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The Successes and Challenges of Using Worked Examples to Integrate MP7: Look for and Make Use of Structure

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THE SUCCESSES AND CHALLENGES OF USING WORKED EXAMPLES TO INTEGRATE MP7: LOOK FOR AND MAKE USE OF STRUCTURE

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In Partial Fulfillment

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By

Jennifer Lynn Barnes

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THE SUCCESSES AND CHALLENGES OF USING WORKED EXAMPLES TO INTEGRATE MP7: LOOK FOR AND MAKE USE OF STRUCTURE

Mathematics

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Jennifer Lynn Barnes

ABSTRACT

The purpose of this action research study was to gain insight into a teacher's successes and challenges of using worked examples to integrate Common Core State Standards (CCSS) Mathematical Practice 7 (MP7) into a high school Algebra 1 classroom. The 22 participants in this qualitative study were 9^{th} – 11^{th} grade students. Ten lessons were taught using worked examples to focus on mathematical structure. Data was collected in the form of reflective teacher journals and student artifacts. Observational data was also collected by a fellow mathematics teacher using an observational protocol. Analysis of the data indicated three successes: a) modeling of structure; b) communication of structure; c) teacher-researcher growth. Data analysis also indicated three challenges: a) nature of worked examples and curriculum; b) challenges of teacher-researcher, specifically the definition of structure, ineffective questioning techniques, and the teacher's need to be in control; c) challenges with students' abilities, specifically struggles with mathematical communication and prior knowledge.

KEYWORDS: Common Core, mathematical practices, MP7, mathematical structure, worked examples, solved problems, Algebra 1

This abstract is approved as to form and content

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I would like to thank my family, friends, and coworkers for the love and support they have shown throughout my life. They have pushed me to always do my best, and I thank them for their constant encouragement. I would like to also thank my Lord and Savior Jesus Christ for giving me hope and a purpose for my life.

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CHAPTER I: OVERVIEW OF THE STUDY

In 2009, the Common Core State Standards (CCSS) were launched to help the United States mathematics curriculum become more focused and coherent on mathematical topics (National Governor's Association Center for Best Practices and the Council of Chief State School Officers, 2010). Along with the CCSS, a list of eight Mathematical Practices (Appendix A) were identified as mathematical dispositions that teachers should develop within their students. According to Choppin, Clancy, and Koch (2012), the Mathematical Practices and the CCSS could potentially "develop the kind of mathematical understanding necessary to succeed in a global economy" (p. 553).

The mathematical goals behind the CCSS and Mathematical Practices were in place before the CCSS was established. The emphasis on problem-solving and reasoning were first established in the publication *An Agenda for Action* in 1980 by the National Council of Teachers of Mathematics (NCTM), as well as *Curriculum and Evaluation Standards for School Mathematics* (1989) and *Principles and Standards for School Mathematics* (2000) (Koestler, Felton, Bieda, & Otten, 2013). In fact, the CCSS Mathematical Practices and the NCTM Process Standards contain similar recommendations. This study focused on Mathematical Practice 7, *look for and make use of structure* (Appendix A), and was similar to NCTM's Connections and Representations Process Standards (Koestler et al., 2013).

Rationale for the Study

As a high school mathematics teacher, I had seen firsthand how a procedural-based curriculum frustrated students and did not promote mathematical understanding. I saw multiple students struggle to earn enough mathematics credits to graduate from high school. I knew my teaching practices needed to change, and I thought the CCSS and Mathematical Practices would help promote problem-solving and conceptual understanding in my students. Researchers have studied the impact of the CCSS in the classroom, specifically the elementary and middle school classroom (Choppin et al., 2012; Davis, Choppin, Roth McDuffle, & Drake, 2017; Swars & Chestnutt, 2016). However, there was a limited number of CCSS studies in the area of high school mathematics (Evans, 2017; Matthews, 2017). This action research study could add to the CCSS research base, as well as become a resource for teachers who are trying to implement the Mathematical Practices into their classrooms.

Purpose of the Study

The purpose of this action research study was to gain insight into a teacher's successes and challenges of using worked examples to integrate Common Core State Standards Mathematical Practice 7 (MP7) into a high school Algebra 1 classroom.

Research Questions

The following research questions guided this study:

1. What successes did the teacher experience while using worked examples to integrate MP7 in an Algebra I classroom?

2. What challenges did the teacher experience while using worked examples to integrate MP7 in an Algebra 1 classroom?

Research Design

My classroom action research study took place November 2017 through January 2018. My participants were 22 out of 24 of my 2nd block Algebra 1 students, as well as myself. All students were in grades 9th-11th at a high school in southwest Missouri. I created 10 lessons using worked examples to emphasize MP7, looking for and making use of structure. In order to emphasize MP7, I used worked examples to help students look for patterns, shift perspective, and apply concepts to related problems (MP7 Definition, parts a, b, and c). I created each lesson with resources from my Algebra 1 curriculum or Kuta software. The lesson formats were either paper notes, a Nearpod presentation, or a teacher-created activity. After each lesson, I recorded my own reflections and experiences in an electronic journal. I also reflected on student artifacts as I wrote in my journal (Appendix B). Artifacts included text and drawing submissions in Nearpod, worksheets, and exit slips. Lastly, a fellow colleague observed my classroom in Lesson 6 and Lesson 10. The observer took field notes on an observational protocol (Appendix C) and also included successful and challenging aspects she saw while implementing MP7. My research journal was organized and analyzed for common themes throughout the research study. The common themes focused on successes and challenges that I faced as a teacher implementing MP7. After some time and reflection, I realized the common themes I found were not based off of MP7. These common themes were found based off of my use of worked examples. The definition of MP7 was clearly stated, and the journals were analyzed again. I looked for challenges and successes that focused on students looking for patterns, shifting perspective, and applying concepts to related problems (MP7 Definition, parts a, b, and c). With the MP7 definition, two successes and three challenges were found within the research.

Significance of the Study

The goal of this study was to gain insight into a teacher's successful and challenging experiences of using worked examples to integrate MP7, *look for and make use of structure*. Prior research supports worked examples as a teaching practice to improve student learning (Barbieri & Booth, 2016; Booth, Lange, Koedinger, & Newton, 2013; Star et al., 2015). As the teacher-researcher, this study aimed to explore how I taught each lesson with worked examples while trying to emphasize MP7. The results of this action research study can help other educators as they incorporate MP7 or the other Mathematical Practices in their own classroom. I hope my authentic reflections can help educators avoid specific challenges as well as encourage educators to try to develop the Mathematical Practices in their students.

Secondly, this study was significant because I was able to learn about teaching practices, as well as learn about myself as an educator. The ability to be a life-long learner is a necessity in education, and this study provided a lot of opportunities to reflect on my teaching and my teaching philosophy. The research findings allowed me to see successful aspects of the MP7 lessons that I can continue to use in my classroom. Also, the findings showed me the areas in my teaching that I need to improve if I want my students to become proficient in problem-solving and mathematical reasoning.

Lastly, this study was significant because I was able to see how incorporating MP7 in my classroom could benefit my students. The research findings allowed me to see my students modeling and communicating about mathematics in ways that I had not seen previously. I hope this research study can encourage educators to include the CCSS Mathematical Practices in order to see their students communicating and modeling mathematics as well.

Assumptions

The following was a list of assumptions I made during the study:

1. I assumed that my students have not seen mathematics lessons with the focus on MP7 before, but have rather seen lessons that were mostly procedure-based.

Limitations

The following was a list of limitations I encountered during the study:

1. Time was a major limitation. I noted in 8 out of 10 journals that I did not have a lot of time when planning and creating lessons. During the school year, I had extracurricular responsibilities that limited my time on making MP7 lessons.

2. Time of day may have also affected my student's participation in the lessons. The class took place from 8:00 – 9:35 a.m. and students were sometimes slow to participate in class since it was the first class of the day.

Definition of Terms

The following was a list of important definitions during the study:

1. MP7: MP7 is an acronym for Mathematical Practice 7, *look for and make use of structure*, and refers to the seventh of the eight Standards for Mathematical Practice as listed in the CCSS. (Appendix A). Student engagement in MP7 will be identified with the following indicators from the CCSS' description of MP7:
    a. Students look closely for patterns.
    b. Students step back for an overview and shift perspective.

c. Students recognize the significance in concepts and models and can apply strategies for solving related problems.

(National Governor's Association Center for Best Practice and the Council of Chief State School Officers, 2010, para. 8).

2. Solved problem: "An example that shows both the problem and the steps used to reach a solution to the problem. A solved problem can be pulled from student work or curricular materials, or it can be generated by the teacher. A solved problem is also referred to as a 'worked example'." (Star et al., 2015, p. 4) Also, a solved problem can be correct or incorrect.

Summary

In an effort to provide the United States with a more focused and coherent curriculum, the CCSS were launched in 2009, along with eight Standards for Mathematical Practice. Similar to NCTM's previous publications, the CCSS recommends that teachers focus on problem-solving and reasoning in the mathematics classroom. The purpose of this action research study was to gain insight into a teacher's successes and challenges of using worked examples to integrate Common Core State Standards Mathematical Practice 7 (MP7) into a high school Algebra 1 classroom. There were 22 students who participated in the study. Ten lessons were created with worked examples to emphasize MP7. Data was collected in the form of an electronic journal, student artifacts, and an observational protocol. I chose to conduct this study in order to improve my teaching practices and help students understand mathematics. This study could contribute to the research base on CCSS, as well as help other mathematics educators who are trying to implement the Mathematical Practices in their classroom. The findings of this action research were also significant in helping me to reflect on my teaching and my teaching philosophy, as well as learning best teaching practices. I assumed that my students had not seen lessons that focused on MP7 previously. Limitations to the study were that the teacher was pressed for time when creating lessons, and the time of day affected the student's behavior. Lastly, two major terms were defined in this chapter. MP7, look for and make use of structure, included three indicators of student engagement: a) students look closely for patterns, b) students step back for an overview and shift perspective, and c) students recognize the significance in concepts and models and can apply strategies for solving related problems. Solved problems or worked examples could be correct or incorrect examples that show both the problem and the steps to the solution.

CHAPTER II: REVIEW OF RELATED LITERATURE

This chapter will provide a summary of literature relating to the CCSS and educators' experiences with CCSS. Also, research conducted on curriculum similar to the CCSS will be included. Lastly, this chapter will provide a summary of teaching strategies that promote structure, which include worked examples.

Implementing Common Core State Standards

Davis et al. (2017) conducted a survey of middle school mathematics teachers' perceptions of the Common Core State Standards (CCSS), the Standards for Mathematical Practice, and the impact of both on the teacher's instruction. From the 39 states that had adopted the CCSS, 1,241 teachers completed the survey from May – June 2015. Out of all the respondents, 40% of teachers believed their curriculum did not align with CCSS, and the majority of teachers said that the CCSS has caused them to change how they use curriculum resources. Teachers also reported less confidence in state CCSS-aligned assessments. Their lack in confidence was due to the fact that the teachers believed that the Standards for Mathematical Practice were not being assessed. Lastly, one-third of teachers responded that their professional development involving CCSS was inadequate (Davis et al., 2017).

Swars and Chestnutt (2016) conducted a mixed-methods study on the experiences and perceptions of elementary teachers using CCSS. The participants included 73 elementary teachers who completed surveys and answered interview questions. Three findings emerged from the data. The first finding was familiarity and preparation to use the CCSS. Teachers indicated their familiarity with the CCSS on the survey. However, teachers stated concerns about feeling prepared to teach the CCSS to various groups of students. The second finding was implementation of the CCSS. Teachers were asked how often they incorporate the Standards for Mathematical Practice into their instruction. Fifty-six percent of teachers noted that they did not incorporate MP7 at all. As far as implementing the CCSS into the classroom, 70% of teachers said the CCSS required a change in their teaching practices. Specifically, teachers identified the need to switch from teacher-led practices to student-centered practices. The last finding was centered on tensions associated with CCSS. While the teachers believed CCSS was beneficial for their students, there were certain hindrances. For example, 78% of teachers said the CCSS requires new or revised curriculum and lesson plans. Teachers also noted that students were not prepared for the CCSS because they were lacking in skills and content knowledge (Swars & Chestnutt, 2016).

Walters, Smith, Ford, and Scheopner Torres along with the Regional Educational Laboratory Northeast & Islands, Education Development Center, Inc., and National Center for Education Evaluation and Regional Assistance (2014) conducted a needs assessment for rural educators implementing CCSS in the classroom. Researchers conducted interviews and surveys that focused on preparation, implementation, and challenges of CCSS for educators. The needs assessment provided researchers with a list of professional development opportunities given to teachers as well as a list of teacher challenges of incorporating CCSS. The opportunities listed included state-created websites that provided CCSS guidance, meetings with regional experts, informational meetings, district professional development, and CCSS adopted curriculum. The following challenges were listed by teachers as they implemented CCSS: deepening students' understanding instead of focusing on topics, developing conceptual understanding, building off of previous standards, developing procedural fluency, and developing the mathematical practices. To overcome these challenges, teachers asked for time to look at the standards and plan lessons, more CCSS training and professional development, and quality CCSS curriculum and resources (Walters et al., 2014).

Evans (2017) conducted a qualitative action research study that focused on successes and challenges of implementing Mathematical Practice 3, *construct viable arguments and critique the reasoning of others*, in a high school Geometry classroom. Data was collected through the use of teacher-researcher journals, student artifacts, and observational data from an instructional coach. The data revealed three factors that lead to students engaging in Mathematical Practice 3: "1) transferring responsibility from the teacher to students; 2) investing into lesson plans, time management, class structure, and relationships with students; and 3) establishing a classroom culture of safety, respect, and high expectations" (Evans, 2017, p. iii). This study discussed the importance of students writing in a secondary mathematics classroom to emphasize the idea of mathematical thinking. It was also noted how complex the teacher's role is during classroom discussion. In order to facilitate classroom discussion, it was important to transfer the responsibility to students. Mathematical discourse was present in this study when the teacher took time to plan questions that involved multiple strategies. Lastly, this study found the teacher incorporating more than one mathematical practice into the lessons and suggests conducting more research on the CCSS mathematical practices and how they link together (Evans, 2017).

Matthews (2017) conducted an action research study with an emphasis on Mathematical Practice 5, *use appropriate tools strategically*, in a high school Algebra II classroom. Although the teacher successfully incorporated GeoGebra into his classroom, he did not integrate all parts of MP5. Students were not given a choice when choosing technology to solve a problem. This was in part due to the teacher's teaching style. It was noted that his teaching style was more procedural than conceptual. For future studies, the teacher implied that it was necessary for teachers to be aware of their teaching practices and beliefs. Lastly, it was found that students engaged in multiple Mathematical Practices while conducting this study, not just MP5 (Matthews, 2017).

Choppin et al. (2012) focused on a series of eight lessons in a middle school mathematics classroom where the Mathematical Practices were emphasized. The teacher used related tasks from the Connected Mathematics Project (CMP) curriculum where students thought about integer operations before making a formal rule or definition. Throughout the study, students looked for patterns (MP7), used appropriate tools (MP5), communicated their own thoughts and evaluated the reasoning of others (MP3). The tasks that the students looked at were not difficult, but provided for multiple solution strategies and multiple opportunities to talk about integer operations. The teacher played an important role in the study by asking students to explain their own reasoning and having the students explain their peer's explanations as well. The teacher only emphasized concepts or ideas after the students had time to think and talk about it. One major finding of this study was that the Mathematical Practices can only be developed when the focus is on problem-based tasks instead of multiple objectives or topics within a lesson (Choppin et al., 2012).

Similar Studies to Common Core State Standards

Sahin, Isiksal, and Koc (2015) researched mathematical discourse within a fifth grade classroom in Turkey. Turkey has also established new curriculum similar to the CCSS in the United States. Turkey's curriculum emphasizes that "students are expected to participate, inquire, response, discuss, understand, involve in problem solving, think, and decide independently" (Sahin et al., 2015). After analyzing the field notes from this qualitative classroom study, they coded student activities as procedural thinking, conceptual thinking, routine problem-solving, justification, and real-life connections. It was found that students used procedural thinking in all 20 lessons, but only used conceptual thinking in 3 lessons. Reasons for lack of conceptual thinking in these lessons were large class numbers, the classroom environment, and the teacher's inability to ask the right questions. The teacher's questions "should make students think deeper about the mathematical idea, and see the connections with prior knowledge and use it" (Sahin et al, 2015). It was also noted that the environment was very teacher-dominated and tasks were not chosen to help facilitate mathematical discourse. The findings indicated that the tasks should include multiple solutions and opportunities for students to explain their thinking (Sahin et al., 2015).

Dennis and O'Hair (2010) completed a qualitative comparative case study that analyzed authentic lessons in different classrooms as well as the different obstacles the teachers faced. Authentic instruction qualifies as lessons that "include asking students to analyze, synthesize, and evaluate information" (Dennis & O'Hair, 2010, p. 4). The participants were five mathematics or science teachers from an alternative school, a charter school, and a regular high school. Each teacher was observed three times throughout the school year for a period of 60 minutes. The teachers were also interviewed and kept portfolios and journals of their experiences in the classroom. The two findings of this study centered on the school setting and the obstacles teachers encountered (Dennis & O'Hair, 2010).

School setting played a part in this study because the study was conducted at three different types of schools. However, the teachers faced the same obstacles. One of the obstacles that teachers noted to Dennis and O'Hair (2010) was that they had lack of time. This included lack of time to prepare and lack of time to get through the required content. Another obstacle faced by the teachers was poor student attendance. Poor attendance became a problem when teachers tried to stretch lessons or projects over more than one class period. Lack of funding and materials, depending on the subject and unit taught, was also an obstacle when trying to teach authentic lessons. Lastly, an obstacle the study discovered was inflexible and traditionally trained teachers. These teachers did not have a willingness to try new things. Also, the teachers were more inclined to teach in a traditional way due to their educational training (Dennis & O'Hair, 2010).

Structure and Worked Examples

In 2015, the Institute of Education Sciences published a practice guide titled *Teaching Strategies for Improving Algebra Knowledge in Middle and High School Students* (Star et al., 2015). This practice guide provided educators with research-based evidence and expertise to face specific challenges in the mathematics classroom. This guide looked into three different recommendations. One of the recommendations focused on structure. This teaching guide defined structure as "an algebraic representation's underlying mathematical features and relationships" (Star et al., 2015, p. 16). To help students recognize structure, one of the suggestions was to solved problems. The teaching guided also emphasized correct mathematical language, using reflective questioning, and using different algebraic representations (Star et al., 2015).

In a study by Booth et al. (2013), two experiments were done to examine the effects of correct and incorrect worked examples on students' understanding and skills. In the first experiment, 116 students Algebra 1 students were chosen from three high schools that used the curriculum Algebra 1 Cognitive Tutor. There were four groups where students were randomly assigned: correct worked examples, incorrect worked examples, both correct and incorrect worked examples, and a control group. All groups concentrated on solving two-step equations. The three worked example groups received eight examples throughout their guided practice, while the control group only received guided practice problems. In the worked example questions, students were asked to explain what happened in the example and why it was correct or incorrect. To show growth, the students were given a pre-test and post-test. The unit was completed in 4 weeks. To analyze the results, a multivariate analysis of covariance was conducted to test the difference between the worked example groups and the control group on students' conceptual understanding and procedural knowledge. The worked example group performed better on both procedural and conceptual questions. Another multivariate analysis of covariance was used to analyze a difference between the three worked example groups, but there was no difference found between the three groups on students' conceptual understanding and procedural knowledge (Booth et al., 2013).

In Experiment 2, Booth et al. (2013) looked at correct versus incorrect worked examples with no control group. Students were chosen from eighth grade Algebra 1 classrooms where the Cognitive Tutor program was used. The same procedures were used that took place in Experiment 1. An analysis of covariance was conducted on scores. Overall, students who were given both correct and incorrect worked examples scored significantly higher in both conceptual and procedural knowledge than the students who received correct worked examples only (Booth et al., 2013).

Another study was completed by Barbieri and Booth (2016) that addressed how to improve Algebra 1 students' learning and self-confidence through the use of incorrect worked examples. The rationale for this study was the fact that adolescent students have been struggling with Algebra 1 for years, and a student's performance in Algebra 1 could affect his or her confidence in math for the rest of high school and higher education. Barbieri and Booth (2016) hypothesized that incorrect worked examples could make an impact on students' learning, as well as an impact on lower Algebra 1 students.

Barbieri and Booth (2016) noted that the participants were 140 middle school students, of which 97% were 8th grade students. These students were in a total of five Algebra 1 classrooms. Students were selected randomly for each classroom. There were three types of classrooms: traditional classroom with practice problems, classroom with correct worked examples, and classroom with incorrect worked examples. Students were given a pre-test and a survey that focused on self-confidence. Over the course of five to seven weeks, students were given four worksheets to complete. A priori and post hoc analyses were used to decide a minimum sample size of students to determine a substantial effect on learning. The study conducted repeated measures on post-tests and post-surveys to determine if the incorrect worked examples benefitted students. Barbieri and Booth (2016) found that students progressed from pre-test to post-test in each group, but there was no significant improvement to support incorrect worked examples. Also, there was no significant evidence to support improvement in self-confidence. However, the results did show that the lower Algebra 1 students performed better with incorrect worked examples than correct worked examples and the traditional classroom (Barbieri & Booth, 2016).

Summary

The literature in this chapter has provided an overview of the research on incorporating CCSS and similar curriculum into classrooms. Davis et al. (2017) found that middle school teachers perceived the curriculum did not align with CCSS. Swars and Chestnutt (2016) surveyed elementary teachers about their perceptions of CCSS and mentioned the following: MP7 was not used by 56% of teachers, change in teaching practices were required, teachers suggested new or revised curriculum, and students were lacking in mathematical skills and knowledge. Walters et al. (2014) found the following challenges while teachers tried to implement CCSS: focusing on understanding instead of topics, developing conceptual understanding and procedural fluency, and developing the Mathematical Practices. Teachers asked specifically for more time to plan, more training, and new curriculum (Walters et al., 2014). Evans (2017) conducted her own action research study on MP3 in which she found the importance of transferring responsibility to students and incorporating questions with multiple strategies. Matthews (2017) found that MP5 was not fully incorporated in his classroom due to his own teacher-dominant style and procedural focus.

Choppin et al. (2012) found that Mathematical Practices were taking place in the classroom when the focus was taken off lessons with multiple objectives, when students were given questions with multiple strategies, and when students were encouraged to explain their thinking. Sahin et al. (2015) noticed a lack of conceptual understanding because the teacher did not ask the right questions and did not have tasks with multiple strategies. Dennis and O'Hair (2010) looked at teachers implementing authentic lessons and found the following challenges: lack of time, lack of resources, and inflexible and traditionally trained teachers.

Lastly, a teaching guide was produced for Algebra teachers that included teaching strategies to help students focus on structure. Solved problems, multiple representations, and correct mathematical language were all included in the guide (Star et al., 2015). Solved problems, or worked examples, has been researched in the Algebra 1 classroom. However, this literature does not address the use of worked examples to support mathematical structure. Booth et al. (2013) conducted two experiments and found that students who used correct and incorrect worked examples scored higher than students who just had guided practice, but there was no difference found between each of the worked example groups. Barbieri and Booth (2016) conducted a study on incorrect worked examples and students' self-confidence. It was found that all students made progress from pre-test to post-test, but there was no significant evidence to show incorrect worked examples have an effect on performance or self-confidence (Barbieri & Booth, 2016).

CHAPTER III: METHODOLOGY

The goal of this study was to gain insight into a teacher's successes and challenges while using worked examples to emphasize MP7. As the teacher-researcher, I created lessons with worked examples and collected data in the form of an electronic journal, student artifacts, and an observational protocol. While analyzing the data, I reflected on successes and challenges I experienced as I tried to emphasize mathematical structure in my Algebra 1 classroom.

Research Design

My study was a classroom action research study. I chose a qualitative methodology because the focus of this study was my own experiences as a teacher. In order to give a thick description of the challenges and successes in my classroom, I needed to look at my lessons, my students, and my own teaching practices and beliefs.

From November 2017 to January 2018, I chose to create 10 lessons using worked examples. The literature stated that worked examples would help students recognize mathematical structure. In order to focus on MP7, I included worked examples in every lesson. The goal of the worked examples was to help students look closely for patterns, step back for an overview and shift perspective, and recognize significant concepts that could be applied to related problems (MP7 Definition, parts a, b, and c). Instead of taking notes like a traditional classroom, I had students look at the worked examples and discuss them in order to find the patterns and significant concepts of structure. At the beginning of the research in Lesson 1, I asked students general questions that were open-ended. For example, I asked “Based on the examples above, what are domain and range?” Another example of an open-ended question was “what do you notice?” By Lesson 6, I started to include more leading questions about the structure of the problems I wanted students to notice. For example, Lesson 6 focused on solving systems of equations by substitution, and I asked the question “how would infinitely many solutions be represented on a graph?” Throughout all of the lessons, I included different types of worked examples. The incorporated worked examples were either correct, incorrect, or both. These 10 lessons were not consecutive in order. I chose lessons based on the time that I had to plan the lesson. I reflected after each lesson in an electronic research journal. Each research journal was open-ended, and my reflections focused on my experiences and my observations of students engaging in MP7. I also wrote in my journal about student artifacts. Student artifacts were collected in the form of worksheets, electronic submissions on Nearpod, and exit slips. To aid in the data collection process, a colleague observed my classroom and wrote field notes of her observations. She used an observational protocol to record her notes (Appendix C). The goal of the observational protocol, reflective journal, and student artifacts was to allow for data triangulation.

Site of the Study

This study took place in an urban high school located in southwest Missouri. This high school had 1,338 students enrolled in the 2017-2018 school year. In 2017, 75.9% of the student population were classified white, 12.6% were classified black, 6.1% were classified Hispanic, and the remaining 5.4% was listed as other. Also, 63.7% of students received free or reduced lunch.

This school instituted one-to-one technology during the time of this study. Each student had access to a Chromebook throughout the entire 2017 – 2018 school year and could also take the Chromebook home. If a student forgot his or her Chromebook, the library had a few Chromebooks available for checkout.

Participants

Since this was a classroom action research study, I participated in my own study as the teacher-researcher. My participation in the study included creating and teaching lessons, writing reflections in an electronic journal, collecting data from students, and analyzing all of the data. The students in my class also participated in the study by participating in each lesson of the study. The participants were selected by convenience sampling. Each student was placed in my class because it fit best in their school schedule. There were a total of 24 students in my 2nd Block Algebra 1 class, but only 22 students participated in the study. Two students did not return a parent permission form. This class contained fifteen 9th graders, four 10th graders, and three 11th graders, and ages ranged from 14 – 17 years of age. The students were composed of 12 males and 10 females. Four students had IEP's with special accommodations. The accommodations included preferential seating, extended time for homework and tests, and alternative setting for tests. Fourteen students were white, six students were African-American, and two students were Hispanic.

Ethical Considerations

Before this research study began, I was granted approval by the Missouri State University Institutional Review Board (Appendix D), my school district, and my building principal. Next, I needed parent/guardian consent and student consent since I was working with students under the age of 18 (Appendix E). Any student names used in the study are pseudonyms in order to keep student information confidential. All 24 students received the same instruction, but data was only used in the study from the 22 students who gave consent.

Data Collection Procedures

From November 2017 to January 2018, ten lessons were created using worked examples to focus on MP7. Each class period was 95 minutes long. The lessons were not taught consecutively. Lessons were chosen based on content and the amount of time I had to create the lesson. I created each lesson either in a word document, a Nearpod presentation, or a handwritten worksheet. Nearpod is an online tool that teachers can use to make presentations interactive (Nearpod, 2018). Instead of just including slides for students to read, teachers can also include slides where students submit text, drawings, surveys, polls, multiple choice questions, etc. The majority of worked examples used were from the Algebra 1 textbook provided by my school district (Charles et al., 2012). Kuta Software was also used to create questions for notes and activities (Kuta Software LLC, 2018). Below is a brief description of each lesson.

1. <u>Lesson 1 (November 14)</u>: I created a lesson in Nearpod with matching notes where students looked at correct solved problems of domain and range of a function, as well as the vertical line test. Students submitted text answers and drawings into Nearpod. (Appendix F and G).

2. Lesson 2 (November 16): I created a Find the Error activity of incorrect solved problems to help review for their upcoming test. All 10 questions were handwritten and created by me. Students worked in groups of 4 to identify the error in each worked example.

3. Lesson 3 (November 27): I created a Nearpod lesson with matching notes that focused on correct solved problems of rate of change and slope. Students submitted text answers and drawings into Nearpod.

4. Lesson 4 (December 5): I created a lesson with correct solved problems of graphing using intercepts, graphing horizontal/vertical lines, and changing standard form to slope-intercept form. Students talked about their observations of each problem. I also created a worksheet with half of the problems worked out correctly. Students could look at the worked examples while solving each standard form equation for y.

5. Lesson 5 (December 11): I created a lesson with correct solved problems of graphing absolute value equations. Students talked about their observations of each problem.

6. Lesson 6 (January 10): I created a lesson with correct solved problems of solving systems of equations by substitution. The notes included guiding questions for the students to think and write about. We talked about all of the questions as a class.

7. Lesson 7 (January 12): I created a Nearpod lesson with matching notes that focused on solving systems of equations by elimination. The notes included guiding questions to help students think through the solved problems. Students submitted text answers into Nearpod. Students also worked on a teacher-created worksheet that looked at the structure of elimination.

8. Lesson 8 (January 23): I created a lesson with correct solved problems of graphing linear inequalities. Students also participated in a teacher-created worksheet called Fix It, where students needed to find and the fix the error in each incorrect solved problem.

9. Lesson 9 (January 25): I created a lesson with a correct solved problem for solving a system of linear inequalities. The notes included guided questions that students thought about and answered. Then we talked about the answers as a class. Students then participated in a Desmos activity that focused on structure and student questioning (Desmos & Eaton, 2018). Desmos randomly paired up students, and students had to ask yes or no questions to narrow down the options to the correct answer.

10. Lesson 10 (January 29): I created another Find the Error activity with incorrect solved problems in an effort to review for their test. The incorrect solved problems were from the resources of the Algebra 1 textbook. Students worked in pairs to find and explain the error of each problem.

The class periods during this time period that were not listed were either a more traditional format without the focus of MP7 or an assessment.

Data during the ten MP7 lessons was collected in various ways. First, I kept an electronic research journal where I wrote in detail about the experiences in the classroom and my own reflections. Each journal was written at the end of each school day. Secondly, I was observed by a fellow colleague. This colleague was also a third year mathematics teacher with experience teaching Algebra 1 students. This colleague was chosen to observe my classroom because her conference period was during my 2nd Block Algebra 1. My colleague observed my classroom during Lesson 6 and Lesson 10. She wrote field notes on the observational protocol (Appendix H). She also included examples of successes and challenges of the lesson, as well as suggestions for future lessons. Lastly, I collected any samples of student work that I thought was helpful in showing evidence of MP7 in the classroom. Examples of student work that I collected were worksheets, Nearpod submissions, and exit slips.

One tool used in the study was the observational protocol. The format of the observational protocol was adapted from two similar action research studies (Evans, 2017; Matthews, 2017). The goal of the observational protocol was to provide data triangulation with the research journal and student artifacts. However, this did not occur due to researcher error. While I made the observational protocol, I included indicators about worked examples instead of indicators about students engaging in MP7. This error was not realized until all of the data was analyzed. Since the protocol was not created based on the MP7 definition, data triangulation was not possible. Even though my colleague was not able to accurately identify instances of students engaging in MP7, she was able to include successful and challenging aspects of the lesson and suggestions for future lessons.

Data Analysis

First, I analyzed my own journal entries by reading through each daily entry. As I read each journal entry, I marked important quotes and made a note if an experience stood out to me as an MP7 challenge or success. After reading and marking through each journal, I identified major themes found within my research. My initial data analysis showed that I was analyzing the data based off of the successes and challenges I had with worked examples. I realized that I did not have a clear definition of MP7. My secondary data analysis allowed me to read through each journal entry again while having the MP7 definition clearly defined. According to the definition, I looked for successes and challenges of students looking for patterns, shifting perspective, and applying concepts to related problems (MP7 Definition, parts a, b, and c). This second analysis provided findings that included three successes and three challenges.

Summary

My classroom action research study was conducted November 2017 through January 2018. My participants were 22 out of 24 of my 2nd block Algebra 1 students, as well as myself. All students were in grades 9th-11th at a high school in southwest

Missouri. I created 10 lessons using worked examples to integrate MP7, *look for and make use of structure*. I created each lesson with resources from my Algebra 1 curriculum or Kuta software, and the lesson formats were either paper notes, a Nearpod presentation, or a teacher-created activity. Data was collected through an electronic journal, student artifacts, and an observational protocol. The observational protocol was created to provide data triangulation, but did not provide this due to researcher error. Data analysis was conducted by examining each journal entry for common themes throughout the research study. The first data analysis did not focus on MP7, so a second data analysis was necessary. Between the first and second data analysis, MP7 was more clearly defined by the teacher-researcher. I looked for challenges and successes that focused on students looking for patterns, shifting perspective, and applying concepts to related problems (MP7 Definition, parts a, b, and c). After the second data analysis, the findings included three successes and three challenges.

CHAPTER IV: FINDINGS

This chapter described the findings of the data analysis in detail and was organized with respect to each research question. Research question 1 focused on the successes as I incorporated MP7 in the classroom. This research question had three findings, which concentrated on students engaging in MP7 through modeling and communication and my own growth as a mathematics educator. Research question 2 focused on the challenges I faced while incorporating MP7 in the classroom. This research question had three findings.

Research Question 1

Two of the three successes I found while using worked examples to incorporate MP7 were related to students' level of engagement in MP7. By definition, students were engaged in MP7 if a) they looked closely for patterns, b) stepped back for an overview and shifted perspective, and c) recognized the significance in concepts and models and can apply strategies for solving related problems (MP7 Definition, parts a, b, and c). The two student successes included modeling of structure and communication of structure. The third success within the findings was related to my own growth as a mathematics educator.

Modeling of structure. In Lesson 1 (Appendix F and G), I created a lesson on domain and range of a function with an online presentation site called Nearpod (Nearpod, 2018). I included worked examples throughout the lesson showing examples of domain and range. Students submitted their answers to each question in a text box slide on their

Chromebooks. None of the text submissions were identified as student engagement in MP7. However, I included different types of questions at the end of the lesson. These questions were called Draw It, where students could submit drawings as their answers. Up to this point in the lesson, we had only practiced procedural questions. The Draw It questions were different because students had to recognize the important concept of a function and apply the concept to a related problem (MP7 Definition, part c). The first question was to draw a mapping diagram that is a function. All students were able to create their own function except one student who submitted a blank drawing. Figure 1 shows some of the student-created mapping diagrams.

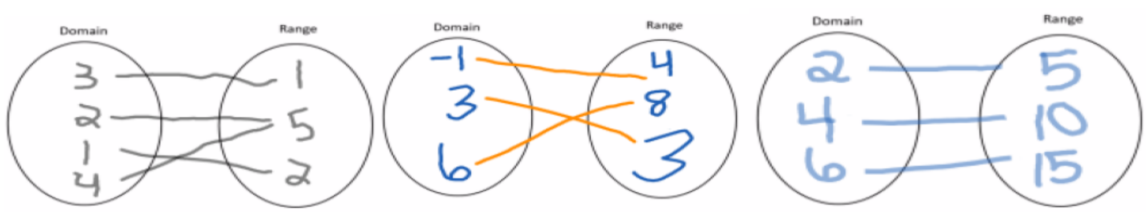

Figure 1. Student-created mapping diagrams that demonstrate functions.

The next question was to draw a mapping diagram that is not a function. Sixteen out of seventeen students were able to create their own mapping diagram that did not depict a function. Figure 2 shows examples of the mapping diagrams the students created.

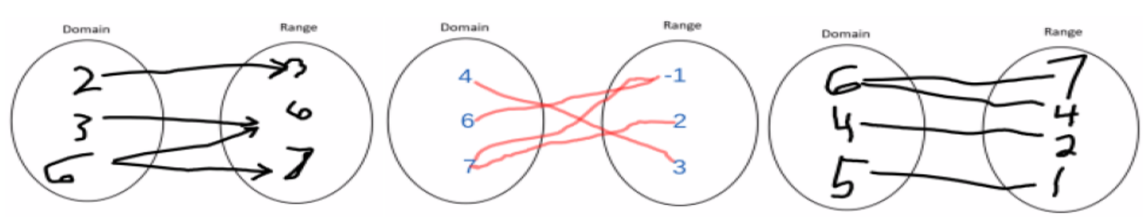

Figure 2. Student-created mapping diagrams that do not depict functions.

To continue the theme of functions, I asked students to create a graph that would pass the vertical line test. Ten out of seventeen students were able to draw a graph that would pass the vertical line test. Figure 3 shows examples of the student-created graphs.

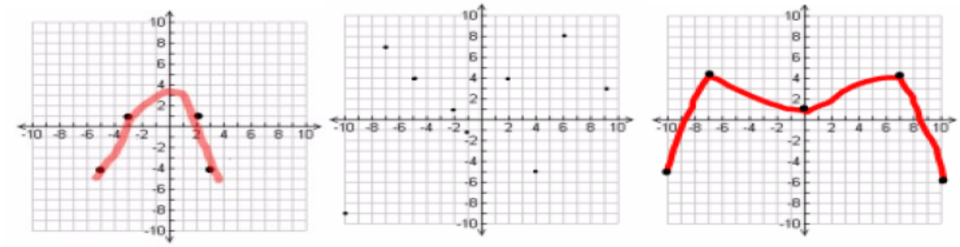

Figure 3. Student-created graphs that would pass the vertical line test.

Lastly, I asked students to create a graph that would not pass the vertical line test. Fifteen out of seventeen students submitted a graph that did not pass the vertical line test. One student submitted a blank graph while the other student submitted a graph of a function. Figure 4 shows examples of the student-created graphs that did not pass the vertical line test.

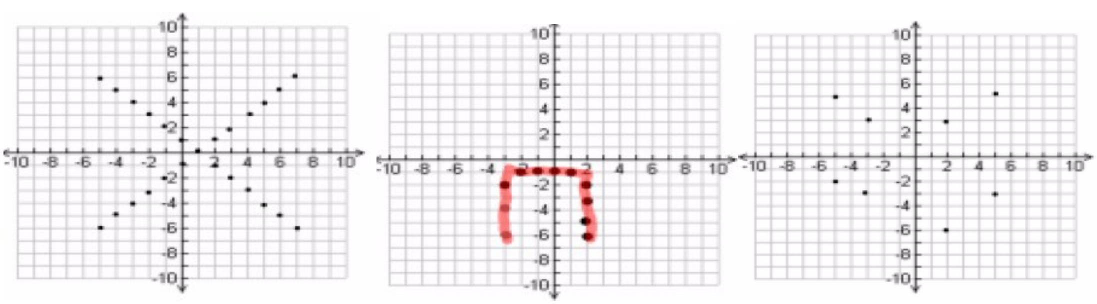

Figure 4. Student-created graphs that would not pass the vertical line test.

Communication of structure. Besides modeling structure, the findings also showed student success in communication of structure. However, a student named Mackenzie was the only student who could verbalize the structure that she was seeing within the mathematics. The interesting part of Mackenzie's story was that Mackenzie had mentioned repeatedly how she did not like mathematics. Even though Mackenzie had a dislike for mathematics, she was engaged in all of the 10 lessons. Most of Mackenzie's responses were not elaborate, but her concise responses were filled with mathematical structure.

In Lesson 3, I created a lesson that focused on rate of change and slope. I tried making the lesson in Nearpod again, but I wanted to include more discussion in class. The first question of the lesson was a word problem that focused on finding the rate of change. I had students look at the question and submit a text response on Nearpod. Then I asked students to talk about what they observed. Mackenzie responded "it looks like a unit rate." This is not an elaborate response, but Mackenzie was able to step back and relate rate of change to the idea of a unit rate. She was able to shift her focus from just looking at the procedure of finding rate of change to connecting it to a previous concept we had learned before (MP7 Definition, part b).

In Lesson 6, I created a lesson on solving systems of equations by substitution. I did not create a Nearpod for this lesson, but we did continue to look at worked examples and answer questions together as a class. The first question was a substitution problem that had one equation already solved for a variable. I listed four main questions that I wanted students to think about. One of the questions was trying to get students to think about structure. I asked "how did this person write their final answer? What does this remind you of?" Mackenzie responded "the intersection point on a graph." Again, Mackenzie's answer was not elaborate and drawn out, but Mackenzie was able to step back and shift perspective back to solving a system by graphing (MP7 Definition, part b).

Lastly, Lesson 9 was a lesson I created about systems of linear inequalities. It consisted of one worked example and five questions for the students to think and talk through. My first question had multiple parts: "Have you seen a problem similar to this before? How is it the same? How is it different?" Mackenzie made another insightful response that actually took me by surprise. She replied "it reminds me of the inequalities we did with the 'and' and 'or'." One regret I have is that I didn't ask her to elaborate on what she was thinking. However, I see what Mackenzie was talking about. Mackenzie saw the system of inequalities similar to an "and" compound inequality because the solutions satisfied both inequalities. Mackenzie was able to step back and look at the question in a different way (MP7 Definition, part b). She was able to make her own connection between what she had learned previously.

Teacher-researcher growth. The last success was related to my own growth as a mathematics educator. One of the ways I saw growth in my own teaching was the transferring of authority to students. During Lesson 1 (Appendix F and G), I created a Nearpod lesson over domain and range. The last activity of the lesson included students modeling and drawing functions. For this activity, the only direction I gave was to model a function or model a relation that was not a function. Students were given the opportunity to draw and model their own functions. Before conducting this research study, I did not even think about doing an activity like this. This was truly the beginning of me deciding to let go of my teacher authority and transfer that authority to the students.

Lastly, this study allowed me to grow as an educator because the action research required me to become reflective of my own teaching and learning. As I wrote each daily journal entry, I had to think about my teaching, the students' engagement, and the lesson as a whole. Through the data collection and analysis, I learned what MP7 entailed. I learned that there was a much deeper level of mathematical structure that the review of literature had not fully described. I truly believe that I learned more by actually conducting the study myself and learning from my challenges.

Research Question 2

The challenges I experienced while incorporating MP7 in the classroom centered around three findings. The first challenge was due to the nature of the worked examples and curriculum. The second challenge was with myself as the teacher-researcher, specifically my definition of structure, ineffective questioning techniques, and my need for authority. The last challenge was students' mathematical communication and struggles with prior knowledge.

Nature of worked examples and curriculum. Since MP7 focuses on students looking for and making use of structure, I needed a tool that would help me focus on structure in my lessons. The teaching guide by Star et al. (2015) mentioned that solved problems would help students with algebraic structure. However, this tool paired with my curriculum did not help students engage in MP7. In fact, the definition of structure from Star et al. (2015) and CCSS's definition of structure are quite different.

The curriculum at my school comes with textbooks and an online homework program (Charles et al., 2012). The nature of the curriculum is very procedural, and I am expected as the teacher to teach as many sections of the textbook as I can. Each section of the textbook has a worked example of each type of problem, and I generally set up my lessons very similar to the textbook. The irony of the situation is that the book has Common Core in the title, but focuses on procedures through every section of every chapter. Even the online homework is procedure-based.

When I paired the required curriculum with worked examples, I got procedures on top of more procedures. During the data collection process, I wasn't really thinking about how this could be a potential challenge for student engagement in MP7. Looking back at the lessons, the majority of my questions focused on procedures. The worked examples were examples of steps in a process. The examples did not focus on patterns, shifting perspective, or applying significant concepts to related problems (MP7 Definition, parts a, b, and c). Also, my observational protocol had criteria that focused on the worked examples, not MP7. Lastly, all of my journal reflections talked and reflected on the worked examples in the lesson. Even though worked examples and my curriculum were tools to use in the study, each of these tools became a major focus that took my focus away from MP7.

Challenges as the teacher-researcher. Unbeknownst to me, I would also bring challenges to the MP7 study as the teacher-researcher. One challenge that was made clear through the data analysis was that I may not have had a clear and specific definition of structure in my mind before starting the study. I had a general idea of the structure I wanted my lessons to focus on, but I was not specific. For this study, I should have had a clear idea of structure and how MP7 was going to work in my lessons.

Another challenge as the teacher-researcher was ineffective questioning. Since I did not have a clear definition of structure in my mind, my questioning techniques were not effective. Looking back at all of my lessons for the study, I asked procedural questions and asked students to do procedural problems in all ten lessons. I should have been asking questions that focus student's attention on the mathematical structure or ideas. Also, the worked examples and curriculum did not lend themselves to good questions because of the procedural nature. For example, I would ask a lot of questions about why a specific step happened in the problem.

The last challenge as the teacher-researcher was the need for authority of the classroom. In 7 out of 10 reflective journals, I noted that I jumped in to answer my own questions or tell the students how to do something. In Lesson 4, we looked at graphing linear equations using x and y-intercepts. I noted the following in my daily journal entry:

> It was dead silence. I thought someone might say something about x and y-intercepts, but nope. My instinct to help jumped in and I then immediately started explaining what was happening in these examples. I even wrote step-by-step what they were doing. 1) Plug in 0 for y, 2) Solve for x-intercept, 3) Plug in 0 for x, and 4) Solve for y-intercept (Journal Entry #4).

In my two and a half years of teaching, I have been a very procedural-focused teacher who likes to explain everything to students. It is my nature to help students all the time, especially when they don't understand a mathematical concept. During the study, I would find myself explaining some things to students even though I knew that I should not. Also, I believe that I unintentionally picked worked examples as a tool to use for MP7 because it was not too far off from my own way of teaching. Without realizing it, I think I chose that strategy because it felt similar to my own teaching. In order for me to incorporate MP7 correctly, I should have transferred some authority to the students.

Challenges with students' abilities. Alongside my own challenges, there were challenges with students' abilities. The first challenge of implementing MP7 with students was their lack of ability to communicate mathematically. Besides my need to control the classroom, I believe I jumped in so much because students did not know how to communicate about what was going on in each problem. In Lesson 3, I asked students to look at the worked example and describe rate of change. Cheryl told me in a flustered manner "I think I know what's going on, but I don't know how to say it." When students were capable of explaining a problem, they were not using correct vocabulary or they would be very vague with their answers.

The second challenge with students during the study was the lack of prior knowledge. During Lesson 6 over solving by substitution, I noted in my reflective journal how excited I was to see students' ability to substitute for another variable. I also mentioned that a lot of students had trouble simplifying and solving the equation after substituting. The students had learned how to simplify and solve multi-step equations four months earlier, but they had forgotten. It was very hard to learn new concepts when the old concepts were not solidified in students' minds. A colleague observed my class during this lesson. She noted on her observational protocol that reteaching was necessary because students' scaffolding was not always solid.

Summary

The data from this study was analyzed and sorted into categories to answer the two research questions. Research question 1 focused on the successes of incorporating MP7 into a classroom, which included three successes. The first success was that students were engaged in MP7 by modeling structure. The second success was that students were engaged in MP7 by communicating structure. Students were engaged in MP7 when their activity fell under one of the parts of the MP7 definition: look closely for patterns, step back for an overview and shift perspective and see the significance in concepts and be able to apply it to a related situation (MP7 Definition, parts a, b, and c). The third success was that I was able to grow as a mathematics educator during this action research study by transferring authority to students and reflecting on my teaching and learning.

Research question 2 focused on the challenges of incorporating MP7 into a classroom, which included three challenges. The first challenge was the nature of the worked examples and curriculum used during the study. The second challenge was challenges as the teacher-researcher, specifically with my definition of structure, ineffective questioning techniques, and my need for authority in the classroom. The last challenge was challenges with students' abilities, which included struggles with mathematical communication and lack of prior knowledge.

CHAPTER V: DISCUSSION AND CONCLUSION

The CCSS Mathematical Practices were put in place in order to help students with conceptual understanding and to help students become proficient in mathematics (National Governor's Association Center for Best Practice, Council of Chief State School Officers, 2010). The purpose of this action research study was to gain insight into the successful and challenging experiences of a teacher using worked examples to incorporate Common Core State Standards Mathematical Practice 7 (MP7). MP7 is defined as student engagement in looking for and making use of structure (National Governor's Association Center for Best Practice, Council of Chief State School Officers, 2010). As a teacher-researcher, I was able to identify successes and challenges of incorporating MP7 that other mathematics teachers will be able to learn from and try in their own classrooms.

Discussion

During this study, I used lessons with worked examples in order to incorporate MP7. Based on the definition (MP7 Definition, parts a, b, and c), I found specific moments of students successfully engaging in MP7, which included modeling and communicating about mathematics. Another success from the study was my own personal growth as a mathematics educator. This first indicator of growth was that I was able to start transferring authority to students (Evans, 2017). Another indicator of growth was that I was able to learn a considerable amount through the reflection that took place during the action research. Along with successes, there were also challenges. One of the main challenges was the nature of worked examples and the required curriculum. Even though worked examples have been researched (Barbieri & Booth, 2016; Booth et al., 2013), the worked examples did not always promote student engagement in MP7. Both the worked examples and curriculum were procedural-focused and did not align with CCSS (Davis et al., 2017; Swars & Chestnutt, 2016; Walters et al., 2014). Research suggests that successful implementation of the CCSS Mathematical Practices should include meaningful tasks with multiple solution strategies instead of procedural-based lessons (Choppin et al., 2012; Evans, 2017; Sahin et al., 2015). Another challenge was myself as the teacher-researcher. First, I did not have a clear definition of MP7 before I started the study. Second, ineffective questioning techniques led me to ask more procedural questions, which did not promote MP7 or mathematical discussion in my classroom (Sahin et al., 2015). Lastly, my need for authority of the classroom did not allow MP7 to take place. I needed to be more flexible and open to less procedural-based lessons (Choppin et al., 2012; Dennis & O'Hair, 2010; Matthews, 2017; Sahin et al., 2015). Also, my lack of flexibility could have been in part due to my teacher training as well as my own teaching beliefs (Dennis & O'Hair, 2010; Matthews, 2017). Lastly, I had challenges with my students. First, my students were unable to communicate mathematical ideas. Research has been done for students who are able to communicate mathematically, but there is little research on students who struggle with communication. Lastly, students struggled during the study because they were lacking in prior mathematical knowledge (Swars & Chestnutt, 2016).

Recommendations for Future Research

Since successful examples of student engagement were found, I believe there is value to teaching all of the Mathematical Practices in the high school mathematics classroom. There have been a few studies conducted over CCSS in the secondary classroom, but more research needs to be studied on the teacher's role in implementing them. Since worked examples were a more challenging tool than successful, more research needs to be done on incorporating MP7 with different teaching methods. Research on students' mathematical communication or lack thereof would benefit all mathematics teachers, elementary through secondary. I believe that communicating mathematical ideas is a way for students to show their understanding of mathematics. Lastly, more research needs to be done on the relationship between a students' prior mathematical knowledge and their ability to participate in the Mathematical Practices.

Recommendations for Future Practice

I found a lot of beneficial ideas for all mathematics teachers in this study. If we want students to know mathematics beyond just procedures and learn the dispositions of the Mathematical Practices, it is necessary to start teaching lessons that are not procedural-based. The focus should be on meaningful tasks that have multiple solution strategies. These tasks will help facilitate mathematical discourse in the classroom.

I recommend that administrators should purchase curriculum that includes meaningful tasks aligned with CCSS because research showed that students engage in the Mathematical Practices when completing task-oriented problems. I also believe that mathematics teachers should have more professional development in the area of the

CCSS and Mathematical Practices. I had a surface-level understanding of the Mathematical Practices, but I did not fully know how to incorporate them into the classroom.

I recommend that action research become a part of a teacher's professional development. I was able to learn so much about my own teaching and the Mathematical Practices through my action research study. I believe that I learned so much because I had to be reflective of my successes and challenges. I gained a much deeper understanding of the CCSS by actually applying it to my own classroom. I believe that all teachers could benefit professionally by going through the same reflective process of action research.

Lastly, I recommend that mathematics teachers evaluate their own teaching practices and teaching philosophy. If we truly want our students to understand mathematics, I do not believe that we can keep teaching all of the procedural-based questions.

Summary

During this study, I used lessons with worked examples in order to incorporate MP7. Based on the definition (MP7 Definition, parts a, b, and c), I found specific moments of students successfully engaging in MP7. However, there were more challenges than successes during this study. One of the main challenges was the nature of worked examples and the required curriculum because the procedural-nature of the questions did not promote engagement in MP7. Research suggested that successful implementation of the CCSS Mathematical Practices should include meaningful tasks with multiple solution strategies instead of procedural-based lessons. I suggest that administrators purchase curriculum that focuses on tasks instead of procedures if they want to promote the Mathematical Practices. Another challenge was myself as the teacher-researcher. First, I did not have a clear definition of MP7 before I started the study. Since I had a surface-level understanding of the Mathematical Practices, I suggest teachers be provided with professional development on incorporating CCSS into a secondary classroom. I also suggest that teachers go through the process of action research to gain a deeper understanding of their own teaching practices. Second, ineffective questioning techniques led me to ask more procedural questions, which did not promote MP7 or mathematical discussion in my classroom. Lastly, my need to have authority of the classroom did not allow MP7 to take place. I needed to be more flexible and open to less procedural-based lessons. Also, my lack of flexibility could have been in part due to my teacher training as well as my own teaching beliefs. I suggest that teachers evaluate their teaching practices and teaching philosophy if they want to encourage students to understand mathematics and not focus on procedures. Lastly, there were challenges with my students' abilities. First, my students were unable to communicate mathematical ideas. Research has been done for students who are able to communicate mathematically, but I recommend that research be conducted on students who struggle with communication. Lastly, students struggled during the study because they were lacking in prior mathematical knowledge. More research needs to be done on how lack of prior mathematical knowledge affects student engagement in the Mathematical Practices.

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APPENDICES

Appendix A: Eight Standards for Mathematical Practice

CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.

CCSS.MATH.PRACTICE.MP2 Reason abstractly and quantitatively.

CCSS.MATH.PRACTICE.MP3 Construct viable arguments and critique the reasoning of others.

CCSS.MATH.PRACTICE.MP4 Model with mathematics.

CCSS.MATH.PRACTICE.MP5 Use appropriate tools strategically.

CCSS.MATH.PRACTICE.MP6 Attend to precision.

CCSS.MATH.PRACTICE.MP7 Look for and make use of structure.

CCSS.MATH.PRACTICE.MP8 Look for and express regularity in repeated reasoning.

(National Governor's Association Center for Best Practice, Council of Chief State School Officers, 2010)

Appendix B: Lesson 1 Journal

In my professional development days this year, we have learned about an online tool called Nearpod. It is basically like an enhanced version of PowerPoint, except it can project onto the students' screens, and I can control what slide everyone is on. Also, Nearpod allows you to include different activities within the slide show. I thought I would give it a try for this lesson. This was my first time using Nearpod ever. However, I also made a copy of the lesson on paper for students to reference later. I also included guided practice problems within the paper copy.

The lesson today was 4.6, which focused on domain and range for the first time and the vertical line test. I thought today I would try ONLY correct worked examples and see how the students respond.

I started off the lesson with asking the students if any of them had heard of domain and range before. Only about 5 students raised their hand. I was curious to see how everyone else would grasp the concept of domain and range. I then asked students to go to the link to access Nearpod on their Chromebooks. Two students were unable to do so because their Chromebooks were dead. (Dead Chromebooks is a recurring issue in all of my classes, unfortunately, because the students are not responsible enough to make sure they are charged). Thankfully, I had made the paper copy so I told those two students to follow along on the paper copy and on my smart board screen. They were able to participate in the guided practice, but none of the activities.

First, I gave the students two side-by-side correct examples of identifying domain and range of each relation. I asked the students to look at the examples and jot down what they think is happening on their paper notes. Nearpod then allowed me to insert an open-ended question for students to answer. The open-ended question was "based on the last two examples, what are domain and range?" The cool thing about Nearpod is that it keeps track of student participation and responses. I had 95% participation and 5% (one student) not answer. 13 out of 19 students were able to look at the two examples and see that domain was somehow associated with the x and range was associated with the y. One student response I really liked was from Anna.

Anna – "The domain is in the X position and the range is in the Y position. For example (X,Y)= (3, 8)"

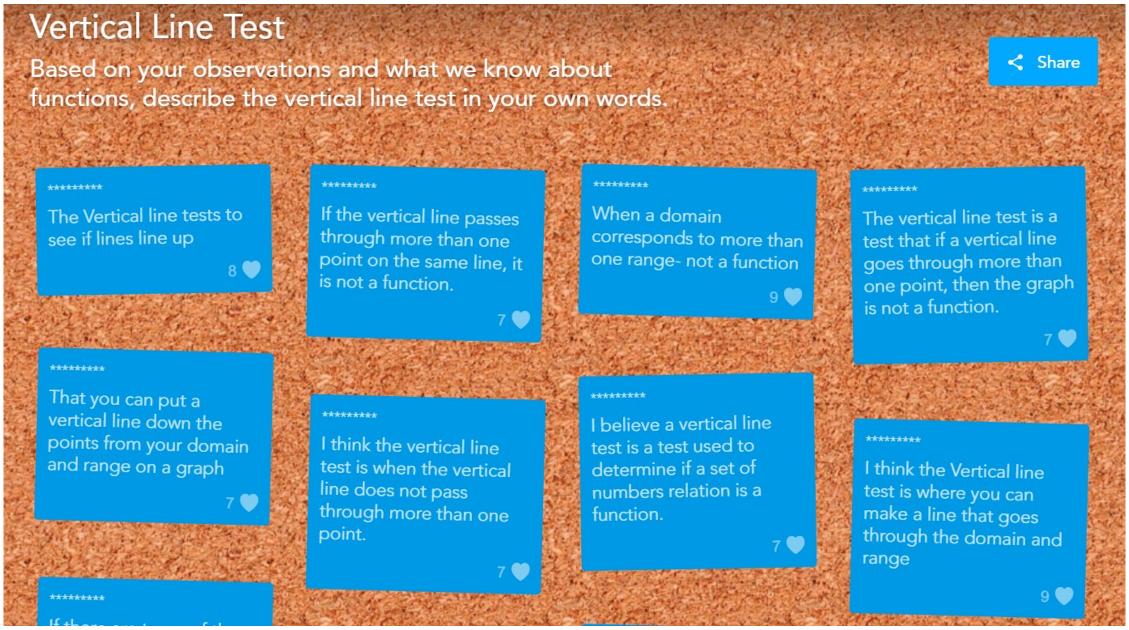
Unfortunately, 5 of the students were unable to say what domain and range were and one student did not answer. Maybe if I gave students more time to discuss what was going on more students would have been able to answer the question.

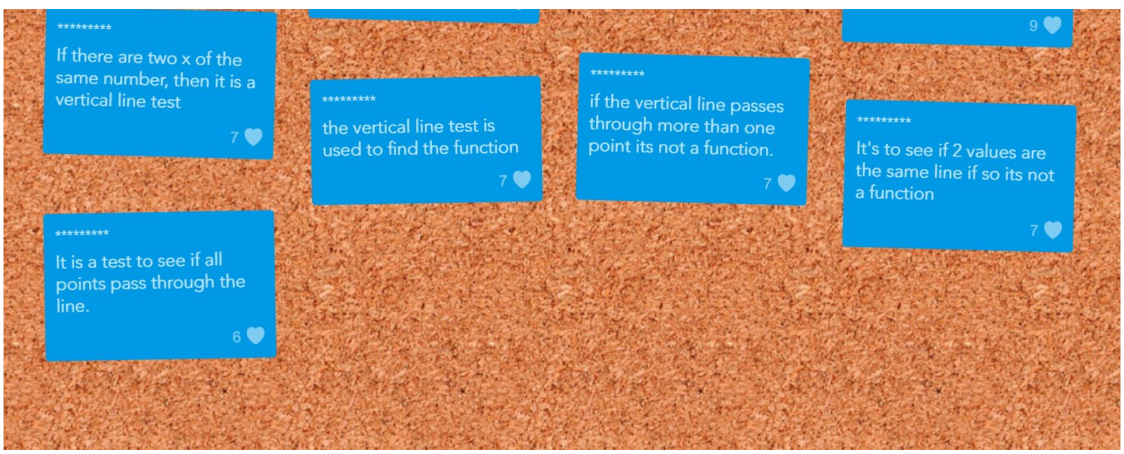
Next, I took the same two examples and expanded it to show how the domain and range can be displayed as a mapping diagram. Then the question posed was "is the relation a function?" The first example was a function, and the second example was not a function. Same format, I asked the students to look at the two examples and jot down some ideas about what they see. Then I asked an open-ended question on Nearpod: "based on your observations of the last two examples, when is a relation not a function?" Overall, I had 95% participation, with one student not responding. Surprisingly, it was a different student than before. Again, 13 out of 19 students were able to answer with responses saying that a relation is not a function when it has more than one range or output.

One response I liked was from Mackenzie.: "A relation is not a function when one input(x/domain) has more than one output(y/range)."

The remaining 5 who answered said responses related to that the numbers did not match up or the numbers were uneven. Those 5 students did not understand the concept of a function.

One really cool thing that I added into the Nearpod was a Draw It option. Students can submit answers as drawings. I inserted a blank mapping diagram and asked students to do 2 draw it submissions. First I asked them to draw a mapping diagram that IS a function and then asked them to draw a mapping diagram that was NOT a function. This was my favorite part of the lesson. It was so exciting and cool seeing my students being creative, engaged, and showing their understanding of functions. I had 100% during this part of the lesson, except one girl either forgot to submit or accidentally submitted a blank mapping diagram. Every student was able to show me a mapping diagram that was a function. My only stipulation was that they have 3 numbers in the domain and 3 numbers in the range, so we didn't spend a ton of time on this one activity. For the mapping diagram that was NOT a function, there was 100% participation, but 3 of them were unable to show a diagram that was NOT a function. After the Draw It, I asked students to do 3 guided practice questions on their paper notes. Here they were given a relation and were asked to draw a mapping diagram and tell if it was a function or not. During the guided practice, we were able to clarify that if you have repeating numbers in the relation, you don't repeat it in the mapping diagram. If we didn't have guided practice problems, I don't think we would have cleared that misconception up. I let the students try the 3 questions on their own, and then I quickly went over them so students could see how they did. Next, I showed students two correct side-by-side examples of using the vertical line test for functions. I asked students to look at the examples and jot down some observations. I asked an open-ended question in a different format. I used the Collaborate option in Nearpod to see what it would be like. It basically allowed students to type their answers that would pop up as sticky notes for the whole class to see. I did not care for this format as much because students started goofing off with what they were typing and not taking it seriously. When I used this format, I only had 13 students respond with appropriate answers. My question was "based on your observations and what we know about functions, describe the vertical line test in your own words." Only a few students were able to accurately communicate what the vertical line test was. Below are images from this collaboration board.





Next, I brought up the Draw It options again. I asked students to draw a graph that would PASS the vertical line test and draw a graph that would NOT PASS the vertical line test. Again, I had 100% participation with the drawings. However, 4 students were unable to show a graph that would pass. For the graph that would not pass, I had 3 students who submitted graphs that did not show a good understanding of the vertical line test and 1 student who did not submit a graph at all. After this, I had students try 3 guided practice problems on their paper. Basically they were identifying functions using the vertical line test.

We had two examples left about finding the output or range of a function. I could tell at this point that the students were starting to get restless. I have to find a way next time to make the Nearpod have less examples than I had this time so I don't overload the students' brains.

The next question was showing a word problem where a person plugged in a number into the function to get the answer. I asked simply "how did this person solve this problem?" All but 1 student was able to tell me that they plugged in 8 for x to get the answer of 2000. I did however have 100% participation.

The last question was where the domain and function were given, and it asked the student to find the range. I only had one correct question showing. I asked students to look at the question and then answer the open-ended question in Nearpod. My question I asked was "given the domain, how did this person find the range?" I had 95% participation with this question and 1 student not answer. Every student that answered was able to explain how the person found the range. I really liked Dylan's answer because he not only explained how they got the answer but also the pattern he noticed in the answers.

Dylan – "They multiplied by 1 then 2 then 3 then 4 and each time they added 4 and they got lower numbers each time because of the negative 1.5 being multiplied."

After this, I had students try 2 guided practice problems on their paper. With these, I could tell there was a little confusion on how to get started. Looking back at the situation, I realized that I jumped in and told students how to do it by making a table. I wish that I would've let them figure it out on their own instead of telling them.

Overall, I thought this was a really good lesson. I liked using Nearpod to receive student feedback from EVERY student and also be able to save it and look at it later. Looking back, I had too many slides and examples in one lesson. I could tell that the students were really exhausted by the end of it and a little restless. I did think that the guided practice problems in-between were beneficial. It gave the students a chance to try what they learned with the worked-out examples. This lesson I just had correct examples. For my next lesson, I will probably look at incorrect examples only and see how it goes.

Appendix C: Observational Protocol

Observer: ___________________________Date of Observation: _______________

As you observe the lesson, record in Column 3 the events of the students as they relate to the following topics:

1. Students' use of correct worked examples.
2. Students' use of incorrect worked examples.
3. Students' use of self-explanation prompts.
4. Students' ability to communicate mathematical ideas and concepts.
5. Students' ability to describe mathematical procedures.
6. Students' ability to transfer their knowledge to new situations.
7. Students' level of engagement.
8. Students' attitudes.

Provide a time stamp in Column 2 to correspond with the events. Fill out the protocol with regards to items 1-8. After the lesson, assign an appropriate topic number for the events described in Column 3 (e.g., 1, 3, 7) in Column 4. More than one line can be used to discuss any event(s). More than one topic number can be used to describe any event(s).

Line:	Time:	Event:	Activity Number(s):
1			
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…			

Overall, list things you saw that were successful implementations of MP7:

Overall, list things you saw that appeared to be challenges as the teacher tried to implement MP7:

Do you have any suggestions of how the lesson could be altered? If yes, please list your suggestions and explain your reasoning.

Appendix D: IRB Approval

Missouri State
UNIVERSITY

To:
Kurt Killion
Mathematics
Gay Ragan

RE: Notice of IRB Approval
Submission Type: Initial
Study #: IRB-FY2017-536
Study Title: Looking For and Making Use of Structure in an Algebra 1 Classroom
Decision: Approved

Approval Date: May 9, 2017
Expiration Date: May 9, 2018

This submission has been approved by the Missouri State University Institutional Review Board (IRB) for the period indicated.

Federal regulations require that all research be reviewed at least annually. It is the Principal Investigator's responsibility to submit for renewal and obtain approval before the expiration date. You may not continue any research activity beyond the expiration date without IRB approval. Failure to receive approval for continuation before the expiration date will result in automatic termination of the approval for this study on the expiration date.

You are required to obtain IRB approval for any changes to any aspect of this study before they can be implemented. Should any adverse event or unanticipated problem involving risks to subjects or others occur it must be reported immediately to the IRB.

This study was reviewed in accordance with federal regulations governing human subjects research, including those found at 45 CFR 46 (Common Rule), 45 CFR 164 (HIPAA), 21 CFR 50 & 56 (FDA), and 40 CFR 26 (EPA), where applicable.

Researchers Associated with this Project:
PI: Kurt Killion
Co-PI: Gay Ragan
Primary Contact: Kurt Killion
Other Investigators: Jennifer Barnes

Appendix E: Parent/Student Informed Consent Form

Dear Parent(s) and Student:

In collaboration with MSU faculty in the College of Natural and Applied Science and College of Education, I will be conducting a study to observe classroom experiences while using teaching strategies to achieve deeper conceptual understanding rather than using the traditional teaching approach. The purpose of this letter is to ask for written permission for your child to participate in this study. Participation in this study involves normal classroom activities. It is the right of the student to choose his or her amount of participation in the class discussions. Thus, students are not obligated to answer any questions, and their participation has no impact on their class grade.

The study will take place in my 2nd Block Algebra 1 classroom in approximately 10 lessons during the first semester. I will teach using research-based strategies in order to help students understand mathematical concepts. I will have other mathematics teachers observe the class and take notes of their observations. I will keep a journal where I will reflect on my own experiences. When student work highlights the challenges or successes that occur throughout the lessons, I would like to use their work as evidence.

Before you make a final decision about your child's participation, please read the following about how the information will be used and how your child's rights as a participant will be protected and respected:

- Participation in this study is completely voluntary. The student may stop participating at any point without penalty.
- The information will be kept confidential and student identity anonymous. Results may be presented to others or in other written reports but will not contain names or other identifying information.

If you consent to your child participating, please fill out the consent form below and return with your child to Ms. Barnes. You can contact me if you have questions or concerns about your child's participation. Thank you very much for your time and consideration.

Sincerely,
Ms. Jennifer Barnes

I agree to allow my child participate in the study in Ms. Barnes' Algebra 1 class.

Parent Name (Printed): ____

Parent Signature: ____

Date: ______________________

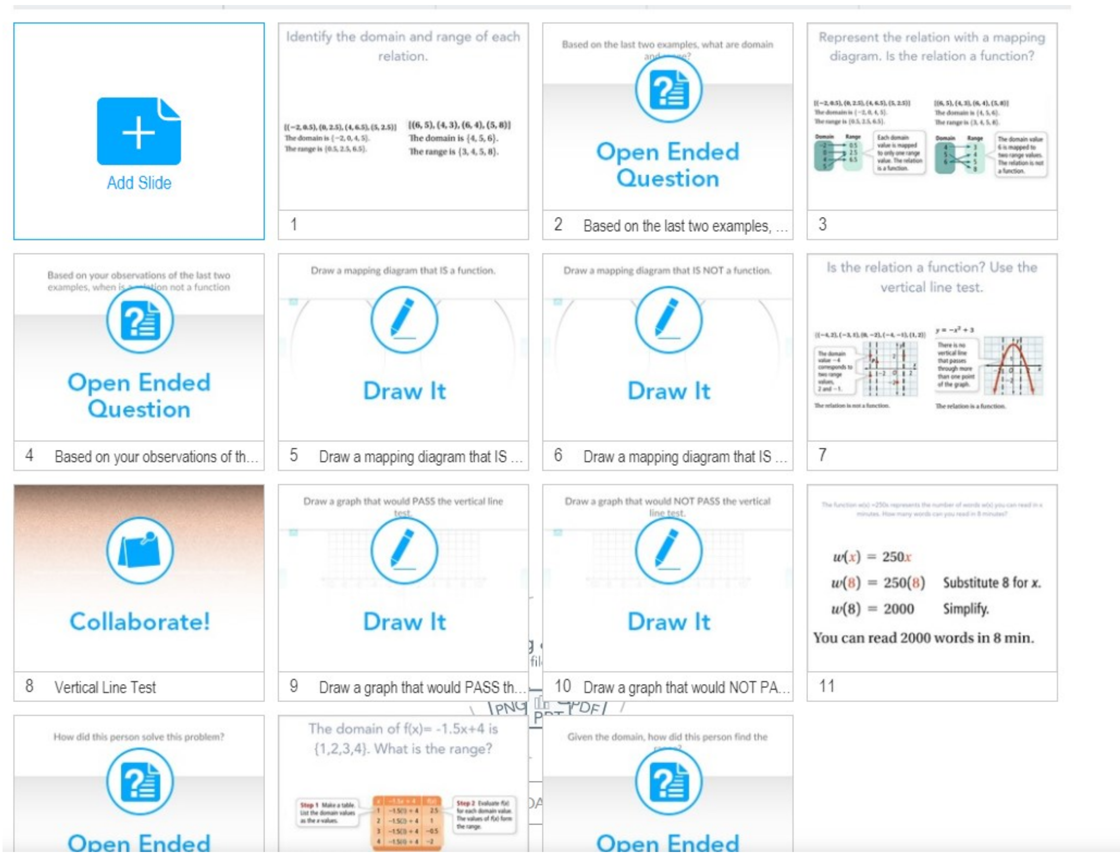
I agree to participate in the study in Ms. Barnes' Algebra 1 class.

Student Name (Printed): _______________________________________

Student Signature: ____

Date: ______________________

Appendix F: Lesson 1 (Nearpod Slides)



Appendix G: Lesson 1 (Student Notes)

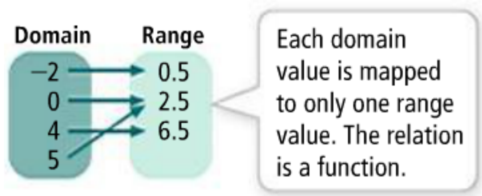
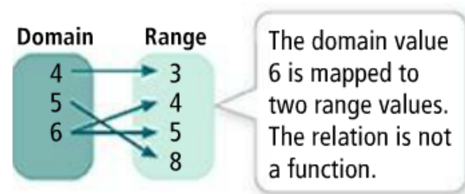
Formalizing Relations and Functions

Example 1: Identifying Domain and Range

$\{(-2, 0.5), (0, 2.5), (4, 6.5), (5, 2.5)\}$ The domain is $\{-2, 0, 4, 5\}$. The range is $\{0.5, 2.5, 6.5\}$.	$\{(6, 5), (4, 3), (6, 4), (5, 8)\}$ The domain is $\{4, 5, 6\}$. The range is $\{3, 4, 5, 8\}$.

Based on the examples above, what are domain and range?

Example 2: Identifying Functions using Mapping Diagrams

$\{(-2, 0.5), (0, 2.5), (4, 6.5), (5, 2.5)\}$ The domain is $\{-2, 0, 4, 5\}$. The range is $\{0.5, 2.5, 6.5\}$.  	$\{(6, 5), (4, 3), (6, 4), (5, 8)\}$ The domain is $\{4, 5, 6\}$. The range is $\{3, 4, 5, 8\}$. 

Based on your observations of the two examples above, when is a relation NOT a function?

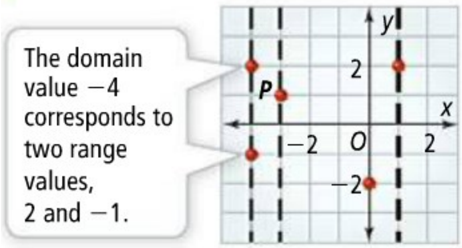
Your turn! Identify the domain and range of each relation. Then use a mapping diagram to determine if the relation is a function.

A) $\{(3,7),(3,8),(3,-2),(3,1)\}$ **B)** $\{(6,-7),(5,-8),(1,4),(7,5)\}$

C) $\{(4.2,1.5),(5,2.2),(7,4.8),(4.2,0)\}$

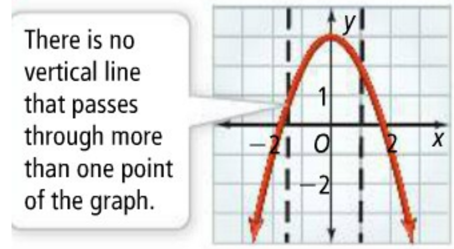
Example 3: Identifying Function Using the Vertical Line Test

$\{(-4, 2), (-3, 1), (0, -2), (-4, -1), (1, 2)\}$



The relation is not a function.

$y = -x^2 + 3$

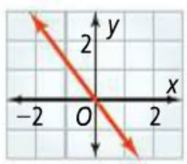


The relation is a function.

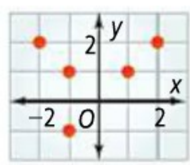
Based on your observations of these examples and what we know about functions, describe the vertical line test in your own words.

Your turn! Use the vertical line test to determine if the relation is a function.

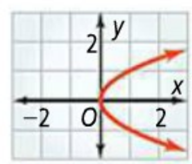
C)



D)



E)



Example 4: Evaluating a Function

The function $w(x) = 250x$ **represents the number of words *w(x)* you can read in *x* minutes. How many words can you read in 8 minutes?**

$w(x) = 250x$

$w(8) = 250(8)$ Substitute 8 for *x*.

$w(8) = 2000$ Simplify.

You can read 2000 words in 8 min.

How did this person solve this problem?

Example 5: Finding the Range of a Function

The domain of $f(x) = -1.5x + 4$ **is** $\{1, 2, 3, 4\}$**. What is the range?**

Step 1 Make a table. List the domain values as the *x*-values.

x	$-1.5x + 4$	$f(x)$
1	$-1.5(1) + 4$	2.5
2	$-1.5(2) + 4$	1
3	$-1.5(3) + 4$	-0.5
4	$-1.5(4) + 4$	-2

Step 2 Evaluate *f*(*x*) for each domain value. The values of *f*(*x*) form the range.

The range is $\{-2, -0.5, 1, 2.5\}$. The correct answer is A.

Given the domain, how did this person find the range?

Your turn! Evaluate the function.

F) You are buying orange juice for \$4.50 per container and have a gift card worth \$7. The function $f(x) = 4.50x - 7$ **represents your total cost f(x) if you buy x containers of orange juice and use the gift card. How much do you pay to buy 4 containers of orange juice?**

Your turn! Given the domain, find the range of the function.

G) $f(x) = 2x - 7; \{-2, -1, 0, 1, 2\}$ **H)** $f(x) = -4x + 1; \{-5, -1, 0, 2, 10\}$

Appendix H: Completed Observational Protocol

Observational Protocol
Part 1 – During Observation

Observer: [redacted] Date of Observation: 1/10/17

As you observe the lesson, record in Column 3 the events of the students as they relate to the following topics:

1. Students' use of correct worked examples.
2. Students' use of incorrect worked examples.
3. Students' use of self-explanation prompts.
4. Students' ability to communicate mathematical ideas and concepts.
5. Students' ability to describe mathematical procedures.
6. Students' ability to transfer their knowledge to new situations.
7. Students' level of engagement.
8. Students' attitudes.

Provide a time stamp in Column 2 to correspond with the events. Fill out the protocol with regards to items 1-8. After the lesson, assign an appropriate topic number for the events described in Column 3 (e.g., 1, 3, 7) in Column 4. More than one line can be used to discuss any event(s). More than one topic number can be used to describe any event(s).

Line:	Time:	Event:	Activity Number(s):
1	8:10	Read through solved problem + answer questions pertaining to the problem	1, 3, 4, 5
2	8:19	Discuss 1st question at table group.	1, 4, 7, 3
3	8:21	1 student shares out their answer to the whole class	6, 3
4	8:22	Barnes leads class discussion about the concept of substitution	
5	8:23	student response to question 2 – talked through steps	6, 3
6	8:25	students attempt a problem on their own using the example as their guide	6, 8
7	8:31	After working the problem, students study a second pre-solved example individually	1, 7, 5
8	8:37	"The problem's different because it's longer + we have to solve for y"	6, 4
9	8:39	"There's no number attached to the y so we solved for it instead of x"	5
10	8:40	"Solve the second equation because that has nothing in front of the y"	5, 6
11	8:41	A student who already finished the packet walks around to help other students	7, 4

Line:	Time:	Event:	Activity Number(s):
12	8:50	walk through the problem as a class	
13	8:51	"when you find x plug it into the original equation"	5, 6
14	8:52	Q & A on infinitely many or no solution based on analysis of ~~the~~ two solved problems	4, 6, 7
15	8:54	"In order to have infinitely many solutions the #s have to equal the same thing"	4, 8
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Overall, list things you saw that were successful implementations of MP7:

- Student's followed directions well and showed ~~a~~ solid critical thinking skills as they analyzed the solved problems.
- Knowledge transfer from the solved problem to the ones' the students solved seemed smooth

Overall, list things you saw that appeared to be challenges as the teacher tried to implement MP7:

- Student's scaffolding was not always solid so some reteaching was necessary
- A lot of redirection was needed throughout the class
- Formative assessment ~~as~~ of the whole class could be challenging as the same few kids seem to answer Q's in class discussion

Do you have any suggestions of how the lesson could be altered? If yes, please list your suggestions and explain your reasoning.

- With problems that need distributing, I would solve one with the students so they see the process as it happens. This gives struggling students greater confidence to try ~~the~~ other problems on their own
- For formative assessment throughout the lesson, have the whole class indicate with thumbs up or a finger scale of 1-5 how confidant they feel in the solving process.