement in an activity that allows students to discover new skills, think, and investigate, test, make decisions, or problem-solve, collect information, and establish relationships and understanding of the targeted content (Bybee, et al., 2006; Bybee, 2014). During the Exploration phase, the teacher encourages students to work together in their groups, observes and listens to the students, and asks probing questions to redirect student thinking. Students think freely within the limits of the activity, test predictions and hypotheses, records observations and ideas, and make judgments. For example, a possible exploration connected to the architect lesson would be: Students work together in groups to find all two-dimensional shapes in the architect's blueprint. Each group of students would then create a three-dimensional model of the two-dimensional shapes using construction paper, tape, glue, etc. provided by the teacher.

Explanation, the third phase of the model, allows for the teacher and students to collectively analyze and make sense of their findings from the exploration activity. During this phase, students' understanding is clarified or modified to the point where concepts, processes, or skills become plain, comprehensible, and clear (Bybee, et al., 2006; Bybee, 2014). The teacher will encourage students to explain the concepts in their own words, ask for evidence from students, and formally provide definitions or new labels using the students' previous experiences as a basis for explaining. Students will explain possible solutions, listen to and possibly question other students' explanations, and try to comprehend any explanations that are provided by the teacher. An example explanation for a mathematics lesson might be: As a class, students discuss the three-dimensional shapes they created. Individual groups will provide descriptions for what they discovered, showing their work making sure to demonstrate the difference between two- and three-dimensional shapes. The teacher will facilitate the discussion between the students and introduce definitions such as cube, pyramid, face, and vertex.

In the next stage, the Elaboration, student thinking is expanded or solidified through an activity that applies to a real-world situation. The activity should provide an extension to the content being explored (Bybee, et al., 2006; Bybee, 2014). During the elaboration the students will apply new labels, definitions, and skills in similar situations, use previous information to ask questions and propose solutions, and draw reasonable conclusions from evidence. One possible elaboration idea would be: In groups, students will extend their thinking by acting as architects. They will use their new knowledge of three-dimensional shapes to create a plan for their dream house. Students will then create a model of the dream home using some pre-made shapes and any shapes they want to create on their own, thus transferring and applying the knowledge they have actively constructed during the prior E's.

The final stage of the 5E model is the Evaluation. Evaluation occurs throughout the lesson, which allows the teacher to assess student performance or understanding of concepts, skills, processes, and applications (Bybee, et al., 2006; Bybee, 2014). During the evaluation the teacher assesses students' knowledge or skills, looks for evidence that the students have changed their thinking or behaviors, allows students to assess their own understanding, and asks open-ended questions. The students will answers open-ended questions using evidence, demonstrate an understanding of the concept or skill, evaluate his/her own progress, and ask related questions that could encourage future investigation. Even though the Evaluation is considered the final stage, evaluation occurs both throughout the lesson and at the end. Formative evaluation often occurs throughout all the stages of the lesson. Often formative evaluation occurs through questioning. Summative evaluation usually occurs at the end of the lesson and can take many forms (e.g., exit slip, observation checklist, quiz). Regardless, it is important that students receive feedback. Students should also be encouraged to assess their own understanding using appropriate assessment tools provided by the teacher or co-developed in conjunction with the students. An example of a summative evaluation would be: Students will complete an exit slip with three questions regarding two- and three-dimensional shapes. Each student will complete this individually to demonstrate what he/she has learned. The teacher will compare the results to each student's bell-ringer outcome.

While the 5E model of inquiry is typically applied to classroom lessons, a variety of courses and workshops are offered to help teachers understand the 5E model of instruction or are developed using the model (Bybee, et al., 2006). The PD created for this study was structured to resemble the 5E model. By using the 5E model to construct a PD, the participants are learning new teaching methods (i.e., building PCK) in the same way that their students will be learning new mathematical ideas, thus reinforcing the newly learned content.

Beginning with the engagement, the participants were immersed in a full 5E model lesson (see Appendix A). The 5E model lesson was designed for a high school mathematics classroom and explored the topic of repeatable permutations. The lesson demonstrated a variety of aspects that are central to the 5E model of teaching, including capturing student attention at the beginning and accessing prior knowledge. The activities in the lesson were group-oriented, with each team member assigned a task. During the explanation, the participants derived the formula for repeatable permutations with scaffolding from the teacher. The evaluation showed another practice of student self-assessment as it allowed students to see how well they knew the material.

In the exploration phase of the PD, participants were challenged to deconstruct the lesson in an attempt to compare and contrast their learning experience and lesson format to other types of mathematics lessons they have experienced during their learning career (e.g., lecture, direct instruction, inquiry). Each participant was given 15 minutes to fill out a 4-question discussion guide (see Appendix B). Each question created for the discussion guide was open-ended, requiring more than just a yes or no answer.

During the explanation phase of the PD, the entire class deconstructed the lesson. Using the questions from the discussion guide as a starting point, the 5E model of inquiry was introduced at this point. Each participant was given a specially designed 5E flipbook (see Appendix C). The flipbook contained a brief description of each of the 5 E's with information about the teacher's role, the student's role, and suggested formatting for activities within each E.

The PD then transitioned to the elaboration phase. During this part of the PD, the participants were paired and challenged to create the beginnings of their own 5E lesson on the topic of similar and congruent triangles (see Appendix D). Due to time constraints, the PD focused on the participants' engagement and exploration ideas. After brainstorming, each group chose their best engagement and exploration ideas to present to the larger group. Using a gallery walk technique, each group then shared their ideas with the rest of the participants and received feedback on their ideas. In the evaluation phase of the PD, participants completed an assessment measuring both their PCK about the 5E model of inquiry and their beliefs about inquiry.

<u>Summary</u>

Teacher education programs are working diligently to train pre-service elementary teachers to meet the demands of current mathematical reform efforts (Darling-Hammond & Bransford, 2007). Unfortunately, the research indicates that pre-service elementary teachers are experiencing difficulties – lacking MCK and PCK for teaching mathematics (Ball, Hill, & Bass, 2005; Clark, et al., 2014; Newton, Evans, Leonard, & Eastburn, 2012), experiencing high levels of mathematics anxiety, and feeling ill-prepared to teach mathematics (Bursal & Paznokas, 2006; Gresham, 2007;Vinson, 2001). Research shows that teachers' knowledge, beliefs, and instructional strategies can be transformed through effective PD opportunities (Boston & Smith, 2009; McMeeking, Orsi, & Cobb, 2012). Therefore, we wanted to answer the following questions to determine if pre-service elementary teachers would benefit from participating in a one-time PD:

1) Do pre-service teachers' beliefs about using inquiry-based practices in mathematics instruction change?
2) Do pre-service teachers' self-efficacy (competence) beliefs for implementing inquiry in the classroom increase?
3) Do pre-service teachers' intentions to use inquiry-based practices in future mathematics instruction change?
4) Do pre-service teachers' knowledge about the 5E model increase?

CHAPTER THREE

METHODS

Data Sources

The participants of this study were 20 elementary pre-service teachers enrolled in a mathematics content course at a small Midwestern university. The sample was comprised of 95% females and 5% males. One-quarter of the participants were minority races (Black and Hispanic) with the remaining three-quarters of the participants being white. At the sample university, the mathematics content courses precede pedagogy courses during the elementary teacher education program; therefore, the majority of participants in the sample had no formal pedagogical training for teaching mathematics or inquiry instruction.

Instrumentation

In the current study, beliefs were measured using a modified version of the measures created and implemented by Forbes and Zint (2010). Their measures consisted of 10 parallel items that represented scientific inquiry practices with three different questions to evaluate participants' beliefs, perceived competencies, and reported engagement in inquiry-based teaching for environmental issues. Their analyses indicated strong internal consistency among the 10 items and the three factors accounted for 69% of the variance in the scores.

For the current study, each scale used 7 parallel items – 5 from the original measures plus two additional items that incorporated specific language from the 5E model of inquiry for teaching mathematics (e.g., *"Perform investigation and gather data about mathematical concepts"*). To measure participants' beliefs about using inquiry-based practices in mathematics instruction, participants rated each item on a 7-point Likert scale assessing the degree to which they agreed with the following question: "When I am teaching mathematics, I should design instruction that requires my students to…." ($\alpha_{pre} = 0.93$, $\alpha_{post} = 0.87$). To measure participants' competency beliefs (i.e., self-efficacy) for implementing inquiry-based instruction in mathematics, participants rated each item on a 7-point Likert scale assessing the following question: "How confident are you in your current abilities to design instruction that requires your students to…" ($\alpha_{pre} = 0.94$, $\alpha_{post} = 0.93$). To measure participants' intentions to use inquiry-based practices in future mathematics instruction, participants rated each item on a 7-point Likert scale assessing the likelihood of the following question: When I am teaching mathematics, I intend to design instruction that requires my students to…." ($\alpha_{pre} = 0.96$, $\alpha_{post} = 0.88$).

Knowledge about the 5E model of inquiry was also measured using a seven question matching and short-answer assessment which was created specifically for the study (see Appendix E). Each question required the participants to match the description given with the stage of the 5E model that was being described. Participants then had to justify their choice by providing 3 specific characteristics of the stage chosen in an open-response format. Questions were assessed using an instructionally aligned rubric. Total score was calculated as a percentage of items correct (0-100).

Procedure

The overarching goal of the project was to test the effects of the PD on elementary pre-service teachers' beliefs about teaching mathematics using inquiry-based practices – specifically the 5E model of instruction. One week prior to the implementation of the PD, participants completed the pre-assessment measures to get a baseline of their knowledge and beliefs about inquiry and the 5E model of instruction. The structure of the PD followed the 5E model format. The PD occurred in a 2.5-hour time frame, and participants took home resources to further their knowledge of the 5E model of instruction and to finish their lessons.

Analyses

In order to answer the research questions one-way, repeated measures analysis of variance (ANOVA) was conducted using the IBM SPSS 23 statistical program. A one-way, repeated measures ANOVA is appropriate to measure the change in beliefs and knowledge from pre- to post-test within a single sample. A p-value less than .05 on any of the constructs (i.e., 5E content, beliefs, self-efficacy, and intentions) demonstrates statistically significant change from pre-test to post-test. To evaluate the importance of the findings and determine the relative magnitude of the differences between the means, we calculated partial eta squared as a measure of effect size. Partial eta squared effect size statistics indicate the proportion of variance of the dependent variable that is explained by the independent value (Tabachinick & Fidell, 2013) or how large the difference between groups actually is (Levine & Hewitt, 2002). To interpret the strength of the effect sizes detected in this study, I used the guidelines proposed by Cohen (1988): small = .01, medium = .06, and large = .138.

CHAPTER FOUR

RESULTS

Prior to conducting the comparison analyses, the data were checked to ensure that they met the assumptions of normality, independence, and homogeneity of variance. Table 1 summarizes the descriptive and inferential findings of the four variables of interest: 5E content, beliefs about inquiry, self-efficacy for inquiry, and intentions to use inquiry. Using a repeated measures ANOVA with a Greenhouse-Geisser correction, there was statistically significant growth from pre-test to post-test in all four variables: 5E content (M_{pre} = 27.98, SD = 16.67; M_{post} = 36.90, SD = 16.80), $F(1, 17) = 5.43$, $p = .03$, beliefs about inquiry (M_{pre} = 5.75, SD = 0.97; M_{post} = 6.52, SD = 0.48), $F(1, 17) = 16.00$, $p = .001$, self-efficacy for inquiry (M_{pre} = 5.02, SD = 1.17; M_{post} = 6.09, SD = 0.80), $F(1, 18) = 15.46$, $p = .001$, and intentions to use inquiry (M_{pre} = 5.98, SD = 0.97; M_{post} = 6.62, SD = 0.47), $F(1, 18) = 11.53$, $p = .003$. Effect sizes for all four variables were strong– 5E content (partial $\eta^2 = 0.24$), beliefs about inquiry (partial $\eta^2 = 0.49$), self-efficacy for inquiry (partial $\eta^2 = 0.46$), and intentions to use inquiry (partial $\eta^2 = 0.39$).

Table 4.1

Descriptive and Inferential Statistics for All Variables

	Pre-Test	Post-Test	Δ	*F*	partial η^2
5E Content	27.98 (16.67)	36.90 (16.80)	+8.92	5.43	0.24
Beliefs	5.73 (0.97)	6.52 (0.48)	+0.79	16.00	0.49
Self-efficacy	5.02 (1.17)	6.09 (0.81)	+1.07	15.46	0.46
Intentions	5.98 (0.97)	6.62 (0.47)	+0.64	11.53	0.24

Note. Standard deviations appear in parentheses next to the means.

CHAPTER FIVE

DISCUSSION

Research suggests that pre-service teachers enter their teacher preparation programs with well-established beliefs about teaching and learning (Lortie, 1975; Pajares, 1992). Once beliefs are established, they are unlikely to change unless challenged (Pajares, 1992). Since most elementary pre-service teachers believe that mathematics should be taught through applying memorized formulas and procedures (Szydlik, et al., 2003), providing opportunities to experience inquiry-based mathematics lessons and professional development (PD) training should challenge the pre-existing beliefs of how mathematics should be taught and inspire potential belief change.

In our study, the findings indicated that elementary pre-service teachers benefitted from a one-time PD about the 5E model of inquiry instruction. By engaging in a PD that required participants to actively investigate inquiry through inquiry, pre-service teachers demonstrated an increase in knowledge about the 5E model (Bybee, 2014), albeit the scores indicate a novice understanding. This finding was to be expected, however, since participants had little to no exposure to the 5E model prior to the PD, and one 2.5 hour session was not enough to help them gain more than a preliminary understanding. By utilizing the 5E model to structure the PD, participants were provided with more opportunities to be engaged throughout the seminar, which some research suggests can be an integral part of an effective PD (Garet et al., 2001; Heck et al. 2008).

In addition, participants believe very strongly that they should design instruction using inquiry-based methods and intend to do so in the future. They also appear to be extremely confident (i.e., highly efficacious) in their abilities to design instructional opportunities using inquiry-based methods. Considering that participants in this study are very early in their educational careers and have had little to no formal pedagogical training outside of the study PD, it would seem plausible that these scores reflect an inflated perception of their capabilities (Pajares, 1992) or "unrealistic expectations" about teaching in general and personal abilities (Weisnstein, 1988, p.32). Continued mastery experiences where pre-service teachers experience success and failure will help to make their self-efficacy beliefs more realistic (Bandura, 1997). However, the finding is positive, as having strong favorable beliefs towards using inquiry during mathematics instruction will influence future instructional decisions (Pajares, 1992; 1996).

While many professional development seminars are commonly criticized for being too short or offering limited follow-up (Penuel, Fishman, Yamaguchi, Gallagher, 2007), it is encouraging to see the impact of a one-time inquiry-based PD on elementary pre-service teachers' 5E content knowledge and beliefs about using inquiry to teach mathematics. Although the 5E instructional tool was not originally designed as a model for structuring professional development workshops (Bybee et al., 2006), findings from this study indicate that elementary pre-service teachers benefited from the experience.

Limitations and Future Research

Although positive results were found in the current study, one must acknowledge the limitations to the study. First, the small sample size is a limitation of the research and restricts the level of generalizability of the findings. In the future, efforts should be made to increase the size and variation of the participants being utilized in the research. In addition, findings from this study are also limited because of the inclusion of only one group using the pre-test post-test design. Employing a pre-test post-test control group design including at least two groups for comparison would strengthen the confidence in the outcomes. Finally, PDs are often criticized for being short and offering limited follow up (Penuel, Fishman, Yamaguchi, Gallagher, 2007) – the PD in this study is no exception. Future work should plan for on-going mentoring and evaluation of pre-service elementary teachers' developing MCK, PCK, and beliefs about implementing inquiry in the elementary classroom throughout a longer period of time (e.g., duration of teacher preparation, through the first year of teaching) to extend the ideas presented in this study and test the efficacy of the efforts made.

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APPENDIX A

Lesson Plan Template

	Name of Teacher: Courtney Inabnitt
Teach Date: 3/4/2015 **Length of lesson: 55 minutes**	Title of Lesson: **Catch the Beat… Discovering Permutations**
Standard for the lesson: CCSS.MATH.CONTENT.HSS.CP.B.9 (+) Use permutations and combinations to compute probabilities of compound events and solve problems.	
Unit goal that lesson addresses:	
Objective/s- **Write objective/s in ABCD format.**	**Evaluation** **In the space below, write at least one question to match the objective you listed or describe what you will look at to be sure that students can do this.**
1. By the end of the lesson, SWBT illustrate the correct number of permutations in one situation using logic scoring a 2/2 on the evaluation rubric.	Measured by evaluation question #1 (worth 2 points).
2. By the end of the lesson, SWBT correctly identify repeatable permutation variables and compute the correct number of permutations in a situation using the repeatable permutation formula scoring a 7/10 on the evaluation rubric.	Measured by evaluation question 2 (worth 4 points) and questions 3b and 3c (worth 3 points each).
3. By the end of the lesson, SWBAT evaluate a given situation, classify as either a repeatable permutation or not, and provide correct justification for their responses scoring a 6/8 on the evaluation rubric.	Measured by evaluation question 3a, 3b, and 3c (worth 8 points).

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Engagement: **Estimated Time:** 7 minutes
Description of Activity:
Students will watch a video clip in order to get a discussion started about improvisation, which will lead to the topic of repeatable permutations in music.

What the teacher does:	What the student does:
"Welcome to class today! We're going to start by watching a short video clip. Has anyone seen Who's Line? Did you like it?" **(PowerPoint)** Discuss how improvisation is used in our daily lives. "Scenes From a Hat is all about improvisation."	
1. What is improvisation?	1. Poll students for responses.
2. What does the clip have to do with improvisation?	2. Answers will vary
3. Where else would you see improvisation? *What about music?	3. Possible student answers include: conversations with others, dancing, music….
4. How does improvisation show up in music?	4. Making slight changes to a song they know, doing what feels right, experimenting *Notes, what they have memorized, what they know about music
"With a show of hands, how many of you all have some musical knowledge? (Allow students to raise their hands.) Well I see that some of you do, but just so we're all on the same page let's take a few moments to review. **(PowerPoint)** A measure is a segment of time corresponding to a specific number of beats in which each beat is represented by a particular note value and the boundaries of the measure are indicated by vertical bar lines. So, the measure we are looking at will include different notes and rests that are combined to form a total of four beats. Now let's take a look at the notes and	

rests that our musician has to work with. **(PowerPoint)** The quarter note and the quarter rest are similar because they both are worth one beat. An eighth note is played a little bit faster. Each one is worth half a beat, so to make a full beat, you would need two eighth notes. Finally we have sixteenth notes, which are a worth a quarter of a beat each. So, if the jazz musician wanted to create one beat using sixteenth notes, he would have to play the note four times." "Do we all understand this? Now that we have reviewed a little about music, let's look at our problem." **(PowerPoint)** 5. Say a musician decides he wants to change up one of the measures in his song, and he can use 4 different musical symbols: quarter notes, eighth notes, sixteenth notes, and quarter rests. How many different ways do you think he could create this measure if it has four counts?	5. Answers will vary.

Resources Needed: PowerPoint

Safety Considerations: None

Exploration: **Estimated Time:** 7.5 minutes **Overview of Activity:** Students will work in groups of two to try to draw every possible 2-count measure. By doing this the students will be able to find a pattern so that they can find how many 4-count measures can be created.	
What the teacher does:	**What the student does:**
"So if we were to try and figure it out by drawing every possible combination of the three notes and one rest, it would take a very long time. Instead of starting with a 4-count measure, why don't we scale it back? Let's try starting with a two-count measure. If we can find a pattern, we can use it to find the answer for a larger measure." Split them into groups of two based on where they are sitting or by randomly grouping them. "In a moment, you and your partner will receive a stack of sticky notes, and each one has two blanks drawn on it. Each blank represents one beat, and your task is to draw as many as many different combinations of two beats as you can think of using the 4 different notes and rests that we have to work with. **(PowerPoint)** So for example, on my first note card I might draw a quarter rest in the first beat and four sixteenth notes in the second beat. Then on my second card, I might swap and draw the sixteenth notes in the first beat and the quarter rest in the second beat. Also, the notes can be played twice in a row, so you could draw a quarter rest in the first beat and a quarter rest in the second beat. Are there any questions?" Hand out baggies with 2 markers and 20 sticky notes per group with two blanks (one per beat) already drawn. As you are passing out sticky notes: "Please wait until I say go to begin drawing on the notecards."	Students will work together to list as many possible ways to create two beats as they can. After a few minutes, they will create a class list.

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Use a timer either on the computer or on a phone for the students. Make sure that the students can hear when the timer goes off. Inform students: "You have 2 minutes. Ready, set, go!" As students work, place the 4 flashcards around the room. After the 2 minutes have expired, have students arrange their sticky notes beneath 4 flash cards that are arranged around the room: Time's up! If you look around the room, you will notice that the four musical symbols you had to work with are posted on the wall. In just a moment, I want each partner to take half of the sticky notes. If you have any combinations that have a quarter note in the first blank, stick them beneath the quarter note sign. Do the same for the other symbols. If you get to a sign and the combination you have is already on the wall, stick yours right on top of it. Are there any questions? Before you do this, have one partner pack up all your materials in your bag and drop them in this box. You have 2 minutes to complete this task. On your mark, get set, go! As students are moving around the room, navigate around and make sure that sticky notes with the same options are placed on top of each other. Once the class charts have been assembled, **ask:** 3. Have we listed every possible option?	 3. yes or no

Resources Needed: PowerPoint; Exploration wall signs (1 of each sign); Pre-made baggies (1 per group) includes: 2 markers and 20 sticky notes with 2 blanks on each

Safety Considerations: None

Explanation: **Estimated Time:** 8 minutes
Overview of Activity:
With guidance from the teacher, the students will discover the formula for repeatable permutations. Students will also see the difference between a repeatable and non-repeatable permutation.

What the teacher does:	What the student does:
Call on students to confirm how many different note and rest options are listed beneath each sign:	
1. ______________, how many unique pairs of notes do you see taped beneath the sign behind you? *Repeat for each sign	1. 4
2. So, how many different pairs of notes do we have for each category? How many different categories do we have? How many totals combinations of notes are there?	2. 4, 4, 16
3. How did we organize these notes on the wall?	3. By the note drawn in the first beat
(PowerPoint) "Here I have a list of all the combinations of notes that you came up with. They are organized by the note or rest in the first beat, just like they are on the wall."	
4. Just a moment ago, you told me there were 16 different combinations of notes and rests taped to the wall. How did you know that without walking around and counting every single option?	4. There were four categories, and four different combinations for each category.
5. a. Refer back to PowerPoint slide: That's correct. Why did we have four different categories? b. So if I look at the category where quarter notes are the first beat, how many different pairs can I create? Quarter rests? Etc.	5. a. There were four different notes and rests b. 4
6. So, we have 4 notes and rests to choose from, and we multiplied each	6. 4 squared

of these 4 options by the number of pairs they could create. What is another way I could write 4 times 4?	
7. **(PowerPoint)** How many different notes and rests did we have to work with? How many beats did we need to fill?	7. 4, 2
8. So, if I wanted to find a quicker way to count all the ways I could write a measure of music instead of drawing them all out, what 2 pieces of information do I need to know?	8. How many notes and rests we have to work with, how many beats are in the measure
"That is correct! The shortcut you just discovered is actually a tool that we can use to solve a number of different problems. You can write this tool as n^r." Give students a notecard to write down the formula and take notes.	
9. In the problem we just solved, what do you think that n was? Right! So if we wanted to generalize that, we could say that n is the number of objects we have to choose from. What was r in the problem with the music notes? Exactly! A way we could say this is that r represents the number of places that our objects will fill. On your notecard, go ahead and write down what "n" and "r" are in your own words.	9. The number of notes and rests we had, the number of beats
10. When I use the tool n^r, I am finding the number of ways that I can do what? *Refer back to note example if necessary	10. Rearrange or group objects
Right! Instead of saying a "group of objects," we're going to use the word "permutation." Write the word "permutation" on the board.	
11. Let's look back at our music problem. Does playing a quarter note and then resting sound exactly the same as resting and then playing a quarter note? So, is the order of the notes important? Right! So, when we are dealing with these permutations, the order of our objects matters.	11. No, Yes
12. Once you use a note for your first beat, can you repeat it again for your second beat?	12. Yes

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Right! So, we can say that n^r helps us to find the number of REPEATABLE permutations. "What we have just discovered is the tool for finding the number of repeatable permutations. The formula only works for repeatable permutations. Let's look at a definition. **(PowerPoint)** "When given a set of n elements, the permutations with repetition are different groups formed by the r elements of a subset such that: the ORDER of the elements DOES MATTER and the elements are REPEATED."	
13. Let's look back at our original question: **(PowerPoint)** Say a musician decides he wants to change up one of the measures in his song, and he can use 4 different musical symbols: quarter notes, eighth notes, sixteenth notes, and quarter rests. How many different ways do you think he could create this measure if it has four counts? Can we use the tool n^r to determine how many different ways a four count measure could be written with these same four notes and rests? Why?	13. Yes; the order of the notes/rests matters and notes/rests can be repeated
With your partner, go ahead and try to figure out the answer to this problem. If you need to write anything down, write it on the back of your notecard. Remember your notecard has a tool on it and if you need to you can use a calculator.	
Ask a few groups:	
14. What was your answer? Where did the base (large) 4 come from? What about the exponent (small) 4? So when you typed in 4^4 in your calculator, what did you get?	14. 4^4; the number of notes and rests, the number of beats
So, the musician can write the measure 256 different ways! Are there any questions?	

Resources Needed: PowerPoint; 1 large notecard per student; calculators (if necessary)

Safety Considerations: None

Elaboration: **Estimated Time:** 15 minutes **Overview of Activity:** Students will expound upon their knowledge of repeatable permutations, by exploring another situation using m & m's to represent ice cream scoops.	
What the teacher does:	**What the student does:**
"Just as permutations are found in music, they are also found in other aspects of life." "Let's see if we can figure out another problem." **Inform the students of the task at hand.** **(PowerPoint)** "You and a friend work at an ice cream shop. Currently, the shop has a special on triple-dip cones, but there are only 2 flavors available" Present them with the question, "How many unique 3-scoop cones could you make?"	
You and your partner will be given a "What's the Scoop?" sheet to arrange your ice cream flavors. One partner will be responsible for scooping out the strawberry ice cream (pink m&m's), and the other will be responsible for scooping out the chocolate ice cream (brown m&m's). Your task is to lay out all the possible combinations of triple dip cones that you can think of.	In groups of two students will model with m & m's the different possible orders they could make. Each group should then check their answer using the formula learned earlier in the lesson.
1. Are the ice cream scoops an example of a repeatable permutation? Why or why not? *Is a stack of chocolate, chocolate, and strawberry scoops the same as a stack of chocolate, strawberry, and chocolate scoops?	1. Yes, flavors are repeatable and the order of the scoops matters *No
Since the ice cream is a repeatable permutation, after you and your partner think you have created all possible options of triple-dip ice cream	

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cones using the two flavors, use the n^r tool to make sure that you and your partner found all the possible options. Pass out "What's the scoop?" sheet and m&m's. **After about 5 minutes call class back together:** 2. How many different 3-scoop cones could you possibly make? Explain how you arrived at your answer. (Make sure to ask what "n" and "r" were)	2. Students should say that there are 8 possible orders that could be made. Students will describe how they were able to find the answer both with the m & m's and through using the formula.
3. Our n^r relationship works for this scenario, but why? *Prompt until you get the answers of repeatability and order matters.	3. Options can be used multiple times (repeatability) and the order of the scoops matters.
"Let's say you get hired at the ice cream store down the street. This ice cream store has 4 different ice cream flavors, and also has a deal on triple-dip cones."	
4. What would be the number of permutations for the 4 flavors and 3 scoops? How did you arrive at this answer? What does n mean? What does r mean? (Emphasize what n and r are) **(PowerPoint)**	4. 4 raised to the third power is 64.
Think, Pair, Share: "Now, I want you to take a moment and consider this: **(PowerPoint)** 5. What if you were told you could only have one scoop of each flavor. Could you still use the formula n^r? Why or why not?	5. No; You only have 3 options for the second scoop once you select one for the first scoop
After you have thought about your answer, take a few moments and discuss this with your partner. Then we will discuss our answers as a class."	
After giving the class time to discuss their answers call the class back together. Repeat the question and call on several groups to answer:	
6. So, what do you think? Is this a repeatable permutation? Why or why	6. No; flavors cannot be repeated

not? Right! This is not a repeatable permutation because the flavors cannot be repeated. Once I get a scoop of chocolate ice cream I can't get another scoop of chocolate. To illustrate this better, I need three volunteers. Select three students. Here I have my three friends Riley, Jack, and Priscilla standing in a group. However, they aren't just a group. They have an order. I've known Riley the longest, so I consider her my best friend. Jack is pretty fun to hang out with, so I consider him my second best friend. Priscilla doesn't really like Riley or me. She just hangs around with us because she likes Jack. But let's say that I have an argument with Riley, and suddenly Jack is my new best friend (swap students). Now the same people are still in the group, but I have a completely different order.	
7. So since the order of the people matters, what word can I use to describe my group of friends?	7. Permutation
8. Are my friends an example of a repeatable permutation? Why or Why not?	8. No; Riley can't be my first best friend and my second best friend
This particular problem is an example of a non-repeatable permutation, which will be a lesson for another day.	

Resources Needed: PowerPoint; "What's the Scoop" sheet (1 per group); m & m's in pre-made containers – 2 colors of m & m's and 12 of each color

Safety Considerations: Due to the potential for student allergies, be sure to use plain m & m's or some other candy that you know the students in your classroom have no allergies to.

Evaluation: **Estimated Time:** 10 minutes **Description of Activity:** Students will demonstrate their understanding of the lesson by answering 3 questions. Once the students have finished, each student will grade their own paper in order to see how well they did.	
Questions:	**Possible student answers:**
"Now that you have had a chance to work on some problems with a partner and discuss your ideas with the class, you're going to have the opportunity to show what you know. On your own, I would like for you to answer the questions on this page (front and back). Once everyone has finished we will go over answers so you can see how well you did." Pass out evaluation sheets and pick up other materials as they take evaluation. 1. **Without using a formula**, use your own logic to answer the following question: You and your friend are arguing about where you should go have dinner. In order to make this decision, you decide to flip a coin three times. The coin has two sides: heads and tails. How many different permutations of heads and tails are possible? **Please show your work and/or drawings.** 2. **Using the formula**, answer the following question: Every time you unlock your cell phone, you are asked to enter a passcode. This passcode is four numbers long, and you may use the numbers 0-9. How many different four-digit passcodes could you create? **Please identify *n* and *r*, and show your work.**	

3. Look at the examples below. 1) Determine which ones are repeatable permutations and which ones are not and explain how you know this. 2) If it is a repeatable permutation, solve the problem and identify *n* and *r*. a) You and some friends are arranging 5 chairs in a row. How many different ways could you arrange the chairs b) You are playing a game in which you roll a die three times in a row. The sides of the die are labeled with the numbers 1-6. Assume that rolling the numbers 6, 4, and then 6 is different from rolling 6, 6, and then 4. How many possible results could you get? c) Social security numbers are made up of the numbers 0-9 and are 9 items long. How many different social security numbers are possible? It looks like everyone is done. Before we look at the answers, I'm going to pass out a rubric so that you can grade yourself as we go. As soon as you get it, go ahead and put your name at the top. Pass out rubric. **(PowerPoint)** In just a moment, I am going to display the answers. Every answer is worth one point. So for example, if you got the answer 8 for question number 1 without using the formula n^r, you would give yourself one point. But questions 3a-c asked you to do a number of different tasks. You will give yourself one point for each different task that you got right. Write down the total number of points you got for each question in the "Score" box for that question. Then at the end, add up the total number of points you got and write it in the "Total" box at the bottom. You can get up to 20 points. If you have any questions, just raise your hand. **(PowerPoint)** Give students 2 or 3 minutes to calculate their scores. Is everyone done? I went ahead and calculated the percentages for the number of correct questions, so here is a list of those. Once you have taken a look at your grade, go ahead and flip your papers over and sit them in front of you.	

Resources Needed: PowerPoint; Evaluation sheet (1 per student); Evaluation Rubric (1 per student)
Safety Considerations: None

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APPENDIX B

What Do YOU Think?

1. What percentage of the time did you feel as though you were engaged (totally focused and participating) in the lesson? Please circle one.
   10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

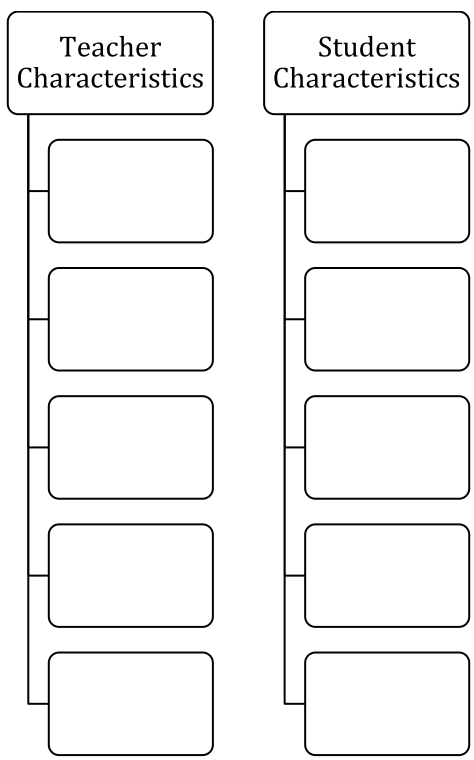
   Please provide 3 characteristics of the lesson that contributed to your level of engagement.

   ____

   ____

   ____

2. Assign descriptive words to the teacher behaviors and student behaviors that you observed during the lesson.

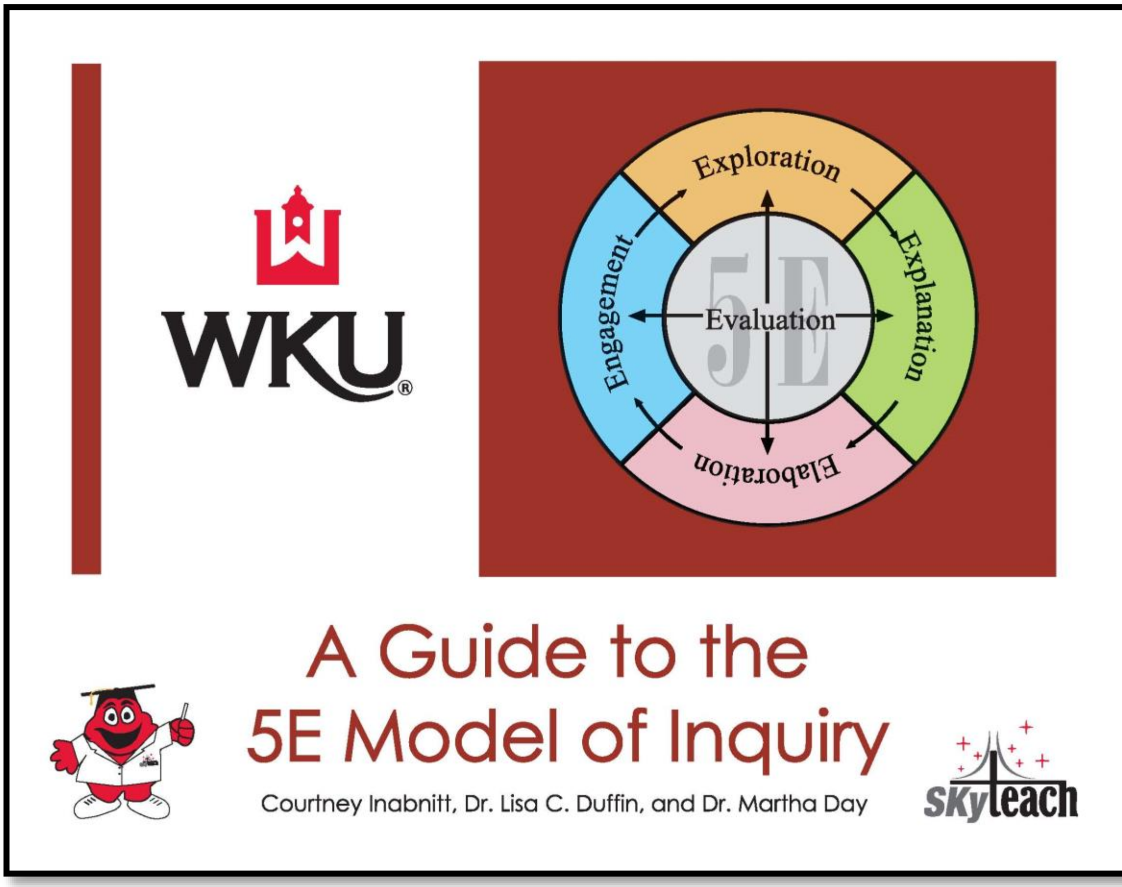


3. As compared to strategies I have experienced in a K-12 mathematics classroom, this lesson is…

SIMILAR To prior experiences in mathematics instruction.	**DIFFERENT** From prior experiences in mathematics instruction.

4. Describe each stage of the lesson.

APPENDIX C


WKU
Exploration
Explanation
Elaboration
Engagement
Evaluation
5E
A Guide to the
5E Model of Inquiry
Courtney Inabnitt, Dr. Lisa C. Duffin, and Dr. Martha Day
SKyTeach

Engagement

Activity which will focus student's attention, stimulate thinking, access prior knowledge, generate interest, and frame the learning.

What the teacher does…

- Creates Interest.
- Generates curiosity.
- Raises questions.
- Elicits responses that uncover what the students know or think about the concept/topic.

What the student does…

- Asks questions such as, Why did this happen? What do I already know about this? What have I found out about this?
- Shows interest in the topic.

Suggested Activities

- Demonstration/Question
- Manipulative activity
- Analyze an illustration
- Interactive Reading
- KWL/KNLQ
- Forced Associations
- Brainstorming Activity
- Connect past and present
- Frames the idea

Exploration

Activity which gives students time to discover new skills, think and investigate/test/make decisions/problem-solve, collect information, establish relationships and understanding.

What the teacher does...

- Encourages the students to work together without direct instruction from the teacher.
- Observes and listens to the students as they interact.
- Asks probing questions to redirect the students' investigations when necessary.
- Provides time for students to puzzle through problems.

What the student does...

- Thinks freely but within the limits of the activity.
- Tests predictions and hypotheses.
- Forms new predictions and hypotheses.
- Tries alternatives and discusses them with others.
- Records observations and ideas.
- Suspends judgment.

Suggested Activities

- Perform an Investigation
- Read to Collect Information
- Construct a Model
- Learn and practice a skill
- Manipulate data/information
- Solve a Problem
- Participate in Discussion
- Cooperative Learning Activities

Explanation

Activity which allows students to analyze their exploration. Student's understanding is clarified and modified through a reflective activity. Concepts, processes or skills become plain, comprehensible, and clear.

What the teacher does...

- Encourages the students to explain concepts and definitions in their own words.
- Asks for justification (evidence) and clarification from students.
- Formally provides definitions, explanations, and new labels.
- Uses students' previous experiences as basis for explaining concepts.

What the student does...

- Explains possible solutions or answers to others.
- Listens officially to others' explanations.
- Questions others' explanations.
- Listens to and tries to comprehend explanations the teacher offers.
- Refers to previous activities.
- Uses recorded observations in explanations.

Suggested Activities

- Student Analysis & Explanation
- Demonstration with Student Talk
- Supporting Ideas with Evidence
- Graphic Organizers – Thinking Maps
- Structured Questioning, Reading and Discussion
- Teacher Further Questions or Explains connections
- Thinking Skill Activities: compare, classify, summarize, error analysis, and interprets

Elaboration

Activity which expands and solidifies student thinking and/or applies it to a real-world situation. Extension of concept being explored that can be communicated with new formal academic language.

What the teacher does…

- Expects the students to use formal labels, definitions, and explanations provided previously.
- Encourages the students to apply or extend the concepts and skills in new situations.
- Reminds the students of alternative explanations.
- Refers the students to existing data and evidence and asks, What do you already know? Why do you think . . .?
- Strategies from Explore apply here also.

What the student does…

- Applies new labels, definitions, explanations, and skills in new, but similar situations.
- Uses previous information to ask questions, propose solutions, make decisions, and design experiments.
- Draws reasonable conclusions from evidence.
- Records observations and explanations.
- Checks for understandings among peers.
- Shows interest in the topic.

Suggested Activities

- Problem Solving within a new context
- Decision Making
- Experimental Inquiry
- Thinking Skill Activities: compare, classify, apply, judge, conclude, synthesize and extend
- Extended Reading

Evaluation

Activity which allows the teacher to assess student performance and/or understandings of concepts, skills, processes, and applications.

What the teacher does...

- Observes the students as they apply new concepts and skills.
- Assesses students' knowledge and/or skills.
- Looks for evidence that the students have changed their thinking or behaviors.
- Allows students to assess their own learning and group-process skills.
- Asks open-ended questions, such as: Why do you think. . .? What evidence do you have? What do you know about x? How would you explain x?

What the student does...

- Answers open-ended questions by using observations, evidence, and previously accepted explanations.
- Demonstrates an understanding or knowledge of the concept or skill.
- Evaluates his or her own progress and knowledge.
- Asks related questions that would encourage future investigations.

Suggested Activities

- Activities scored using a rubric
- Performance assessment
- Produce a product
- Journal entries
- Peer Feedback Response
- Problem-based Learning Scenarios
- Portfolio
- Bloom's Higher Level Questioning

APPENDIX D

PD TASK

Challenge: You and your partner will try to create an engagement and exploration for a lesson on similar ***or*** congruent triangles.

STANDARD: CCSS.MATH.CONTENT.K.G.B.4 Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/"corners") and other attributes (e.g., having sides of equal length).

1. Choose your topic (similar ***or*** congruent triangles) and consider the following objective.
    a. By the end of the lesson, students will be able to identify attributes that make two triangles similar or different using the triangles' parts and other attributes.
2. Review yourself on the topic if needed.
3. Brainstorm ideas for a 5E lesson* focusing on the engagement and exploration for this PD.
    a. Technology can be incorporated in the lesson if you wish to include it.
    b. Technology (i.e. cell phones, computers, tablets, etc.) can be used to generate ideas or refresh yourself on the topic.
4. Choose your best ideas for engagement and exploration
5. Write your best engagement and exploration ideas on the large post-it note that is provided. Make sure you have included enough detail for a person who knows nothing to understand your ideas!

*NOTE: If you finish these two sections you may go ahead and create the explanation, elaboration, and evaluation. Your team will be required to submit one typed, finished lesson plan along with an assessment (the evaluation) to Dr. Gerberry by Wednesday April 8th. An electronic template will be provided to you for the assignment.

Teachers:
Date:
Subject / grade level:
Standard: CCSS.MATH.CONTENT.K.G.B.4 Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/"corners") and other attributes (e.g., having sides of equal length).
Lesson objective(s): By the end of the lesson, students will be able to identify attributes that make two triangles similar or different using the triangles' parts and other attributes.
ENGAGEMENT
EXPLORATION
EXPLANATION
ELABORATION
EVALUATION

APPENDIX E

INSTRUCTIONS: Each item below represents a stage in the 5E model. Read each item. Decide which stage of the 5E model is being described and place the letter that corresponds to the stage in the blank provided. Justify each choice by relating the item description to at least 3 specific characteristics of the stage chosen.

Some E's will be used more than once.

A. Engagement
B. Exploration
C. Explanation
D. Elaboration
E. Evaluation

1. ______ Students work together in groups to find all two-dimensional shapes in the architect's blueprint. Each group of students will then create a three-dimensional model of the two-dimensional shapes.

   Justification:

   1.____

   2.____

   3.____

2. _____ Students will complete an exit slip with three questions regarding two- and three-dimensional shapes. Each student will complete this individually to demonstrate what he/she has learned. The teacher will compare the results to each student's bell-ringer outcome.

   Justification:

   1.____

   2.____

   3.____

3. _____ The teacher will tell the students that she is building a house and the architect wants them to review the blueprint or plan for accuracy. The teacher asks the students if they know what an architect is and what they do. Then she shows them the blueprint and presents the challenge: To figure out what types of two-dimensional shapes are in the plan for the house and to figure out how to make those two-dimensional shapes three-dimensional.

Justification:

1.____

2.____

3.____

4. _____ As a class, students discuss the three-dimensional shapes they created. Individual groups will provide descriptions for what they discovered, showing their work making sure to demonstrate the difference between two- and three-dimensional shapes. The teacher will facilitate the discussion between the students and introduce any definitions.

Justification:

1.____

2.____

3.____

5. _____ In groups, students will extend their thinking by acting as architects. They will use their new knowledge of three-dimensional shapes to create a plan for their dream house. Students will then create a model of the dream home.

Justification:

1.____

2.____

3.____

6. _____ The teacher will show pictures in a random sequence of two- and three-dimensional shapes. Each student will have cards – one that is red with a two on it and the other that is yellow with a three on it. When the teacher presents a picture, each student will display the card that corresponds to what they believe the defining characteristic is.

   Justification:

   1.____

   2.____

   3.____

7. _____ Students will be given the task of finding three-dimensional objects in the real world to apply their newly constructed knowledge. Students will be given a list of three-dimensional shapes and while outside they will be required to describe where they found the shape and/or take a picture of the specified shape (i.e., compile data).

   Justification:

   1.____

   2.____

   3.____