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Student Discourse and Problem Solving in a High School Mathematics Classroom

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STUDENT DISCOURSE AND PROBLEM SOLVING IN A HIGH SCHOOL MATHEMATICS CLASSROOM

A Master's Thesis

Presented to

The Graduate College of

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In Partial Fulfillment

Of the Requirements for the Degree

Master of Science in Education, Secondary Education

By

Natalie Chism

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ABSTRACT

The purpose of this study was to explore the problem-solving process and discourse in three high school Algebra 2 classes and analyze how discourse might be used to facilitate the problem-solving process. High school Algebra 2 students in this study were asked to engage in discourse with their peers in order to reach conclusions in open-ended problem-solving tasks. The teacher acted as the facilitator and encouraged students to act as the mathematical authorities. On two different days, students were given two different real-life problem-solving tasks and asked to reach possible conclusions to those tasks. Three research questions guided the study: the role of discourse in the problem-solving process, the role of the teacher in discourse, and students' perceptions of discourse. The study found that students who were engaged in the discourse had the opportunity to use discourse as a part of the problem-solving process. The teacher had a role in creating a classroom environment focused on discourse, creating appropriate tasks, and facilitating student discourse. While some students did not engage in the discourse process or think the discourse process was helpful for their understanding, many students stated their learning was enhanced because they were able to hear from a variety of perspectives.

KEYWORDS: discourse, problem-solving process, high school, mathematical authority, teacher role

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CHAPTER I: OVERVIEW OF THE STUDY

My desire is to always improve my teaching strategies. Therefore, I conducted this research to improve a specific teaching strategy I use regularly. I always want my students to have the best learning opportunities possible, and I want to know how best to provide them with those opportunities. In this study, I explored a specific mathematical practice designed to enhance the learning of students. Mathematical Practice 3 (MP3), established by the Common Core State Standards, proposes that all students, regardless of grade level, should have the ability to "construct viable arguments and critique the reasoning of others" (National Governor's Association Center for Best Practice [NGACBP], Council of Chief State School Officers, 2010, para. 4).

Appropriate implementation of mathematical practices helps students learn and understand mathematics at a deeper level by directing their focus to foundational concepts, rather than simply focusing on surface-level understanding and rote memorization. I believe students will understand mathematical concepts more thoroughly when they are allowed to discuss those concepts in large and small groups with their peers, as opposed to only being told those concepts in a lecture-style format presented by the teacher.

Aldrich (1951) proposed that critical thinking and problem solving are not merely school topics but rather are foundations of good citizenship. Aldrich also suggests that critical thinking can best be developed through controversial issues. If there is exactly one right answer in a situation, problem solving and critical thinking skills may not be necessary. However, when there are a variety of methods to reach several possible

conclusions, problem solving becomes relevant and necessary. Individuals trying to reach conclusions in such situations must analyze all components of a problem to determine the available tools to solve the problem and then evaluate if their conclusions are logical. Since problem solving is a relevant aspect of daily life, it is important that students learn and develop methods of reaching the conclusions to problems presented to them.

According to Kieran (2001), in regard to mathematical discourse, "an interaction is regarded as educationally productive if it has an impact on students' future participation in related mathematical problem-solving activity, whether that future participation involves individual or group work" (p. 195). The purpose of student discourse is not merely to engage in the answering the current question, but rather to learn and engage in problem-solving activities that will be useful in the future. Therefore, students who engage in MP3 while problem solving are expected to become better problem solvers in the future, whether they are solving problems on their own or in conjunction with others.

Rationale for the Study

In my classroom, I have often provided students with only a few methods to learn the required concepts—usually through verbal instruction and visual notes. I showed the students the way to solve equations, and the students learned my specific algorithm used to solve the mathematics equations. Students rarely had the opportunity, necessity, or requirement to develop problem-solving strategies on their own using their own methods. Rather, I explained the procedures and students copied specifically what I wrote and said.

This lecture-based style of teaching provides little, if any, necessity for students to engage in MP3. Rote memorization and recitation encourages students to learn basic mathematical calculations but does not allow students any freedom or opportunity to learn problem-solving strategies or incorporate other possible equation solving methods. Unless my students approached another teacher or tutor for remediation, they were only exposed to the algorithms I showed them in order to solve equations.

The limitations to teaching styles were further perpetrated by the curricular requirements of the district and the state. State end-of-course exams encouraged a focus on mathematical calculations with little emphasis on problem-solving skills and higher-order thinking. These expectations were reflected in the district curriculum. Few opportunities existed for students to engage in problem-solving situations as a result of the time required for dedication to understanding of mathematical calculations. Due to the curricular expectations, little time was previously devoted to encouraging and allowing students to develop problem-solving skills.

In my classes, lack of problem-solving skills on the part of the students became a concern for me. Students only knew how to answer questions and solve equations presented in the same format they originally learned. When I have asked students to solve equations presented in a different way or a different format than they had originally been taught, many of the students had shown confusion in how to approach those equations. Although they had been taught the mathematical algorithms necessary to solve the equations, they did not know how to transfer their understanding to solve equations presented in the new format. Additionally, my students had been generally unsuccessful when I have asked them to extend their understanding further or incorporate

several types of solving equations into solving one equation. For example, my students had been taught how to rationalize radical expressions and how to solve radical equations. However, when students were asked to solve a radical equation which also required rationalizing, many of those students were confused on what the expectation was and how to even begin solving the equation. This confusion was evidence of a larger concern for me—students who are unable to use rational thinking and problem-solving skills to answer questions that exist outside of the classroom.

I have often encouraged my students to check their answers with a partner, but this process only allowed students to determine if they have correctly understood and applied the necessary computational algorithms. Because their answers were easily identified as correct or incorrect, there was no need for student discourse. Students utilized rote memorization of mathematical facts and practiced using the solving algorithms on their own, or even with a partner, but I did not provide them with questions which required any type of discussion or development of problem-solving strategies. Even on the occasions when I would ask students to solve word problems and real-life examples, I acted as the mathematical authority in the room—students looked to me for the final say in whether their answers were correct or incorrect. There was no problem-solving strategy involved, but rather students employed rote memorization and basic mathematical skills to answer basic questions. As a result of this lecture-based style of teaching, I did not often provide students with opportunities to solve higher-order thinking tasks and thus there was no need for my students to develop deeper understanding of the concepts or engage in problem-solving strategies.

Purpose of the Study

The purpose of this study was to explore problem solving and discourse in three Algebra 2 classes and analyze how discourse might be used to facilitate the problem-solving process. A portion of this analysis was focused on student development of MP3—construct viable arguments and critique the reasoning of others. Students were provided with opportunities to interact and talk with their classmates, specifically to solve two open-ended problem-solving tasks related to systems of equations. Because the tasks had no specifically correct answers, students could not look to me to determine if their answers were correct. Rather, they were expected to converse in groups regarding possible conclusions and the reasonableness of those conclusions. Through these opportunities, I studied how students used discourse with their classmates to develop their problem-solving strategies and reach conclusions to open-ended tasks.

Research Questions

The following questions guided the research:

1. What was the role of discourse in problem solving?
2. What was the teacher's role in facilitating discourse?
3. What were students' perceptions of discourse?

Research Design

In this action research study, students in three different high school Algebra 2 classes were provided opportunities to engage in discourse with their classmates in an effort to solve two different open-ended problem-solving tasks on two different class days (see Appendices A and B)—one task each day. Because the high school uses a modified block format, and because of the depth to which I expected the students to

analyze the problem-solving tasks, I conducted this study on two block days, each lasting 94 minutes.

The specific tasks presented to the students were related to the concepts of solving systems of equations, with the intention of allowing students to discuss the tasks and reach various conclusions. Students were asked to solve the problems in their groups and to talk with their peers regarding possible solutions or methods to reach a conclusion. Part of this process involved the students providing immediate feedback to each other. My expectation was that students would state their conclusion or reasoning for a particular aspect of the task. Group members would then be expected to state that they either agreed or disagreed with that conclusion or reasoning. I further expected that disagreement with particular statements would result in the first student either defending their position or changing their opinion. This process would continue until the group reached a consensus for each aspect and generated a conclusion to the entire task.

Before and after the small-group discourse, I led a whole-class discussion on both days in order to identify common struggles, ideas, and conclusions between the groups. I expected that students would answer my questions and respond to the answers of their classmates. I expected that there would be times when students would affirm what their classmates said, while other times students might contradict their classmates' conclusions using their own reasoning.

At the end of each day, students were asked complete a student discourse survey to self-reflect on particular aspects of discourse that occurred during the small-group and whole-class sessions (see Appendix C). This survey focused on how the students perceived the discourse, the challenges and successes they experienced because of the

discourse, how the discourse helped them understand problem-solving concepts differently, and what they thought should have been different about either the discourse or the problem-solving tasks. I observed the student discourse and self-reflected on my instruction and participation during student discourse using my research questions as a guide. I kept a journal and recorded my observations both during and after the student discourse time. The school curriculum coach also observed the student discourse and offered written feedback about his perceptions of the student discourse and the teacher's role in student discourse using an observational protocol (see Appendix D). I video recorded class sessions to accurately quote student conversations, specifically seeking out instances of students engaging in discourse for the purposes of problem solving and reaching conclusions.

When analyzing the data, I used information gathered from my journal, the observational protocol, the student discourse surveys, and the video recordings. For each of the findings, I used data from at least two of these sources to support the conclusion of that finding.

Significance of the Study

The Common Core State Standards (CCSS) Initiative, formed in 2009, developed and established eight Standards for Mathematical Practice. These Standards for Mathematical Practice, published in 2010, provide a list of best practices that students at all grade levels should develop and teachers should encourage in their students. This study will further develop the learning that is taking place regarding the mathematical

practices. My desire for this study was to encourage my students to engage in MP3 while also developing their problem-solving skills.

This study also has a significant focus on encouraging students to use discourse to engage in the problem-solving process. Students were expected to use their discourse with their peers to analyze two different open-ended problem-solving tasks and reach conclusions to those tasks. This study is significant because it analyzed how students used their discourse during the problem-solving process.

I expect that this study will also have an effect on the way high school mathematics teachers in my district, and me specifically, teach classes. I plan to incorporate more opportunities for student discourse into future units and other classes I teach. Through this study I desired to discover some challenges and successes in involving students in developing problem-solving skills through discourse. I also hope to use what I learned to encourage and inform other teachers in their classroom instruction.

Assumptions

The following is a list of assumptions I made while conducting my study:

1. The students in my study had not previously been in a mathematics classroom focused on constructing viable arguments and critiquing the reasoning of others (MP3). I assumed the majority of my students' mathematical learning had been similar to the way I had previously taught—the teacher as the mathematical authority figure and students having little opportunity for interaction with peers.
2. The students would act and respond in a similar manner to the way they normally acted and would not behave differently than any of my other students would in a similar situation.

Limitations

The follow is a list of limitations I encountered during my study:

1. Some students were more comfortable working on their own and solving problems using their own methods, rather than engaging in discourse with others. These students were reluctant to participate in the discourse, and one student refused to participate at all, despite my repeated encouragement.
2. Due to his schedule, our curriculum coach was only able to observe the class discourse on the first day of problem solving. I was therefore unable to obtain data from him on the second day of problem solving and was limited in what I learned from him through the observational protocol.
3. Due to time constraints and district requirements of what I am expected to teach over the course of a year, I was only able to spend two days focusing specifically on student discourse and its role in problem solving using open-ended problem-solving tasks.
4. Due to the natural course of absences and illness, not all students attended school both days.

Definition of Terms

The following is a list of terms defined for the purposes of this study:

1. Discourse: For the purposes of this study, discourse is defined as specifically relating to students interacting with others through discussion of mathematical problems or concepts through verbal or written communication. This interaction may be between two or more students, or between a student or students and the teacher. Evidence of meaningful discourse includes a challenge of or affirmation of other students' work or language, students seeking clarification of fellow students' ideas, or students creating justification for their own mathematical ideas. Productive, meaningful discourse will have "an impact on students' future participation in related mathematical problem-solving activity, whether that future participation involves individual or group work" (Kieran, 2001, p. 195).
2. MP3: This is an acronym for Mathematical Practice 3 and refers to the third standard for Mathematical Practice from the CCSS. MP3 states that students should be able to "construct viable arguments and critique the reasoning of others" (NGACBP, Council of Chief State School Officers, 2010, para. 4).
3. Problem solving: This refers to an individual's ability to reason through a challenge and reach a conclusion. Problem solving is not simply "skill-and-drill" or rote memorization. In problem solving, different individuals may reach different conclusions as a result of their prior knowledge or solving strategies. Polya (1945) identified four stages in the problem-solving process—understand the problem, devise a plan, carry out the plan, and look back at the solution.

Summary

In my classroom, students are not given enough opportunities to solve problems and reach their own conclusions. In this study, I focused on implementing MP3 into my classroom by providing students with opportunities to converse with their peers and reach conclusions to two different open-ended problem-solving tasks on two different days. As a result of the student discourse, students were expected to become the mathematical authorities in the classroom. On two different days, students were expected to converse in their groups in order to engage in the problem-solving process to reach conclusions to two different open-ended tasks. The data analysis focused on self-reflection by students through a student discourse survey, feedback from the school curriculum coach guided by an observational protocol, journal notes of my own observations, and video recordings of student discourse.

CHAPTER II: REVIEW OF RELATED LITERATURE

A wide variety of teaching methods are used in high school classrooms. From my experience, direct instruction or lecture format, cooperative learning, and discussion-style format are some of the most common. While direct instruction may be more traditional in mathematics classrooms, that style of teaching does not generally allow students to engage in MP3. Instead, the teacher is the mathematical authority in the classroom and information is presented to the learners with little conversation or discussion (Baumann, 1988). This chapter addresses the meaning of discourse, the role of the teacher in discourse, and how discourse can be used in the problem-solving process.

Meaning of Discourse

Pirie and Schwarzenberger (1988) created a definition of mathematical discussion, which helped inform the definition I used for discourse. They defined mathematical discussion as "Purposeful talk on a mathematical subject in which there are genuine pupil contributions and interaction" (p. 461). By this definition, teachers introducing material to students is not considered discourse if the only student response is merely factual answers to teacher questions. Therefore, a lesson containing only a teacher-led lecture will not be the best style of instruction if the goal is to help students develop problem-solving skills through discourse.

According to Goldenberg (1992), educators have attempted to make teaching more relevant to students for several hundred years (p. 316). "Unfortunately, instructional conversations—or good classroom discussions—are notable not only for

their desirable attributes, but also for their rarity" (p. 318). Goldenberg elaborates on defining characteristics of an instructional conversation (IC)—it must be interesting, engaging, and relevant to students. An IC must have a clear focus, and all students must participate and engage in the conversation. Furthermore, an IC must be both instructional and conversational. This can sometimes be paradoxical, as instruction "requires a deliberate and self-controlled agenda" whereas conversations "appear to be natural and spontaneous interactions" (Goldenberg, 1992, p. 319). Therefore, a good IC must include characteristics of both spontaneous conversation and a structured format.

Moschkovich (2007) conducted a study on student-teacher discourse. She reflected on a specific question-response discussion between a teacher and student regarding features of a trapezoid. She explored the different background knowledge and meaning of words brought in by teachers and students, and how that prior knowledge or viewpoint may alter the discussion or change the way a question is answered. She further discussed how even formal definitions of mathematical topics, such as the word 'function,' have changed over time or as new understanding is gained. As a result of these changes, there may be confusion or misunderstanding between individuals involved in a discussion, even when they are using appropriate mathematical words or phrases.

It is possible that a question, to the teacher's knowledge, has one highly specific answer but could be answered several ways depending on the student's prior knowledge. In the discourse observed by Moschkovich (2007), a student saw a trapezoid as half of a parallelogram, because of his understanding of those quadrilaterals. He understood a trapezoid to contain one pair of parallel lines and a parallelogram to contain two pairs of parallel lines. By that understanding, it made logical sense to the student that a trapezoid

would be half a parallelogram. Even when questioned by the teacher, the student remained firm in his understanding. Moschkovich (2007) specifically acknowledged that "no question has a single meaning" (p. 26). Even simple questions such as "Is this figure a parallelogram?" may have contradictory meanings for different students, based on their understanding of the definition of a parallelogram and other quadrilaterals or the type of answer they think they are expected to give. The same could potentially be true of any question asked of students. While the teacher may expect a question to have a single answer, or even a general type of answer, student understanding of the question and prior knowledge may have an impact on the way students answer that question. This prior knowledge may cause two students to answer the same question in completely different ways.

Teacher Role in Discourse

Evans (2017) studied the incorporation of student discourse into her classroom. Over the course of two months, Evans spent time encouraging students to take charge of their own learning by engaging in MP3. She pushed them to have authentic discourse with their classmates in an effort to have students understand mathematical thinking and reasoning more thoroughly. One of Evans' goals through this process was to transfer the responsibility of learning from herself as the teacher onto students as the learners. She based this on the understanding that "when the teacher is doing the work, the teacher is only guaranteeing that she has learned the material" (Evans, 2017, p. 93). This is further addressed in a phrase commonly used among my colleagues and myself, "the person doing the work is the person doing the learning." Evans (2017) acknowledged that many

times in her teaching career, she would resort to using one strategy she determined would be "easiest, fastest, or most likely to be used later in their mathematics careers" (p. 94). However, through her study, she consistently tried to shift the responsibility of learning and understanding onto her students. She did this through consistently implementing MP3 and establishing mathematical discourse as a foundation of her classroom culture.

Ghousseini, Lord, and Cardon (2017) examined elementary classrooms and noticed that many teachers complained about their students' abilities to successfully engage in group discourse. Their students struggled with how to work together in groups and how to ask their group members for help instead of asking the teacher. Some teachers also expressed their concerns that their students simply did not know how to work together. Ghousseini et al. (2017) offered ideas and examples of how a teacher might potentially avoid these concerns. First, the teacher should model good discourse practices. The teacher should give examples of what productive discourse looks and sounds like, and what to do if a partner says something incorrect. Next, the teacher should provide opportunities for students to both listen and respond to others' ideas. To set the stage for this, the teacher should allow students to practice responding to their neighbor's thinking and building upon what they have said. Ghousseini et al. (2017) found that teachers wanting to engage their students in discourse should provide examples and practice in discourse before actually assigning the small groups with the tasks. They discovered that this scaffolding will help students become more successful and engaged in the discourse process.

Banse, Palacios, Merritt, and Rimm-Kaufman (2016) observed four teachers in fourth- and fifth-grade classes containing at least 40% English Language Learner

students. Their results were similar to those of Ghousseini et al. (2017). During mathematical discussions in class, the teachers used scaffolding to help guide the students in their thinking and understanding. They started by asking open-ended questions, usually containing the words "how" or "why." In the observed class, the teacher asked students if a given shape was a square, and why or why not. The teacher allowed students to discuss the question in groups before asking the class as a whole. This format allowed students time to think critically and discuss their ideas before the formal discourse time. After asking open-ended questions, the teacher asked a series of closed-ended questions. This type of questioning allowed time for the student to solve the problem in a more structured format. Banse et al. (2016) also suggests that both open- and closed-ended questions should be used by the teacher in order to facilitate strong discourse in students.

Dale and Scherrer (2015) explored the amount of scaffolding necessary for students to be successful during discourse. They provided three scenarios in which three different teachers wrote a word problem on the board involving two students eating portions of a pizza, and students worked in groups to answer questions about the word problem. In all three scenarios, the teacher walked around the room while students were working, but each teacher provided a different type and amount of scaffolding for students. Dale and Scherrer (2015) then explained which scenario would help students to be the most successful. In the first scenario, the teacher only observed the group work. She saw some students correctly understanding and solving the problem, some students confused about the problem, and other students debating pizza toppings. In the second scenario, the teacher immediately corrected students when they made a mistake. He did

not allow the groups time to think about the problems on their own, but instead told them exactly what they had done wrong and fixed it for them. When he noticed several groups making the same error, he stopped the whole class and explained a correct solving method to the entire class. In the third scenario, the teacher asked questions of all the groups, whether they had the correct answer or not. If they did have the correct answer, she asked them why they had that answer, how they got it, and what it meant. She also suggested they should find another way to explain their solution. If they did not have the correct answer, she guided them to find the correct answer. She did not tell them what to do, but instead helped them think through the problem and decide methods they could use to solve the problem.

The first teacher, while walking around and observing student conversations, did not respond, correct, or encourage students in any way. She provided no scaffolding and never told the students if their answers were correct. This process left students confused and frustrated, and the teacher did not know if the students understood the concept. The teacher in the second scenario provided too much guidance for the students and did not allow any struggle time or thinking time on their own before he jumped in to address their mistakes. Although he made sure all the students had the correct answer, he did not allow them to figure it out on their own. As a result, his students may not be able to solve similar problems without his help in the future. The students may expect him once again to answer all their questions without needing to work on their own to find the answers. The third teacher provided an appropriate amount of scaffolding to increase the understanding of the students who got the answer immediately and encourage students who were still struggling. Dale and Scherrer (2015) explain that "the key to making

student struggle productive is providing the right amount of scaffolding" (p. 61), as demonstrated by the third teacher. She allowed her students to struggle like the second teacher, but stepped in before they were frustrated, as was the case with the first teacher.

Several other researchers (Batista & Chapin, 2019; Bertolone-Smith & Gillete-Koyen, 2019; Gresham & Shannon, 2017) have also examined tools a teacher might use to help facilitate discourse with their students and help their students be successful in the discourse process. They offered similar suggestions: the teacher should scaffold the discourse time by asking a variety of open-ended and closed-ended questions, allow students to practice discourse, encourage all students to voice their thoughts and answers, and encourage students to constructively criticize their own answers and the answers of others.

How Discourse Facilitates Problem Solving

According to Polya (1945), there are four steps in the problem-solving process; an individual engaging in the problem-solving process must understand the problem, devise a plan, carry out the plan, and look back at the solution. Polya (1945) also discussed how essential it is that students work through the four steps in order. For example, it is nearly impossible to start calculations if the question is still unclear. Although Polya (1945) described how an individual could work through the four steps, this information is transferable and could be extended to a group dynamic, where students working in a group must engage in discourse to work through the four steps to reach conclusions.

Goldenberg (1992) states that "instructional conversations stand in contrast to many relatively 'traditional' forms of teaching (e.g., lectures, recitation, direct

instruction), which are based upon the assumption that the teacher's role is to help students learn what the teacher already knows and can do" (p. 324). Therefore, instructional conversations are not based on what the teacher presents but rather what the students contribute to the conversation. He also argues that instructional conversations are not necessarily always the best instructional method. Instructional conversations should be used along with other instructional methods such as lecture or direct instruction, and the method used may depend on the material being presented. Nevertheless, Goldenberg (1992) states that instructional conversations should be used for concepts that are relevant and engaging for students. He explains that "each statement or contribution builds upon, challenges, or extends a previous one" (Goldenberg, 1992, p. 318).

Combining the works of Polya (1945) and Goldenberg (1992), discourse can be an effective tool to use in helping students engage in the problem-solving process. Students can use their discourse to enhance the understanding of their peers, and this deeper understanding can then inform the plan and solution in the problem-solving process.

Summary

While research regarding discourse and problem solving is ongoing, many researchers are identifying common themes and procedures to enhance discourse with students. Allowing students time to practice discourse and properly scaffolding discourse has been shown to increase student engagement during discourse. Banse et al. (2016) and Ghousseini et al. (2017) showed this in their research by analyzing effective scaffolding

practices established by teachers. The phrasing of questions and knowledge of background information will inform the answers provided, as shown by Moshkovich (2007). Through using proper procedures, teachers can develop a culture of discourse in their classrooms that will encourage students to talk with their classmates in a productive and helpful manner, as shown by Evans (2017). The role of mathematical authority should also be shifted from the teacher to the students, as found by Evans (2017). Additionally, allowing student to use discourse in the four steps of the problem-solving process may also help students engage in the process and develop better problem-solving skills, as shown by Polya (1945) and Goldenberg (1992).

CHAPTER III: METHODOLOGY

The purpose of this study was to explore problem solving and discourse in three Algebra 2 classes and analyze how discourse might be used to facilitate the problem-solving process. This chapter will describe specific components of the research study, including the research design, site of the study, study participants, ethical considerations, data collection procedures, and data analysis processes.

Research Design

This action research study was conducted in three of my high school Algebra 2 classes. Two weeks before the study, I organized students into groups of three or four and created a seating chart accordingly. I explained to my students that their groups were composed of the students in their rows so that they could begin working with each other and getting to know each other. I wanted my students to have an opportunity to interact with their group members over time, not only on the days I specifically assigned the problem-solving tasks. When I created the groups, I made sure they were composed of students who had a variety of mathematical knowledge. In each group, I placed at least one student who had consistently performed well in my class, as evidenced either by their course grade or what I had learned of them through prior interactions that year. My goal through this process was to have at least one person in each group who had a good understanding of the concepts and would be able to assist their group members. I also intentionally chose to assign the groups rather than let students pick their own groups. I have found in the past that if students pick their own groups, they often work with their

friends and end up engaging in more off-topic conversations. Based on my prior understanding of my students, if I knew that two or three students were more easily sidetracked when working together, I assigned those students to separate groups.

This study occurred in three different Algebra 2 classes on two different days in February. On both days of this study, I provided students with problem-solving tasks about possible real-life scenarios. The first task (see Appendix A) was based on vehicles used for a road trip. Students were given information about two different vehicles available and were asked to determine other information about the vehicles, such as gas cost per mile. Ultimately, students were asked to reach a conclusion about which vehicle would be best for a particular trip and provide their reasons behind that conclusion. The second problem-solving task (see Appendix B) was about a student who can use his birthday money to download computer games or music. Students were asked to identify possible purchasing combinations and determine the best combination.

On the two days of data collection, I gave students two different open-ended problem-solving tasks (see Appendices A and B) and had students discuss those tasks in their groups. I chose those tasks because they were similar to problem-solving tasks we had previously used in Algebra 2. However, I adjusted the questions to make them open-ended. For example, one of the original questions asked "How much will it cost to drive each vehicle 200 miles?" I changed the question to ask "Suppose your family drives from XXXXXXX, MO to XXXXXXX, MO. Which is the better vehicle for that trip?" Through this process of creating open-ended questions, my goal was to allow students to reach a variety of conclusions based on their prior understanding and personal viewpoints. The original question had one specific answer that students would either

answer correctly or not. The new question had several possible answers, any of which could be correct depending on the students' reasoning.

As students were working on both days, I observed and video recorded student conversations. Although I knew students would ask me questions as I was observing, I almost always redirected the students to ask those questions of their group members. My goal was to ensure that most of the discourse those days was between students. The problem-solving tasks were intentionally open-ended so students could not ask me if their answers were strictly correct. Instead, I wanted the discussions to be student-focused—analyzing the problems from various viewpoints and conversing about various conclusions to the problems.

My own reflections as the researcher were also included in the data. Using my research questions as a guide, I documented my reflections in a journal, and I included information from the journal in my findings. During the class discussion times, as well as after class each day, I documented conversations I heard between students and conversations I had with students. I also wrote about my involvement in their discussions and the things they told me about their discourse.

In an attempt to gather as much data as possible, I also created an observational protocol (see Appendix D) and had the school curriculum coach observe the class sessions on the first day. His purpose was to specifically document situations of students using discourse to reach conclusions and solve problems, as well as my interactions with students. He also offered suggestions on teaching elements I could have done differently, either before or during the student discourse, to guide the students to be more engaged in the discourse and problem solving.

After the small-group discourse time, I again led each class in whole-class discussion. This discussion time focused on the specific conversations that had occurred in the small groups and allowed students to discuss the tasks as a whole class. I encouraged the students to ask and answer questions of each other, as well as explaining their own thoughts and problem-solving methods.

At the end of both days of problem solving, students completed a student discourse survey (see Appendix C). This survey asked students to reflect and respond to their participation in the discourse each day. They were asked to explain what they learned from the discourse as well as some challenges they experienced in the discourse.

Classroom Environment on Day 1. On the first day I conducted this study, I spent approximately 15 minutes at the beginning of class explaining and discussing the idea of discourse with the whole class. I asked them to tell me what discourse should entail. Some students gave me answers like "speaking with other people." Others said discourse was "having a conversation," some simply said discourse was "interacting." I then asked what would not be included in a discourse and they responded with statements like "being angry" or "having random side conversations and getting off topic." I then gave my students a possible scenario, hoping to get them to think about discourse at an even deeper level. The following discussion occurred in one of my classes and illustrates student understanding of the discourse process.

> Me: "What if we are having a discussion and I say that elephants are purple. What would be your response?"
> Mark: "I disagree. I watch the nature channel."
> Me: "Well, when I was 5, I drew a picture of an elephant and it was purple. Therefore, elephants should be purple."
> Megan: "Just research it. Google 'what color are elephants?'. It still might come up with purple elephants though [laughing]."
> Jesse: "I would say it really depends on the person's perception of pigment."

Me: “Okay, so maybe what looks to me as purple might actually be gray.”
Jesse: “Or if they’re colorblind, they’re out of luck.”
Mark: “Who is to say the research we look up is actually right? I think elephants are gray, but I’ve never actually seen a real elephant.”
Sally: “Or maybe they just paint them gray.”
Me: “So what’s a way we could figure it out for sure?”
Several students: “Look it up. Google.”
Me: “So for most people, if I said ‘elephants are purple,’ you wouldn’t just agree with me and move on. You would either try to get more information about why I think that, or you would try to prove me wrong. What you’re not going to say is ‘You’re wrong, you don’t know anything.’ That’s a little harsh. What you would do is look it up and show me that elephants are actually gray.”

The main goal in this part of the beginning of class discussion was to give students an idea of appropriate and inappropriate discourse. I explained that in quality discourse, all parties are involved and are able to give their opinions. If one member of the group makes a statement and another member disagrees, they discuss why they disagree and attempt to reach a conclusion. They provide evidence for their reasoning and continue discussing the issue until they agree. I also explained that if someone in the group says something factually incorrect, such as the purple elephant example, it is the responsibility of the other members to correct their wrong information, rather than affirming an incorrect statement.

I then gave students an open-ended problem-solving task (see Appendix A) and had them discuss that task in their groups. The goal of this discourse was not only for students to reach a conclusion to the problem, but also to have meaningful dialogue with their peers about different ways to reach different conclusions. The problem-solving task on the first day of discourse was about two possible vehicles a family could take on a road trip. One vehicle was owned by the family while the other could be rented. However, the rental vehicle earned better gas mileage. I asked students to discuss the

information in their groups in order to find and calculate information about both vehicles, such as fuel cost per mile and when the cost of the vehicles would be equivalent. They were then asked to discuss in their groups about what that information meant and reach a conclusion about which vehicle would be better for a day trip and a weekend road trip.

For the last 20 minutes of the class period, we spent time discussing the problem-solving task as a whole class. I asked students from various groups to tell the whole class some of the things they discussed in their groups as they worked through the problems. My goal for this portion of the discourse was to see if some groups considered information that other groups had neglected and to ensure that all students in the class had the opportunity to learn from that information.

Classroom Environment on Day 2. On the second day of discourse, I again started with a whole-class discussion. I knew that some of the students and groups had told me they struggled on the first day with identifying the best scenario. We, therefore, spent about 10 minutes discussing how the word "best" is subjective and why the best for one person might be different than the best for another. This conversation was necessary for the students, because their understanding of the word best informed the types of answers they reached.

I then assigned students the second problem-solving task (see Appendix B). The second task was about a student who is given money for his birthday and can spend that money to purchase either games or music. Students were asked to identify possible purchasing combinations and determine which combination might be the best for different scenarios. Students worked in the same groups on the second day and were again expected to discuss the problem-solving task with their group members in order to

reach conclusions to the task. For the last 20 minutes of the day, we again spent time as a whole class discussing the conclusions students had reached and allowing students from various groups to explain their reasoning.

Site of the Study

The research took place in three Algebra 2 classes at a high school in south central Missouri. The high school has approximately 1,500 students in grades 9-12. According to the 2010 U.S. Census Bureau, 94.1% of residents were white, 1.3% African American, 0.6% Native American, 0.7% Asian, 0.1% Pacific Islander, 0.7% from other races, and 2.4% from two or more races. The high school has 51% students who qualify for free and reduced lunch.

The high school operates using a modified block schedule. This means that for a typical 5-day week, for the first three days, students attend 7 classes for 47 minutes each. On the other two days, block classes occur lasting 94 minutes each. On the first block day, students attend 4 classes. On the second block day, students attend 3 classes followed by a study hall time for the last 94 minutes.

Participants

The participants in this study were the students in my three high school Algebra 2 classes and myself as their teacher. Two of the classes had 19 students and the third class had 21 students, for a total of 59 student participants consisting of 10 sophomores, 48 juniors, and 1 senior. One student had an IEP because she is autistic. These students were chosen as a convenience sampling because they were students in my classes. As

high school students, they were between the ages of 15 and 17. By dividing the students in each class into groups of three or four, I had six groups in each class.

Ethical Considerations

Prior to implementation of this study, I received approval from the Missouri State University Institutional Review Board (see Appendix E). The IRB approval number is IRB-FY2019-301 and it was approved January 30, 2019. This study was conducted with high school students who were minors, so I received consent from students' parents (see Appendix F). I also obtained approval from my building principal.

Any data reported was completely anonymous. For any quotes made by specific students, a pseudonym was used in order to maintain that student's anonymity.

As the teacher of these students, I had already developed a relationship with them. Therefore, I made sure that my personal feelings towards students did not affect my data gathering or reporting. I did this by talking with all groups equally and responding in a similar manner to all students. I attempted to remain objective, and the qualitative data I gathered was not skewed by what I thought a student should have said or should have been capable of. I ensured this by encouraging all students, when they asked me questions, to discuss those questions within their groups. I provided suggestions on approaches they might take to reach a conclusion, but I treated each student and each group in the same manner. I also attempted to ensure my data was objective by triangulating the data from my journal and from the video recordings with information obtained through an observational protocol completed by our curriculum coach.

Data Collection Procedures

This section explains the types of data used in this study and how that data was collected. The instruments used were an observational protocol (see Appendix D) and a student discourse survey (see Appendix C). Data was also collected from a teacher journal and video recordings. Data from the observational protocol, the teacher journal, and the student discourse surveys answered the first research question. Data from the teacher journal, the video recordings, and the observational protocol answered the second research question. Data from the student discourse surveys, the video recordings, and the teacher journal answered the third research question.

Instrumentation. I created an observational protocol (see Appendix D) to be used by our school curriculum coach while he observed the class sessions. This observational protocol asked the curriculum coach to identify and give examples of specific instances of students engaging in MP3 with their classmates, critique the student discourse, examine the teacher's role in the discourse, and offer suggestions of things the teacher might have done differently to help students be more engaged in the discourse and problem-solving process. Data from the observational protocol helped answer my first two research questions.

During and after each class session, I kept a journal of my reflections of the student discourse. While writing in my journal, I kept my research questions in mind and made notes of my interactions with students as well as their interactions with each other. I recorded comments students made to me, both during and after the discourse, regarding their perceptions of the discourse and how they felt the discourse was helping them or not. I also video recorded the class sessions and group discussions as a means of

accurately documenting conversations. Information from my journal and the videos helped me answer all three of my research questions.

At the end of each class session, I had students complete a student discourse survey (see Appendix C) which asked them to self-reflect on their participation during the discourse, their perceptions of the discourse, and their perceptions of the problem-solving tasks. Student feedback from the student discourse survey helped me answer my first and third research questions.

Role of the Researcher. As the teacher and participant in the study, my own reflections were also a part of this study. I kept a journal of my teaching practices and participation in the study. I reflected on the ways I thought implementing MP3 affected the way my students answered questions in the problem-solving tasks. During the small-group discourse, I checked with each group periodically to gather information about how they were progressing through the problem-solving tasks, which I documented in my journal.

Data Analysis

There were four types of data collected (discourse surveys, video recordings, teacher journal, and observational protocol), and each was analyzed separately but in a similar manner. During the data analysis process, I relied heavily on a protocol focused on scoring, coding, and sorting data and participant responses by theme. These themes heavily informed my findings. This themed data then, in turn, answered each of the research questions.

Student Discourse Surveys. I started by analyzing and scoring student discourse surveys. For each of the six questions, answers were assigned a value of 0, 1, 2, or 3. A value of 0 meant that the question was not answered or the student gave an irrelevant response—such as "I don't know," "none," etc. A value of 1 meant the student gave an answer, but it was not relevant to the question asked. A value of 2 meant the student gave a meaningful answer, but the response was partial and only moderately thoughtful. A value of 3 meant that the student answered the question thoroughly and thoughtfully, providing a full and complete answer.

Once I scored each of the answers for every student, I tallied how many of each score there was for each question (see Figure 1 and Figure 2). The threshold of inclusion for responses from the surveys was a 2 or 3 (responses that demonstrated relevancy to the question) to identify the study's main findings. However, it was also interesting to note how many answers for each question were coded as a 0 or 1.

After I scored each reply on the student discourse surveys, I compiled a list of the answers to each question that received 2 or a 3. I then categorized and sorted those answers, grouping them according to commonly reoccurring theme. Those categories became the main findings of the study (see Figures 3 and 4). Once I had a list of main findings, I analyzed the other sources of data (teacher journal, video recording, and observational protocol) to determine if those findings were supported by other sources.

Video Recordings. One source of data was the video recordings I made during student discourse. After both days of the study were completed, I listened to the video recordings to hear conversations between students, noting instances when students used their discourse to help answer questions in the problem-solving tasks, as well as

statements students made expressing their opinions and perceptions of the discourse. These in-class comments were transcribed. In a manner similar to the student discourse surveys, useful and relevant comments were sorted by theme and included in the findings.

Teacher Journal. Another source of data was the journal I kept of my observations of the class discourse sessions, guided by my research questions. I took notes about my role in the student discourse, from the way I started the class and introduced the problem-solving tasks, to interjections I made or questions I asked and answered during student discourse times. I also wrote about statements I heard from students, either to their peers or to me. Similar to the surveys and video comments, the statements in my journal were sorted by theme. This data was used to enhance the findings from the other sources.

Observational Protocol. The school's curriculum coach observed three of the six class sessions and answered questions through an observational protocol regarding his observations during the student discourse. These observations included both student discourse notes and the ways the teacher interacted with the students. Comments and observations from the observational protocol were (in a similar manner as before) coded and sorted by theme. This provided further insight when triangulating data for the main findings.

Summary

This study focused on student discourse as a means of developing problem-solving skills. Students in three high school Algebra 2 classes solved two open-ended

problem-solving tasks while discussing those tasks in small groups. The teacher observed and recorded student conversations and kept a journal of her thoughts and participation during the discourse. The school curriculum coach also observed the student discourse and completed an observational protocol of his observations. Following the class discussions, students completed a student discourse survey detailing their experience with the discourse and their thoughts of the problem-solving tasks. Data collected from the teacher journal, the video recordings, the observational protocol, and the student discourse surveys was used to answer the three research questions.

CHAPTER IV: FINDINGS

The purpose of this study was to explore problem solving and discourse in three high school Algebra 2 classes, and to analyze how discourse might be used to help students engage in the problem-solving process. Students were presented with two different problem-solving tasks on two different days and asked to converse with groups of their peers in order to reach conclusions to those problems. Along with our school curriculum coach, I observed student conversations and noted instances of students engaging in meaningful discourse within their groups. I video recorded student discussions to accurately quote conversations and reflect on student conversations. I kept a journal about my reflections of the student discourse and my involvement in their discourse. I also had students complete a survey at the end of each day, asking them to self-reflect on their reflections of the discourse. Findings from common thoughts of students in that survey, specific conversations between students, observations from the curriculum coach, observations from the video recordings, and notes from the teacher journal are found in this chapter.

At the end of each of the two days of this study, students completed a student discourse survey (see Appendix C). I scored their answers to each question as a 0, 1, 2, or 3 based on quality and depth of response, as explained in the Methodology Data Analysis section in Chapter 3. I tallied the number of answers to each question that received each score. There were 51 survey responses on Day 1 and 35 survey responses on Day 2. Figure 1 shows the breakdown of scores for each question in day one. Figure 2 displays the breakdown of scores for the second day.

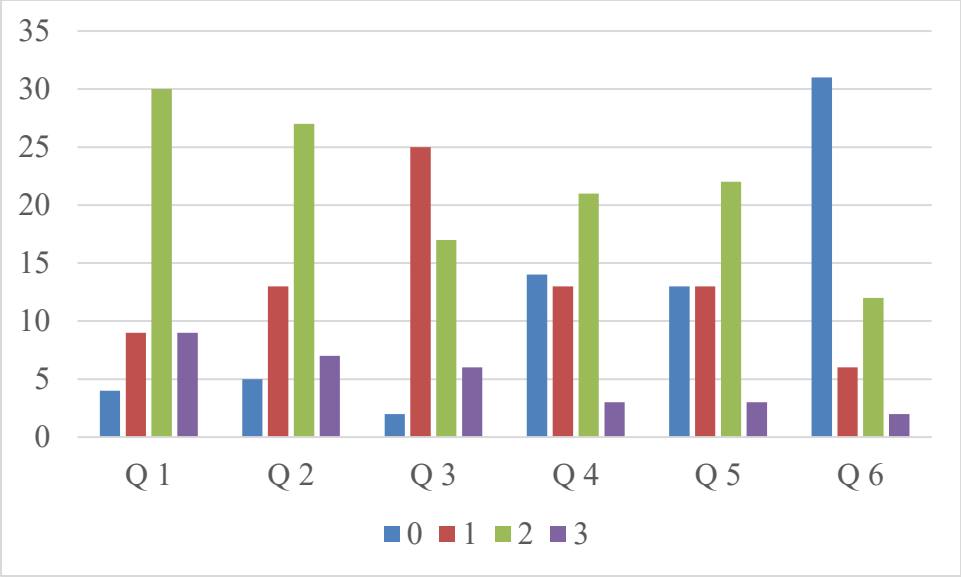

Figure 1. Distribution of Day 1 student discourse survey results sorted by question.

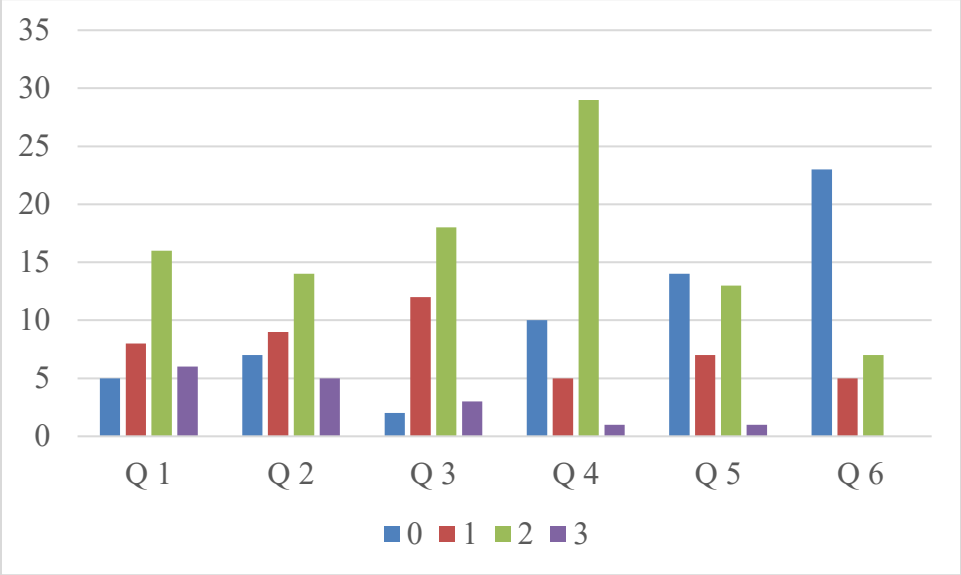

Figure 2. Distribution of Day 2 student discourse survey results sorted by question.

As can be seen in Figures 1 and 2, most student responses were useful and relevant (scored as a 2 or 3), although that answer may not have been thoughtful. Question 6, however, shows a high number of students whose answers were irrelevant, such as “I don’t know”, “none”, etc. (a 0 score).

After compiling a list of student discourse survey answers that were valued at 2 or 3, responses were sorted according to theme, as explained in the Methodology Data Analysis section on Chapter 3. These themes were ranked according to prevalence in each question. As can be seen from Figure 3, several themes (such as Hearing Different Perspectives, Talking to Others, and Multiple Methods) were common and reoccurred in multiple questions in multiple students' replies.

Question 1	Question 2	Question 3	Question 4	Question 5	Question 6
Hearing Different Perspectives 23/61 38% Talking to Others 8/61 13% Multiple Answers Exist 7/61 11% Considering Outside Information 7/61 11% Did Not Help Me 6/61 10% Real-Life Relevance 5/61 8% Multiple Methods 3/61 5% Other 2/61 3%	Multiple Methods 20/50 40% Hearing Different Perspectives 13/50 26% Talking to Others 7/50 14% Considering Outside Information 3/50 6% Utilizing Personal Preference 3/50 6% Did Not Help Me 2/50 4% Multiple Answers Exist 2/50 4%	Talking to Others 23/40 58% Verbalizing Thoughts 9/40 22% Fighting and Arguing 5/40 12% Other 3/40 8%	Considering Outside Information 11/41 27% Multiple Methods 8/41 20% Multiple Answers Exist 3/41 7% Miscellaneous* 19/41 46% *Questions 4 and 5 required students to provide specific counterexamples. The responses were highly individualized and unique and were therefore unable to be categorized by theme. Rather, these responses were placed under a general Miscellaneous category.	Showing Other Methods 12/38 32% Miscellaneous* 26/38 68%	More Task Information 12/17 71% More Background Knowledge 3/17 18% More Teacher Instruction 2/17 12%

Figure 3. Student discourse survey themes from both Day 1 and 2 sorted by question.

As shown in Figure 3, Hearing Different Perspectives is a theme that emerged in both Question 1 and Question 2. Of the 61 relevant responses to the first question, 23 were related to the theme of Hearing Different Perspectives, or 38%. Talking to Others was another extremely common theme for the first three questions. Also note that because Questions 4 and 5 required students to provide highly specific counterexamples from the discourse, the majority of relevant responses were individualized and vastly unique. Those responses were place under a general Miscellaneous category.

Figure 4 shows how the themes represented in Figure 3 align and contribute to the findings discussed later in this chapter. Several themes connect to multiple findings, and some findings encompass multiple themes.

Theme	Related Findings
Hearing Different Perspectives	Building on Others' Statements
Talking to Others	Group Dynamics Facilitating Student-Student Discourse
Multiple Answers Exist	Shift in Class Structure Differing Conclusions are Appropriate
Considering Outside Information	Accommodating for Lack of Prior Knowledge
Did Not Help Me	Students' Reactions to Discourse
Real-Life Relevance	Utilizing Problem-Based Tasks to Enhance Discourse
Multiple Methods	Shift in Class Structure
Utilizing Personal Preference	Language and Phrasing in Discourse
Working with Others	Facilitating Student-Student Discourse
Verbalizing Thoughts	Facilitating Student-Student Discourse
Fighting and Arguing	Group Dynamics Students' Struggles with Discourse
More Task Information	Shift in Class Structure Nature of the Tasks
More Background Knowledge	Accommodating for Lack of Prior Knowledge
More Teacher Instruction	Shift in Class Structure Change in Authority

Figure 4. Relationship of student discourse survey themes to major study findings.

Figure 5 shows the four sources of data used in this study—student discourse surveys, video recordings, teacher journal, and observational protocol. This figure shows the connection between the findings discussed later in this chapter and the sources used to support those findings. Each X represents a specific piece of evidence referenced in this chapter.

	Student Discourse Survey	Video Recordings	Teacher Journal	Observational Protocol
Building on Others' Statements	X	X	X	
Utilizing Problem-Based Tasks to Enhance Discourse	X	XXX	X	
Shift in Class Structure	XXX		XXXX	X
Change in Authority	X	X	X	
Language and Phrasing in Discourse	X	X	XXXXXX	
Facilitating Student-Student Discourse	XXX		XX	X
Group Dynamics	XX		XXX	
Accommodating for Lack of Prior Knowledge	XX	XX	XX	
Differing Conclusions are Appropriate	X		X	
Nature of the Tasks	X	XX	XX	XX
Students' Reactions to Discourse	XXXXXXXX	X	XXXXXX	
Students' Struggles with Discourse	XXXX		XXXXX	

Figure 5. Distribution of data sources used to support findings.

As can be seen in Figure 5, most of the data came from the student discourse surveys and the teacher journal, while the observational protocol provided the fewest data points. It can also be seen in Figure 5 that every finding was supported by at least two data sources.

Role of Discourse in Problem Solving

Polya (1945) identified four stages in the problem-solving process. An individual engaging in the problem-solving process must understand the problem, devise a plan, carry out the plan, and look back at the solution. This section explains how discourse was used to help students engage in the problem-solving process.

Building on Others' Statements. A key component of discourse is that individuals respond to or build upon statements made by others. Discourse cannot consist of a series of individual statements, but instead must build to a final conclusion. In the video recordings I noticed several instances of conversations where students built upon statements made by their group members in order to reach conclusions. Jane and Sara had such a conversation, where their statements built upon each other. On the first task, when answering Question #2 [Create a function modeling the fuel cost of driving the SUV *m* miles.], Jane and Sara engaged in the following conversation:

> Jane: "We should test out our equation [f(x)=0.12m] using a random number of miles."
> Sara: "We should test 18. Because it should equal 2.136 or we did it wrong."
> Jane: "You're right. We should plug 18 into our equation, because the answer should be what it says in the problem."

In their conversation, Jane offered a way to check their answer, and Sara suggested a way to check that would yield an already established result. Without this

discourse, Sara may not have thought to check her answer and Jane may have chosen to check using a random number of miles with no evidence of if the answer was ultimately correct. They each built on statements made by their group members to enhance their problem-solving strategy and ultimately reach a better conclusion.

Abby, Jacob, and Shelly needed a little encouragement from me but ultimately used their discourse, both within their group and with me, to decide if their conclusion to Question #1 [What is the gasoline cost per mile?] made sense. I documented a conversation in my journal, which is recorded in Figure 6.

Abby: "Can you tell us if this is right?"
Me: "I will not. What [answer] do you have?"
Abby: "$0.12 [cost per mile]."
Me: "Is that a logical answer?"
Jacob: "I think so. Because I'm thinking about what I would do in my car. If I drive 200 miles, it's about $24 to fill up. So that makes sense."
Shelly: "Yeah, that makes sense."

Figure 6. Example of student discourse.

Without Jacob's explanation, Abby and Shelly may not have known if their answer was logical. And without Shelly's reassurance, Abby and Jacob may have still been unsure about their conclusion. Through this discourse, the group used previous statements to build on their own statements and reasoning. They were better able to answer the question because of their discourse. Jacob also used the questions I asked to reassure himself of his conclusion, even though I did not actually tell him he was correct. Because of my statements, the group was better able to think through the reasoning behind their conclusions. They had more than just a conclusion—they had a reason they knew their conclusion was correct. Additionally, Shelly wrote in her student discourse

survey that she "had the chance to see and work from a different perspective," which helped her understand the mathematical concepts in a new way.

Through these examples, it can be seen that a key component of discourse is making statements that build on the statements made by others. Through this process of building on statements made by others, students were more fully able to engage in the discourse process and therefore better able to engage in problem solving. In both of these situations, students used their discourse to look back at their solutions—step 4 in Polya's problem-solving process. Both of these examples demonstrate students using their discourse and building on statements made by others to engage in the problem-solving process.

Utilizing Problem-Based Tasks to Enhance Discourse. The purpose of this study was not simply for students to solve problems. Although that was one of the results for students, the goal was for students to reach a variety of conclusions to open-ended problem-solving tasks by engaging in discourse with their peers. To that end, I encouraged students to think about aspects of the questions beyond simply the given information. On the first day, when determining which vehicle would be better for a road trip, Robert realized that if a family was going skiing in Colorado, the SUV would probably do better on the mountains and in the snow. Madison noticed that going to Colorado would probably take a few days, costing a rental fee of $42.99 every day, making the SUV more cost effective over several days, regardless of fuel prices. Larry knew that if a family was taking a trip for a long weekend to go skiing, there would probably be more baggage, making the SUV the better choice because of its storage capacity. Each of these students expressed these observations to their small group and to

the whole class, which then encouraged their peers to engage in further discussion of other outside factors that may influence their decisions and affect their final conclusions. Without considering outside factors such as these, the decisions students made were based solely on which vehicle earned the best gas mileage. However, when considering extra information such as weather conditions in Colorado, drive time, etc., the conclusions students reach may change. Students voicing their understanding of outside factors was an important component of the students using discourse to reach conclusions. The students engaged in the first step of problem solving—understand the problem—to further inform the way they answered the questions. Because they understood the full scope of the problem, they were able to justify their conclusions more thoroughly. Students were then able to channel that understanding in their discourse with their peers.

A large portion of my students told me verbally on the first day how frustrating it was to not know if their answer was correct or not. I connected this frustration and confusion back to everyday life, where we do not always know if the choices we make are strictly correct. Sometimes we make choices that we think are the best for our current situation and hope we chose correctly. Jessica specifically stated her frustrations at the end of the first day regarding the time it took to answer the questions. I also used that as an opportunity to relate back to real-life scenarios, asking "Is it okay that sometimes problems in life might take us more than a few seconds to understand and solve?". The students generally agreed that in a real-life scenario, it might take a while before a conclusion is reached. Melanie further expanded on this idea in her student discourse survey, stating that the discourse "helped me with math that could be used in the real world and real-life scenarios." The problem-solving tasks presented to the students were

based on possible real-life situations they may encounter in the future. I felt it was important that students develop problem-solving skills to deal with those types of scenarios, where there may not be an obvious answer or where it takes a longer period of time to reach a conclusion. Sometimes those problems require a lot of information before it is possible to reach a conclusion. My participation in the discourse allowed students to connect the open-ended tasks to real-life scenarios. Because I engaged in the discussion with them, I was able to show them how they could use their mathematical understanding to solve problems outside of the classroom.

Teacher Role in Facilitating Discourse

The teacher has a foundational role in the routines and functions that govern a class period. From the class structure to the types of activities and questions presented to students, the teacher is the guiding force in the classroom. This section explains the role the teacher had in facilitating the classroom discourse.

Shift in Class Structure. Due to the expectations I had for students on the days of problem solving, I knew I would have to initiate a shift in class structure. Without guidance and explanation from me on the changes in my expectations, I knew my students would assume these days would have a similar structure to their normal class days—I would teach, and they would listen. Since that was not my plan for these days, I had to clearly communicate my expectations to my students. Even after a thorough verbal explanation from me on the class structure for these days, most of my students still struggled with adjusting to a different format.

The students struggled with the concepts of talking with their group instead of asking me for help, of not knowing if their answers were correct, of using technology appropriately, and of taking 10 or 15 minutes to answer a question. Through all of these situations, I had to guide students through this shift in class structure. I had to continue encouraging students to work through those struggles rather than giving up. In one instance, I should have worked harder at encouraging students to work through their struggles, before they became frustrated and stopped working. Our curriculum coach noticed this and made a comment about it in is observations during that class period. He wrote that "Group 2 [David, Jamie, and Katelyn] may have needed more encouragement…. How do you know when productive struggle turns to unproductive and frustration?" I quickly discovered that I cannot change all of my expectations for the class structure without giving students direct guidance and support through those changes. Otherwise, they may all give up and stay frustrated. The following are specific shifts in class structure that affected, either directly or indirectly, the discourse that happened in the classroom.

Talking with Students Rather than the Teacher. During the small-group discourse, I made an effort to only observe student conversations rather than involving myself in them. I attempted to be noncommittal in my answers to students' questions and instead direct them to ask their group, because I wanted to observe the discourse happening inside their groups. On the first day of this study, prior to assigning the first problem-solving task, I spent 15 minutes talking with my classes about discourse. During this time, I explained my expectations to them for the small-group discourse. I expected them to contribute to the conversations in their groups in a polite manner. If

someone in their group reached an incorrect conclusion, they were to correct their group member using evidence. They were to work together as a group and not move on alone, so one person would not finish the task before the rest of the group. Ultimately, I expected my students to discuss questions, concerns, and conclusions within their small groups rather than asking me those questions and telling me those conclusions. While my students are usually encouraged to talk and work together during a regular class period, the expectations during this discourse time were vastly different than on a regular day. Because of this shift in class structure, it took many of the students and groups a few minutes to adjust. Most of the groups still wanted to ask me if their answers were correct, despite my explanation that I would most likely not directly answer their questions. Turning to the conversation I had with Abby, Jacob, and Shelly (see Figure 6), they had an answer to a question, and their answer was correct, but they wanted to ask me for help rather than relying on their group discussion. When this happened, I asked questions designed to help them think and reason through their conclusions as a group instead of looking to me for confirmation.

Most students found it to be quite a challenge to ask their group for help rather than asking me. Wendy wrote in her student discourse survey that the most challenging part of the day had been "not getting help from the teacher to know if we were right or not." Because this type of class structure was a shift for them, their discourse was affected indirectly. I guided them through this shift by repeatedly encouraging them to ask their group members for help rather than asking me. I attempted to only ask and answer questions with the intent of helping students think about their conclusions and continue to discuss those conclusions as a group.

Shift in Types of Answers. The second day of problem solving, I spent time discussing the idea of "best" to set the tone for my expectations of the second problem-solving task. This discussion was important so students would understand that there was more than one possible correct answer, and I expected my students to think about all aspects of the question rather than just the first thing that came to mind. This expectation caused a shift in class structure which forced students to adjust the way they thought about answering questions and in turn caused a change in the way students discussed the questions. While a normal question on a typical class day will have one specific answer, the questions on these days had a variety of possible conclusions. This shift was a challenge for students like Jamie, who wrote in her student discourse survey that she likes to have a specific formula to use when answering specific questions. On the other hand, the shift in types of answers was helpful in encouraging students to consider other possible correct answers, such as when Luke wrote in his student discourse survey that the discourse "helped me find out that there are multiple right answers at times."

When I reviewed the video recordings, I also noticed this shift in the answers resulted in a shift in the discourse. While discussing the best possible purchasing combinations on the second day of problem solving, Lacy said that 7 games and 1 song would be the best because games can last a long time. Conversely, Jeremy said it would depend on what James prefers and did not give an actual possible combination. Both of these students had discussions in their groups that resulted in a shift in the way they thought about the question which ultimately affected the way they reached a conclusion.

Shift in Technology Usage. On a typical class day, the expectation is for student electronic devices to be put away. Due to the nature of the first task, however, it was

impossible to answer the questions without seeking out extra information on the internet. This raised some concerns with Kane, who verbally told me he thought that Dan should not have looked up the gas mileage on his phone. When I asked Kane why he thought that, he related back to normal class periods where students are expected to stay off their electronic devices. Jamie, David, and Katelyn had similar concerns. Even after I suggested to them that they could look up the information on their phones or computers, they were still uncomfortable using an electronic device to find the information. They did not believe that I would give them a problem where they specifically had to use their device to find missing information when that process goes against normal class procedure. This shift in class structure and expectations was confusing for those students, despite my encouragement that they were allowed to use their devices. For those students who had concerns about appropriate technology usage, their discourse was affected because they were focused on what technology they were allowed to use instead of discussing the actual questions. They were discussing a concern in class expectations rather than using their discussion to reach a conclusion.

Shift in Time Commitment. On a typical day of class with the types of questions I normally ask students to complete, each question takes a relatively short amount of time. For the problem-solving tasks I presented to the students on these two days, however, it was not unusual for some of the questions to take considerably longer. The first question on the first day, for example, asked students to find several pieces of information and perform several calculations. David told me his group took 20 minutes to finish that first question. I expected the problem-solving tasks to take students a while to understand and complete, so I was not surprised by the time it took. However, Jessica

told me that “math problems should not take 20 minutes.” I think the students in my classes were expecting to be solving mathematical algorithms in a similar manner to the ones we do every day in class. For those problems, it is reasonable to take 30 seconds or a minute to reach an answer. My students were therefore frustrated when the problem-solving tasks required more of a time commitment.

This frustration affected student discourse indirectly. Because they were expecting questions which could be answered quickly, they were not prepared to work on a single question for 20 minutes. Therefore, some of their discussion revolved around that frustration rather than on the questions themselves. This ultimately affected the type and quality of discussion students had regarding the assigned tasks. Additionally, 71% of students who had relevant answers to the last question of the student discourse survey stated that more information about the problem would have helped them better understand the task.

Change in Authority. When we have approached word problems and real-life examples at previous times in class, I have acted as the mathematical authority in the class, and students have listened to the ways that I told them to solve the examples. Those previous examples were closed-ended with one correct answer, and I guided them in how to find that answer. During this study and with these problem-solving tasks, there were multiple possible conclusions and I did not act as the mathematical authority. Rather, my goal was to shift the role of mathematical authority onto the students. I wanted them to be the authorities and reach conclusions influenced by their discourse with their classmates. The students were expected to ask questions of their group members rather than me, and I told them I most likely would not answer questions directly but would

instead redirect them to ask their group. Rather than discussing questions or concerns with me, the students were expected to discuss those issues within their groups.

When reviewing the video recordings and my journal notes, I observed that students in every group on the first day still wanted to ask me if their answers were correct, despite my previous explanation that I would most likely not directly answer their questions. As I was observing student conversations during small-group conversations, every group requested assistance or asked if their answer was correct. When this happened, I always redirected them to first ask their groups members those questions. Any questions I asked or replies I gave were given with the intent of placing the role of mathematical authority back on the students. This was shown in the conversation I had with Abby, Jacob, and Shelly (see Figure 6). I did not directly answer their questions, which would have placed me in the role of mathematical authority. Instead, I asked questions and guided their discussion so they could assume the roles of mathematical authorities.

This change in authority seemed to be quite frustrating for many of my students. They assumed I would be the final authority in determining if their conclusions were correct, similar to a typical class day. When I would not just tell them the answers, some students became frustrated. This was shown in Wendy's statement in her student discourse survey, that the most challenging part of the day had been "not getting help from the teacher to know if we were right or not." In those situations, I encouraged my students not to get frustrated. I reminded them that my goal was to listen to their conversations and hear the conclusions they reached as a group. Encouraging my students to accept a role as mathematical authority was an important underlying factor in

their discourse. When students became the mathematical authorities, as was the case with Abby, Jacob, and Shelly, the students were then able to engage in more meaningful discourse.

Language and Phrasing in Discourse. An important component of the teacher's role in facilitating discourse is the phrasing of questions, both verbally during discourse and written in the tasks.

Understanding Personal Preference Phrasing. During whole-group discussion on the second day, we discussed what words like "best" and "better" meant, in terms of answering the questions and reaching conclusions to the problem-solving tasks. Students explained that best is a personal preference and will probably depend on the situation. For example, even though the Ford Focus earns better gas mileage, most students decided the SUV was better because it was the cheaper option. One of my classes in particular really engaged in this discussion with me, as evidenced by the following discussion from the video recording.

> Me: "When I say better, what type of answer am I looking for?"
> Ellie: "Which one would be cheaper."
> Me: "Is the cheaper one always the better one?"
> Jesse: "It depends on what you're buying."
> Mark: "It depends also on what you want to leave for your carbon footprint. Like, some people want to choose what's better for the environment but other people just say 'I'm going to die in the next 50 years so it's not that big of a deal'."
> Mary: "We also said last time that if we take the rental, we don't have to worry about if it gets damaged."
> Me: "So let's get back to that word best. If I'm choosing the best option, what qualifies something as the best?"
> Mark: "I guess it mostly comes down to personal preference."

We concluded as a class that asking for the best is asking an opinion that may change based on the situation. Because the task as a whole was asking for an opinion

[Which vehicle is better for a road trip?], students understood why I had been unable to tell them if their conclusions were correct. I spent that time on the second day discussing the idea of "best" to set the tone for my expectations of the second problem-solving task. The second task also asked some opinion questions [What is the best purchasing combination?], so I wanted students to understand my expectations on those types of questions.

As a result of that whole-class discussion, I observed on the video recordings that for some of the open-ended questions in the second task (see Appendix B), more students answered those questions with statements showing their understanding of best and personal preference. Question #10 asked "James decides he wants to spend all of his birthday money. What might be the best purchasing combination [downloading video games and music] for him to use?" As documented in my journal, Cody, Valerie, and Joseph told me the best option was "7 games and 1 song because games will last for a good amount of time while with songs you go through them a lot quicker and you can get them for free with any music app." Robin, Will, and Maxine on the other hand told me that "it would depend on James' preference" and did not even offer an example of a possible purchasing combination. While both of these groups were answering the same question, they answered it in different ways based on their opinions and what they thought might be best. Furthermore, question #11 asks "What would be some reasons why your answer to #10 might not actually be a good choice for James? What might be a better option for him? Why?" Cody, Valerie, and Joseph told me that "it will be dependent on whether he wants more games or more music." Similarly, Ian, Ashley, and Cherry stated, "it might not be the better option if he wants one more than the other." On

the second problem-solving task, every group noticed the type of questions being asked and recognized many of them to be opinion questions. Since we had not had that discussion on the first day, students were frustrated because they assumed there should be one correct answer. But once we had the conversation about opinions, students were much less frustrated and much more understanding of the freedom they were given in answering the questions. Once students understood the types of answers they were expected to give, they were more comfortable engaging in the discourse. In my journal, I noted that Molly told me she felt much better on the second day than she had on the first day because she was not limited to a specific answer. As a result of this, she felt she had a better grasp of the way she was expected to answer the question, so she could have better discussions with her group. Jessica told me the second day was better because her group as a whole was able to have more relevant conversations due to their understanding of the questions. Robin wrote on her student discourse survey the second day that the understanding of personal preference helped her think about the concepts and problem solving in a different way. For each of these students, the language of the questions helped inform the discourse they had in their groups.

Phrasing in the Tasks. Some students struggled with how to create an inequality from the provided information, as required on the second task, Question #5 (see Appendix B). For instance, some students tried to use the information to create two inequalities instead of one. I noticed Destiny, Wendy, and Laura in particular had made this error. While the correct inequality should have been $6.99g + 0.99m \leq 50$, they had answers of $6.99g \leq 25$ and $0.99\,m \leq 25$. Without prompting from me, the group noticed their error.

Destiny: “I think our answer is wrong.”
Me: “Why do you think it’s wrong?”
Wendy: “Because it’s two inequalities.”
Laura: “Yeah, the question says ‘Write *an* inequality.’ We need to change it so it’s just one inequality.”

This group used their understanding of the phrasing in the question, as well as building upon statements by their group members, to guide the way they answered the question. The nature of the question provided the information they needed in order to understand that their answer was incorrect, and as a group they discussed why their answer was wrong and how to fix it. Robin, Will, and Ashley had a similar conversation in the first task regarding Question #1 [What is the gasoline cost per mile?].

Robin: “Our answer is wrong.”
Me: “Why is it wrong?”
Robin: “We found the price per gallon, but it’s asking for price per mile.”
Will: “So we didn’t even find the right thing.”
Ashley: “We need to find the price per mile instead.”

Both of these conversations were examples of how students were able to use their understanding of the phrasing of the question to know if their answer was correct or not. These groups understood that their answers did not make sense because their answer did not match the type of question being asked. If their answer was not even in the correct format to answer the question, they knew it could not be correct. Ultimately, it is important for the teacher to help facilitate the discourse by ensuring that the phrasing of the question matches the type of answer that is expected. If the phrasing in the problem-solving tasks is appropriate, then students will be better able to discuss the situation and better able to reach appropriate conclusions. Additionally, both of these situations showed students engaging in Polya’s fourth step of problem solving, look back at the

solution. Engaging in this step allowed students to reconsider their answers reach better conclusions.

Facilitating Student-Student Discourse. During the small-group discourse, I made an effort to only observe student conversations rather than involving myself in them. I attempted to be reserved in my answers to students' questions and instead direct them to ask their group. For some students, this was a source of frustration. On a typical class day, when their answers are either right or wrong, I can quickly show them how to check their answers or simply tell them if their answers are correct. However, since there was not a single correct answer for these tasks, I could not just tell them if they were correct or not. My goal was to ask and answer questions with the intent of helping students think about their conclusions and continue to discuss those conclusions as a group. The conversation between Abby, Jacob, and Shelly is an example of how I used questioning techniques to guide students in their thinking (see Figure 6). I did not answer Abby's question directly, even though the question clearly had a correct answer (and she did in fact have the correct answer). My goal was not merely for them to have the correct answer, but to reason through why their answer was correct and how to check their answer logically. My discussion with Abby and Jacob helped them to reason through the problem on their own and understand why their answer made sense, without the need for me to tell them if their answer was correct or not.

Some students asked clarifying questions of me, to make sure they were approaching the problem correctly. On the first day, for example, several students simply did a Google search of "gas mileage of Ford Focus" or something similar. Once they did that, they quickly discovered that the year and available features of each Ford Focus

resulted in a different gas mileage, as did the difference between city and highway driving. When they asked me what year they should choose or if I was wanting the city or highway mileage, I always redirected them to discuss it as a group. My goal was not for them to reach an exact answer. Rather, I wanted to see if their discussions could help them reach a conclusion with which they were all satisfied.

This redirection from me for students to focus their discussion within their groups was frustrating for students like Wendy who wrote in her student discourse survey that the most challenging part of the day had been "not getting help from the teacher to know if we were right or not." However, other students like Jacob found the student-student interaction to be positive and helpful, stating that "getting to converse and work with other people was a good way to understand" the concepts in a new way.

Other students struggled with the student-student aspect of the discourse, such as Cody, who wrote in his student discourse survey that the most challenging part of the discourse had been getting others to understand what he was saying and how he was explaining the concepts. Robin agreed with Cody's assessment, writing that "telling the reasoning behind my opinions" had been the most challenging part of the day. While these students did not seem to have trouble understanding the tasks and questions, verbalizing their thoughts and opinions proved to be a challenge to them.

The school curriculum coach observed the classes and noted my involvement in the student discourse. During one particular class, he tallied the number of questions and statements I made to the groups. During the hour of small-group discourse, he counted that I asked 60 questions [how do you know that, where did you get that answer, etc.], made 12 corrective statements [that is not a function, tell me why, etc.], and 84

nonjudgmental statements [sounds good, okay, etc.]. This data, as well as my own reflections in my journal, showed that my focus was on encouraging students to engage in discourse with their group members rather than answer their questions myself. While I did make corrective statements, the majority of my interactions with students focused on my general acknowledgment of their statements or questions designed to redirect their questions towards their group members.

Group Dynamics. I have two Algebra 2 classes of 19 students each and one class of 21 students, so I divided each class into six groups of three to four students each. I thought this would be an appropriate size of group because everyone would have a chance to express their thoughts, but they would also have the chance to hear from more than just one other person. I also decided to assign those groups rather than allowing students to choose their own groups. When I have allowed students to choose their own groups in the past, I have noticed that they tend to work only with their friends and as a result are able to get off task easier. I intentionally split up students I knew had trouble staying on task while working together.

When creating the groups, I placed at least one student in each group who I thought had a good understanding of Algebra 2 concepts, based either on their current grade in my class or what I knew of them as a student. I was not expecting that student to be the leader in the group or do all the work. Rather my hope was that if the group as a whole had trouble with a particular aspect of the problem-solving task, perhaps that student would be better able to assist and guide their group members. For the most part, this grouping appeared to be helpful. However, in Nick's case, he was the quietest person in the group. Nick rarely talks in class but always does well on class work and

assessments. He was in a group with Jasmine and Megan, who did not seem to know what to do on the problem-solving task but also did not ask Nick many questions. If they did ask Nick a question, he would answer them, but he did not actively start conversations. As a result, Jasmine and Megan mostly talked between themselves and Nick mostly worked on his own. When I would walk by to check on their group, Jasmine and Megan would pick their pencils up and act like they were working, but I also noticed they were mostly just copying the answers Nick had on his paper. Although Nick understood the problem-solving tasks, he did not engage in discourse with Jasmine and Megan. For this group in particular, the assigned grouping was actually a barrier to discourse, not because of their level of understanding but because of their personalities. Megan also wrote in her student discourse survey that "we didn't talk a whole lot, so I wasn't really sure what was happening."

Lane also noted how his assigned group was slightly detrimental. Because of a student absence the second day, he was in a group with only Ellie. Lane wrote in his student discourse survey how that had been a challenge for him, because he only had the opportunity to hear Ellie's opinions. The nature of their group and the fact that one of the group members was absent limited the amount of conversation they could have.

Due to the way the groups were created, some groups had more collective real-life experience than others. While this was not originally an intended outcome, it provided an opportunity for me to observe how students reacted to the situations differently based on their previous experience. For some groups, like Destiny, Wendy, and Laura, who had little experience with driving, this proved to be detrimental and required more guidance from me. While most of my students are old enough to drive, or at least to understand

how gas mileage works, Destiny's group had no understanding of those concepts. When the first question asked them to find the cost per mile of the vehicles, the found an answer that was completely unreasonable. However, due to the collective lack of experience in their group, they had no understanding of why their answer did not make sense. For this group, their lack of real-life experience affected their discourse because they were unable to connect their experiences to the assigned task. They had no foundation upon which to build their discourse and were therefore hoping their conclusions were correct without any prior knowledge to support those conclusions.

Some of my students also recognized that they were not limited in their groups. On the second problem-solving task (see Appendix B), Mary was struggling with how to check her answers. Knowing that I would just tell her to ask her group, and knowing that her group was also struggling, she asked the student next to her. She knew Larry was not assigned to her group, but she also listened to his conversations and knew he had figured out how to answer that question. Mary therefore used resources available to her to reach a conclusion, even though it meant searching for answers outside of her group. Mary was able to use her discourse, even though it was not within her assigned group, to reach a conclusion.

The creation of the groups was a key component of ensuring the small-group discourse worked well. Without appropriate grouping, some groups may have finished quickly with little need for discourse, while other groups may have easily gotten off task and not worked on the problem-solving tasks at all. While these situations did happen to a small degree, I worked at creating the groups in order to attempt to minimize these situations as much as possible.

Accommodating for Lack of Prior Knowledge. For other groups struggling with details such as how rental car dealerships operate in real life, I gave them more guidance and helped provide background information so those students would not be stuck on details and could focus on what the questions were really asking. In these situations, it was necessary for me to provide additional information to these students. Without that additional information, these students were hung up on details which prevented them from having meaningful discourse. Instead, they were focused on minor details of the questions. Once I explained those details more fully, students were able to engage in discourse focused on what the questions were actually asking. For example, I documented in my journal that most of my students did not understand how to rent a car and what was included in the rental fee. Abby thought the cost of gas would be included in the fee, while Will was insistent that nothing was included in the fee, not even insurance. For the groups struggling with those details, I gave information about how rental car dealerships operate in real life so those students would not be stuck on those details and could focus on what the questions were really asking.

In some instances, I noticed a few groups struggling more than others and attempted to give them more guidance. On the first day of problem solving, I observed that Destiny, Wendy, and Laura were still struggling with the first question [Find the cost per mile of the vehicles.] after 30 minutes. When I looked at their papers, I noticed they had divided incorrectly and found an unreasonable answer. While the correct fuel cost for the SUV should have been about $0.12 per mile, they had concluded the fuel cost was $8.42 per mile. After talking with them, I discovered that Wendy was the only one in the group who had a driver's license. When I asked her if their answer made sense, she told

me she did not really know because she just puts gas in her vehicle whenever it gets empty. Because this particular group had no real-life experience to give validation to their answer, they assumed that whatever answer they got was correct. Once I understood their lack of real-life experience, I decided to give them more guidance than the other groups for that particular aspect of the task. I knew if I did not help them reason through the first question, none of the rest of the task would make sense. Destiny also wrote in her student discourse survey that if she had her own car to drive, she would better understand how much gas was being used. Destiny recognized that her lack of prior knowledge affected the conversations she had in her group and ultimately the decisions they were able to make.

In both of these situations, lack of prior knowledge was a barrier for student discourse. Students who did not have appropriate background information were hindered in their ability to have relevant discussions. When I helped students find the appropriate information, those barriers to discourse were lifted and students were then able to focus on using their discourse to answer the questions.

As documented in the video recordings, Madison noticed that going to Colorado would probably take a few days, costing a rental fee of $42.99 every day, making the SUV more cost effective regardless of fuel prices. Larry knew that if a family is taking a trip for a long weekend to go skiing, there would probably be more baggage, making the SUV the better choice because of its storage capacity. Madison and Larry used their understanding of road trips and locations to influence their decisions and ultimately to reach their conclusions. They also used this understanding to guide their discussions with their small groups and to inform the conclusions made by their group members.

Differences in prior knowledge did not appear to be an issue, however, during the second problem-solving task. While not every student had previously downloaded games or music from the internet, I observed on the video recordings that they all appeared to have a general understanding of how that process worked and did not require extra explanation from me. Ashley, for example, wrote in her student discourse survey that she understood the second problem-solving task better than she had understood the first one. Because the students had a more solid understanding of the situation in the second task, their discussion was improved. Students were able to focus their discussion on the problem-solving tasks rather than being impeded by details.

All of these situations showed me that at least a general understanding of the types of situations presented are necessary for students to fully comprehend the tasks. Without that general understanding, students were lost and confused, unsure of how to even appropriately check their answers or if their conclusions were reasonable. This confusion and frustration led to a lack of focus in student discourse, because the discussions were based on the frustration they had about the questions rather than being based on reaching a conclusion.

Differing Conclusions are Appropriate. During the whole-class discussion at the end of the first day, I addressed reasons why different groups might have reached different conclusions. I documented in my journal that many students brought up the point that their answers would be different if they chose a different year Ford Focus to determine the gas mileage. Because of that choice, the rest of their answers, and even their final conclusions, might also be different. As a result of that class discussion, students realized that their choices at the beginning of the task affected the rest of the

task. I explained that my goal for their discourse was not for them to reach an exact answer. Rather, I wanted to see if their discussions could help them reach a conclusion with which they were all satisfied. Because the task was open-ended and allowed students to choose some of the information they used, I wanted the students to understand that it was appropriate, and possibly even expected, for different groups to reach different conclusions.

I knew that the second problem-solving task (see Appendix B) was also open-ended and gave the students opportunities to choose the best conclusion from a variety of possible conclusions. I also recalled how students had struggled with the concept of having many possible conclusions on the first task, so I spent about 15 minutes at the beginning of the second day reminding them that it was okay if they had different answers than their classmates. The choices they made as a group would ultimately affect the final conclusions they reached. I did not want to tell them if their conclusions were correct or not. Rather, I wanted the students to act as the mathematical authorities and reach conclusions influenced by their discourse with their classmates. Since different groups had different prior knowledge and different conversations regarding the tasks, it was logical that they might reach different conclusions.

When students understood that it was acceptable and encouraged to reach a variety of conclusions, their discourse changed as well. They went from attempting to find the correct answer to having deep and meaningful discussion about the many possible conclusions available. The students also recognized this shift. Laura noted in her student discourse survey that this discourse helped her see different perspectives and that that there might be more than one correct answer.

Nature of the Tasks. There were several aspects to the tasks used during the two days of this study. Information about creating the tasks, acknowledgement of intentional missing information presented in the tasks, and the types of questions asked in the tasks can be found in this section.

Creating the Tasks. When creating and adjusting the problem-solving tasks, I intentionally made the tasks open-ended. If there is one correct answer to a question and one way to find that answer, there is little problem solving needed and little reason for group discourse. I therefore took problems and questions that I have used in Algebra 2 classes in the past, and I adjusted the tasks to better facilitate group discourse. The second problem-solving task (see Appendix B), for example, originally asked questions such as "How much would it cost for James to buy 3 games and 5 music downloads?" or "How much would James have left from his birthday money if he bought 5 games?" Those questions had only one correct answer and would not require any student discourse to find the answer, so I changed the questions to be more open-ended. The new questions asked things like "James decides he wants to spend all of his birthday money. What might be the best purchasing combination for him to use?" and "What would be some reasons why your answer to the previous question might not actually be a good choice for James?". When creating the problem-solving tasks, I had to keep in mind my goal for the tasks. I did not want students to be able to complete the task and know their conclusion was the only possible correct conclusion, because that type of task did not require much discussion. I wanted the problem-solving tasks to have many possible conclusions and the students to have many opportunities to discuss those conclusions with their peers.

Missing Information. For the first problem-solving task (see Appendix A), some information was purposely left out. Students were given the gas mileage for the family's SUV but were not provided similar information for the rented Ford Focus. The goal in omitting information was to encourage students to use all resources at their disposal. Some students immediately pulled out their phones or laptops and began searching for information about a Ford Focus, while others tried to complete other parts of the task, simply stating that they did not have enough information to fully answer the questions. Even after I suggested to some groups that they could look up the information, a few did not feel that was the correct way to find the information. Their reasoning for this line of thinking was that the expectation in my classroom is for their electronic devices to be put away. They did not believe that I would give them a problem where they specifically had to use their device to find missing information when that process goes against class procedure. Yet due to the nature of the task, there was no other way to find or calculate that missing information. Students were required to find that information online. One of the questions I asked each class at the end of the day was "How many of you read the first question (see Appendix A, Question #1) and immediately thought to yourself 'I know exactly what to do right now to start this problem'?". In reviewing the video recordings, I observed that none of the students in any class stated that they had felt that way at the beginning. David actually said, "the first question took us 20 minutes to figure out." Other students also explained that they had been confused at first because I had not given them all the necessary information in the instructions of the problem-solving task, whereas on a typical class day I would always give them whatever information is required to answer the questions. They had been unsure of how to start answering the

questions and where to find the missing information. Many students, such as Jacob, wrote in their student discourse survey that the most challenging part of the discourse had actually been about finding the missing information in the problem, rather than the discussion itself.

Despite the frustrations students encountered, almost all students participated in the small-group discussion on the first day. The school curriculum coach noted in the observational protocol (see Appendix D) that the student discourse was effective in helping students engage in the problem-solving process (Question #5). For one class he wrote "watching the productive struggle resulted in 100% participation." For the other two classes, he stated that all but one student in each class were involved and working on the task. The struggle and challenge of the tasks required more involvement and participation from the students in order for them to reach a conclusion.

The second day, students did not appear to have those same struggles. The second task provided all of the relevant information at the beginning, so students were not required to find information on the internet as they had on the first task. From the video recordings and my journal notes, every group, without exception, was able to begin the first problem immediately. I did not observe any situations where even one student seemed unsure of what was happening in the first four problems.

Open-Ended Questions. At the beginning of the second day, students recounted how they had been unsure on the first day if their answers had been correct. Prior to giving students the second problem-solving task, I addressed that issue as a whole class. While some of the questions were closed-ended and had a correct answer, such as "What is the price per mile of the SUV?" others were designed to be open-ended such as

"Suppose your family decides to go skiing for the weekend. You all drive from XXXXXXX, MO to Colorado Springs, CO. Which vehicle is the better option for that trip? How did you come to that conclusion?". Because the task as a whole was asking for an opinion, students understood why I was unable to tell them if their conclusions were correct. I knew that the second problem-solving task (see Appendix B) was also open-ended and gave the students opportunities to choose the best conclusion from a variety of possible conclusions. Therefore, starting the second day with that discussion helped students better understand the purpose behind the task and the types of conclusions they were expected to reach.

The nature of the tasks and the types of questions asked guided the types of discussions students had. If every question had been closed-ended, there would have been little need for discussion or explanation. But there needed to be a few closed-ended questions to guide students through the problem-solving process and reach a final conclusion to the task. Additionally, the amount of information provided to the students on each of the tasks altered the type of discussions they had in their groups. The first task, which did not provide as much information, required discussion focused on how to find the missing information. The second task, which provided more information, allowed for more discussion focused on the task itself and the variety of possible conclusions students could reach.

Students' Perceptions of Discourse

The third research question addressed students' perceptions of discourse. This section explains students' reactions to discourse, both positive and negative, students'

reactions to the tasks, some of the struggles students encountered in their discourse, and times when discourse may not be necessary.

Students' Reactions to Discourse. On the second day of problem solving, I noted in my journal that there were fewer instances of students asking me for help while they were stuck on specific questions. This may have been because they had already had one day in a similar situation and were more comfortable working through the problems in their group. I knew it was a big shift in class structure for students to ask questions of their group members rather than me, so having a previous day of experience with that type of class setup likely affected students' attitudes and behaviors on the second day. They seemed much more comfortable starting their group discussions on the second day, knowing that they were expected to talk and reach conclusions with their group, rather than asking me if their answers were correct. As I reviewed the video recordings, I observed that on the first day, students had shown more hesitation to begin discussing the problem within their groups. However, when I gave students the second problem-solving task and asked them to start working with their groups, they all began discussing the problem immediately.

This comfort with group discourse also may have been because the second task provided more information to start with, so students were less confused at the beginning of the day. The first task required much more outside knowledge (how to rent a car, how gas prices work, knowing to look up excluded information on the internet), whereas the second task provided students with all the necessary information. I wrote in my journal that as I was observing student conversations, I checked in with every group to see how they were doing. They all said they were doing much better than the previous day and

they felt much better about that day's task since they already had all the relevant information. They started the day and the task feeling more confident, which made the entire day and task easier and more comfortable for them. Ashley wrote in her student discourse survey "I understood functions way more than the last activity. The problems told me what was what, unlike the last problem where we had to use our electronic devices."

Positive Student Reactions. I noted in my journal that as I observed students during their discourse, several students made verbal comments to me expressing how they felt about the problem-solving tasks and the general activity of discourse. On the first day, George told me, "our discussions are good because it took us a lot of deliberating to figure out that y = .12 [on Question #1]." Josie said she liked having the opportunity to share her thoughts and hear from her group. Many other students had similar comments and feedback to give me throughout their discourse time. They told me that they liked working in their small groups because they were able to discuss their ideas with just a few people, rather than having to talk to the whole class. They also liked hearing different perspectives from their group members and having the chance to work through the tasks together.

In the student discourse survey, many of the students stated their discourse with their classmates helped them understand the problems better. Jackie said the discourse "helped me to see how being cooperative can help when problem solving. It also helps to look at different angles." Josie said that "having to explain myself" helped her think about problem-solving in a new way. Melanie stated the discourse "made me think of logistics for all answers that I could have given." Although not every student agreed that

the discourse was useful, many said similar things to Jackie, Josie, and Melanie. They expressed that the discourse had helped them view the problems from multiple perspectives and reach conclusions based on those multiple perspectives.

Negative Student Reactions. There were a few students who did not find the group discourse to be helpful. In the student discourse survey, David wrote that the discourse "didn't help me at all, it just confused me." Jamie expressed her frustration, "I did not talk to my group. I get stressed out when I don't know how to do anything, and I didn't know what formulas to use." Jessica wrote that the discourse "honestly frustrated me and made me feel even stupider than I am." Jessica also told me verbally several times on the first day that she was confused and felt ill-equipped for the task. These students felt that the discourse was not helpful for their understanding and was actually detrimental to their learning. However, I suspect that with added encouragement from me and more practice, effort, and investment from the student, the discourse process could be more successful with additional repetitions.

Students' Reactions to the Tasks. I observed that many students answering the questions about discourse on the student discourse survey actually talked about the tasks rather than the discourse itself. For example, of the 51 students who completed the survey on the first day, 10 stated that the most difficult part of the discourse was trying to find missing information from the task. Other students wrote that the most challenging part of the discourse for them had been to remember the types of math to use and how to set up the equations. While these challenges existed for many of my students, these types of answers on the student discourse survey did not provide a complete picture of the challenges students had with the discourse itself. Although the two are related and build

on each other, students' answers to these questions showed me they did not understand the difference between working through the task and discussing the task with their classmates.

Students' Struggles with Discourse. Not every student reacted to the discourse in a positive manner. While some students had frustrations with the tasks, others were dissatisfied with the discourse itself. This section details times when students were not engaging in the discourse, frustrations in the whole-class discourse, and times when discourse may not be necessary.

Students Not Participating. There were two times I noticed one student who seemed to have a concern with statements or conclusions made by the rest of the group, but they did not always verbalize those concerns or force a change in their group. In the first problem-solving task, when some information was missing, many students used a phone or computer to find that information. Kane, however, thought that was not the correct method. He knew that on a typical class day, students are not allowed to be on their phones during class. Kane felt this class procedure should still apply and thought his group members were doing something wrong by looking up that information. Kane attempted to tell Dan that they should not do that, but Dan ignored him and looked up the information anyway. Although Kane stated his opinion and disagreement with Dan's plan, Kane did not say anything to make Dan change his mind. Ultimately, Kane went along with what his other group members chose to do rather than continuing to argue.

I wrote in my journal about a similar situation that happened with Ian and Julie. Their found a fuel cost of $0.118 and Ian thought they should round that to $0.12. Julie disagreed and started to say so, but then relented and allowed the rounding without

actually expressing her concerns. Ian appeared to want to round because it would allow for easier calculations later in the task. I do not know Julie's reasoning for not wanting to round their answer, because she did not verbally state her opinion. I observed Julie participating in the conversation at other times, so I know she had no fears of talking. Perhaps she felt this particular issue was not something worth debating, or perhaps she did not feel strongly enough about her reasoning to think that her reasoning would have been accepted. Ultimately, Julie chose to simply go with what her group member said at that time, even though she disagreed. In both of these situations, both students showed a reluctance to participate in the discourse in that particular moment. Although they were active participants for the rest of the small-group and whole-class discourse, they chose to not provide their thoughts at these specific times.

While I was pleased overall with my students' participation and effort throughout this study, there were a few students who did not engage in the discourse process within their groups. Charlie is a student who does not talk at all. He has never spoken a word in my class, either to me or to his peers. Other teachers, both from this year and previous years, have told me the same thing happens with him in their classes. I have been told he will talk at home or with his friends at lunch, but I have never observed this myself. While Charlie did not verbally speak with his group during these discourse times, he did write down what they were discussing and answered the questions on his paper. He also mentioned in the student discourse survey that the discourse helped him "listen to other people's arguments" and "understand different ways to do a problem." Even though he was not speaking and verbally participating in the discourse, he was still able to learn and develop his problem-solving skills because he was listening to other students' discourse.

On the second day of problem solving, I noticed Paige was not talking with her group or writing anything down. When I asked her why she was not participating, she told me the camera was making her nervous and she could not focus. I reminded her the camera was only for me so I could accurately quote conversations. I continued to circle around the room to observe other groups, and I came back to her group a few minutes later. At that point she was still not participating. I told her that at a minimum, she could just write down what her group was saying. She still refused, and I was at a loss for what to do. She did not write anything the entire time and simply wrote 'No' on every answer in the student discourse survey that day.

While neither Paige nor Charlie spoke during the group discourse time, Charlie's level of participation showed that he was still engaging in problem solving. He did not let his personal characteristics influence his participation in the discourse. He was still an active listener and was still involved in the problem-solving task. Paige, on the other hand, could not overcome her personal fears to engage in the discourse. She refused to discuss the tasks with her group, despite my repeated and continual encouragement.

Not every student engaged in discourse at the same level. Some students appeared entirely comfortable engaging in the discourse time while others struggled to participate. From Paige and Charlie, I learned that I can provide opportunities for my students to learn and engage in discourse with their classmates, but ultimately the choice is up to them. They can either participate or not, and it is up to me to provide them with that choice.

Whole-Class Discussion Frustrations. In two of my classes, I thought the whole-class discussion time was productive and students were able to express their thoughts

kindly and succinctly. There was positive interaction between students of different groups, and they were able to reach further conclusions as a whole class. While they did not always agree on every conclusion, they were given the opportunity to see other students' viewpoints and everyone had a chance to voice their opinions. However, my other class has many opinionated students who ultimately ended up just arguing about why their conclusion was correct and the other students were wrong. In the student discourse survey, many students in that class stated that the whole-class discussion was not helpful to their learning and actually was confusing and frustrating for them. Ashley recognized she was acting this way and stated that "the people who talk all the time [referring to herself] are overbearing to others." She also said that the most challenging part of the discourse had been "not screaming at Ian too much when he refuses to let people talk." Robin said the most challenging part of the discourse had been "the arguing and yelling. Opinions and considerations could be shared, agreed with, or disagreed with, without the fighting." For the students in that class, the whole-class discussion time was not helpful because many students refused to listen to the opinions and conclusions of their classmates. They stated their own thoughts but would not change their opinion if another student stated something contradictory. The students in that class were not engaging in discourse, because their statements were not building upon each other.

When Discourse is Not Necessary. There are times when discourse may not be necessary. At the beginning of the second task, students were immediately able to answer the first four questions and quickly determine if their answers were correct. Despite students appearing to be more confident in how to begin the second task, those first four questions were closed-ended, single-answer questions, so there was little

necessity for discourse regarding their answers. They worked with their group members to answer the questions, but there was only surface-level discussion. They would state the answer and move on to the next question. Their answers could easily be confirmed to be correct, so there was no need to discuss their conclusions at a deeper level. If there is one correct answer to a question and one way to find that answer, there is little problem solving needed and little reason for group discourse. That was the case with all of the closed-ended questions in both of the tasks. While the tasks as a whole were open-ended and asked students to ultimately reach overarching conclusions, specific questions within the tasks were closed-ended and required little discourse to reach an answer.

Summary

This study focused on three main topics—the role of discourse in problem solving, the role of the teacher in discourse, and student perceptions of discourse. The study found that students were able to reach conclusions based on their discourse with others by building upon statements made by their classmates or the teacher. The teacher had a wide variety of roles as a facilitator of the discourse. The teacher created appropriate groups for the students, designed the problem-solving tasks, facilitated whole-class discourse, and guided students through a shift in class structure and change in mathematical authority. The nature of the tasks influenced whether discourse occurred or not, and the level of discourse that did occur. The majority of students found the discourse time to be helpful to their learning, since they were able to voice their thoughts in a small-group setting and hear the statements made by their classmates. Some students did not find the discourse helpful, whether because the shift in class structure was a

challenge for them, because they generally prefer to work on their own, or because their particular group was not cohesive for discourse.

CHAPTER V: DISCUSSION

The purpose of this study was to explore problem solving and discourse in three high school Algebra 2 classes, and to analyze how discourse might be used to help students engage in the problem-solving process. There were three research questions I expected to answer through this study regarding the role of discourse in problem solving, the teacher's role in facilitating discourse, and students' perceptions of discourse. This study analyzed small-group and whole-class discourse regarding two open-ended problem-solving tasks on two different block days. The purpose was to focus on MP3—construct viable arguments and critique the reasoning of others.

Summary of Study

On two different days in three Algebra 2 classes, I presented students with two open-ended problem-solving tasks (see Appendices A and B) and asked them to converse with their classmates in small groups to reach conclusions to those tasks. These tasks were purposely open-ended with the intent of allowing students to discuss possible conclusions in their groups, rather than simply finding the only possible answer. At the end of the small-group discourse, I had students explain to the whole class some of the conversations they had in their groups and the conclusions they reached. I video recorded student conversations, kept a journal of my observations and involvement during the discourse, asked the school curriculum coach to observe student discourse and my involvement in the discourse, and asked students to complete a student discourse survey following the discourse.

While observing student discourse, I focused on seeking out instances of students specifically using their discourse to solve problems. When students asked me questions, I directed them to ask their group and reach a conclusion they were all satisfied with. When I noticed students were reaching conclusions that did not make sense logically, such as the group who said the fuel cost was $8.42 per mile. I encouraged them to talk through those conclusions more to see if there was a mistake they had made.

During the whole-class discussion after the small-group discourse, I asked students to explain some of their reasoning and conclusions to the rest of the class. My goal for this time was to help students hear even more perspectives than just the ones expressed by their small group. For the most part, students were able to enhance their understanding and either change or solidify their conclusions.

Summary of Findings

Through this study, I focused on three main questions—the role of discourse in student understanding, the role of the teacher in facilitating discourse, and students' perceptions of discourse. The study found that students were able to reach conclusions to open-ended problem-solving tasks based on their discourse with others by building upon statements made by their classmates or the teacher, which answered the first research question. The teacher had a wide variety of roles as a facilitator of the discourse, which answered the second research question. The teacher created small groups for the students, designed the problem-solving tasks, facilitated whole-class discourse, and guided students through a shift in class structure and change in mathematical authority. The majority of students found the small-group discourse to be helpful to their learning,

since they were able to voice their thoughts in a small-group setting and hear the statements made by their classmates. A smaller number of students did not find the discourse helpful, whether because the shift in class structure was a challenge for them, because they generally prefer to work on their own, or because their particular group was not cohesive for discourse. Both of these findings answered the third research question.

Discussion

One of the main components of true discourse is the fact that statements should build upon each other. Simply stating random facts or saying something not related to the topic does not constitute discourse. Pirie and Schwarzenberger (1988) created a definition of mathematical discourse and further described specific components of that definition. In defining genuine pupil contribution, they explained that "we are attempting here to distinguish between the introduction of new elements to the discussion and mere passive response, such as factual answers, to teachers' questions" (Pirie & Schwarzenberger, 1988, p. 461). This example of quality discourse was evident in my study as demonstrated in the conversation between Jane and Sara—they had a discussion in which they built on each other's statements. They engaged in true discourse and were better able to reach a conclusion to their problem. On the other hand, the class that spent the whole-class discussion arguing with each other did not engage in discourse during that time. While they were stating facts or opinions related to the topic, those facts and opinions were not building upon each other and were therefore not discourse.

Evans (2017) studied the effect of incorporating student discourse into her regular mathematics lessons. Through this incorporation of student discourse, she also expected

students to take on the role of mathematical authority. My findings were consistent with hers, because she found that students who engaged in discourse were better able to become the mathematical authorities in her classroom.

This study was helpful for me as a teacher to pull myself away from being the mathematical authority in the classroom and observe the students while they took on the role of mathematical authority. In real-life situations, students will need to make decisions and reach conclusions on their own, and they will not always have a teacher or parent telling them if their decision is correct. As a result, students need to practice making decisions and reaching conclusions in a low-risk environment. The problem-solving tasks I provided were based on possible real-life situations students may encounter in the future, where one answer is not necessarily better than the other.

Moshkovich (2007) analyzed a specific conversation regarding the words and phrases used in questioning. Although a teacher may ask a question with a specific response in mind, a student's prior knowledge may affect the way that student perceives the question. While creating the problem-solving tasks used by students on the two days of this study, I attempted to use appropriate phrasing and wording to ensure the meaning of the questions was clear. In some instances, this phrasing was helpful for students. In the case of Robin, Will, and Ashley, they knew their conclusion was not correct because of the way the question had been phrased. The format of their conclusion did not answer the question that was being asked, so they knew they had to adjust what they had written. In other instances, students misunderstood the phrasing of the questions, even though I had thought the meaning was clear. In both problem-solving tasks, students were asked to determine the best option out of many possible choices. On the first day of problem

solving, students thought that phrasing meant there was only one best option, and they were confused and frustrated when I would not tell them if their choice was the best or not. Because of this confusion, I spent time at the beginning of the second day explaining what I meant by best. After clarifying my expectations, students appeared much less frustrated and confused regarding the type of conclusion I was expecting. Students told me verbally and wrote in their student discourse surveys that they felt much better about the second problem-solving task after I had clarified my expectations.

Banse et. al (2016) analyzed the types of questions asked by teachers and found that students were most successful when teachers asked a mix of both open-ended and closed-ended questions. When creating the problem-solving tasks and in my discussions with students during group discourse, I also attempted to ask a variety of types of questions. In the problem-solving tasks, some of the questions were closed-ended (What is the gas price per mile? What is the maximum number of games James can buy?). These closed-ended questions provided foundational information for the problem-solving tasks. The tasks then also required open-ended questions (Which vehicle might be best for a road trip? What might be the best purchasing combination for James? Why might your answer not be the best choice?). These types of questions allowed students to utilize problem-solving strategies and ponder aspects of the problem they may not have considered before. Mark recognized that even though the SUV had a better overall price, the Ford Focus earned better gas mileage and may be more preferable for someone who is environmentally conscious. Because of the mix of open-ended and closed-ended questions, students were able to analyze each component of the task individually but also look at the task as a whole to reach a final conclusion.

Dale and Sherrer (2015) studied the amount of scaffolding necessary for students to be successful in problem-solving situations. If students or groups did not have enough guidance, they gave up quickly and did not continue trying to solve the problems. But if students had too much help, they did not learn appropriate problem-solving strategies on their own. I found similar results in my study. Although I did not experience any situations where I provided students with too much help, there was one situation where I did not provide enough help. Jamie, David, and Katelyn did not have enough scaffolding and quickly became frustrated with the problem-solving task. Their task was the same as everyone else's, but they struggled to understand the concepts and could not continue. Our curriculum coach noticed this and wrote that the group could have used more encouragement. Jamie also wrote in her student discourse survey that she had felt the discourse had been a challenge for her. She did not know what formulas to use, so she became frustrated and gave up.

Recommendations for Future Research

While I was pleased overall with my students' participation and effort throughout this study, there were a small number of students who did not engage in the discourse process within their groups—specifically Paige and Charlie. In the future, I would like do additional research about these types of students, to determine reasons behind their reluctance to participate. Are they always the same way in other classes? Do they comprehend the problems well enough on their own that they do not require group input? Or do they simply not want to participate and have other personal reasons behind those feelings?

I would like to do more research to determine how the size of the group would affect the level of discourse. I chose groups of three to four because of the sizes of my classes. I had two classes of 19 students and one class of 21 students, so this grouping allowed for six groups. I would be curious how the small-group discourse would be different if students were only with a single partner or if the groups were larger. Additionally, I wonder how student understanding might be affected when there is no time provided for small-group discourse. When we have approached problem-solving tasks in the past in my class, we have only discussed those tasks as a whole class and I have led those discussions. I would like to compare the two discussion options further and see how students' reactions and understanding is different.

I think further studies could be conducted regarding the relationship between the type of problem-solving task and the level of discourse. How might the discourse change if the questions are more or less open-ended? How might the discourse change if there are more open-ended or more closed-ended questions? The problem-solving tasks I presented were ultimately an opinion, asking students to choose the best option. How might the discourse change if I gave students more guidance from the beginning about what is meant by the word best? What other types of open-ended problem-solving tasks might allow for more small-group discourse? How might the questions or tasks be changed to increase student involvement in the discourse?

I would also be interested to know if different levels of scaffolding in the problem-solving tasks might help students understand the tasks better. In this study, the first problem-solving task provided less information in the instructions but involved systems of equations, which is earlier in the curriculum unit. The second problem-

solving task provided more information in the instructions but involved systems of inequalities, which is at the end of the curriculum unit. In the future, if I were to incorporate similar tasks into my lessons all year, I would like to start the year with tasks where more information is provided. I think this might help students understand the process of discourse and working with their classmates to solve problems, without the frustrations associated with the missing information. As students become more familiar and comfortable with the discourse process, I would like to adjust the tasks so students are required to use other resources to acquire the necessary information. I think this method would better prepare students for real-life problem-solving situations, where ultimately none of the information is provided and students would need to discern for themselves how to find appropriate answers to their problems.

Recommendations for Future Practice

Due to time constraints and state educational requirements, I was only able to spend two days focusing specifically on student discourse as a component of the problem-solving process. However, I think this practice would be more effective if my students were given more opportunities throughout the year to converse with their classmates. I often encourage students to check their answers with a partner, but their discussion is usually simply looking to see if their answers are the same and rarely involves higher levels of thinking or discourse. If I were to engage students in deeper discourse with their peers throughout the year, I would hope they would become more familiar with discourse as a practice and process. On the first day of problem solving, when students broke into groups, they seemed hesitant at first because they were unsure

how to engage in problem solving through discourse in small groups. However, when students broke into their groups on the second day, they all immediately started talking and engaging in meaningful discourse. They were familiar with the expectations and were more comfortable with the concept of discourse. If this were a practice I incorporated starting at the beginning of the year, I think students would have no difficulty conversing with their peers at a deeper level throughout the year. For a future teacher wanting their students to use discourse to help them engage in the problem-solving process, I would recommend beginning this process earlier in the year to help their students become more familiar with the expectations.

Similarly, I would recommend incorporating more problem-solving tasks into the regular curriculum. It would be helpful for students if they were given more open-ended real-life problems to solve on a regular basis. This consistency would provide students with more opportunities to engage in problem solving and more practice becoming familiar with the process of using discourse to engage in problem solving. Additionally, I would encourage anyone who is wanting to repeat this study to encourage their students to persevere through several days of incorporating discourse and problem-solving tasks. My students were naturally reluctant to participate because both the discussion and the problem-solving tasks were new and unfamiliar to them. I expect that once students became more familiar with the expectations and shift in class procedure, they would be much more successful throughout the entire process.

For the purposes of this study, students were in the same groups on both days. If this study were to be repeated, I would recommend changing the groups every few weeks, or even every day. If that were the case, students would have an opportunity to

talk with many members of their class, rather than just the two or three they were originally assigned. In the student discourse survey, many of my students reported that listening to what their classmates had to say helped them understand the problems better. Changing the groups would allow students to hear from even more students and hear even more perspectives. Additionally, not every student will get along with every other student. Since I assigned the groups, there were a few groups that did not seem to work as well together as other groups did. Changing groups would allow those students to still have a chance to engage in the discourse process without the struggle inside their group.

I would also recommend more explanation to students regarding the shift in mathematical authority. Many of my students were confused and frustrated when they were expected to discuss the questions and answers with their group members, rather than asking me those questions and telling me those answers. Even though I told students verbally what my expectations were, there was still some frustration with that. I would recommend more explanation, including examples and practice for students, involving the transfer of mathematical authority.

Summary

The purpose of this study was to explore problem solving and discourse in three high school Algebra 2 classes, and to analyze how discourse might be used to help students engage in the problem-solving process. The findings in this study were consistent with those of other studies. Students engaged in discourse by building on statements made by others, and the teacher encouraged students to take on the role of mathematical authority. Using appropriate questions in the verbal explanations and

written tasks helps guide students to think about the type of questions asked and types of answers expected. Asking a combination of open-ended and closed-ended questions also guides students through the task. The amount scaffolding provided to students is an important component of the amount of engagement students will have in the problem-solving process. Several recommendations were given for future research, including a study of students who do not engage in discourse, the effect of the size of the groups, the relationship between the type of problem-solving task and the amount of discourse, and the relationship between the amount of scaffolding and the level of discourse. Several recommendations were also given for future practice, including encouraging students to engage in discourse more frequently throughout the year, incorporating more problem-based tasks into the regular curriculum, changing the student groups, and giving students more guidance through the change in mathematical authority.

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APPENDICES

Appendix A: Problem-Solving Task – Day 1

Travel Options Name: _____

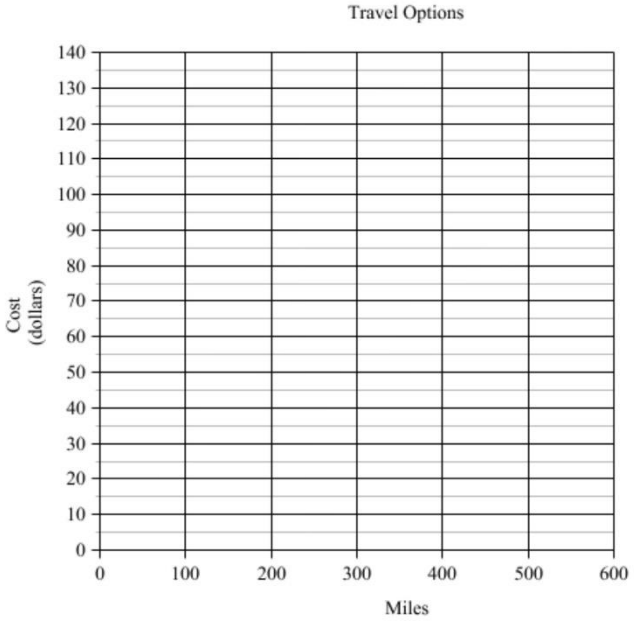
On February 21, 2019, the average price for unleaded gasoline in Missouri was $2.136 per gallon (Source: https://www.gasbuddy.com/USA.) Your family owns an SUV that gets 18 miles per gallon. Dollar Rent a Car, Inc., offers a Ford Focus car rental for $42.99 per day.

1. What is the gasoline cost per mile for the Ford Focus and the SUV? How did you find that information?

2. Create a function modeling the fuel cost of driving the SUV *m* miles.

3. Create a function modeling the fuel cost plus rental cost of driving the Ford Focus *m* miles.

4. Graph your functions from #2 and #3 below.



5. Estimate the point of intersection of the graphs in problem 4. What might this point of intersection mean in real-world terms?

6. Set up a system of equations using the equations from 2 and 3. Then solve the system algebraically. What might this solution mean in real-world terms?

7. How are the solutions to #5 and #6 related?

8. Suppose your family drives from XXXXXXX, MO to XXXXXXX, MO. Which vehicle is the better option for that trip? How did you come to that conclusion?

9. Suppose your family decides to go skiing for the weekend. You all drive from XXXXXXX, MO to Colorado Springs, CO. Which vehicle is the better option for that trip? How did you come to that conclusion?

10. Can you think of other factors that have not been included in the story that might affect the driver's choice for #8 or #9? What might those be? Could there be a reason to go against the better price? If so, what?

Appendix B: Problem-Solving Task – Day 2
Budgeting Birthday Money Name: _____

Apple iTunes sells music downloads for $0.99 per song (Source: www.apple.com). Random Games 4 Sale sells computer game downloads for $6.99 each.

1. James is given $50 for his birthday. What is the greatest number of games James can buy?

2. Describe the problem-solving method you used to answer #1.

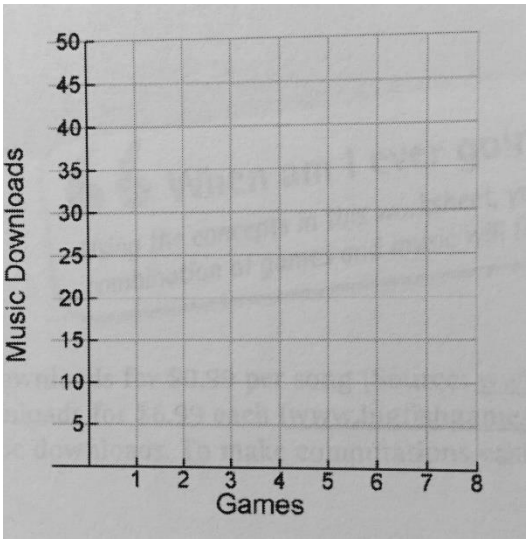
3. What is the greatest number of music downloads James can buy with that $50?

4. Describe the problem-solving method you used to answer #3.

5. Rather than spending his money on just games or just music downloads, James decides to spend his birthday money on a combination of both. Write an inequality modeling the total cost of buying g games and m music downloads. Recall that James has at most $50 to spend.

6. Using your previous answers, how can you check your model for #5? Adjust your answer to #5 if needed.

7. Graph the linear inequality you made in number 5 on the axes below.



8. Where do your answers to #1 and #3 appear on the graph?

9. Determine some possible purchasing combinations James has. Refer to your model in #5 or your graph in #7 if needed.

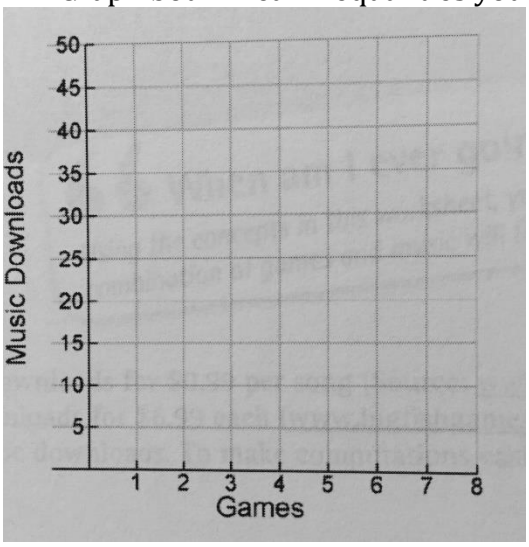
10. James decides he wants to spend all of his birthday money. What might be the best purchasing combination for him to use?

11. What would be some reasons why your answer to #10 might not actually be a good choice for James? What might be a better option for him? Why?

12. Suppose James wants to buy at least twice as many music downloads as games. Write an inequality to model this situation.

13. Using your answer for #12, what are some possible purchases? Use your answers to check your model. Adjust your answer to #12 if needed.

14. Graph both linear inequalities you have created (#5 and #12).



15. Using the graph from number 14, determine the number of music downloads that are possible if five games are purchased.

16. James decides he wants to purchase ice cream at lunch on his birthday before downloading games and music. How might this adjustment change all of your answers?

Appendix C: Student Discourse Survey

Name: _____

What about the classroom discourse today helped you understand the mathematical concepts in a new or different way?

_____
_____
_____
_____

What about the classroom discourse today helped you think about problem solving in a new or different way?

_____
_____
_____
_____

What was the most challenging part of the discourse for you today?

_____
_____
_____
_____

What counterexamples did you hear in your group dialogue that made you reconsider your own problem-solving methods?

_____
_____
_____
_____

What were some counterexamples you provided in your discussion that you think helped your classmates reconsider their problem-solving methods?

_____
_____
_____
_____

Were there any discussion questions you think would have helped you better understand the concepts or problems?

_____
_____
_____
_____

Appendix D: Observational Protocol

Date: _____Block: _____

While you are observing my classes today, please make note of the following questions and prompts to determine to what level students are using discourse to engage in problem solving. On the back of this document are some definitions of terms that may help guide your answers.

1. Examples of students actively involved in discourse with their peers:

   _____
   _____
   _____
   _____
   _____

2. Examples of students constructing viable arguments:

   _____
   _____
   _____
   _____
   _____

3. Examples of students critiquing the reasoning of their peers:

   _____
   _____
   _____
   _____
   _____

4. What is the teacher's involvement in the discourse? Was this level of involvement effective?

   _____
   _____
   _____
   _____
   _____

5. From your perspective, was the student discourse productive in helping students engage in the problem-solving process?

   _____
   _____
   _____
   _____
   _____

6. What might the teacher have done differently, either before, during, or after the discourse time, to help students be more engaged in the discourse and problem solving?

   _____
   _____
   _____
   _____
   _____

1. Discourse: For the purposes of this study, discourse is defined as specifically relating to students interacting with others through discussion of mathematical problems or concepts through verbal or written communication. This interaction may be between two or more students, or between a student or students and the teacher. Evidence of meaningful discourse includes a challenge of or affirmation of other students' work or language, students seeking clarification of fellow students' ideas, or students creating justification for their own mathematical ideas.

2. MP3: This is an acronym for 'Mathematical Practice 3' and refers to the third standard for Mathematical Practice from the CCSS. MP3 states that students should be able to 'construct viable arguments and critique the reasoning of others'.

3 Problem solving: This refers to an individual's ability to reason through a challenge and reach a conclusion. Problem solving is not simply skill-and-drill or rote memorization. In true problem solving, different individuals may reach different conclusions as a result of their prior knowledge or solving strategies.

Appendix E: IRB Approval

IRB #: IRB-FY2019-301
Title: Student Discourse and Problem Solving in a High School Algebra 2 Classroom
Creation Date: 11-2-2018
End Date: 1-31-2020
Status: Approved
Principal Investigator: Kurt Killion
Review Board: MSU
Sponsor:

Study History

Submission Type Initial Review Type Expedited Decision Approved

Key Study Contacts

Member Kurt Killion Role Principal Investigator Contact kurtkillion@missouristate.edu
Member Kurt Killion Role Primary Contact Contact kurtkillion@missouristate.edu
Member Gay Ragan Role Co-Principal Investigator Contact gayragan@missouristate.edu
Member Natalie Schroeder Role Investigator Contact schroeder789@live.missouristate.edu

Initial Submission

1A. What is the full title of the research protocol?
Student Discourse and Problem Solving in a High School Algebra 2 Classroom
1B.
Abstract/Summary
Please provide a brief description of the project (no more than a few sentences).
This will be a case study in my Algebra 2 classroom investigating student discourse and its role in helping students develop problem solving skills. I will create an environment and opportunities for students to have authentic discourse with their classmates in small groups with the goal of solving various problems I present to them.
1C.
Who is the Principal Investigator?
This MUST be a faculty or staff member.
Name: Kurt Killion
Organization: Mathematics
Address: 901 S National Ave , Springfield, MO 65897-0027
Phone: 417-836-6385
Email: kurtkillion@missouristate.edu
Who is the primary study contact?
1D.
This person may be the Principal Investigator or someone else (faculty, staff, or student). This person, in addition to the PI, will be included on all correspondence related to this project.
Name: Kurt Killion

Organization: Mathematics
Address: 901 S National Ave , Springfield, MO 65897-0027
Phone: 417-836-6385
Email: kurtkillion@missouristate.edu

1E.

Select the Co-Principal Investigator(s).

This MUST be a faculty or staff member. Persons listed as Co-PIs will be required to certify the protocol (in addition to the PI). This person will also be included on all correspondence related to this project.

Name: Gay Ragan
Organization: Mathematics
Address: 901 S National Ave , Springfield, MO 65897-0027
Phone: 417-836-8704
Email: gayragan@missouristate.edu

1F.

Select the Investigator(s).

An investigator may be faculty, staff, student, or unaffiliated individuals.

Name: Natalie Schroeder
Organization: Mathematics
Address: 901, S. National Avenue , Springfield, MO 65897-0027
Phone:
Email: schroeder789@live.missouristate.edu

If you could not locate personnel using the "Find People" button, please request access at Cayuse Logon Request
For additional help, email irb@missouristate.edu.

2A.

Describe the proposed project in a manner that allows the IRB to gain a sense of the project including:
the research questions and objectives,
key background literature (supportive and contradictory) with references, and
the manner in which the proposed project will improve the understanding of the chosen topic.

Research Questions:
What are students' perceptions of discourse?
What is the teacher's role is guiding student discourse?
How might student discourse help students develop problem solving skills?
Key Background Literature:
Moschkovich (2007) conducted a study on student-teacher discourse. She reflected on a specific question-response discussion between a teacher and student regarding features of a trapezoid. She explored the different background knowledge and meaning of words brought in by teachers and students, and how that prior knowledge or viewpoint may alter the discussion or change the way a question is answered. She further discussed how even formal definition of mathematical topics, such as the word 'function' have changed over time or as new understanding is gained. She discussed four branches of mathematical discourse practices - everyday, professional, academic, and school.
Moschkovich (2007) also explained that "the terms are complex and contested and the categories are not mutually exclusive" p 26. By this she means, for example, that teachers use school mathematics every day. But these types of discourse "can serve to clarify how we conceptualize Discourse practices" p 27.

Pirie and Schwarzenberger (1988) created a definition of mathematical discussion, which I will be using. They defined mathematical discussion as "Purposeful talk on a mathematical subject in which there are genuine pupil contributions and interaction" p 461. By this definition, teachers introducing material to students is not considered discourse if the only student response is merely factual answers to teacher questions.
Evans (2017) studied the incorporation of student discourse into her classroom. Over the course of two months, Evans spent time encouraging students to take charge of their own learning by engaging in Mathematical Practice 3 (Construct viable arguments and critique the reasoning of others). She pushed them to have authentic discourse with their classmates, in an effort to have students understand mathematical thinking and reasoning more thoroughly.
How Project Will Improve Understanding:
This study will add to the small body of research that currently exists regarding the mathematical practices. The Common Core State Standards (CCSS) Initiative, which was formed in 2009, developed and established the mathematical practices. The Standards and practices were then published in 2010. Schools, teachers, and students are all still learning how the standards and practices affect teaching and learning. The proposed study will further develop the learning that is taking place regarding the practices.
This study will also have an effect on the way high school math teachers in my district, and me specifically, teach classes. If the study shows that student-student discourse is a helpful learning strategy for students, I will incorporate more opportunities for student discourse into future units and other classes I teach. I will also use what I learn to encourage and inform other teachers in their classroom instruction.

2B. Check all research activities that apply:

✔ Audio, video, digital, or image recordings
Biohazards (e.g., rDNA, infectious agents, select agents, toxins)
Biological sampling (other than blood)
Blood drawing
Class Protocol (or Program or Umbrella Protocol)
Data, not publicly available
Data, publicly available
Deception
Devices
Diet, exercise, or sleep modifications
Drugs or biologics
Focus groups
Internet or email data collection
Materials that may be considered sensitive, offensive, threatening, or degrading
Non-invasive medical procedures
✔ Observation of participants
Oral history
Placebo
Record review
Specimen research
Surgical procedures
✔ Surveys, questionnaires, or interviews (one-on-one)
Surveys, questionnaires, or interviews (group)
✔ Other

Please specify:

Instructor journal

2C.

Describe the procedures and methods planned for carrying out the study. Make sure to include the following:
site selection,
the procedures used to gain permission to carry out research at the selected site(s),
data collection procedures,
and an overview of the manner in which data will be analyzed.
Provide all information necessary for the IRB to be clear about all of the contact human participants will have with the project.

The study will take place at Lebanon High School, where I am employed as a Mathematics Teacher. I will introduce and assign students problem solving questions and tasks. They will solve these problems by discoursing with their classmates in groups of 2-3, which I will assign. I will audio record the class sessions. I will journal during and after the class sessions about my involvement in the discourse and my reactions to the student discourse. The school curriculum instructor will observe the class sessions and provide written and verbal feedback on his observations. Following the class sessions, students will provide written feedback on their experience.

I will transcribe the audio recordings taken during class in order to use specific quotes made by students. I will focus on discussions that either exemplify or show struggles with students having authentic mathematical discourse. Parent permission forms will be sent out and returned, and all student names will be coded to ensure anonymity.

Student Survey.docx

Observational Protocol.docx

2D.

Attach surveys, questionnaires, and other social-behavioral measurement tools, if applicable.

3A. Specify the participant population(s). Check all that apply.

Adults

✔ Children (<18 years)

Adults with decisional impairment

Non-English speaking

Student research pools (e.g. psychology)

Pregnant women or fetuses

Prisoners

Unknown (e.g., secondary use of data/specimens, non-targeted surveys, program/class/umbrella protocols)

3B.

Specify the age(s) of the individuals who may participate in the research.

The participants are high school students in my Algebra 2 classes. They are between the ages of 14 and 18.

3C.

Describe the characteristics of the proposed participants, and explain how the nature of
the research requires/justifies their inclusion.

The proposed participants are students in my three high school Algebra 2 classes. The proposed case study explores student discourse and problem solving, so the study requires students to solve problems by discussing the problems with their classmates.

3D.

Provide the total number of participants (or number of participant records, specimens, etc.) for whom you are seeking Missouri State IRB approval.
66 students.
3F.
Estimate the time required from each participant, including individual interactions, total time commitment, and long-term follow-up, if any.
The main component of the study will occur during two 90-minute class sessions during normal school hours. If I notice an increase in student discourse later in the semester as a result of this study, I will personally journal about and document those findings. There is no more expected time requirement from students. There will be no documentation of discourse outside of school hours or after the semester is over. There will be no long-term follow-up.
3G.
Describe how potential participants will be identified (e.g., advertising, individuals known to investigator, record review, etc.). Explain how investigator(s) will gain access to this population, as applicable.
These are students currently in my high school Algebra 2 classes.
3H.
Describe the recruitment process; including the setting in which recruitment will take place. Provide copies of proposed recruitment materials (e.g., ads, flyers, website postings, recruitment letters, and oral/written scripts).
There will be no recruitment process.
3H.1. Attach recruitment materials, if applicable.
3I.
Will participants receive compensation or other incentives (e.g., free services, cash payments, gift certificates, parking, classroom credit, travel reimbursement, etc.) to participate in the research study?
Yes
✔ No
Parental Consent form.docx
Principal Approval Letter.pdf

4A.
From the list below, indicate how consent will be obtained for this study. Check all that apply.
Written/signed consent by the subject
✔ Written/signed consent (permission) for a minor by a Parent or Legal Guardian
Written/signed consent by a Legally Authorized Representative (for adults incapable of consenting).
Request for Waiver of Documentation of Consent (e.g. Verbal Consent, Anonymous Surveys,
etc.)
Waiver of parental permission
Consent will not be obtained from subjects (Waiver of Consent)
4B.
Describe the consent process including where and by whom the subjects will be approached, the plans to ensure the privacy of the subjects and the measures to ensure that subjects understand the nature of the study, its procedures, risks and benefits and that they freely grant their consent.

The participants are students in my three high school Algebra 2 classes. I will mail information to their parents regarding the nature of the study and requesting their signature of permission.
Any conversations reported in my findings will use coded names for students to ensure their confidentiality and privacy.

4B.1.

Attach all copies of informed consent documents (written or verbal) that will be used for this study.

Sample documents: Informed Consent Examples

4B.2.

Attach all copies of assent documents that will be used for this study, if applicable.

Sample documents: Assent Examples

5A.

Describe all reasonably expected risks, harms, and/or discomforts that may apply to the research. Discuss severity and likelihood of occurrence.

Consider the range of risks - physical, psychological, social, legal, and economic.

Some students may feel uncomfortable having group discourse. Some students may prefer not to talk, but rather to think and work through the problems on their own. They may feel uncomfortable having their classmates critique their reasoning.

5B.

Describe the steps that will be taken to minimize risks and the likelihood of harm.

I will encourage students to critique the reasoning of their classmates, not the students themselves. I will encourage all students to participate in the discourse, rather than one student doing all the talking in a group.

5C.

List the potential benefits that participants may expect as a result of this research study.

State if there are no direct benefits to individual participants.

Student will develop a deeper understanding of mathematical concepts as a result of discourse with other students.

5D.

Describe any potential indirect benefits to future subjects, science, and society.

Other teachers will have the opportunities to learn from my experiences. Future researchers will have the chance to build on what I have discovered in my research. Students may develop better mathematical discourse skill and can use those later in my class or in future math classes.

5E.

Discuss how risks to participants are reasonable when compared to the anticipated benefits to participants (if any) and the importance of the knowledge that may reasonably be expected to result.

The slight risk that some students may feel uncomfortable is very small compared to the benefits they will gain by developing not only their mathematical knowledge, but skills to solve real-world problems.

Missouri State University is committed to keeping data and information secure. Please review the Missouri State Information Security policies. Discuss your

project with the MSU Information Security Office or your College's IT support staff if you have questions about how to handle your data appropriately.
6A.
Statement of Principal Investigator Responsibility for Data
The principal investigator of this study is responsible for the storage, oversight, and disposal of all data associated with this study. Data will not be disseminated without the explicit approval of the principal investigator, and identifying information associated with the data will not be shared.
✔
By checking this box, all personnel associated with this study understand and agree to the Statement of Principal Investigator Responsibility for Data.
6B.
How will the data for this study be collect/stored?
Check all that apply.
✔ Electronic storage format
✔ On paper
Describe where the data will be stored (e.g., paper forms, flash drives or removable media, desktop or laptop computer, server, research storage area network, external source) and describe the plan to ensure the security and confidentiality of the records
6C.
(e.g., locked office, locked file cabinet, password-protected computer or files, encrypted data files, database limited to coded data, master list stored in separate location).
At minimum, physical data should always be secured by lock and key when stored.
Electronic data should be stored on University secure servers whenever possible (Office 365 or other secure campus server). If data has to be stored off campus, the file should be encrypted and the device password protected. Additionally, any data to be shared outside the University network will require a SUDERS request be filed and approved.
See https://mis.missouristate.edu/Central/suders/creat...
Written feedback from students and my journal notes will be on paper and will be stored in my locked desk. Recorded class sessions will be stored on my computer, which is protected with a reliable password. The computer remains in the researcher's possession when not in use. When the analysis is completed, all data will be transferred to a flash drive and deleted/removed from the computer. All paperwork will be stored in a locked file cabinet in the principal investigator’s office and will be retained for 3 years.
6D.
Describe how data will be disposed of and when disposal will occur.
At minimum, Federal regulations require research records to be retained for at least 3 years after the completion of the research (45 CFR 46). Research that involves identifiable health information is subject to HIPAA regulations, which require records to be retained for at least 6 years after a participant has signed an authorization. Finally, funded research projects may require longer retention periods, you may need to follow the sponsoring agency guidelines.

All paper copies and electronic data will be retained for at least 3 years after the completion of the study. After the analysis is completed, all electronic data will be placed on a flash drive and deleted/removed from the computer. All paperwork will be stored in a locked file cabinet in the principal investigator's office where it will be retained for 3 years. After at least 3 years, the data on the flash drive will be erased and the paperwork will be shredded.

7A.
Is this study externally funded?
For example, this research is funded by a source outside Missouri State; a federal agency, non-profit organization, etc.
Yes
✔ No
Potentially (this study is being submitted for funding, but has not yet been awarded)
7B.
Is this study internally funded?
For example, this research is funded by a source inside Missouri State; departmental funds, the Graduate College, etc.
Yes
✔ No
Potentially (this study is being submitted for funding, but has not yet been awarded)

8A.
Does your study contain protected health information (PHI)?
PHI is any information in a medical record or designated record set that can be used to identify an individual and that was created, used, or disclosed in the course of providing a health care service, such as a diagnosis or treatment.
Yes
✔ No
Parental Consent form.docx
Principal Approval Letter.pdf
CITI certificate.pdf

9A.
Human Subjects Training Certificates
Attach human subjects training certificates for all listed personnel. To access your training documents, please go to CITI Training.
9B.
HIPAA Training Certificates
Attach HIPAA training certificates for all listed personnel, if applicable. To get more information about HIPAA training and/or to access your training documents, please go to HIPAA Information for Researchers.
9C.
Informed Consent Documents
Attach all copies of informed consent documents (written or verbal) that will be used for this study.
Sample documents: Informed Consent Examples

9D.
Assent Documents
Attach all copies of assent documents (written or verbal) that will be used for this study.
Sample documents: Assent Examples
Problem Solving Day 1.docx
Problem Solving Day 2.docx
Student Survey.docx
Observational Protocol.docx
9E.
Recruitment Tools
Attach copies of proposed recruitment tools.
9F.
Surveys/Questionnaires/Other Social-Behavioral Measurement Tools
Attach surveys, questionnaires, and other social-behavioral measurement tools.
9G.
Other Documents
Attach any other documents that have not been specified in previous questions, but are needed for IRB review.

10A. Would you like to add additional information?
Yes
✔ No

Appendix F: Parent/Guardian Informed Consent

Dear Parents,

I will be conducting a study in our classroom to investigate the challenges and successes involved with student discourse and problem solving in an Algebra 2 class. The study will take place in my Algebra 2 classes during two different block days during the semester. I will incorporate research-based strategies for students to use authentic discourse with their classmates in order to develop a deeper understanding of problem-solving skills. I will observe and record student conversations, as well as have them complete a survey following the class session.

I am writing to ask permission to use the data I collect from your child during this process. Participation in this study involves only regular classroom activities. Any data reported will have coded names so student identity will be completely anonymous. You may contact me at any time regarding your child's participation. My phone number is XXX-XXX-XXXX and my e-mail address is xxxxxx@xxxxxxx.xxx.xx.xx. The principal, XXXXX XXXXXX, has approved this study.

Please check the appropriate box below, sign the form, and return.

- ☐ I give permission for my child's data to be used in this study. I understand that I will receive a signed copy of this consent form. I have read this form and understand it.
- ☐ I do not give permission for my child's data to be included in this study.

_____ _____

Student's Name Signature of Parent/Guardian

_____

Date