ENGAGING DEVELOPMENTAL MATHEMATICS STUDENTS IN PROBLEM POSING

by

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ABSTRACT

JOHN N. SEVIER. Engaging Developmental Mathematics Students in Problem Posing. (Under the direction of DR. ANTHONY FERNANDES)

This study examines the impact of problem posing on developmental mathematics students. Currently, students enter post-secondary institutions underprepared for college mathematics and are required to take developmental mathematics courses. Given their past challenges with mathematics, the students tend to have negative beliefs and attitudes toward mathematics. Despite these beliefs and attitudes, many developmental mathematics courses still teach the same content to the students in a lecture format; thus, reinforcing their negative perceptions about mathematics. Problem posing has been shown to engage students at all levels by allowing the students to build on their experiences. Based on a quasi-experimental design, this study investigated the impact of problem posing and the effect it had on developmental mathematics students' engagement, attitudes and beliefs, and mathematical proficiency. Developmental mathematics students engaged with a scaffolded approach to problem posing that drew on their personal interests and experiences to design word problems. The study shows that developmental mathematics students are willing to engage in problem posing in a meaningful way and appreciate the autonomy afforded in the process. The students constructed problems that built on contexts that were relatable to their everyday lives, like money and family, and special occasions similar to Thanksgiving. This autonomy impacted attitudes on self-exploration and views of success, however, had limited impact on the students’ beliefs about instructional needs and scaffolding of the posing levels. Beliefs also hindered students from engaging with new tasks if they did not foresee successful outcomes. The students enjoyed engaging in problem posing if they found the contexts of the problems relatable to their everyday lives, resembled previously done tasks or familiar contexts and felt they would be successful if they engaged with the task. The students noted the high cognitive load when they engaged with problems where they were provided a context and asked to come up with their own numbers. Students with a deeper understanding of the content were more likely to persist with numerical free problems and show more growth. Students from the lowest performing group in the pre-test showed the greatest growth in the post-test. This study illustrates that problem posing can be a promising avenue for developmental mathematics students, especially those who may initially underperform on entrance tests.

Keywords: problem posing, developmental mathematics, engagement, attitudes, beliefs

DEDICATION

This dissertation is dedicated to my family. To my parents, Ken and Cynthia Sevier, thank you for giving love, encouragement, and support to know that hard work pays off and teaching me the life lessons that got me to this point and will take me beyond. To my brother Charlie, thank you for your support and paving the way, showing me what I had to look forward.

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Philippians 4:13

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Introduction

Mathematics has not always come easy to me. This is a statement that I hear from many of my students. Even students studying a field where mathematics is crucial. Over time, many of my students have overcome their challenges in mathematics; however, there are others who believed that they would never be successful in mathematics. I did not comprehend these issues with the students' identities as mathematics learners till my first year of teaching high school algebra. I was given the opportunity as a first-year teacher to teach an Algebra 1 course exclusively for students who failed the course at least twice. This was significant in the current age of standardized testing. Being an eager first year teacher fresh out of college with an undergraduate degree, I took this as a challenge and set out on a mission to help these students. As the semester progressed, I found many of the students' attitudes and feelings towards mathematics were deeply rooted in prior experiences that extended back to elementary school. Some said that once they passed my course and graduated, they would find a line of work, get a degree, or find a lifestyle that did not involve mathematics. Students found mathematics challenging and would easily disengage. My students were able to pass the semester and most of the students demonstrated growth. However, they continued a dislike for the subject. After these experiences, I was motivated to change my students' beliefs about mathematics through my teaching. So, at the end of the semester when I was given an opportunity to teach an advanced algebra course for upperclassmen, I declined, and chose to continue working with the '*low*' students.

Later as an instructor for developmental mathematics, my students cited the monotonous material and the artificial contexts as some of their reasons why they disliked mathematics. Students had studied topics like fractions from sixth grade and were still challenged when they encountered these topics in college. These multiple experiences with students from high school and early college motivated me to examine other avenues of engaging these students.

In this study I will engage developmental mathematics students in problem posing through the personalization of word problems. My goal is to introduce developmental mathematics students to a pedagogical approach that differs from the traditional direct teaching approach. Research reports that such an approach has the potential to engage the students in the content and foster positive beliefs and attitudes towards mathematics in the process (Hidi & Harackiewic, 2000).

Statement of Problem

As technology advanced through the 1960's and 1970's, there was a push for equal educational opportunities for all, with a greater need and incentive for students to enter four-year institutions (Brothen & Wambach, 2012). However, with the increase in enrollment, many students were underprepared for the college mathematics courses (Bader & Hardin, 2002; Bibb, 1998). In a bid to prepare these students, the development mathematics courses were introduced. The goal of these courses was remediation to improve on basic skills prior to credit bearing courses (Bader & Hardin, 2002; Bibb, 1998).

Lewis and Ferris (1996) found that 30% of first-time college freshmen enroll in one or more developmental courses, with most of them in mathematics. Students were classified as traditional, if they enter college directly from high-school, and non-traditional, if they enter college after several years of completing high-school. Students entering the mathematics developmental courses are diverse and come from varying backgrounds and instructional styles.

Word problems are a major area of concern for students. Despite the importance of problem solving skills in the learning of mathematics, many students seem to lack the ability to translate mathematical word problems into a form necessary for effective computation due to the lack of relatability (Davis-Dorsey, Ross, & Morrison 1991; De Corte, Verschaffel, & De Winn, 1985; Dossey, Mullis, Lindquist, & Chambers, 1988; Lewis, 1989). Even when word problems cover an array of contexts in and out of the mathematics field, students have trouble engaging, relating to, addressing, understanding, and answering these problems. This lack of relatability to the problems has created a disconnect within the students from lack of interest and disengaging them from mathematics. The disengagement has created negative attitudes and beliefs within the students.

Despite their lack of interest and negative beliefs and attitudes, students are still required to complete some mathematics courses at university. Mathematics achievement is increasingly important for students' educational and economic futures (Cogan, Schmidt, & Wiley, 2001). Thus, a large portion of students enroll in four-year universities underprepared. Engaging students in problem posing has the potential to generate interest in mathematics among the students and connect to their lived experiences outside the classroom.

Problem posing is a process that involves the creation of a new problem from given criteria, situations, or previously presented problems (Arikan & Unal, 2015) as well as reformulating a problem during the solving process (Lavy & Bershadsky, 2003). Walkington and Bernacki (2015) view problem posing as the activity of students authoring their own mathematical problems. Within this self-creation of their problem, the student can extract/identify a new problem from the multitude of data or information available (Singer & Voica, 2013) based on their own experiences or aspirations. Problem posing will be used to engage the students with the content by allowing them to create and self-author problems that are relevant to them and their experiences. This allows the students to use areas that are more relatable to the personal experiences. Within the college context, problem posing can engage developmental mathematics students in content that moves away from the traditional remediation approach that tends to reinforce the negative beliefs and attitudes that these students tend to have about the subject.

Purpose of Study

The purpose of this study is to explore how developmental mathematics students engage with problem posing. When students create new personalized problems with problem posing, will this approach make word problems more relatable, engaging, and motivating? Further, what types of problems will the students design? The impact of this study is to examine the potential of using problem posing to engage developmental mathematics students who are generally challenged with mathematics. The problem posing approach will engage these students in an approach that differs from traditional instructional methods.

Research Question

How do developmental mathematics students engage with problem posing? More specifically, what problems do developmental mathematics students design based on their personal interests/experiences? Further, what impact does problem posing have on their beliefs and attitudes to mathematics and their mathematics proficiency?

Significance of Study

With the continued increase of enrollment at the college and university levels, students entering underprepared is increasing. In fall 2015, total undergraduate enrollment in degree-granting postsecondary institutions was 17.0 million students, an increase of 30% from 2000, when enrollment was 13.2 million students (Provasnik, Malley, Stephens, Landeros, Perkins, & Tang, 2016). The National Assessment of Educational Progress, also known as "NAEP", found that the majority of students in the 4th and 8th grade are not proficient in mathematics and as of 2015, only 25% of 12th grade students had scored at or above the proficient level on the NAEP math assessment (NAEP, 2015). With the increasing levels of students entering as undergraduates and 75% are deemed not proficient, there is a need of research to help bridge the gap of understanding and bring these students to the level of proficiency. The College and Career Readiness Standards for Adult Education (CCR) notes major shifts need to occur to help bridge this gap. CCR mentions that the importance of college readiness for adult students cannot be overstated and increasingly, students entering the workforce are discovering that they need critical knowledge and skills that are used on a regular basis

(Career and College Readiness, 2013). In 2013, a major shift occurred within the CCR standards where instructors were racing through topics in order to cover the vast array of material. This addressed the concern of instructors not focusing strongly where the standards focused. The CCR stated that instructors need both to narrow and deepen the manner in which they approach mathematics, instead of racing to cover topics (CCR, 2013). Many students entering are products of the hasty pace of instruction, not having a deeper understanding of content. Students have not secured the mathematical foundations, conceptual understanding, and procedural skills. These students that enter postsecondary institutions are entering underprepared.

There is little prior research that examines the way developmental mathematics students engage with problem posing and the impact this has on their beliefs, attitudes and mathematics proficiency. This study seeks to fill this gap and test a new approach that has the potential to make a difference with this population of students. The results can also inform teacher development at the university level.

Organization of Study

Chapter 2 will provide a review of the literature in three areas of developmental mathematics, beliefs, attitudes, and problem posing. Chapter 3 will discuss the research design, instrumentation, data collection and analysis. Chapter 4 will outline the results from the study. Finally, chapter 5 will discuss the results in the study with further recommendations for research and practice.

CHAPTER TWO: LITERATURE REVIEW

Chapter 2 will summarize prior research in the areas of the student enrolled in developmental mathematics, salient issues of engagement with mathematics and how this disengagement is attributed to lack of interest in the material, especially with word problems. With the understanding of the developmental mathematics student and the role of word problems in the mathematics classroom, research in problem posing will be highlighted how to address both area's pertinent concerns. This chapter begins with the discussion of the conception and foundation of developmental education and emergence of developmental mathematics student. The current study will focus on the attitudes and beliefs of the developmental mathematics students and their relation to interest and engagement within the mathematics curriculum, specifically problem solving and word problems. Next, the chapter will discuss problem posing, and students' engagement with mathematical problem posing, with a special focus on word problems. Lastly, the literature review will provide an overview of how problem posing will be used to address specific needs of the developmental mathematics students.

Developmental Education

Most if not all colleges and universities provide services for those who enter those institution, who are not prepared for specific coursework (Boylan, Bonham, & White, 1999). These services range in a variety of one on one instruction such as tutoring and individualized remediation to traditional non-credit bearing courses or seminar settings (Boylan, Bonham, & White, 1999). These services have existed in one form or another since the earliest days of higher education in the United States (Maxwell, 1997) but was not formalized until the 1960s (Boylan, Bonham, & White, 1999). A comprehensive term for these services of preparing students is developmental education. This term embraces a holistic approach in developing the individual student beyond improving specific skills in a subject area (Boylan, Bonham, & White, 1999). This holistic approach began to evolve more than 50 years ago (Kozeracki, 2000).

In the late 1950's, developmental education was considered a philosophy that applied to any student and assumed that all could improve their learning skills (Piper, 1998). Developmental education incorporates human development theories, which are intended to bring together academic and student support services to assist students in preparing to make choices appropriate to their current stage in development and focuses on the intellectual, social, and emotional growth of the students and is not limited to a certain student but open and appropriate to all learners (Casazza, 1999; Kozeracki, 2000). Professionals in developmental education assess and identify student talents, needs, and make some judgement as to the type and duration of intervention needed to help students accomplish their academic goals using such talents. (Boylan, Bonham, & White, 1999; Casazza, 1999; Kozeracki, 2000). They recognize that students must develop both their personal and academic skills in order to be effective learners (Bloom, 1976). Consequently, the interventions of professional developmental educators are usually comprehensive, combining instructional activities with diagnostic, advising, and counselling activities (Boylan, Bonham, & White, 1999). The conception of developmental education as being appropriate for a wide range of students is especially appropriate considering differing standards and criteria that each institution uses to determine which courses and what students are categorized as *remedial* (Kozeracki, 2000; Lewis and Ferris, 1999; The Institute for Higher Education Policy, 1998).

Developmental courses are considered college level with a larger focus on academic development and college readiness rather than content preparation (Boylan, Bonham, & White, 1999). While *remedial courses* and *developmental courses* are often used interchangeably by the general public and many scholars, those in the field draw distinctions between these terms and strongly prefer the use of developmental (Kozeracki, 2000). Historically, remedial courses are the common choice in developmental education because the convey information to many students at the same time (Boylan, Bonham, & White, 1999). Many institutions have moved away from the use of remedial because of the negative connotations (Clowes, 1980) that posit the courses as a remedy that will fix the student, or some weakness exhibited by the student (Kozeracki, 2000). Thus, developmental is now mostly used to describe any structured class that falls under the heading of developmental education (Boylan, Bonham, White, 1999). This work will refer to these courses throughout as developmental.

The Developmental Mathematics Course

The term developmental mathematics refers exclusively to courses generally considered to be pre-college level. Consistent with the literature, developmental mathematics courses include arithmetic, algebra 1, and geometry (Adelman, 1995; Fulton, 1996; Hegedorn, Siadat, Fogel, Nora, & Pascarella, 1999; Sagher & Siadat, 1996) and focus on rote procedural skills related to manipulating algebraic expressions to assist problem solving and other procedural processes (Larnell, 2016). Developmental mathematics is an initial college course where basic computational content is covered but the purpose of the course is to bridge the gap of high school preparation with the expectations of the university and college mathematics courses (Boylan, Bonham, &

White, 1999). The expectation of the university is for students to be at higher level thinking and obtain advanced mathematical understanding (Lesh & Zawojewski, 2007). McCabe (1996) emphasizes the importance of developmental education with helping students strengthen their basic academic skills such as, "the ability to read, write, analyze, interpret and communicate information" (p. 4) at a higher level, which are the fundamental skills needed for college mathematics. This transcends to career opportunities beyond graduation. Drucker (1994) indicates that the labor market is being transformed, and job opportunities will be most plentiful for "knowledgeable workers." Hence, helping students develop their basic academic skills is an important first step into expanding opportunities for success in their mathematical coursework, and within the information age (McMillan, Parke, & Lanning, 1997), provide more career opportunities. Many students who successfully navigate through high school mathematics coursework find themselves less prepared entering college coursework due to changes to entrance standards and higher education curriculum. Unfortunately, developmental mathematics is still considered for many of these students a barrier or gatekeeper for curriculum and career aspirations.

Mathematics has been shown to be the gatekeeper for curriculum and career pursuits for its students (Larnell, 2016; Moses and Cobb, 2011). Larnell (2016) notes that "algebra continues to serve as a gatekeeper to college and plays a unique role in mediating both the entrances and the exits at 4-year universities" (p. 235). Furthermore, Moses and Cobb (2001) add to the previous claim stating:

> So, algebra, once solely in place as the gatekeeper for higher math and the priesthood who gained access to it, now is the gatekeeper for citizenship; and

> people who do not have it are like the people who couldn't read or write in the industrial age. But because of how access to the learning of algebra was organized in the industrial era, its place in society under the old jurisdiction, it has become not a barrier to college entrance, but a barrier to citizenship. (p. 14)

With mathematics being viewed as a barrier, developing an understanding of the root causes explaining why the math course is positioned with higher educational as a career gatekeeper. Clues can be found in who enrolls in the developmental mathematics course and the math/cultural identity of these students, some of which created from their prior experiences.

Developmental mathematics student. Previous research states that the enrollment in developmental mathematics courses has risen sharply in the last 20 years (Larnell, 2016). For students enrolling for the first time at public four-year institutions, 33% enrolled in developmental mathematics between the years of 2003 and 2009 (United States Department of Education, 2017). Although the mathematics performance gap among White students and African American and Hispanic students has narrowed, substantial differences remain (Dossey et al., 1988; Hagedorn, Siadat, Fogel, Nora, & Pascarella, 1999; Manzo, 1994). Hegedorn, Siadat, Fogel, Nora, and Pascarella (1999) found an over representation by women and minorities in the college developmental mathematics courses. Many of these students in developmental mathematics courses more likely to come from families with lower incomes and lower educational levels.

Much of the discrepancy is due to the type of universities and colleges students are enrolling in. A broad section of the population is served in developmental mathematics, including recent high school graduates as well as students who have been out of high school for many years (McMillan, Parke, & Lanning, 1997). Knopp (1996) reported that the majority of those enrolled in developmental courses are nontraditional. Breneman and Haarlow (1998) reported that many of the nontraditional developmental students, with a particular proportion at the community college, have at least a part time job and occupy a variety of adult roles, such as parents, workers, and voters. Hardin (1998) has developed a seven-category typology that describes characteristics of developmental mathematic students based on the reasons they placed in developmental mathematics courses. These overlap with basic demographics mentioned above but now add deeper dimensions of the individual student and their identity. Boylan, Bonham, and White, (1999) summarize Hardin's (1998) seven characteristics which are:

1. *The poor chooser* - those who made poor academic decisions that have adversely affected their academic future, such as not taking college preparatory courses in high school.
2. *The adult student* - those over twenty-five years old who have been out of school for several years and must cope with managing adult roles and responsibility while adjusting to college-level academic expectations.
3. *The student with a disability*- those who suffer from physical or learning disabilities that prevent them from performing as well in the present as non-disabled students and have often kept them from learning as much as other students in the past.
4. *The ignored*- those whose physical or psychological disabilities or other learning problems have gone undiagnosed or whose learning needs have consistently been ignored in prior schooling.

5. *The limited English student* - those who acquired their early schooling in foreign countries and, as a consequence, have limited English language and verbal skills to apply at the college setting.
6. *The user*- those who attend college simply to attain the benefits thereof and who often have no clear academic goals, objectives, or purposes.
7. *The extreme case* - Those who have severe emotional, psychological, or social problems that have prevented them from being successful in academic situations in the past and continue to do so in the present. (Hardin, 1998, p. 89)

These diverse characteristics of developmental students extend to another point. Hardin (1998) discusses, it is false to assume that those in developmental courses exclusively “18-year-olds who slept through high school and now want a second chance to learn at taxpayer’s expenses” (p. 15). These students represent a wide range of adult learners (Boylan, Bonham, & White, 1999). With the varying types of students who take developmental mathematics, there is not a template or singular outward identity that represents this population. These students are all different. They share a common trait; mathematics is a barrier to their academic aspirations to earn a college/university degree. This opens the potential of an internal identity based on their experiences for their placement in this course. Such identities stem from personal beliefs and have constructed attitudes created from previous experiences. Beliefs and attitudes have been shown to affect student outcomes and performance, most notably, in mathematics (Aiken, 1970;1972; Alkhateeb & Hammoudi, 2006; Amato, 2004; Becker, 1981; Lester, Garofalo, & Kroll, 1989; Ma, 2003; Meyer & Koehler, 1990; Nasser & Birenbaum, 2005;

Saeed & Mitias, 1996). Therefore, discussion about how attitudes and beliefs will help unpack further salient issues that are hindering developmental mathematics students.

Attitudes and Beliefs

Studies have shown that attitudes toward mathematics play an important role in learning mathematics (Alkhateeb & Hammoudi, 2006; Amato, 2004; Becker, 1981; Lester, Garofalo, & Kroll, 1989; Ma, 2003; Meyer & Koehler, 1990; Nasser & Birenbaum, 2005; Saeed & Mitias, 1996) and when negative, the attitude holds the student back from understanding mathematical concepts. Attitudes toward mathematics was defined by Neale (1969) as "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless" (p. 632). Additionally, Aiken (1972) refers to attitudes as "a learned predisposition or tendency on the part of an individual to respond positively or negatively to some object, situation, concept, or another person and is commonly considered to be partly cognitive and partly affective or emotional (pp. 551). Very simply, Alkhateeb and Hammoudi (2006) refer to mathematical attitudes as the like or dislike of mathematics. Both Aiken and Neal describe how an attitude frames the level of engagement towards mathematics and Aiken points out that it is greatly recognized that attitudes toward mathematics in adults be traced to early childhood (Aiken, 1970; Morrisett & Vinsonhaler, 1965) and are deeply rooted in their beliefs and past experiences.

Beliefs have also shown to impact student mathematical outcomes. (Francisco, 2013; Walsh, 2008; Wilkins & Ma, 2003). With this, there is not a consensus on a definition of beliefs (Francisco, 2013; Furinghetti & Pehkonen, 2002; Hofer & Pintrich, 1997; Leder, Pehkonen, & Törner, 2002; McLeod & McLeod, 2002; Pehkonen & Hannula, 2004). It has varied within the different disciplines and researchers (Pehkonen & Hannula, 2004). Schoenfeld (1998) defines beliefs as “mental constructs that represent the codification of people’s experiences and understanding.” Beliefs has also been viewed as statements or stances the individual hold true (Francisco, 2013). Depending on the level of student, the belief can vary based on their experience with content and instruction as well as subject matter (NCTM, 2000). For this study, beliefs will be viewed through the lens as meanings and views about performing and learning mathematics based on their mathematical experiences (Francisco, 2013).

In an early study, McDermott (1956) found that in a case study of college students who were afraid of mathematics, many of them developed having first met frustration during the elementary grades (Aiken, 1970). Aiken (1970) also reported students developed their beliefs about and attitudes toward mathematics throughout various grades, but most commonly in grades fourth through sixth. With frustration, many students became unsuccessful with mathematics and disengaging from the subject. While students at an early age did not engage and make stronger connections to the material, they focused on the basic procedural processes to progress as needed. Many students lost interest and disengaged with mathematics, due to early frustration, lack of early success, and only understanding the concepts at a surface level, developing negative attitudes and beliefs based on their experiences in mathematics. Pajares (1992) notes that based on the student's attitude, they will reject new information, consider it irrelevant, and disregard new approaches to avoid conflicting with their beliefs (Schinck, Neale, Pugalee, &

Cifarelli, 2008). This disconnect of interest and engagement continues to widen the gap of understanding as students progress though their mathematics coursework.

Interest/engagement within mathematics. The notions of interest and engagement have researched within wide range of pedagogical approaches (Nyman, 2017). For example, Dewey (1913), approached student interest as a need for school improvement and Hidi (1990), in contrast, takes a psychological approach, where cognitive and affective features of interest contribute to motivation (Hidi, Reninger & Krapp, 2004; Nyman, 2017) and engagement of the student. The individual's interest, defined by Hidi and Renniger (2006) and summarized by Walkington and Bernacki (2015) as "stable and enduring preferences held by people towards objects, events, or ideas is the psychological state of engaging those events, activities, or objects in a positive manner" (p. 173). Students are more prone to engage with areas of interest. Thus, interest is important for mathematics because it contributes to mathematics learning (Rellensmann & Schukajlow, 2017) and the varying types of interest may affect the meaningful connection to the content and mathematical activity at hand. Along with the engagement of the activity. A student that is interested in solving a mathematical problem can be expected to be more focused while working, to use more deep processing strategies, and to persist for longer in the face of difficulties than an uninterested or motivated peer, all of which can contribute to a better learning outcome for the interested student. This type of interest triggered in the moment by characteristics of the environment such as relevance or connection to goals (Hidi & Renninger, 2006). This interest can be maintained over time if the student is still engaged in that instructional activity (Walkington & Bernacki, 2015). Disinterest in contrast, can contribute to a lack of motivation and affect the learning outcome and level of engagement.

This lack of engagement and motivation can also be derived from the students' lack of confidence in understanding mathematics and the application of mathematics (McCoy,2005), and the negative attitude from which much of has been created from disinterest and lack of relatability over the student's experiences. This has been shown to occur during algebra courses (McCoy, 2005) as early as grade school to post-secondary curriculum, where much problem solving with word problems occurs, and students and teachers often are finding algebra disconnected from everyday experience (Chazan, 1999; Walkington & Bernacki, 2015). A perennial issue in mathematics education concerns the use of problems that are closely related to students' interests and experiences (Kilpatrick, 1969) or in many cases the lack thereof. This lack of interest is creates a vacuum of engagement at all levels of mathematics. Schools today face pressing problems with student motivation and engagement (Hidi & Harackiewic, 2000), especially at the secondary and post-secondary level where interest in subjects like mathematics has decreased (Walkington & Bernacki, 2015), based on the beliefs that students see mathematics as mostly memorization and procedural problem solving. However, while other studies have shown mathematics to be seen by students as a creative, interesting, and useful discipline in which students learn to think (Mji & Glencross, 1999; Schoenfeld, 1989), the type of instruction is categorizing the two learning approaches. Those who are interested and engaged, are developing a deeper understanding, while those who are not, are learning mathematics at a surface level. These two levels distinguish between strong mathematics students and weak ones.

A surface approach involves minimal engagement with the problems as the student focuses on memorizing or applying procedures without reflection and mere completion of the problems (Mji & Glencross, 1999; Schoenfeld, 1989). A deep approach in contrast, involves an intention to understand and give meaning to the material by focusing on relations between parts of the subject matter or the structure of the problem, creating more student engagement with the material (Mji & Glencross, 1999; Ramsden, Martin, & Bowden, 1989). Here, the students are intrinsically interested in what they are learning and attempt to understand and relate to previous knowledge and personal experience (Mji & Glencross, 1999; Watkins & Regmi, 1995). Students who adopt a surface approach to a learning mathematics do so with intention centered on reproduction of knowledge, while those who adopt a deep approach do so with the intention to understand (Alkhateeb & Hammoudi, 2006; Ramsden, Martin, & Bowden, 1989). Mji and Glencross (1999) found that in a study to observe surface and deep approaches for first year college students, in the end of year examinations, of the 67 students who showed a preference for a surface approach, only 24 (35.8%) passed, whereas for those who preferred the deep approach, 18 of the 25 (72%) passed and was found to be statistically significant. Additionally, Alkhateeb & Hammoudi (2006) in a similar study of 180 enrolled in a first-year university course, found a positive correlation between favorable attitudes towards mathematics and a deep approach to learning (and vice versa for a surface approach). The level of engagement seems to distinguish the two approaches of surface and deeper understanding. Where more engagement persists, students are approaching mathematics in a more intrinsic manner, going beyond the rote memorization and procedural approach to learning mathematics, and finding more interest and motivation to learn mathematics, thus becoming strong and more prepared mathematics students.

Students enrolling in developmental mathematics are arriving ill prepared and much of this is due to the lack of engagement they experienced throughout much of their mathematical career. This lack of engagement stemming from a lack of interest has created a student that is basing their beliefs and attitudes on mathematics that are centered on rote memorization and a procedural focus. This focus of surface understanding being utilized in conjunction with standardized testing has taken place over most of the students' mathematical educational careers. Historically, where the developmental mathematics course is doing a disservice for these students is that it keeps the same focus of rote procedural skills related to manipulating algebraic expressions to assist problem solving and other procedural processes (Larnell, 2016), thus continuing cycle of disinterest, lack of engagement, and keeping mathematics and now itself at the gatekeeper. One area that can help break the monotony and holds of surface level understanding is within problem posing. Problem posing may provide the key to a deeper understanding of mathematics for the developmental mathematics student.

Problem posing, a form of problem solving, is a key part of mathematics, and though challenging, can engage students in the content. Problem solving is central to mathematics and instruction should give students daily experiences with it (Kilpatrick, Swafford, & Findell, 2001; Yee & Bostic, 2014) and literacy activities such as problem posing within problem solving, should be required in all developmental courses (Boylan, Bonham, & White, 1999). Additionally, this personalization of problem solving through problem posing can be found to be more relatable and engaging to the student. This section will outline the general literature with problem posing within problem solving and how personalization of problem-solving leads to increased interests and illustrate how problem posing can serve the needs of developmental mathematical students.

Problem Posing: A Form of Problem Solving

Yee and Bostic (2014) define a problem from works of Polya (1945) and Schoenfeld (2011) as a developmentally appropriate challenge for which the participant has a goal but the means for achieving it are not immediately apparent. Kilpatrick (1985) and NCTM (1980) each define the problem-solving process as a place of individual engagement or being engaged with a task to reach a given state or goal for which the solution is not known. In everyday life, people naturally solve problems to satisfy needs and unlike problems in the school context, everyday life problems are much less structured and require effort by the individual to use the resources at hand to identify and reformulate problems to better prepare for similar problems to arrive in the future (Singer & Voica, 2013). Toluk and Olkun (2001) refer to this effort as problem solving.

Problem solving is a series of steps and this sequential activity is an active process within traditional education (Arikan and Unal, 2015). Polya (1945) describes a model of problem solving through four stages with beginning by understanding the problem, then drawing a plan to assess the correct implementation of a procedure, implementing the procedure to solve the problem, and lastly, to review the process to ensure that the problem was solved. This model lays the groundwork for teachers to implement these strategies in mathematics education and for others to build and enhance problem solving because context is an integral part of any discipline.

Mathematical problem solving. Schoenfeld (1989) defined a mathematical problem as a task in which the student is interested and engaged and for which they wish to obtain resolution even though the student does not have a readily accessible means by which to achieve that resolution. Most of the past research with problem solving in mathematics has looked at the execution of well-established procedures and with the current research investigating how mathematical knowledge becomes "alive" and extends to solving novel problems (Anderson, Lee, & Fincham, 2014). Newman (1977) describes mathematical problem solving as the result of the following series of sub activities related to Polya's four stages. Here, students read the problem and once they understand what they read; they carry out a mental transformation from the words of the question to the selection of an appropriate mathematical strategy. The students then apply the procedural skills needed by the selected strategy and reach a conclusion. Lastly, they must translate the answer in an acceptable written form (Singer & Voica, 2013). Both models serve a specific purpose. Polya's is a general problem-solving approach, and Newman's is a cognitive approach with student interpretation on approach and individualized outcome. Newman's process is limited to one step word problems (Singer & Voica, 2013) where many word problems could cover an array of problems with varying levels of difficulty and depending on the level and type of the problem, the existence of a solution is uncertain because the means to attain a solution is yet unknown (Lesh & Zawojewski, 2007; Polya, 1957; Schoenfeld, 2011; Yee & Bostic, 2014). Therefore, the conceptual understanding of content and strategies is key in problem solving and because problem solving is a daily necessity, it must continually be improved, built, and progressed (Skemp, 1987). The varying strategy allows mathematics to serve the need of continued practice and exercise in problem solving, creating problem solving criteria, approaches, and goals.

Problem solving is a foundational component of mathematics. The National Council of Teachers of Mathematics (2000) standards underline problem solving as an essential part of mathematics learning. Much literature has been written specifically addressing problem solving in the context of mathematics and many scholars have addressed it in varying ways. In the last 60 years, mathematics educators have perceived mathematical problem solving in varying ways and has evolved as a heuristic process (Polya, 1945), a logic based program (Newell & Simon, 1972), a means of inductive and deductive discovery (Lakatos, 1976), a framework for goal-oriented decision making (Schoenfeld, 1985, 2011), methodologies with multiple variables (Kilpatrick, 2004), a standard (NCTM, 1989), and a model eliciting activity (Lesh & Zawojewski, 2007; Yee & Bostic, 2014). Each approach of problem solving listed enlists active participation of the individual. For example, a complex skill like algebra problem solving involves a rich mixture of perceptual, cognitive, and motor activities (Anderson, Lee, & Fincham, 2014).When manipulating a traditional equation to be reduced, a student has to scan past lines of equations, identify the next critical step, determine what the new equation will be, and then write that equation (Anderson, Lee, & Fincham, 2014). Active participation and strong engagement allow students to begin to address similar problems with varying approaches, depending upon what is given. This allows the student to be better prepared for problems that may be different but use similar strategies to solve. Teachers use word problems with different context and subjects to assess if students can apply these strategies and processes to reach conclusions. When students find processes and approaches that allow them to be successful in these problems, they adhere to those processes, making them routine and a part of their personal problem-solving criteria. These criteria are then applied to varying problems presented by the instructor as word problems.

Word problems. Word problems are a familiar type of problem solving. Word problems are designed to give context to problems to solve for unknown quantities. This is a critical component to mathematical understanding of concepts. Duan, Depaepe, and Verschaffel (2011) state that word problems are useful because they can motivate students and help develop their logical thinking. Context provides and allows students to develop problem solving skills. The context in word problems allows students to draw on their lived experiences as they engage with the mathematics. This helps students bridge the abstract conceptual mathematics to applied mathematics within a real-world context.

Even though this is an overarching approach and despite the importance of contextualizing problem solving in mathematics, many students are challenged by the process of translating mathematical word problems into the form necessary for effective computation (Davis-Dorsey et. al, 1991). Prior research indicates that word problems are challenging for children of all ages (De Corte, Verschaffel, & De Winn, 1985; Ku & Sullivan, 2000; Vicente, Orrantia, & Verschaffel, 2007; Walkington, Clinton, & Shivraj, 2018; Walkington & Bernacki, 2015). Garcia, Jimenez, and Hess (2006) note that this is mainly due to the traditional school curriculum, which emphasizes procedural knowledge, at the expense of conceptual knowledge. Students focus on memorization of facts and computational skills rather than on developing a conceptual understanding and applying mathematics to real world situations. Wallkington & Bernacki (2015) conducted interviews with two waves of students in grades sixth through tenth taking an introductory algebra course. The researchers found that students would tend to solve word problems by plugging in numbers with little understanding of the problem-solving processes. The students struggled to productively apply real world knowledge and make meaning of complex and ambiguous mathematical language, and informal, situation-based reasoning (Walkington & Bernacki, 2015). In sum, this body of research shows that students are disconnected from the word problems and as such take little interest in the problem-solving process. Often, word problems can be differentiated into types of problems and these types can be determined by the context of the problem (Powell, 2011) and students gravitate or disassociate themselves based on the context. Problems created by curriculum developers or researchers will always be relatively shallow and disconnected from students' actual experiences, as it is not feasible to write unique problems that perfectly match the experience of each learner (Walkington & Bernacki, 2014), furthering the disconnect to the problem-solving process. Additionally, some studies show that if a word problem includes ambiguous wording, it is even harder for unsuccessful problem solvers than ones including wording consistent with relatable context (Gunbas, 2015).

Context within word problems. Since the time of John Dewey, the emphasis has grown on the need to make education practical and relevant (Aiken, 1970). This could not be truer in mathematics. Bernstein (1964) argued that educators have failed to stress sufficiently the use of mathematics for studying and controlling our physical and social environment where meaningful relation can be made in the classroom curriculum. Until the movement of increased science, technology, engineering, and mathematics (STEM) in the classroom, we see meaningful relations between the curriculum and students that promote deeper understanding. Gunbas (2015) reiterates that students should be taught mathematical problem-solving skills within realistic problem-solving contexts finding that it can positively affect students' mathematics problem solving performance, solving transfer questions, and motivation. Problem solving includes distinct constructivist elements. This involves the student connecting situational contexts within the problem to their experiences, beliefs, and cultural constructs. This can play a huge role in how individuals approach problem solving (Lesh & Zawojewski, 2007; Schoenfeld, 2011; Yee & Bostic, 2014). Nilsson (2009) found that there were three specific contexts to analyze for mathematical understanding and make problem solving more relatable: situational, cultural, and conceptual. (Yee & Bostic, 2014). The cultural context refers to discursive rules, conventions, and patterns of behavior; the situational context refers to the interaction of the individual with the materials, environment, sensations, and actions involved; and the conceptual context is involved with personal constructions of concepts of the situation (Yee & Bostic, 2014). Each context involves a unique relationship that the student has with the material being presented, making it more relatable and personal. This body of research suggests that a personal connection to context bridges the disconnect that many unrelatable word problems create in problem solving. The next section examines the literature that relates to the personalization of word problems.

Personalization of word problems. Walkington and Bernacki (2015) define personalization as an instructional approach where students engage in school-based learning in the context of their out of school interests in topics like sports, video games, and movies bringing real world context to the school setting. Research suggests that personalization can improve both immediate performance and long-term learning in reading and in mathematics. Bernacki and Walkington (2015) found that personalized algebra problems were most effective if the connections made to students' interests. Deeper context problems related to how students might actually reason with quantities in their interest area, rather than surface-level characteristics of their interest area (Walkington & Bernacki, 2015). Ku and Sullivan (2000) performed a study with 72 fifth grade elementary Taiwanese students to investigate the effects of group personalization on the instruction. Using the notion of interest theory, Ku and Sullivan (2000) hypothesized that students would work harder and be more successful on solving problems that interest them than problems that did not. They found that subjects across the two treatment groups performed significantly better on the personalized material than on the non-personalized problems given. The belief was that this familiarity with the problems with personalization may reduce the cognitive load in conceptualizing and processing the elements of the problem and may thereby enable students to solve it with less difficulty (Sullivan & Ku, 2000). In a separate study, Jitendra, DiPipi, and Perron-Jones (2002) working with four middle school students with learning disabilities found that positive benefits may be attributed to the personalized contexts during acquisition learning. Additionally, Davis-Dorsey, Ross, and Morrison (1991) found through testing 68 second graders and 59 fifth graders, personalization made the problems more motivating, made it easier to construct a meaningful conceptual representation to connect the problem information and solution strategies, and made successful encoding and retrieval more likely. Ross and Anand (1987) found that personalized context of instruction containing familiar items, such as learner interests and background, increased achievement on word problems among 54 fifth and sixth grade students in a university-affiliated school.

Personalization can make the problem situation more concrete by placing it in a context that is familiar (López & Sullivan, 1992) and increase the student motivation to pursue the completion of the problem, even if found challenging or difficult. If a problem is considered difficult (Kilpatrick, 1987), many students do not have the persistence to solve such problem and reach a conclusion if they cannot make a personal connection. Personalization allows the problem-solving experience to be interesting and meaningful. Thus, allowing students to gain conceptual understanding of the mathematical concepts.

Personalized problem solving. Students tend to think of arriving at the solution as a key aspect of problem solving. Thus, making problem solving a routine activity. Personalized problem solving allows for a deeper experience in problem solving and encourages students to be active problem solvers instead of focusing on solutions. Yee and Bostic (2014) through studying middle and high school students, found students experiencing rich personalized problem-solving instruction have better problem-solving outcomes than peers in exercise laden learning environments How the students viewed the problem, addressed and moved from the problem to the conclusion was dictated by their previous problem solving experiences. Those with a poor or negative personal experience affect their process to problem solve. Thus, prior personal experiences influence students' problem-solving performance (Bostic, 2011; Lesh & Zawojewski, 2007; Yee & Bostic, 2014). When the process of solving is a successful one, a solver successively changes his/her cognitive stances related to the problem via transformations that allow different levels of description of the initial wording (Singer & Voica, 2013).

Unsuccessful problem solvers mostly focus on numbers and keywords in problems (Gunbas, 2015), while successful problem solvers construct a mental model of the problem situations (Gunbas, 2015) and find relationship to the problem and are able solve it. Through personalizing, these students will look beyond the numbers of the problem and focus on the context.

Transition to problem posing. The National Council of Teachers of Mathematics (1980) emphasized that students should solve mathematics problems in different ways and generate their own problems in given solutions. This allows students to understand the concepts at a deeper level as opposed to surface understanding. Using a personalized approach, this moves students to the potential of the deeper level of understanding. Everyday life problems require identification and reformulation to be tackled with the resources at hand; hence, in everyday life, it is not only useful to solve problems but the capacity to synthesize the complexity of situations seems to be important as well, to anticipate possible problems (Singer & Voica, 2013). Singer and Voica (2013) suggests that everyday life problems require reformulation, personal attention given by the individual to the problem-solving process based on their previous experiences, and the way they reformulate and construct a viable procedure to solve the problem becomes unique to the individual. Problem posing when used in the mathematics classroom, allows the reformation of problems to be better assessed by the individual and therefore, personalized based on the student's prior experiences, personal interest, and other motivating factors. The next section highlights what problem posing is and how it allows for this personalized approach to problem solving with word problems to promote increased interest in the content.

Problem Posing

One of the earliest references to involving students in problem posing was made by Belfield (1887) when he listed 13 suggestions for teacher in his Preface in his book *Revised Model Elementary Arithmetic* (Ellerton, 2013). Later, Einstein and Infeld (1938) noted and reiterated by Ellerton (2013) that:

> The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skills. To raise new questions, new possibilities, to regard old questions from a new angle, requires creative imagination and marks read advance in science. (Ellerton p. 88)

Paulo Freire (1970) brought problem posing to the forefront in education as an alternative to banking education (Arikan & Unal, 2015). Freire wanted to develop an instructional approach that allowed students to have more control of their learning and work along with their teacher. He wanted to counter the dominant model of banking education where the students receive information from the teacher for reproduction in the exam, without any input on their part. Freire (1970) felt that banking educational practices treated students as objects of assistance as opposed to problem posing, which allows the students to be critical thinkers and promotes independence by using their own ideas as learning aids. Problem posing did not emerge as an important pedagogical approach for mathematics education until the 1980s and 1990s when research about mathematical problem posing began to appear (Brown & Walter, 1983; Ellerton, 1986; Ellerton, 2013; Hashimoto, 1987; Silver & Cai, 1996; Silver & Mamona, 1989; Stoyanova & Ellerton, 1996).

The term “problem posing” in the mathematical literature refers to an activity in which the problem posing itself is the focus of attention and not a problem-solving tool (Lavy & Bershadsky, 2003). Problem posing has also been defined as engaging a person in a mathematical task, with the goal of generating a new problem from a given set of conditions (Kontorovich, Koichu, Leikin, & Berman, 2011; Silver, 1994). Stoyanova and Ellerton (1996) define problem posing in the context of mathematics as a process by which students construct personal interpretations of concrete situations and from these situations formulate meaningful (non-trivial) mathematical problems. Each definition provides unique emphasis on aspects of problem posing. Stoyanova and Ellerton’s (1996) meaningful formulation and a non-trivial creation guides understanding of the types of problems created, relating to Kontorovich et. al (2001) and Silver’s (1994) engagement to a task. This study builds on these ideas and use the following definition of problem posing in this study: Problem posing refers to the process of engaging students with creating problems based on a given set of conditions and constraints that are meaningful to the students and are non-trivial.

Student role in problem posing. The current study considers the students’ role in problem posing as an *active* role. This is in contrast to the traditional *receptive* role when teachers (or other students) model a solution to a problem, or the *passive* role when they read examples in a textbook (Ellerton, 2013). Many problem-solving strategies have moved students to where they are receptive or passive in their roles due to the disconnect of the material, situational understanding (Yee & Bostic, 2014), and disengagement and lack of motivation (McCoy, 2005) to the content. This only allows students to gather a surface understanding of the content. With problem posing, students must transition into the active role through careful instruction while keeping focus on problem solving. Students who are engaged in problem posing activities become active learners and have the opportunity to navigate the problems they pose within their areas of interest (Lavy & Bershadsky, 2003; Goldenberg, 1993; Moses, Bjork, & Goldenberg, 1990). Silver (1997) claimed that instruction involving problem posing within problem solving can assist students in developing more creative approaches to mathematics. This is an accepted approach to students learning how to solve mathematical problems. Building off Polya's four steps to solve a mathematical problem, many researchers are now including problem posing as a fifth step (Abu-Elwan, 1999). This step insures a deeper understanding of the content covered but also the problem-solving procedures. The role the student takes on as a problem solver, in turns addresses the role the student takes on as a problem poser.

Problem posing as a problem-solving activity. Problem posing is a problem-solving activity (Arikan & Unal, 2015) but can be distinguished as its own process. The National Council of Teachers of Mathematics (NCTM) (1980) emphasized that students should solve mathematical problems in different ways and generate their own problems in given situations. Arikan and Unal (2015) observed when studying 20 gifted and 85 non-gifted middle school students, that those students who used multiple approaches performed better than those who did not. Most of the students used multiple approaches, utilized problem posing, and showed greater success, while non gifted students who used multiple approaches found the process of problem posing complicated and difficult. Due to this difficulty, many of the non-gifted students did not approach problem solving with more than one approach. Arikan and Unal (2015) did note that 40% of the gifted students felt that problem posing was unnecessary while only 3.8% of the non-gifted students felt in the same way. However, the non-gifted students found problem posing, enjoyable, useful and necessary (Arikan & Unal, 2015). The problem posing process positively affects problem solving capability (Grundmeier, 2003). Problem posing may activate students' interest in learning mathematics as it is a challenging and generative activity, and the problems students pose themselves may draw upon students' interest and knowledge in topic areas other than mathematics in which mathematics could become a component of interest in everyday activity (Lesh & Zawojewski, 2007). However, if one does not understand the problem, relate to the problem, or find interest in the problem, one cannot or will not pose a problem (Ellerton, 2013); therefore, there must be steps in place to assist students in how to understand problems. Varying structures and stages can allow for student scaffolding to take place to help understand how to pose a problem.

Structures of problem posing. Extending upon this notion of problem posing being an important component of problem solving, Arikan and Unal (2015) note problem posing can be related to but not limited to three main situations that can help students create or pose new problems (Lavy & Bershadsky, 2003). These include structured posing, semi-structure posing, and free posing (Arikan & Unal, 2015; Lavy & Bershadsky, 2003; Southwell, 1998; Stoyanova & Ellerton, 1996; Van Harpen & Presmeg, 2013;).

A structured problem posing situation refers to the case in which the learner is asked to suggest new problems relying on a specific problem (Lavy & Bershadsky, 2003; Stoyanova & Ellerton, 1996) given or presented by the instructor. This level of posing is the foundation for students to understand what posing problems is. Teachers also have constraints in place to assess the understanding of the student's content and are able to build accordingly to the conceptual understanding of the student.

In a semi-structured problem posing situation, the students are then requested to explore the structure of the presented problem, solve the problem and pose a similar problem (Lavy & Bershadsky, 2003; Stoyanova & Ellerton, 1996). This problem posing experience allows the students to infuse their interests into a mathematical task and take authorship of the problem. The experience allows more freedom for the students, with enough parameters to prevent frustration. Further, the process ensures that the students do not mimic previous problems and build their conceptual understanding of the material and problem structures. Many scholars conjecture that the semi-structured problem posing opens a space for deeper understanding. In a study with 16 high achieving 10th grade students in Israel, Kontorovich, Koichu, Leikin, and Berman (2012) examined the semi-structured problem posing. The students were asked to write questions based on a given context (e.g. Billiard Ball Mathematics (BBM) task from Silver et al. 's (1996) study) (cf. also Cifarelli & Cai, 2005). The study found that the open endedness of the problems posed by the students was unique to the individuals and the groups that they were in. This opened the teachers and researchers to hidden forces that affected student performance. This was mainly due to open ended task of the problem posing, semi-structured stage.

In a free problem posing situation the students are asked to write a problem based on a certain topic without further guidance (Lavy & Bershadsky, 2003; Stoyanova & Ellerton, 1996). Students can author problems based on their interests and motivations by investigating the specifics of the content. Specific questions that can arise and create situations that are centered on the interests of the student and how they understand the task and material context presented by the instructor. Students should be able to answer varying questions about the subject matter at this level and show a deeper understanding about the mathematical content.

The three levels of freedom allow the instructor to scaffold and assist in the creation of the problem. This creates a classroom context at which students have equal part in the problem-solving process. They include the task the students are faced with and must act upon, which is a major part in each stage but increasing each level as the teacher provides less constraints. This allows instructors to help assist students with making strong connections to the content. Lavy & Bershadsky (2003) were able to show these three stages at work with advanced mathematics students from the United States and China. Ninety-nine eleventh and twelfth grade students from China and thirty United States students were selected for this study. All at which were in advanced mathematics strands in their perspective grades and curriculum. When given a fifty-item content test, students from both China and the United States were able to pose problems through the three stages. One note was that the students were able to do this due to their exposure to higher level mathematics, which it did influence their posing of new viable problems.

Application to non-advanced learners. The three stages also allow students with weak prior knowledge, poor computational skills, negative attitudes towards mathematics, and are disengaged with the material to take ownership of the problem-solving process. Problem posing as mentioned earlier, is a cognitively demanding task (Arikan & Unal, 2015), however when students relate their interests, this allows the potential to leverage students' motivation for prior knowledge of their interests and overcome these issues (Arikan & Unal, 2015). Research has shown a strong relation with individuals who cannot understand the problem, will not be able to find and use suitable strategies (Ellerton. 2013); additionally, they will not be able to explain what they are doing or why and will lose interest and motivation to solve the problem (Arikan & Unal, 2015). Overcoming these issues allows students to move beyond the surface understanding to move to a deeper understanding. Walkington and Bernacki (2015) found that when interviewing twenty-four middle to early high school students over the problem posing process, their out of school interests were used to pose problems and they were found they were learning more mathematical content. Additionally, this improved those students' attitudes towards mathematics (Walkington & Bernacki, 2015). The personalized effect of the problems created served to engage the students with the content. For a student to be able to pose a problem correctly, they must demonstrate a deeper understanding of the content and this is shown by the level of problem created.

With the structured, semi-structured, and free stages being fluid and unique to the individuals, the activity of problem posing can take place before, during, or after solving a given problem (Lavy & Bershadsky, 2003). Much of this will depend on the level of student and disposition towards the content and mathematics. Researchers emphasized the inverse process in which the development of problem-solving skills can be helpful in developing problem posing skills (Brown & Walter, 1993; English, 1997; Lavy & Bershadsky, 2003). This further ties problem solving with problem posing, creating a nexus at which both and satisfy and supplement one another. Additionally, with such a close tie to one another, it also addresses the focus of solution as much as it addresses the process at which problems are solved.

Problem posing and the developmental mathematics student. With what problem posing has to offer to the problem-solving process, the developmental mathematic student can benefit greatly. The salient issues that surround the developmental student with lack of motivation and interest from mathematics, continuing negative attitudes towards mathematics due to being focused on rote problem-solving skills and only addressing surface understanding, and solution outcomes can be addressed. Addressing these issues can improve engagement and overall understanding. The initial issue that must be addressed is the lack of interest in the material.

Personalized problems and increased interest. With incorporating word problems as the medium in problem solving, the initial need for developmental mathematics students is the need to address interest in the problem. With problem posing, students are able to use their personal interests, being out of school or career and major interests, they can create their own subject to the problem's context presented by the instructor. Through the varying studies, this application of increased interest provides a higher opportunity of engagement and understanding (Rellensmann & Schukajlow, 2017). Students that are more engaged, are more like to be motivated to work within the mathematical material. This personalization of the word problems and problem-solving process builds of the interest and increases the attitudes towards the content and material.

Addressing content preparation. Further interest and engagement moves students beyond the surface level understanding to a deeper understanding within the posing process, thus furthering the understanding of the content at hand. It is noted however, were many studies highlighted students who were "gifted" and "advanced", these students were exposed to more problem-solving strategies and content as opposed to others. Content preparation is needed to solidify the computational understanding prior to problem solving and problem posing occurring. The CCR notes that instructors need to focus deeply on the major work of each level will allow students to secure the mathematical foundations, conceptual understanding, procedural skills and fluency, and the ability to apply the math they have learned to solve all kinds of problems, inside and outside the classroom (CCR, 2013). Developmental mathematics curriculum is already in place to serve this need. The focus for this course is to improve upon the conceptual, procedural, and foundational understanding to better prepare students. This can be supplemented with problem posing to addresses the much-needed improvement in the problem-solving area. This satisfies outcomes of studies showing the students who performed well with problem posing and problem solving had received more mathematical content (Arikan and Unal, 2015; Arikan, Unal, & Ozdemir, 2012; Ellerton, 2013; Lavy & Bershadsky, 2003; Van Harpen & Presmeg, 2013; Yee & Bostic, 2014) and allowed to work with advanced material to begin to build a deeper computational understanding.

Student interaction and collaboration. Teacher and student interaction within the developmental course also allows the problem posing process to take shape with students working from one another's problems. Occurring in the semi-structured or free posing stage, developmental mathematics students can work with one another collaboratively to solve and understand one's problems. The collaborative approach to problem solving was highlighted through a study conducted by Dees (1991) in a college remedial/developmental course. Seventy-seven students took part in this study with an average age of twenty-eight years old. Half of the students were right out of high school, while the other half have been out of secondary school for some time (Dees, 1991). Students were divided into two sections, one represented the control, while the other represented the treatment. The control was conducted with the normal protocols for the course, while the treatment emphasized the increase of group and partner collaboration. Pretest and post-tests were given with attitudinal two item questionnaire. Students were asked to work in groups of four to six students for most of the semester. When the problem-solving unit was presented, students were divided into new pairs and further collaboration was emphasized. Upon completion, students who worked together in the treatment, outperformed those in the control who did not. Specifically focusing on the work problem section, students who collaborated during the treatment group scored higher than those who did not. Dees (1991) noted that this study made a favorable argument to use cooperative learning in a college setting with remedial/developmental students.

New norm for the classroom and for the developmental student. This new classroom norm or social mathematical norm (Yackel & Cobb, 1996) allows for student learning to be more conducive to the understanding the concepts through collaboration. It allows students to build confidence in oneself with help and scaffolding form their peers. The increase of confidence directly relates to improve attitudes and better understanding. Problem posing can serve in this sociomathematical norm, drawing on developmental mathematics student interests with collaboration from peers through careful stages of scaffolding but the instructor, opens students to more engagement with mathematics. When this is achieved, students will have the opportunity to perform at a higher level with a deeper understanding of mathematics, no longer being denied access to upper mobility due to mathematics.

Problem posing has been researched with a wide range of subject populations, including high achieving elementary students (Singer & Voica, 2013), advanced secondary students in China (Lavy & Bershadsky, 2003), advanced middle (Walkington & Bernacki, 2015) and high school students in the United States (Arikan & Unal, 2015; Arikan & Unal, 2012; Van Harpen & Presmeg, 2013;Yee & Bostic, 2014) and Israel (Kontorovich et. al (2011), university students preparing to become elementary and middle school teachers in Israel and the United States (Ellerton, 2013; Lavy & Bershadsky, 2003), and university students in a numerical analysis course in Portugal (Silver, 2013). The variation in the ages and mathematical experiences of the various subject populations in these studies, as well as the diverse purposes for which subjects engage in problem posing, suggests the robustness of the topic as a matter of interest in mathematical education across the span of schooling from elementary school to university and across a wide range of task settings (Silver, 2013). Claims have long been made about the potential value of problem posing in assisting students to become better problem solvers (Brown & Walter, 1983; English, 1997, 1998; Kilpatrick, 1987; Silver, 1994, 2013) through increased engagement and heightened motivation (Lesh & Jewojawksi, 2007; Lavy & Bershadsky, 2003). These areas of increased interest show an increase in favorable attitudes towards mathematics and problems solving.

The goal of the study is to explore how problem posing affects/impacts proficiency of developmental mathematics students and observe the relationship between the problems created, the interests used in the creation, how problem posing related the to the level of engagement with the material and how it affected students' attitudes and beliefs about mathematics. Frameworks on how the study will address procedures in methods of curriculum creation, student work organization and data collection will be discussed in chapter 3.

CHAPTER THREE: METHODOLOGY

This chapter will outline the methodology used in this study. After a description of the methodology, I will discuss the results of a pilot study. The research questions guiding this study is "how do developmental mathematics students engage with problem posing? More specifically, what problems do developmental mathematics students design based on their personal experiences? Further, what impact does problem posing have on their mathematics proficiency, and beliefs and attitudes about mathematics?

Prior to the start of this study, Institutional Review Board approval was obtained from the university and the university at which the site of the research is taking place. After obtaining IRB approval I conducted a pilot study at the same location as the proposed study. The goal of the pilot was to test and refine instruction approaches, data collection procedures, and assessment tools. The pilot was conducted over a five-week period in a summer developmental mathematics course with students who shared similar characteristics to the same course in the regular semester (e.g. age, prior mathematics courses). The next section describes the methods and results of the pilot study. Following the pilot study, I will discuss the methods for the research study.

Pilot Study

The pilot study was conducted at a public university in the southeastern United States. This university was selected for convenience to the researcher. I was the instructor of record for the developmental mathematics course and have taught this course regularly for three years. There were eleven students in the course.

The pilot study was conducted during a five-week summer developmental mathematics course (See Figure 1). The first four weeks of the course focused on algebra foundations and computations and the last week focused on word problems and problem posing. The focus of the problem posing was restricted to algebra word problems in the pilot. The students were introduced to problem posing in three phases with a gradual release of control (See Table 1). In the initial phases of structured and semi-structured problem posing, instruction in the study was set up dividing material and approaches in the posing phases, structured, semi-structured and free. The initial study was the designed to only use structured and semi-structured posing due to the complexity of posing with a few sections of free posing in the later sections.

Figure 2 provides an outline of the summer course and a timeline for the pilot and Pre and Post Survey. Figure 2 provides the specifics of the pilot schedule and data collection. Figure 3 provides the changes made to material presented, types of data collection and problems posed. Figure 4 provides posing instructional focus based on topic and data collected. The last two columns related to the actions of the pilot study. The instructional focus outlines the times when I introduced the students to a particular type of problem posing. The last column refers to the data collection related to the pilot. Note that in addition to the data, I maintained a detailed journal about my reflections on the study and my informal interactions with the students, both in and out of class.

Analysis of Pilot Data

The major goal of the pilot was to test the instruction of the varying levels of problem posing within the word problem section. Further, I wanted to test the assessments, questionnaires, timing of instruction, and data collection. I developed summary matrices to get a sense of the overall data (Miles, Hubermann, and Saldhana, 2014) (see Appendix for a summary of the Tables). Tables 2 and 3 outline the represent the comparison of the pre and post survey subtopic questions: beliefs and attitudes. They marked to see if any changes occurred in student responses from pre to post within each subtopic. Frequency of categorical change was calculated as well. Figure 5 represents the varying levels of posing within each unit/topic area, the types of problems students provided, and the frequency of problems from each section. Color coding was used to observe the overall trend of the problems students posed (See Table 4). I paid special attention to the interests that they listed and the context of the problems they were posing.

Results

Pre and post questionnaire. The questionnaires are in two parts with questions rated on a 5-point Likert scale. Questions for attitudes and beliefs were scored and labeled as follows: (1.0) Strongly Disagree, (2.0) Disagree, (3.0) Undecided, (4.0) Agree, and (5.0) Strongly Agree. Questionnaire 3 asked demographic questions. Questionnaire 2 and questionnaire 3 were given at the beginning and end of the word problem/problem posing unit. Within the pilot, the questionnaires were referred to as pre survey and post survey. Both surveys provided information about student beliefs and attitudes, as well as demographic information. The pilot study, found to be a sound method for collect attitude and belief data, also providing more insight into building additional questions in questionnaire 1.

Beliefs. Beliefs were found to play a role in the posing of questions in each phase - structured, semi-structured, and free. The students believed that problem posing would be challenging given that they had little to no exposure to it. This had an impact on the students' problem completion. Results from the pre and post beliefs survey showed change in outcomes for 15 of the twenty items (Table 2). Changes were noted as good, bad, no, and situational. The label of good represented the student outcome to adjust, increase or decrease based on the question in a way students altered their beliefs. Good change was viewed by the researcher views as being aligned with the extent of research. Bad was labeled as well but represented what the research deemed not aligned with the research. No change represented students Likert responses that did not change from pre to post survey. Additionally, a label of situational was used by the researcher to note if outcomes were based on the timing of the survey and biased to the immediate events at that time during the course. Biases were based on student comments at the times of the questionnaires. Tallying the results, eleven of the 15 changes were labeled as good, two were labeled as bad, and 3 were labeled as situational. Total change was measured by finding the absolute of each outcome and totaled. Good changed by 2.5 Likert points, bad changed by .5 points, and situational changed by 1.0 points. The greatest change in good was for question 10, "*Being able to successfully use a rule or formula in mathematics is more important to me than understanding how and why it works,*" with a change of -0.7. This showed students began to believe that it was not as important to know a rule or a formula to know how or why it works. Other good changes were between .1 to .3. For the bad labeled questions, both involved increase in student's belief that the most important part of mathematics was computation and main purpose was to get the right answer and getting the right answer was the most important part of mathematics.

Where these findings could be deemed situational due to giving the survey on the final exam date, were viewed as negative. The no change labeled questions did not come as a surprise. Students still believed that getting good grades in mathematics is more of a motivation than is the satisfaction of learning the mathematics content and do not believe in developing and exploring their own way when learning something new. Students also believed and either disagree or are uncertain that mathematics still consisted of many unrelated topics and that math is rigid and an uncreative subject. One motivating factor to continue to use the belief survey was there was positive change with sixteen of the twenty items.

Attitudes. Like the beliefs portion, attitudes presented some change. Only two questions showed no change in the pre and post questionnaires. These results can be found in Table 3. Good was labeled on ten of the twenty questions while bad was labeled on eight of the twenty questions. This portion showed more change with student attitudes good or bad than beliefs; this much of the data reported conflicts within its outcomes. For example, in question 12, "*When I hear the word mathematics, I have a feeling of dislike*," increased by 0.7 opposing question 17, "*I have never liked mathematics, and it is my most dreaded subject,*" which decreased by 0.8. Other examples of this are represented in question 11 "*Mathematics is something that I enjoy a great deal*," decreasing by 0.5 where question 14 "*I really like mathematics*" increased by 0.5. Similar calculation to how beliefs were scored based on absolute value was used for attitudes overall good verse bad comparison. After reviewing the results while students completed the final exam, I noticed this trend but did not realize it was this contradictory. I asked the students on the way out of the class their thoughts and attitudes about this section. Almost all the students mentioned gaining some confidence in problem posing. However, they also pointed out feeling stressed and anxious about the final exam. Results reaffirmed this feeling. Students stated it was due to giving the post survey on the same day as the final exam. The timing of the beliefs and attitude portions of the post survey made the results situational.

Reflections on instruction. The pilot study was conducted in a five-week summer class and I scaffolded their engagement in problem posing in three stages - structured problem posing, semi-structured problem posing, and free problem posing. Given the link between my instruction and the student activities, the instruction and the student problem posing will be intertwined.

Results of structured problem posing. Students were challenged with structured and semi posing during the first day of instruction. Each of the eleven students produced three problems of structured posing and three for semi-structured. These results are highlighted in Figure 5 and Figure 6. In both attempts, none of the problems were personalized or drawn from their personal interests documented in class. The problems presented numerical statements and consecutive integers. For example, I attempted free posing within these examples, and although, none of the eleven students personalized numerical statements, all eleven attempted consecutive integers through mimicking previously discussed problems. From this point, students stated that they did not "know how" to create new problems and each of the students stated that they had never created their own problems in prior coursework. I observed that a missed opportunity occurred. In the next iteration I introduced the students to modeling and problem posing earlier in the instruction sections than in the more advanced topics. This was highlighted during the next phase of unit in the Figure 5.

Once the topic of problem posing was discussed with class, students showed great gains and utilized personal interest more than previous material. During the markup and markdown section, within the structured posing, four of the eleven created problems that used personal interests highlighted in green, three mimicked previous examples highlighted in blue, and four did not finish the exercise. Since students (1, 5, 8 and 11) moved quick to personalizing, I bypassed semi-structured posing and moved directly to free posing to investigate how the students reacted. The students were asked to pose as many problems as possible after the class discussion from the structure posing. During this exercise, the class posed twenty-five markup mark down problems total. Two did not attempt the exercise due to being absent. Of the twenty-five posed problems, two were mimicked from previous problems (highlighted in blue) and one was an original problem posed but did not use the students personal interests (highlighted in orange). Sixteen problems used personal interests that the students had reported before in writing (highlighted in green) while four were from class discussions (highlighted in yellow). Based on class discussions, a number of students were more comfortable creating problems that related to money. From this point on in my instruction, I attempted more free posing to understand what type of problems engaged students. With more examples of each type of posing phase modeled for the class, students began to understand the posing process and provided more examples of posed word problems.

Results of free problem posing. During the final test assessment with posing, students were asked to pose four free posing problems and one semi-structured problem. For the semi-structured posing, students were asked to pose a problem from the numerical statement $49.90 + 0.29(X) = 100$. Of the eleven students, six did not attempt this problem. Of the five students that that preformed the task, one mimicked a previous problem, three used personal interests, and one posed problems that were original but not mimicked. For the four free posing, two students did not attempt the problems. Of the other nine students, 15 of the problems posed mimicked previous class examples, while twenty-one problems were created from personal interests. This illustrated that more students engaged with problem posing and personal interests than not.

Overall, the class of eleven posed forty-three structured questions, seventy-eight semi-structured, and ninety-two free problems. Observing the structured problems, thirty-six posed problems did not use personalized interests in the posing process. This was not out of the ordinary due to the instruction and framework of the structure posing did not require and ask for personal interests to be integrated. However, the remaining seven problems in the structured section were personalized without instruction to do so. This was done by four separate students. The four students incorporated their own interests of money into the problems and is believed to be due to the subject matter of percentage increase and decrease in topic linear equations. This in addition to the method of free posing that of already being introduced.

Within the semi-structure posing, thirty-three problems that were posed were not collected. Thirty-three problems did not include personal interests. This was after it was prompted to incorporate different subjects or contexts into the problem. Three problems mimic the examples I provided during instruction, copying the subjects and information, not including their own interests. Four posed problems did incorporate personal interests into their problems. two problems were personalized based on the class context. This included classmates, myself and subject matter discussed in class but did not reflect themselves or personal interests they and documented. Lastly, the remaining three semi-structured problems posed, students attempted posing but created new problems with different subject matter and values. This was closer to free posing but did not use personal information. The problems were completely restructured to represent a different algebraic expression. These problems also were not solvable, where all other semi-structure problems were. Two units of the material were not observed in the semi-structured section due to testing the free posing

In the free posing grouping, eleven problems were posed but not collected. These were kept in the student's notes for reference. Twenty-seven of the free posing were mimic from previous problems given as examples in class. Within these problems the students posed problems in with different values but used the same subject matter previously shown in previous lecture examples. 15 of these problems occurred out of the thirty-six posed problems on the final exam. Eleven occurred all within one unit of material, consecutive integers. This was due to the timing of the material and sequencing of the posing within this particular topic. Five of the mimic problems came on the on within the subject material of interest problems.

The remaining posed problems all utilized some varying level of personalized creation. Thirty-five problems posed were personalized based on written student interests while nineteen problems were personalized based on verbal interests. The highest frequency of problems occurred in linear equations with percentage increase or decrease. These are referred to as markup and markdown problems. Thirty problems were posed with twenty-one being personalized based on documented student interests while the other nine were based on subjects from the class and other situational oral discussions that were not written by the student. The largest grouping of posed problems involved money, or products/items being purchased. The items all related to some aspect of their personal interest.

Most items that were posed occurred in the unit of ratios, proportions and percentage change within a linear equation (See Figure 5). These problems posed represented fifty of the ninety-four attempted personalized problems posed with only seven of the twenty-two mimic problems posed. This may be attributed to one full day was given to this unit with follow up discussion during the previous class as well as semi-structure problems were not attempted during this unit. I observed seven students attempting to pose structured problems with personalized components. It was from this I bypassed semi-structured and incorporated more free posing instruction. It is to note that forty-four other free posing problems were required but were documented on what context the problem was posed.

Student feedback. At the end of the word problem test, students were asked a final question about problem posing. The questions states, "*Discuss your thoughts about problem posing. Is it useful, hard, easy, confusing, fun, etc*?" Students responses varied. Two students found it useful. Student 2 stated that "It is very useful. Most of the problems that we did, I wouldn't have been able to do without problem posing," with Student 3 stating "I thought that the problem posing help me understand the math of the problem much better." Similar to these two students, Student 1 stated, "It was helpful with the markup and markdown problems to first create an actual equation then write a word statement after. The way we broke up word problems was helpful but sometimes it was confusing like with the Kool-Aid problem and having multiple mixtures. I feel like we could have done one or two more examples." This feedback was useful due it giving specific problems that problem posing benefited. It also gave suggestions on what would have improved the instruction.

Others that had constructive feedback included other insights. Student 4 stated:

> "Overall, I don't think it is extremely difficult. I honestly believe that is gets more difficult as you add variables (unknown variables) and multiple equations sets to the mix. I do believe that it is useful though and very practical in real world use."

This student found application with problem posing and reaffirmed other data that more examples might have helped with more difficult problems. A couple of students found posing difficult, but on the computational side of the problem posing. Student 6 stated "My thoughts on problem posing is that it's very hard for me to think of good problems that make sense and have a solution. I understand that it is useful to be and to understand them and solve them but coming up with solid problems is tough," similar to Student 7 who stated "Problem posing is difficult to me because hard to come up with something that makes since and fits." This alluded to the overall focus on the values being correct in the computation as opposed to the subject of the problem.

Some students found problem posing difficult as well, and some did not see usefulness with it. Student 9 stated "It's hard and stressful. It can be helpful sometimes, but this has just been a lot." Student 5 concurs with Student 9. They stated that "To me it is hard and confusing. I already have a difficult time with words problems and making my own just added to that difficulty." For these two students, the difficulty of the posing, did not contribute to understanding but further confusing about word problems. Interesting enough, most students were not for or against problem posing but somewhere in the middle. Only two strong were opposed to it or found it difficult and two found it very easy and useful.

I plan to build on the pilot study as I move ahead with the next phase. From the pilot, several key changes have been made for the study and will be discussed in the following sections.

Adjustments for Study

Surveys and questionnaires. Based on the survey outcomes and student feedback, the questionnaires in the study were given on non-assessment days. This was done to avoid student responses based on situational events. Additionally, along with the Likert scale, students were asked open ended questions about their attitudes and beliefs. These data were very revealing within the pilot and served to be documented and crossed examined with their scored questionnaire outcomes.

Instruction. To draw from what I learned from the pilot, class sections were structured differently. Where is it was noted students performed and produced free posing better than anticipated, free posing was integrated into the instruction of the study. Additionally, more preparation of what “posing” is was addressed as well. Students from the pilot noted that it would have helped to discuss what posing was and modeled it prior to the start of the lesson. This was utilized within each phase of posing. Even though very little structured posing was conducted at the end of the study, it served areas of lesson preparation to have smoother transitions in the later sections of posing. Moreover, it allowed the study to be consistent with the framework of the study. The pilot illustrated the need of each phase and the progress from one phase to another. Each phase was presented in equal parts within each unit of study.

Another observation based on the creation of the table was areas that were incomplete due to not collecting student data and allowing them to leave it in their notebook with their notes. Student work was collected on specific forms within each posing session. This allowed for a more complete data collection. It also allowed me to separate the student work by posing phase.

Additionally, from free posing, it was noticed by the students and myself that they were able to correct their own mistakes in algebra and computation while verifying if the problem posed was a “sound” problem or a problem that “made sense.” For example, a student created a markup problem for a lab assignment. Student 1 explained their problem but switched their variables. It was easily found from their “personal” narrative in the problem due to the subjects and variables in reverse. Student 1 also self-discovered their mistake rather than waiting on the me to prompt them. Student 1 stated, “it did not sound right so I rethought what I had written and switched to two things in the problem.” By her discussing this with the class, she was able to help others draw attention to similar issues. Student 1 also added that they would not have tried unless it was with a problem that interested them. The personal connection was an important component. This helped reaffirm the use of personalization with their own interests. This provided better insight in creating questions for the questionnaire 1 to retrieve more specific personalization information about student interest.

Content alignment. From the pilot, the content alignment was divided based on the sections from the course material. This was difficult for the students due non sequential progression of the topics. For example, solving system of linear equations was presented at two separate points in the course outline within the pilot section. For the study, content was realigned to better the flow of the topics and progress in level of involvement.

Pre and posttest. A pretest was not given in the pilot due to the lack of time. This was adjusted for the research study. The posttest involved all questions that have been either posed or that utilized personal interest of the students. More posed problems were on the posttest than personalized problems. Afterwards the students discussed that they liked having the personal aspects. However, they wished there were a few more of the basic problems or non-student posed that looked very similar to the examples from the class. For the study which had more students and involved a control and intervention group, personalized problems were still placed in the posttest as well as posed problems. Just like the pilot, the personalized problems were the same representation of the basic non personalized problems represented from the control class. Subject matter was utilized from both groups' questionnaires. For the study and differing from the pilot, a balanced portion of personalized problems (4) and posed problems (4) were on the posttest for both control and intervention groups. This provided more balance to the questions and drew from the modeled questions as well that both groups will be exposed to.

Interviews. No formal interviews were conducted during the pilot. However, lines of questioning based on the questionnaires were used during open class discussed to drawout student insight and opinions on the process, their personal beliefs and attitudes towards the subject matter, problem posing process. This was utilized the same way in the research study but had more formalized interviews at the end of the instruction.

The Research Study

The study involved two developmental mathematics courses offered by the university through its mathematical sciences department. Each course usually has a minimum enrollment of 16 students and a maximum enrollment of 52. This minimum by the university based on factors such as cost, is set as the minimum needed to hold class and the maximum is based on the maximum capacity of the room in which the courses are being taught. The class demographics were at random and based on student enrollment. No special codes or descriptors were placed on the class to alter enrollment or deter individuals from not selecting a specific course in favor for the other. Times of the courses were selected to be close to one another so as to reduce bias. Courses were observed at 8 am and 9 am EST.

I served as the instructor of record for both the courses. I randomly selected one of the courses to serve as the control class (Control). The control class received no change in instruction from the typical course curriculum. The other class served as the intervention class (Intervention). The Intervention group received adjusted instruction.

Problem posing intervention. Students engaged in problem posing around algebra. This material was within the curriculum of the coursework and was revisited to prepare students for the concurrent coursework. Silver (1994) and Brown and Walter (2005) express that problem posing occurs in three situations, one of which, students create new problems from given constraint based on their personal experiences. Students created and posed their own problems based on the constraints and concepts covered in the course using their own personal experience and interests. Based on the Adapting Active Learning framework from Ellerton (2013) in Figure 7, each mini unit was be divided into the three posing phases; structured, semi-structured, and free posing. Highlighted in Figure 7, each posing type took place over all three classroom instructional periods. Structured tasks along with instruction took place in the first two stages of Ellerton's active learning framework, semi-structured will took place within the middle two stages, and free posing took place in the last two stages of the framework. As the framework progresses, students moved from a passive role found with the structured phase of posing to an active role which finished in the free posing phase. See Figure 8 for combined model.

Likewise, in the pilot, students engaged in problem posing phases within algebra with progression of freedom for student to utilize personal interests. Table 5 illustrates the progression of the problem posing phases that was utilized within this study. Free posing was divided based on the variation of problems students posed in the pilot.

Students continued to focus on posing problems involving varying algebraic representation such as fractions, decimals, percentages, integers, and whole numbers. Student examples were collected throughout each phase with labeled sheets representing each phase of posing. Student examples that showed strong understanding was used as models for similar problems in the posttest. Both courses were an initial wording table to help students review common words that represent the basic algebraic operations and symbols and begin to understand basic wording within word problems (See Figure 9).

Overview of the data collection process. Data collection was conducted using questionnaires, pre and posttests, student work, interviews, and reflective journal. These methods along with questions that were addressed are highlighted in Table 6. Questionnaires were utilized to observe attitudes and beliefs of the students. The pre and posttests were used gauge student proficiency. The student work was used to observe the engagement of the students and problem posing. Interviews and reflective journal were used to triangulate the questionnaires, pre and posttests, and student work. Figure 10 represents the outline of the Control and Intervention courses. A timeline (Figure 11) illustrates the progression of data collection within both courses.

Table 6

Data Collection Instruments by Research Question

Question	Data
1) How do developmental math students engage with problem posing?	Student work/matrix, interviews, reflective journal
2) What problems do Developmental Students design based on personal interests?	Interviews, student work/ matrix
3) What impact does problem posing have on students' Attitudes and Beliefs?	Questionnaires, interviews
4) What impact does problem posing have on their mathematics proficiency?	Pre-Test and Posttests, Interviews

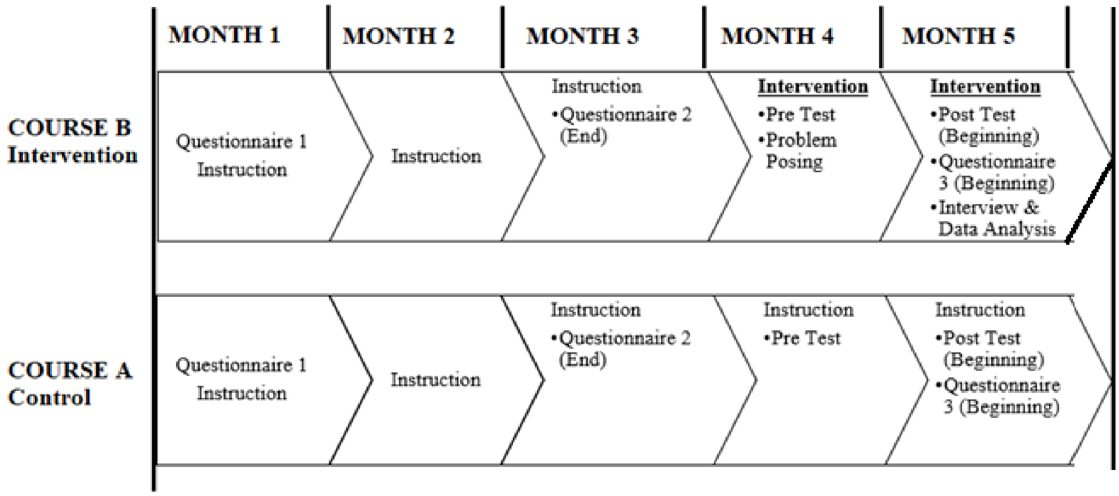


Figure 11: *Data Collection Timeline*

Questionnaire 1 was administered to the students in the Control and Intervention courses at the beginning of the study. Both courses received the instruction through months 1, 2, and 3. At the end of month 3, questionnaire 2 was be given to both Control and Intervention courses. Entering month 4, I gave the pretest to both courses. The pretest was identical for both courses. The Control course continued with traditional instruction and worked through problems from the textbook. The lessons were scripted to ensure consistency in the instruction for the Control course.

The Intervention course received the intervention instruction of problem posing. I focused on the framework of Ellerton highlighting the three phases of posing, Structured, Semi-Structured and Free. Within Structure posing, students were asked to create problems with the same structure and numbers of the given problems but with different subjects. Within Semi- Structure posing, students were asked to create problems using personal interests but based on specific subjects of the problem and numerical expressions. Within Free posing, students were asked to create problems using personal interests based on the numerical expression and create problems using personal interests based on the given subject matter. See Figure 12 for the daily outline in month 4. Student work of each phase was collected from the Intervention course.

During month 5, the Control and Intervention courses were given the posttest. The posttest served as the unit assessment, which is a regularly scheduled assessment for both courses. Additionally, both the Control and Intervention courses completed questionnaire 3. Students in Intervention self-selected for interviews to discuss results from questionnaires, student work, and pre and posttests. At the conclusion of the study, data analysis of the study was conducted in months 6-10.

Data analysis instrument procedures. This section will describe the data analysis for this study. The data will consist of three questionnaires, a pretest and a posttest, collected student work examples, interviews of students from the Intervention course, and fieldnotes with in an observation journal kept during the study. Each individual analysis tool will be discussed in more detail below pertaining to the research questions.

Student work. To determine how students engaged with problem posing, student work was collected from the Intervention course throughout the study. Problems assigned were categorized as structured, semi-structured, context free, and numerical free. Student work was either assigned in class or as a homework assignments. Like in the pilot, the student work represents the varying levels of posing within each unit/topic area, the types of problems students provided, and the frequency of problems from each section. Student work was collected accordingly on assignment due dates. The student work was summarized in a matrix to get an overall sense of the data and level of engagement

(Miles, Huberman, & Saldhana, 2014). Student interest from questionnaire one and three were included in the matrix to cross reference written student interests. The same color coding was used to observe the overall trend of the problems students posed as in the pilot. (See Table 4). I paid special attention to the interests that they listed and the context of the problems they were posing. Types of problems and trends were analyzed based on student examples, work, and test posed problems. Posed problems were analyzed and cross referenced with student class discussions recorded in the observation journal and student interviews (if applicable) for overlap of themes or trends of types of problems posed, context engagement, and underlying mathematical thinking.

Interviews. Students from the Intervention course were interviewed to investigate why the posed specific problems. The objective was to discuss the student engagement with problem posing and only students from the Intervention course were given the treatment of problem posing. Interview questions were built from the attitude and belief questions from questionnaire 1, 2, and 3 as baseline questions and were continued by questions created from the student work and class observations recorded in the observation journal. Interviews were audio recorded and students were allowed to discuss openly about their experiences during this study and how posing their own problems and personalized approach to problem solving affected their engagement. Upon the end of the interviews, using qualitative analysis, student statements were coded, categorized, and placed in themes. Interviews were organized based on codes, categories, and themes and were quantified and tallied. Codes, categories, and themes from each interview was compared to one another to observe trends that emerged. Trends were cross referenced to questionnaires 1, 2, 3 and the pre and posttests. Interviews served to answer how students engage with problem posing, what types of problems do the pose, and how does problem posing affect their beliefs and attitudes.

Questionnaires. To observe what impact problem posing has on students' beliefs and attitudes, students in both the Control and Intervention courses were given all 3 questionnaires. Questionnaire 1 served as a baseline to the attitudes and beliefs of the students, their extracurricular and major/professional interest. Attitudes and beliefs portions of the questionnaire were collected using a Likert scale and open-ended questions. The attitudes portion of the questionnaire was developed from Aiken (1970,1972). The beliefs portion of the questionnaire was developed by Yackel (1984) and field tested and referenced by Quillen (2004) and (Cifarelli, Goodson-Espy, & Chae, 2010). Both attitudes and beliefs sections on the questionnaires were designed in two parts on a 5-point Likert scale. Questions for attitudes and beliefs are scored and labeled as follows: (1.0) Strongly Disagree, (2.0) Disagree, (3.0) Undecided, (4.0) Agree, and (5.0) Strongly Agree. Interest portions on questionnaire 1 were developed from collaboration of the researcher methodologist. Interest data was used to create problem examples for instruction and assessments. Questionnaire 2 served as a measure of attitudes and beliefs prior to the start of the last unit of study. It contained the same attitudes and beliefs questions found in questionnaire 1. Questionnaire 3 served as a measure and comparison at the end of the unit of study. It was the same as questionnaire 1 with additional request of demographic information. This information included, age, race, and gender. Questionnaires 1, 2, and 3 were compared within and against each course. Upon completion of the study, quantitative and qualitative analysis was performed with the questionnaires. Questionnaires were compared within each course and to the other course.

Quantitative analysis of questionnaires. Statistical analysis on the Likert scores was be performed on questionnaires 1, 2, and 3 within both the Control and Intervention courses and against one another. Only students that completed all three of the questionnaires were used in statistical comparison calculations. Beliefs questions (Q1) and Attitudes questions (Q3) were compared separately. The mean, standard deviation, and standard error of Likert scores were performed for each question within each questionnaire. Means, standard deviations, and standard errors of questions were compared to each questionnaire within its course and compared across both the Control and Intervention courses. Change was calculated within each course and against both courses. Graphical analysis with standard error of the mean was created and analyzed for each question compared between the Control and Intervention courses.

Likert scores were also be scaled and scored according to positive questions scoring high and negative questions scoring low. Students were given a score from one to five for each statement, where one was awarded for strongly disagreeing with a positive statement or strongly agreeing with a negative statement and five was awarded for strongly agreeing with a positive statement or strongly disagreeing with a negative statement (Grundmeier, 2002). Students' scores on this measure could range from 40 (one for each of the 20 belief statements and one for all the 20 attitudes statements) to 200 (five for each of the 20 belief statements and five for each of the 20 attitude statements). 120 would represent a neutral score (three for each of the 20 belief and 3 for each of the 20 attitudes statements). The mean, standard deviation, and standard error was performed for scaled question within each questionnaire. Means, standard deviations, and standard errors of all questions were compared to each questionnaire within its course and compared across both the Control and Intervention courses as done in unscaled Likert scores. Change was observed within each course and against both the Control and Intervention courses. Graphical analysis with standard error of the mean was created and analyzed for each of all scaled responses compared between the Control and Intervention courses. Outcomes that are statistically influential were compared to interviews (if applicable), student work, and qualitative responses on the protest test and questionnaires 1, 2, and 3.

Qualitative analysis of questionnaires. Qualitative analysis was performed over questionnaires 1, 2, and 3 for both the Control and Intervention courses. Student open ended responses on their student beliefs (Question 2) and student attitudes (Question 4) were compared among each response from questionnaire 1, 2, and 3. Only students that completed each survey within each course were observed. Student responses were gauged if beliefs and/or attitudes changed throughout the semester.

Pre and posttest

Definition of Proficiency. The expectation of students entering developmental mathematics is that they are prepared to perform at least equally to their peers who do not enter developmental mathematics. This level of success is measured by how students due who take developmental compared to those who do not. Based on this assertion, previously enrolled developmental students were found to enroll into one of two courses beyond this developmental course. These courses are Math for non-STEM majors and College Algebra. These courses will be reference by their course IDs as Mat 1010 and

Mat 1020 respectively. Based on student enrollment records from the previous 10 terms, it was found that students to be successful in either Mat 1010 or Mat 1020, students must earn approximately a B or 83%-87% average. For students who earn a C or 75% average, the level of failure increases. With this unit representing the word problems and cumulative of previously taught concepts, and the posttest representing the culmination of this unit, it serves as a cumulative representation of the course. It is with this understanding that comparison between student posttest score and previous terms will be analyzed to address proficiency.

To observe the impact problem posing has on mathematical proficiency, students from both the Control and Intervention courses were given a pre and posttest. The pretest was given prior to the start of the study and the posttest was given at the conclusion of the study. The pretest served as a baseline for both courses. Questions from this test was populated with traditional questions retrieved from the text of the course. The pretest served as a baseline to the posttest and allow for comparison in proficiency. The pretest consisted of nine algebraic word problems and the posttest consisted of seven similar algebraic word problems and one open ended question for the Control course and two open ended questions for the Intervention course. The first open ended question for the Intervention course requested the intervention course to pose their own problem. This is highlighted in the student work section. The other question, like the Control course, asked for the student opinion on how they were instructed within the study. Both tests were built form course material found within the developmental curriculum traditional taught within both courses.

The Posttest served as the measure and comparison of the implementation of the new methods in the Intervention course and the Control course. The posttest for both courses was populated with personalized and non-personalized problems. The personalized problems were created based on the interests extracted from the questionnaire 1, questionnaire 3, or classroom trends observed within the field notes recorded in the observation journal. Traditional problems represented half of the posttest and student personalized interest problems represented the other half. The posttest questions consisted of themes covered in the study from both the Control and Intervention courses. Two problems were not included due to the lack of time covering additional examples. All questions on the posttest represent material from the pretest or students in both courses were given ways of solving certain word problem themes that were not covered. Students from both courses were graded based on criteria outlined in Table 7.

Table 7

Pre and Posttest Scoring Criteria

Score	Criteria for Score	Mark	Value of Score
Correct	Student completed problem to its entirety with a correction solution	C	4
Partial	Student completed problem correct work but did not give solution	P	3
Incomplete	Student showed some work but was not close to solving problem	I	2
Wrong	Student gave incorrect answer without work	W	1
Blank	Problem was left blank and not attempted.	B	0

Upon grading each student test, mean, standard deviation and standard error was calculated on each course's outcomes on both pre and posttests. Student growth was also be calculated utilizing possible points earned to show percentage growth. Calculation of this percentage growth is referenced in Figure 13.

$$\frac{\text{Student Difference Score (Post Test- Pre Test)}}{\text{100-Student Differnce Score (Post Test- Pre Test)}}$$

Figure 13: *Percentage Growth Calculation*

Percent growth was compared between the Control and Intervention courses to observe any statistical difference. The opened questions were not scored. Students were scored on both mark and value of the word problem questions.

Additional comparisons of growth will be observed within each course. Students were divided based on their pretest scores. Students were grouped within groups of either high, medium, or low. High represented the top 33%, medium represented the middle 33%, and low represented the lower 33%. Both the Control and Intervention courses were divided based on thirds as opposed to quartiles due to the proportionality of the number in each group. Thirds were closer in sizes than quartiles. From these groupings, students within each group will be compared within each course and against the other courses similar group i.e. (highest to highest, lowest to lowest).

Post scores will also be compared to previous courses scores to address what is proficient within developmental and the expectation for the course leading into its concurrent courses. T test analysis was run to compare significance between courses as a whole and within courses to compare between the highest and lowest groups.

Triangulation of data analysis instruments. Upon completion of each instrument analysis, outcomes were compared to observe any common themes, responses, or changes in student outlook. The focus of student understanding of concepts, engagement with problem posing, and student affect was based on their pre and posttest outcomes, questionnaire responses, problems posed, observation journal, and interviews (if applicable).

CHAPTER 4: RESULTS

The study was conducted at a public university in the southeastern United States. This university was selected for convenience. I was the instructor of record for the developmental mathematics course and have taught multiple sections of this course regularly for three years. Additionally, I utilized the outcomes, reflections, and adjustments from the pilot study conducted prior to the research study. Two of my developmental mathematics sections were selected for this study and I chose one of them randomly to implement the intervention (Course A - Control; Course B - Intervention) Forty-four students enrolled in the Control course and 43 in the Intervention course. Of the students enrolled in each course, 38 from the Control course and 35 from the Intervention course elected to participate in the study. Those who elected to participate will be referred as participants. The demographics of the participants in each class are outlined in Table 8. Values for male, female, minority, traditional, and nontraditional are counts, where mean age are averages.

Table 8

Student Demographic Information

			Gender			Enrollment Classification	
Courses	Response Rate	Average Age	Male	Female	Minority	Traditional	Non-Traditional
Control	32/38	19.56	19	13	3	24	8
Intervention	27/35	19.37	10	17	5	21	6

The intervention research study was conducted during a 15-week semester session in the Intervention course. Course semester schedules for both the Control and Intervention courses are highlighted in Figure 14 and 15 respectively. A side by side comparison is highlighted in Figure 16. The first eleven weeks of each section focused on algebra foundations and computations and the last five weeks focused on regular instruction of word problems (Control) and word problems with problem posing (Intervention). Figure 12 highlights the data collection within the research study period only.

Recall that the research questions guiding this study are:

1. How do developmental mathematics student engage with problem posing?
2. More specifically, what problems do developmental mathematics students design based on their personal experiences?
3. Further, what impact does problem posing have on the mathematical proficiency, and their beliefs and attitudes about mathematics?

The following sections will discuss each research question in order. Note that the numbers referred to from now on will be the number of participants who agreed to participate in the study and not all the students in the course.

Question One: How do developmental mathematics students engage with problem posing?

The participants of the course engaged in problem posing for five weeks at the end of a semester term. Within this course, 35 participants participated through engaging with problem posing within word problems. These participants were assigned four levels of problem posing - structured (1), semi-structured (15), context free (27), and numerical free (10) in the last five weeks of the course. Some of the problems were assigned in class and some for homework. The participants were graded for participation. However, all the study participants did not return the assigned problems. Table 9 represents the problems that were assigned in each category and the problems that were completed by the participants and returned to the instructor. In some cases, the participants completed more problems than they were assigned. For example, when asked to pose a problem related to percentage markup and markdown, a student designed two problems that built on the same given scenario. Overall, there were 25 instances where the participants posed more problems than assigned.

Out of the four categories, the highest number of posed problems returned was context free problem posing (399), followed by semi-structured (270), numerical free (192), and structured (14). Assuming that the returned problems reflect the engagement of the participants, there were some variations in the problems returned for each problem assigned; as seen in the last column of Table 9. There were 18 returned per semi-structured problem which could reflect more student engagement in this category. On the other hand, other returns of other levels of posing could point to some challenges the participants may have had with these approaches to problem posing. A detailed description of the participants' problem posing is discussed in the next sections.

Engagement in structured problem posing. In the structured problem posing, the participants were given a problem and asked to design a similar problem which involved them and another individual. The goal was to elicit the participants' interests and engage them in structured problem. The participants were assigned the following structured problem: *The sum of $1600 is to be divided between two people in the ratio of 7 to 2. How much does each person get? Design a similar problem where you and another individual are actors in the problem.*

Fourteen out of the 35 participants returned their work. All the 14 participants designed a problem that drew on their interests to personalize the problem. Most of the participants designed problems that related closely to the original problem. For example, S102 designed the following problem in Figure 17.1.

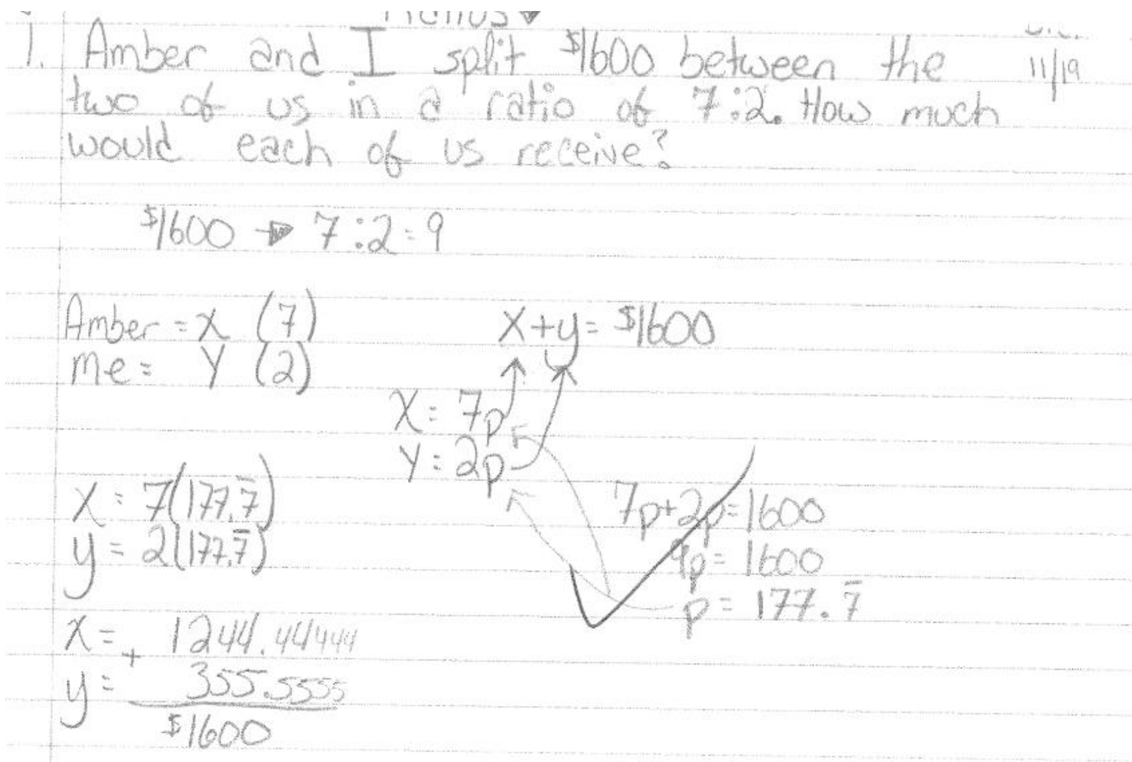
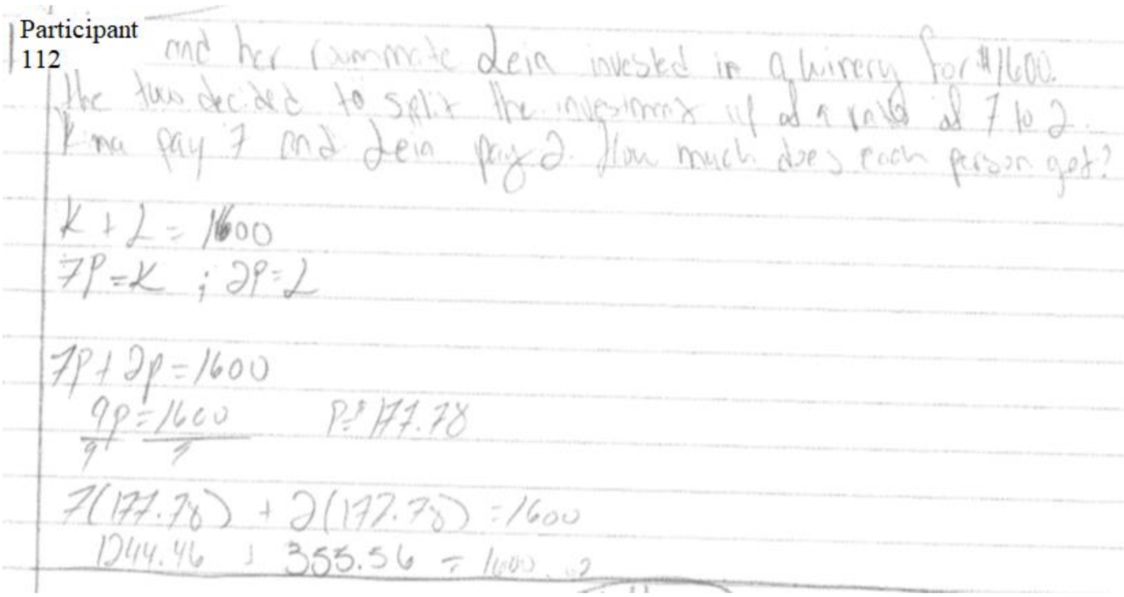


Figure 17.1*: Structured Example 1*

Given that this was the first exposure of the participants to problem posing, it was understandable that participants were hesitant with a different approach than they had experienced in previous mathematics classes. However, some participants went beyond and provided more details related to the context of the problem. For example, Figure 17.2 represents Participant 112's (Note that the participants will be referred to as S###, i.e. Participant 112 as S112) response (Figure 17.2).


Participant 112

and her roommate Dein invested in a winery for $1600. The two decided to split the investment up at a ratio of 7 to 2. K... pay 7 and Dein pay 2. How much does each person get?

K + D = 1600
7P = K ; 2P = D

7P + 2P = 1600
9P/9 = 1600/9   P = 177.78

7(177.78) + 2(177.78) = 1600
1244.46 + 355.56 = 1600

Figure 17.2: *Structure Example 2*

S112 designed a problem that built on the familiar context of a winery, popular in the region around the university. This personalization allowed the participant to make the problem she posed more meaningful to them. Like S112's problem, S129 (See Figure 17.3) also posed a more elaborate problem also moving beyond the suggested requirements.

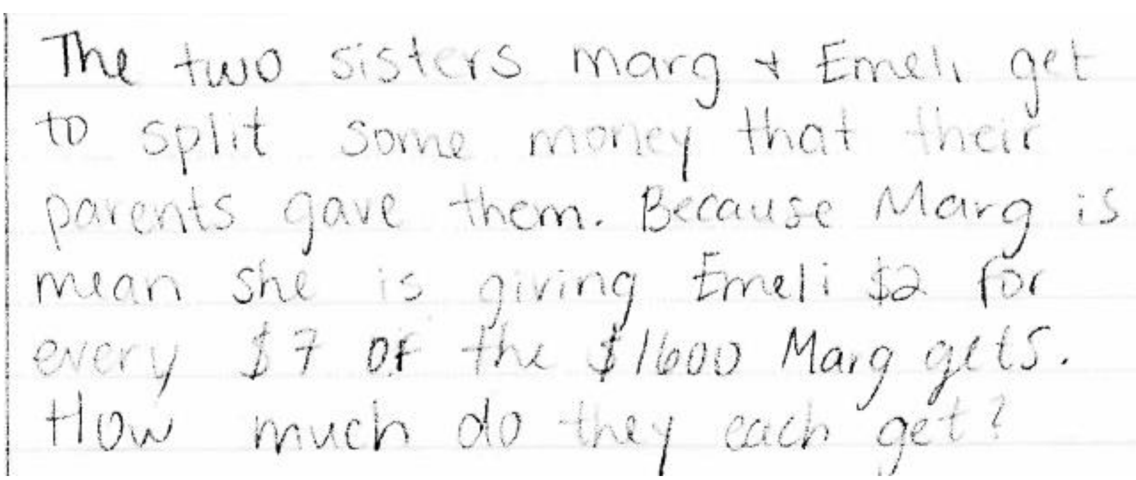

The two sisters marg + Emeli get to split some money that their parents gave them. Because Marg is mean she is giving Emeli $2 for every $7 of the $1600 Marg gets. How much do they each get?

Figure 17.3: *Structured Example 3*

S112 and S129 represent participants who went beyond the requirements that were provided and engaged by drawing on their personal experiences. The next section discusses semi-structured problem posing.

Engagement with semi-structured problem posing. The participants returned 270 of the 15 semi-structured problems that were assigned; a rate of 7.7 problems per student. This represented 51% of the problems assigned. Among the 15 assigned problems, the mark up/down problem yielded the highest number of participant responses with 96. Overall, participants returned approximately 2.7 semi-structured problems from the markup/mark down unit. For example, a typical student response was like that provided by S102 (see Figure 17.4). The assigned task was: *Create problems from the numerical statements below using money within the markup/mark down context. b) x + .35(x) = 22.*

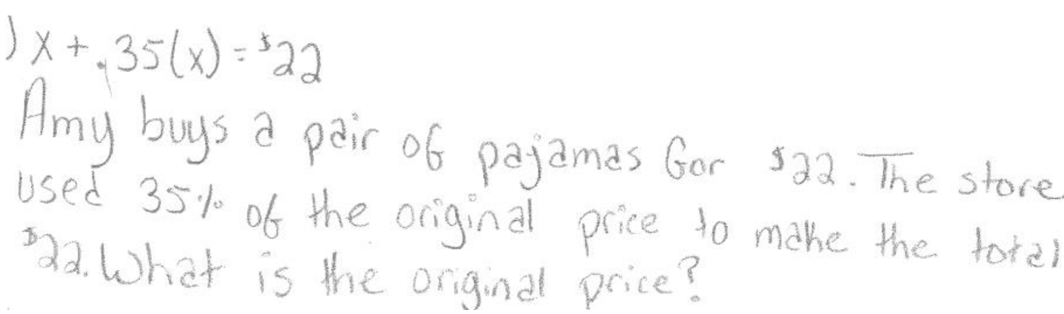


Figure 17.4: *Semi-Structured Example 1*

As we can see from S102's posed semi-structured problem, she posed a problem based on the given numerical statement and the given context of percentage mark up and mark down. She incorporated a friend in the problem as well as an item that is being marked up by 35%. When S102 was asked why she engaged with these problems, S102 stated she enjoyed how we as a class were discussing topics that related to his personal experiences, like money, and she further stated, “I like that it's very structured that like there's like a formula, like the original price, the discounted price, you know, like it just like that there's a formula.” This was a common theme among the participants, where it was mentioned she liked having the formulas (numerical statements) and the context of the problem. The context of the problems also had an impact on the rate of return. For example, the lowest return in the semi-structured problems was from the ratio unit. On average, participants returned one problem. Figure 17.5 shows S129’s semi-structured ratio problem based on the instructions: *Pose and write problems based on the following ratios that relate to either dividing a sum of money or a population: 5 to 2.*

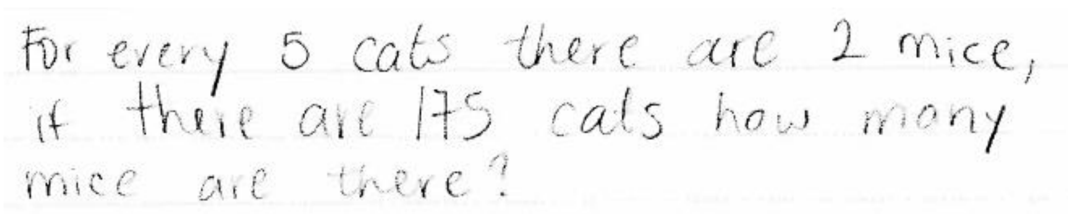


Figure 17.5: *Semi-Structure Example 2*

All the other participants posed problems that were like the example provided by S129. S129 went beyond the money and population context that was mentioned in the problem statement and developed a different scenario as seen in Figure 17.6. (*Pose and write problems based on the following ratios that relate to either dividing a sum of money or a population: 5/6.*).

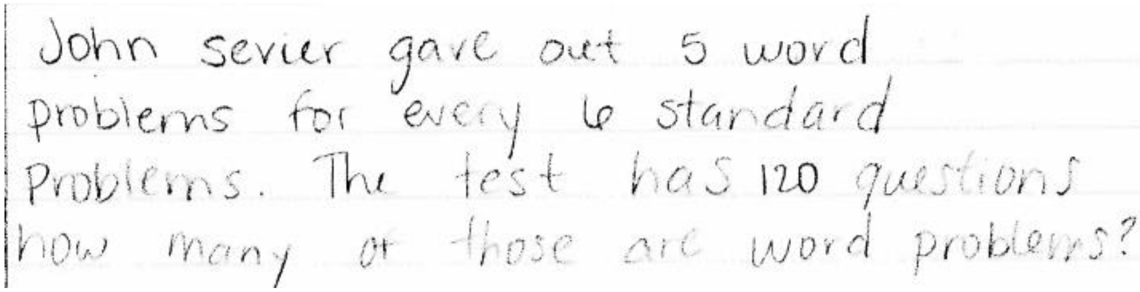


Figure 17.6: *Semi-Structure Example 3*

Like S112's structured problem, this problem is another representation of the participants moving beyond the given parameters and develop another context that was meaningful to them. This participant was more creative in their subject than merely using the money and population and incorporated a new scenario that resembles context free posing more than semi-structured posing. Note that some challenges with the low return rate for the ratio problems could be associated with the challenges noted in the research of school participants within the context of ratios and proportions.

Engagement with context free problem posing. The context free problem posing category generated the most return per problem with 12.6. Overall, 442 of the 27 assigned problems were returned; representing 47% return. Note that in context free problem posing the participants were given a numerical statement (e.g. $2x - 4 = 16; 11x + 13 = 9x + 9$) and asked to design a problem that would fit the statement. Of the 27 assigned problems, most returned occurred within the first unit of numerical statements. See Figure 9 for the wording table. On average, participant return for this type of context free problem posing was 4.7 problems per participant. The participants did not tend to draw on personal contexts for these tasks. Additionally, this was also the participants first posing assignment. For example, participants were asked to: P*ose written statements based on given numerical statements*. $2x - 4 = 16; -x + 4 = -24$. Note that the 'free' in the problem-posing context meant that the participants were not given a context, like the semi-structured category; instead the participants were free to choose a context that was personally meaningful. Since the participants were not provided with a context, most of them chose to focus on numbers, rather than tie in a context. S132 posed the following problems for the given numerical statements.

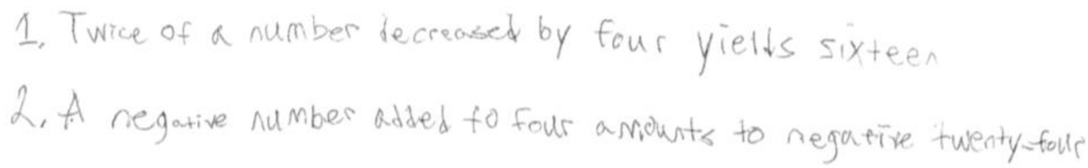


Figure 17.7: *Context Free Example 1*

Since the participants were not constrained to a context, many were more comfortable working with the abstract statements. These statements also resembled the problems he had engaged with in prior mathematics classes. An extension of numerical statements, participants were tasked to: *pose consecutive integer problems*. Most of these were posed in similar fashion as the numerical statements. S111 posed an example similar to most of the other participants. Participants were tasked to: *pose a consecutive integer problem similar to previous examples*. Figure 17.8 represents S111's baseline consecutive integer problem.

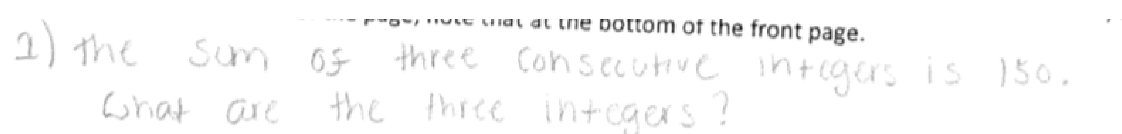


Figure 17.8: *Context Free Example 2*

S111 also posed two separate problems that involved consecutive integers but utilized personal interest (See Figure 17.9) that went beyond giving basic statements.

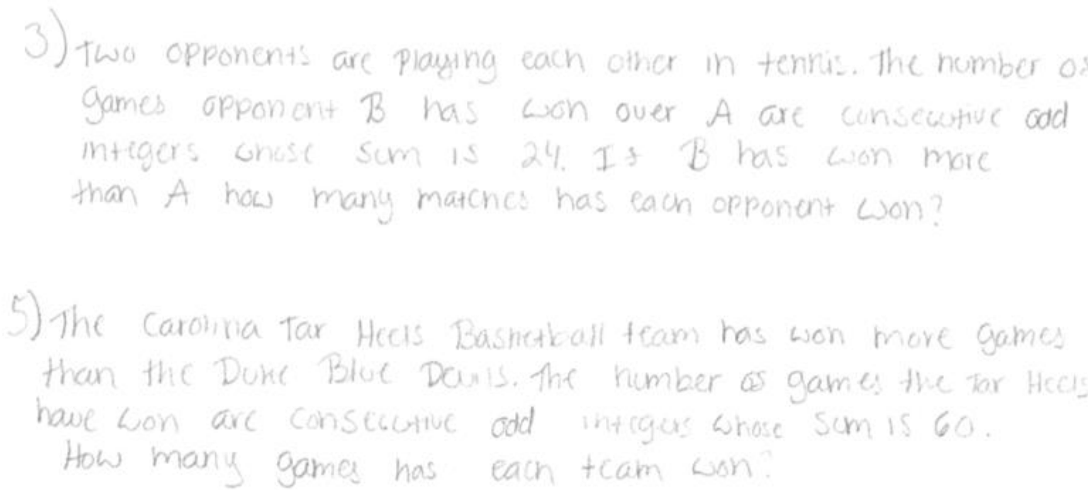


Figure 17.9: *Context Free Example 3*

It is notable that S111 posed these problems with more contextual information compared to the other participants.

When the numerical statements were excluded, the total rate of return went to 28% of problems returned and participants returned on average 7.51 problems per participant. Other units were approximately 2 problems per participant. These units were mixtures (system of equations) at 2.08 problems posed per participant, mark-up/mark down and other linear equations at 2.4 problems posed per participant, and consecutive integers which was an extension of numerical statements at 2.42 problems posed per participant. The lowest return occurred with ratios at .75 problems posed per participant. Once again reflecting a pattern of response rate seen in the earlier category with proportional reasoning problems. Though most of the participants posed standard ratio problems, there were two exceptions where the participants drew on their personal experiences. S116 posed one of the more exceptional ratio problems with Figure 17.10. Participants were asked to (*Create as many word problems as you can based on the* *following proportions: (9/7).* In Figure 17.10, S116 found the ratio between to waiters' tips at the end of a night.)

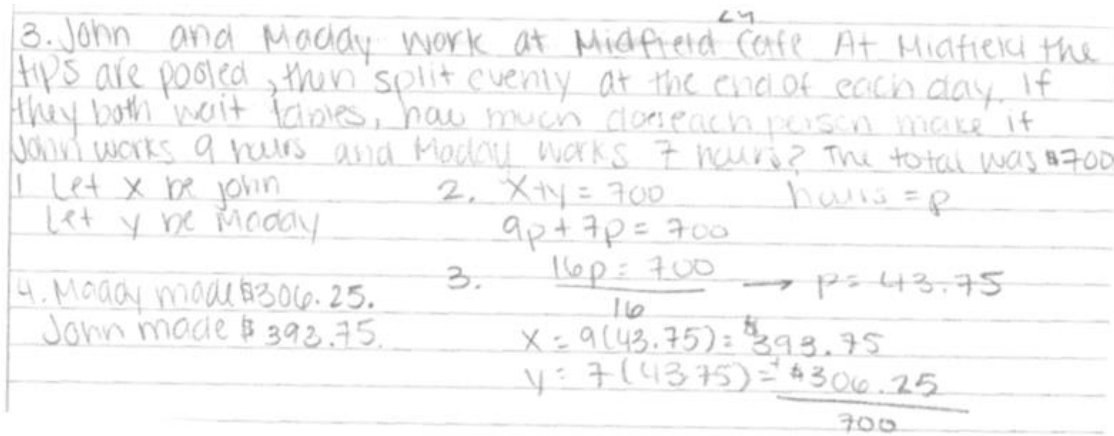

3. John and Maddy work at Midfield Cafe At Midfield the tips are pooled, then split evenly at the end of each day. If they both wait tables, how much does each person make if John works 9 hours and Maddy works 7 hours? The total was $700
1 Let x be john
Let y be Maddy
2. x+y = 700 hours = p
9p + 7p = 700
3. 16p = 700 / 16 → p = 43.75
x = 9(43.75) = $393.75
y = 7(43.75) = $306.25
700
4. Maddy made $306.25.
John made $393.75.

Figure 17.10: *Context Free Example 4*

Here S116 was able to pose a problem dividing money based on hours worked. S116 utilized personal information and personal experience within the problem; a point highlighted by S116 in the interview. In addition to the use of personal interest and experience, the student also worked out the problem and showed the detailed solution. When asked, S116 discussed that she wanted to make sure the values worked out and the ratio was correct. This examples also showed how S116 utilized other procedures discussed throughout the course and recalling how to insure a valid solution.

Engagement with numerical free problem posing. The last level of posing was numerical free. Recall that the participants were given the context and asked to develop their own values, numerical statements based on the given context. The numerical free differed from the context free problem posing in the previous category in that the numerical statements were provided, and the participants were asked to develop a context. Out of the 10 problems that were assigned, 143 were returned representing 40%

of the assigned problems. Participants return rates were 4 problems per participant. Of the 10 problems assigned, the highest returned occurred within the numerical statements at 2.3 problems per participant returned. Like the context free posing, participants were asked to create numerical statements. These problems had less context and did not need additional context to pose these problems. All returned problems, but one, posed basic numerical statements similar to the example in context free posing. In Figure 17.11, S126 gives the numerical statement and posed problem about this statement. Even though the statement does not match the posed problem entirely, it does represent S126 engaging with posing and attempting to engage with their personal interests.

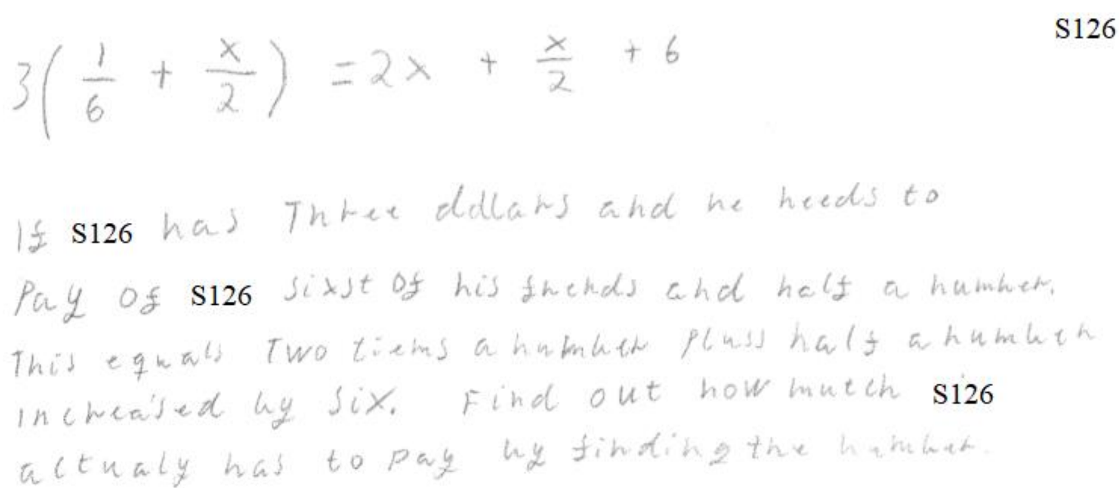
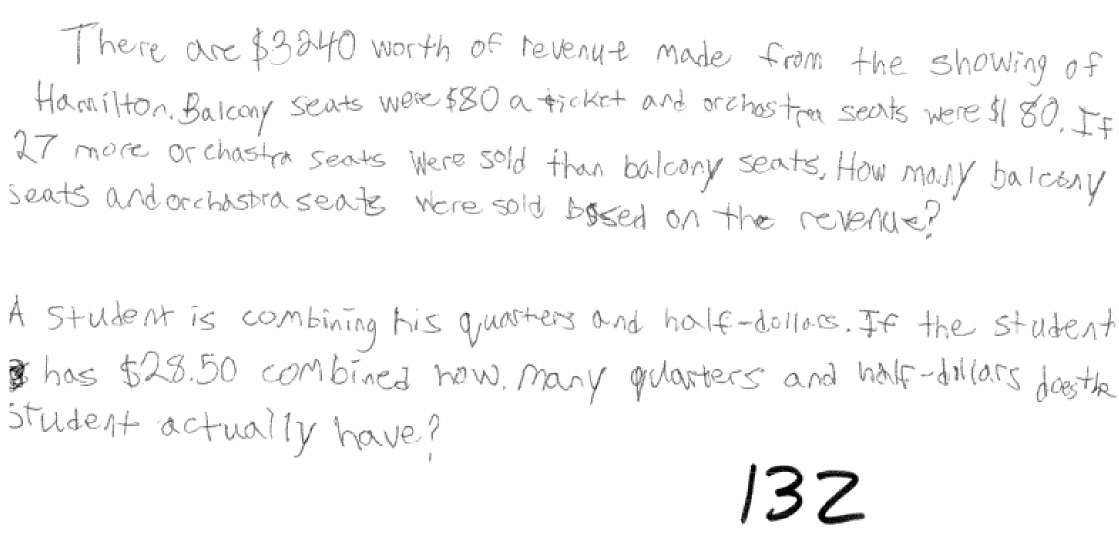


Figure 17.11: *Numerical Free Example 1*

The remaining two types of numerical free problems were from ratios and mixtures (systems of linear equations). Ratios had a return rate of .48 problems per participant and mixtures had a return rate of 1.23 problems per student. Though the numerical free category had a low return, the student problems were interesting, and the problems reflected a diverse range of personalization.

Within the category, the lowest return was for the mixture problems. In class the participants engaged with problems where that involved mixing candy or liquids (e.g., *A student is combining candy worth $6 per pound with candy worth $8 per pound. The student wants to obtain 144 pounds of candy worth $7.50 per pound. How much of each type of candy should the student use in the mixture?*). When asked to develop as many problems as they could using contexts that were of interest, the participants personalized the problems in interesting and diverse ways. For example, S132 came up with two problems based on her interest in the theatre and saving money (Figure 17.12).



There are $3240 worth of revenue made from the showing of Hamilton. Balcony seats were $80 a ticket and orchestra seats were $180. If 27 more orchastra seats were sold than balcony seats. How many balcony seats and orchastra seats were sold based on the revenue?

A student is combining his quarters and half-dollars. If the student has $28.50 combined how many quarters and half-dollars does the student actually have?

132

Figure 17.12: *Numerical Free Example 2*

Though the student developed interesting contexts, she did not check the validity of the answers which in this case yielded -6.23 balcony seats sold and 20.77 orchestra seats sold. In contrast another student, S116, provided complete solutions to ensure the validity of the problem (see Figure 17.13).

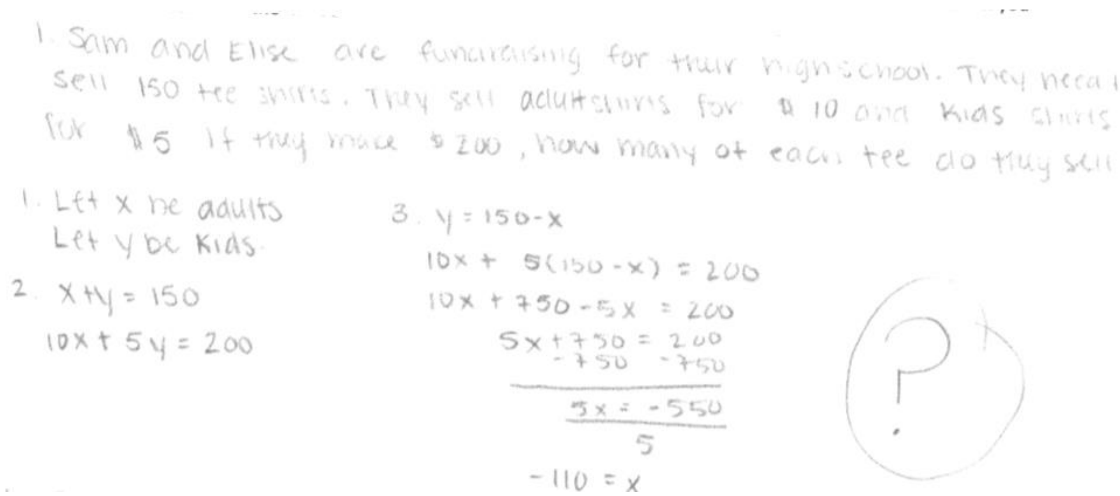


Figure 17.13: *Numerical Free Example 3*

In the process S116 noted that the numbers did not work and later tried to redo the numbers so that they worked (see Figure 17.14). Student S116 persisted with problem posing in context and in trying to resolve the numbers developed a new context with values that were more relatable.

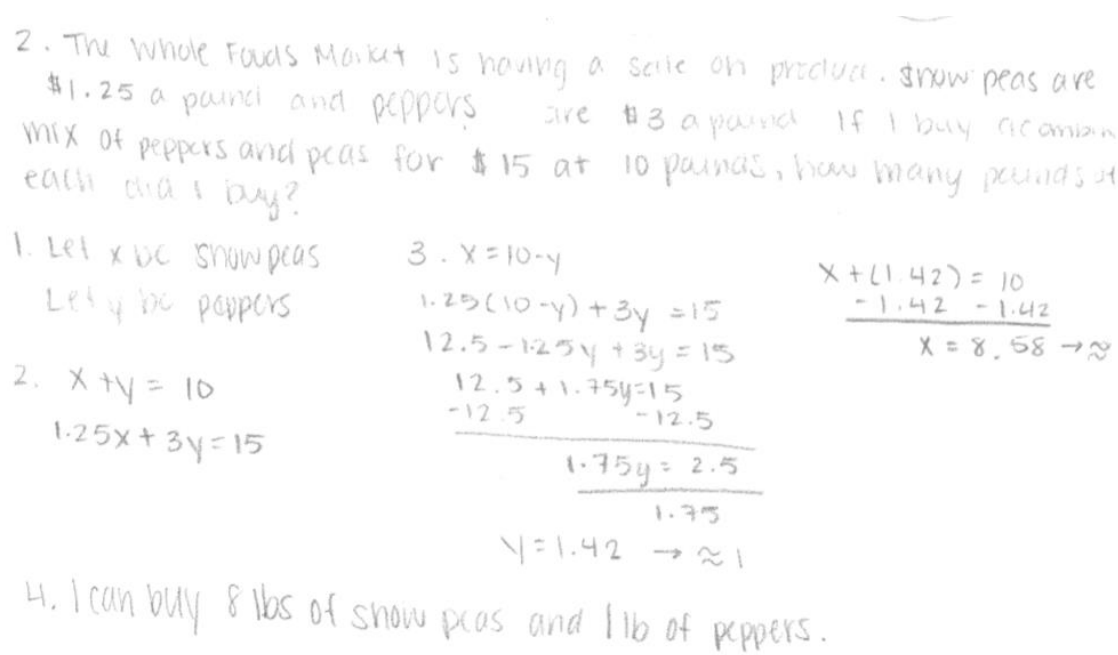


Figure 17.14: *Numerical Free Example 4*

In addition to working through the problem, S116 also examined the answers and tried to reason about the practicality. The participant stated that she had $15 and usually worked with weights that were whole numbers in real life. As such S116 determined that she could purchase 8 lbs. of snow peas and 1 lb. of peppers.

S132 and S116 engaged with the numerical free problems and showed that they had an underlying understanding that they were working with two unknowns and had to use simultaneous equations. S116 showed a high level of engagement by doing the extra work of solving and verifying the solutions.

Level of engagement through personalization. One of the overarching goals of this study was to examine how developmental mathematics participants would engage with problem posing that was tied to their existing developmental mathematics course work. In general, developmental mathematics participants engage with mathematics in the traditional lecture format with little freedom to draw on their own experiences. This section will examine how the participants of this study drew on their own experiences and interests to design problems. Given that there was a scaffolded approach in this study (e.g. structured to free problem posing), not all the activities allowed the participants the option to draw on their personal experiences. This section will focus on the problems that allowed for the participants to come up with their own context. Examining all the problems that were posed by the participants in the four levels, there were certain personal experiences that were used for the problem-posing. An analysis of the problems the participants designed was completed based on their personal interests and statements given in questionnaire one, questionnaire three, observation journal, and participant interviews. Due to the nature of the posed problems, each posed problem was categorized

(See Table 4 and 10) and analyzed. The analysis of the qualitative data yielded three categories - mimicked personalization, and original problems. Personalized (written), Personalized (non-written), and non-personalized were combined to represent the personalized category. The remaining categories of mimicked and original remained the same. The three categories and totals within are highlighted in Table 11. Further details of the labels are discussed within each section.

Mimicked problems. The lowest number of coded posed problems were the mimicked problems. These were problems that built on the context and/or the values from previous examples done in class. For example, if a participant used the same values from a class example within a numerical free posed problem, or the same subjects from a class example within a context free posed problem, it was categorized as mimicked. Given that the participants were engaging in problem posing for the first time, it is natural that they sought to 'copy' problems that were done before with the expectation that this was what the instructor wanted to see. Only 40 problems were coded to be mimicked or copied from previous problems. Most of these problems were posed in the semi-structured level (21). In Figure 17.15, shows examples of S101's posed mimicked semi-structured problem. Participants were asked to: *Pose and write problems based on the following ratios that relate to either dividing a sum of money or a population: 10 to 3*

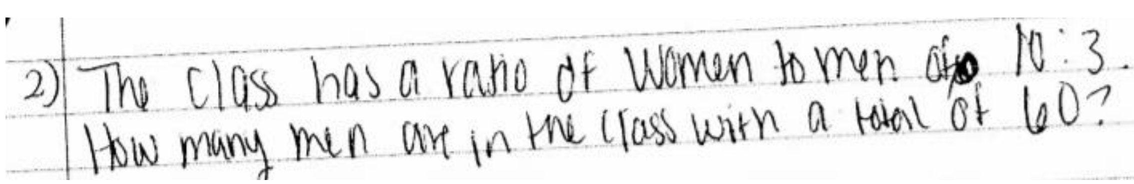


Figure 17.15: *Mimicked Example 1*

S101 used the set up and subject from the example with the new given numbers: *Your class has a ratio of men to women of 5 to 9. How many women are in the class with the total enrollment of 42?*

Of the remaining 19 posed mimicked problems, nine were posed within context free posing problems, seven in numerical free problems, and three in structured problems. A large collection occurred within the mixture section, a sub-section within the two equation two unknown's unit. Seven of the 19 were posed within the mixture section. Figure 17.16 shows the numerical free posing problem by S129. Participants were asked to: *Create as many mixture problems you can that are similar to the previous examples involving your personal interests.* This was similar to the example done earlier in the class: *How many milliliters of pure acid must be added to 150 milliliters of a 30 % solution of acid to obtain a 40% solution?*

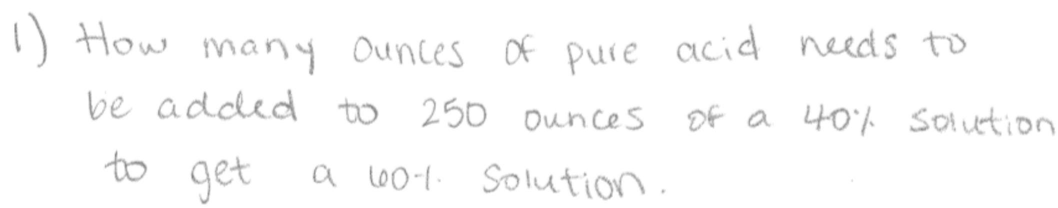
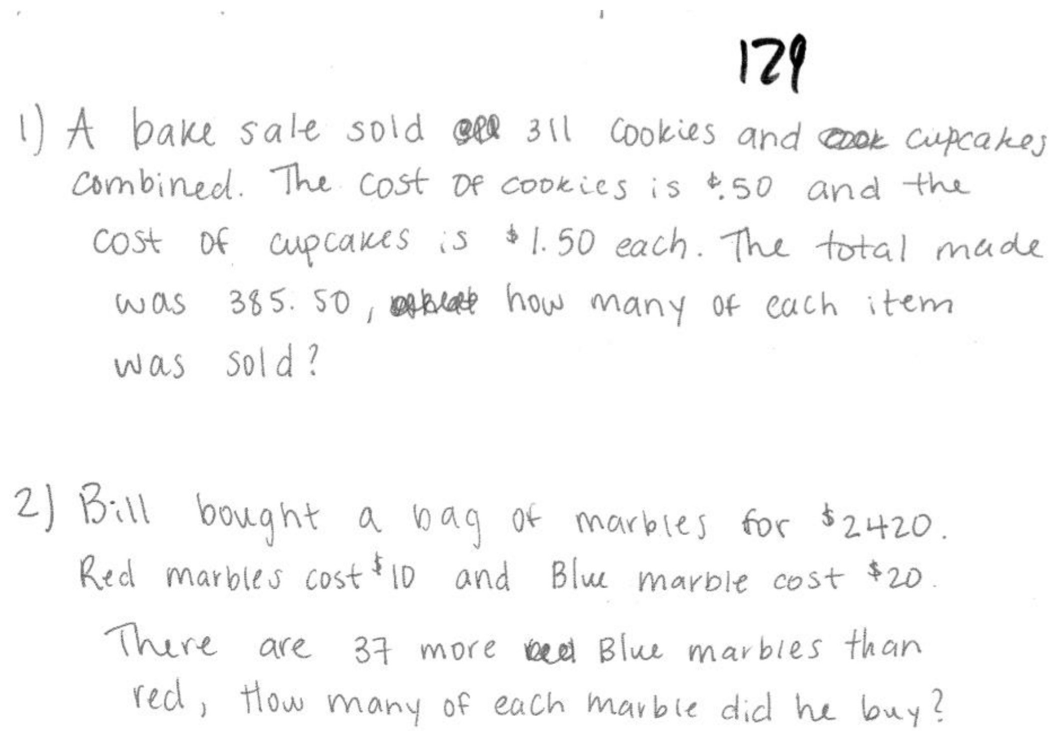


Figure 17.16: *Mimicked Example 2*

S129 changed the values of the percentages and units. Two other examples of mimicked problems also came from S129. The participants were asked to: *Create as many mixture problems you can that are similar to the previous problems.* S129 posed two problems from this assignment (See Figure 17.17).



129

1) A bake sale sold 311 Cookies and cupcakes combined. The cost of cookies is ¢.50 and the cost of cupcakes is $1.50 each. The total made was 385.50, how many of each item was sold?

2) Bill bought a bag of marbles for $2420. Red marbles cost $10 and Blue marble cost $20. There are 37 more Blue marbles than red, How many of each marble did he buy?

Figure 17.17: *Mimicked Example 3*

S129 used values for both problems from examples done in class. The problems were solved in class and had valid solutions. Other mimicked problems done by other participants were posed in a similar fashion. Participants mentioned mimicking the problems because they knew that the values worked out; an indication of their discomfort with mathematics and that they were at the early stages of problem posing. Similarly, S132 discussed this in the interview at the end of the study. S132 discussed how he needed the class examples to understand how to pose similar situations, which help relate it to previous personal experiences (see Figure 17.18).

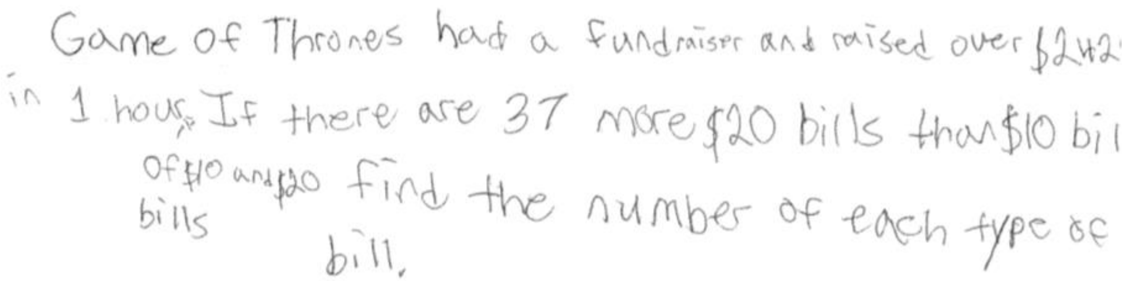


Figure 17.18: *Mimicked Example 4*

S132 noted that he mimicked problems and drew on his interests. S132 engaged with problem posing though mimicking values from a previous class example but utilized one of his favorite shows as the subject of the problem. S132 also noted that if there was no previous example to model his work, he would find it challenging to pose the problem. This point was also mentioned by S129 and others in class. Several participants discussed that they mimicked previously given problems numbers and solutions to build their own. Each of the participants that mimicked wanted reassurance that they were either doing it correctly or would have a problem with a valid solution. This mimicking was mostly on the set up and values but most of the participants included their own interests.

Original problems. Participants posed 373 original problems, nearly as many as the personalized problems. Original problems were based upon algebraic expressions and statements along with other introductory algebraic concepts. Most of the original problems were designed around numerical statements (e.g., *pose your own statements based on given numerical statements: 2x – 4 = 16*), consecutive integers (e.g., *Pose your own consecutive integer problems.*), and triangle problems (e.g., *Based on the previous triangle example, use the numerical statements below to write your own problems: Situation 2: Angle 1=50; Angle 2=60; Angle 3=70*). The consecutive integers and triangle topics were designed to be extensions of numerical statements. Numerical statement posed problems account for 230 of the 373 original posed problems. The remaining 143 represented the topics of consecutive integers within context free posing (82) and triangles within semi-structure (61). These problems represented the first introduction to problem posing for the participants. The high return indicates a high level of engagement with problem posing. For example, in Figure's 17.18 and 17.19 is an example of S139's context free and numerical free posing of numerical statements. Participants were asked to "*pose their own statements based on given numerical statements:2x – 4 = 16 and -x + 4 = -24."* Figure 13.19 represents the context free posed problem of S139.

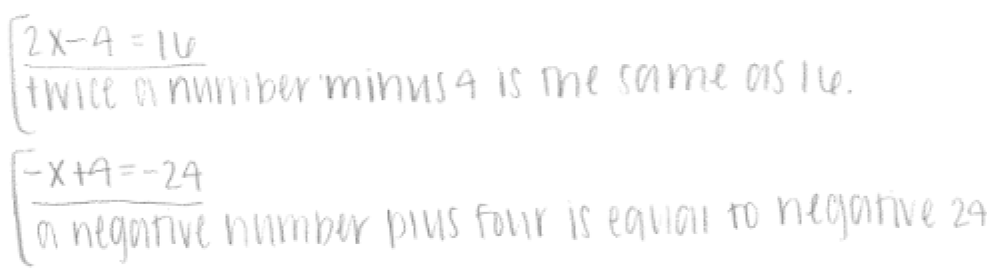


Figure 17.19: *Original Example 1*

Figure 17.20 is an example of S139's numerical free posing. Participants were asked to "*Pose three written single variable statements based in the following criteria: each must include all four basic operators and a equals, one has to include two fractions in it, one has to include a solution that is a non fraction, and you cannot use more than one of the previous statements on the previous slide."*

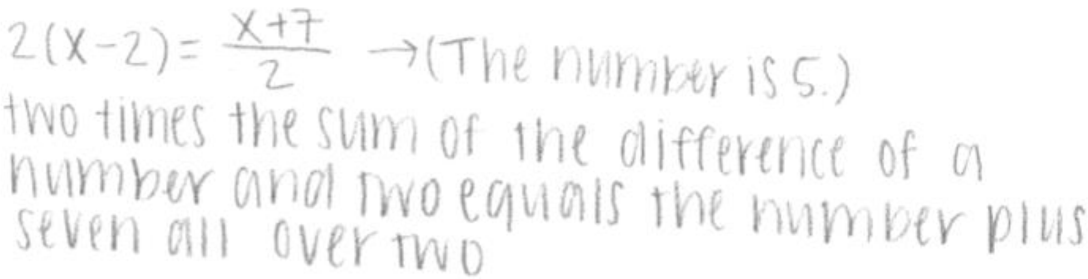


Figure 17.20: *Original Example 2*

Note that it would be typical for the participants to mimic problems related to other numerical statements that they may have encountered in previous classes, however participants engaged with different wording and phrases than previously given examples. So, while the two problems seem similar, they were categorized as original in the analysis. The intent of the task: "*Pose three written single variable statements based in the following criteria: each must include all four basic operators and a equals, one has to include two fractions in it, one has to include a solution that is a non-fraction, and you cannot use more than one of the previous statements on the previous slide,"* was to have participants to continue to engage and build on their previous numerical statement unit and incorporate multiple statements into a newly defined scenario, consecutive integers. Figure 17.21 represents a consecutive integer problem from S103. Participants were given the task: *Pose your own consecutive integer problems.*

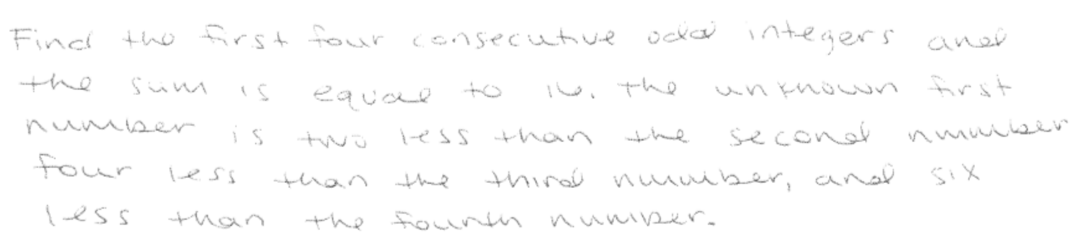


Figure 17.21: *Original Example 3*

Similar to numerical statements, S103 posed an original problem that was not based on other values or examples from the class. S103 used the understanding of posing numerical statements to engage in the extension of consecutive integers. S120 a posed a triangle problem (Figure 17.22) that was an extension of numerical statements but with less flexibility in the posing. Participants were given three sets of three angles and were asked to: *Pose your own triangle problem based on the given situations below.* Here S120 was given the angle measures (angle 1 = 50°, angle 2 = 60°, and angle 3=70°) and had to pose a problem using the given measures.

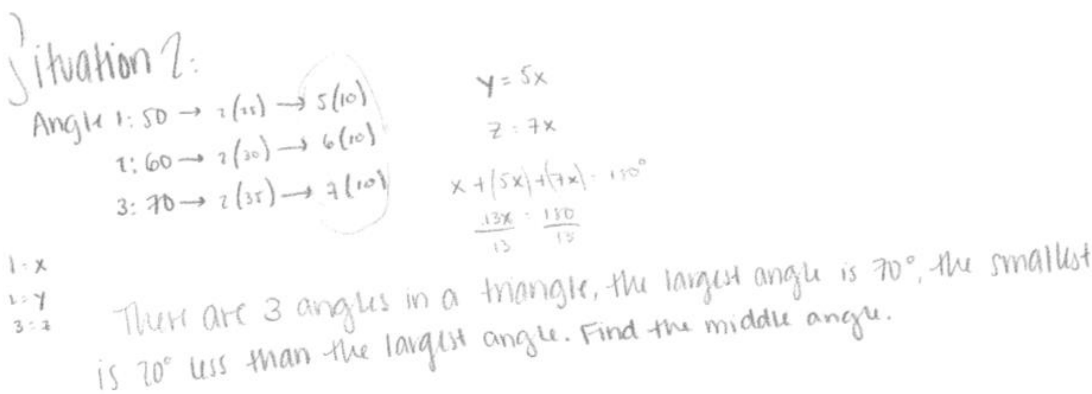


Figure 17.22: *Original Example 4*

S120 was able to pose a basic problem of finding the middle angle. This posed problem represents S120 developing a more in-depth problem based closer to the numerical statements presented prior to this unit. Even with minimal flexibility in the angle measures S120 set up elaborate equations to find the missing quantity that could be used to find the angle measures of all three. S120 concluded by posing a problem to ensure that it included the given values and that it had a valid solution. So even though there was no personalization in the original problems, participants engaged with problem posing by building on previously learned material.

Personalized problems. Personalized problems represented the largest coded set of problems. These were problems that drew on the participants' interests that were either stated in the questionnaires, discussed in class, or contexts/subjects in the posed problems that were not in the class examples. Many of the posed problems drew on varying interests such as family, previous experiences, personal interests, and other topics that students found interesting, useful, or personal. The level of engagement with personal interests depended upon the type of problems and constraints given. For example, in Figure 17.23, is an example from S119 of a context free posed personalized problem. Participants were asked to: *Pose two-word problems based on the following numerical statements. Use the previous as an example to create your own problems. Let the variable represent an unknown quantity. 0.50x + .15(70) = 35.5*

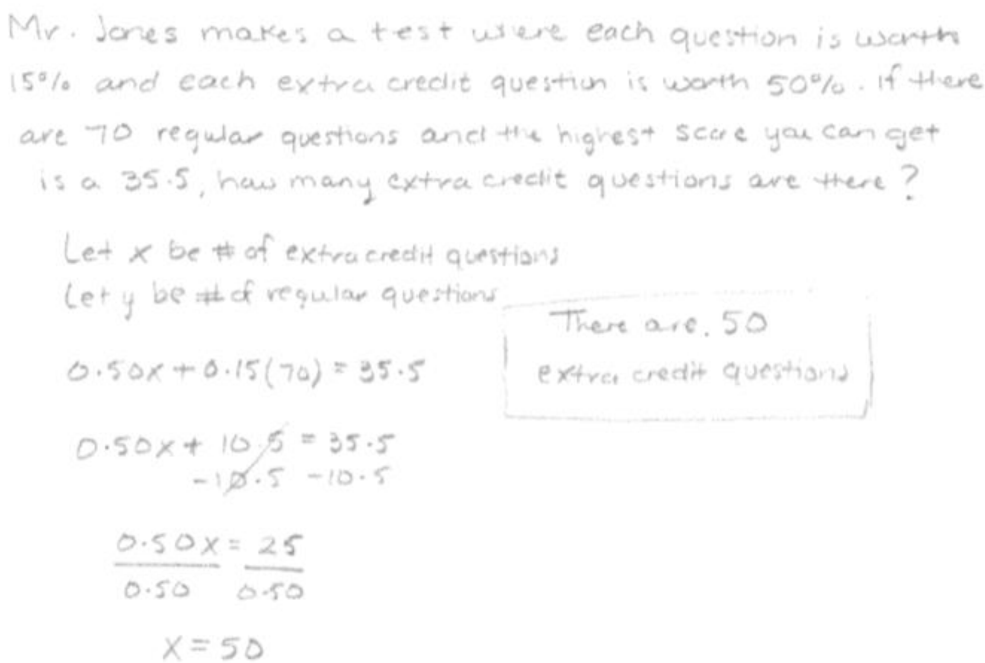


Figure 17.23: *Personalized Example 1*

S119 engaged with problem posing through using a context that was not written in the questionnaire or discussed in class. S119 presented a context that was unique and not like any of the class examples.

Similarly, S119 posed a systems of equations problem (see Figure 17.24) based on the task: *Using the statements below, create as many problems as possible using personal interests: System1: 8x + 6y = 1080 and x + y = 144.*

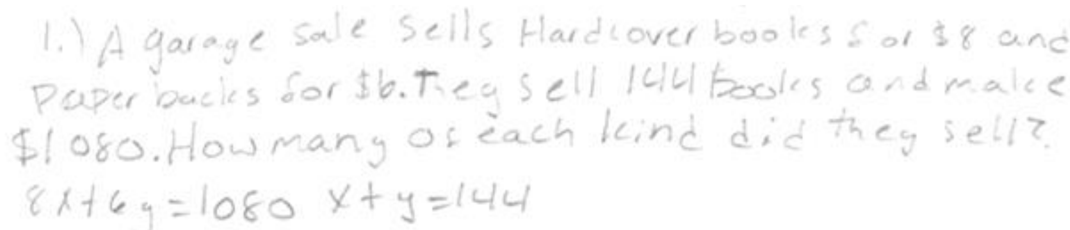


Figure 17.24: *Personalized Example 2*

In the questionnaire S119 stated: "*I enjoy reading for school and on my free time, I am always reading at least two novels at any given time…,".* Thus, demonstrating S119 drawing on his interest of reading for problem posing. In another example, S116 drew upon personal interests is a context free posed problem (Figure 17.25) (*create as many word problems as you can based on the following ratios: 8:2*).

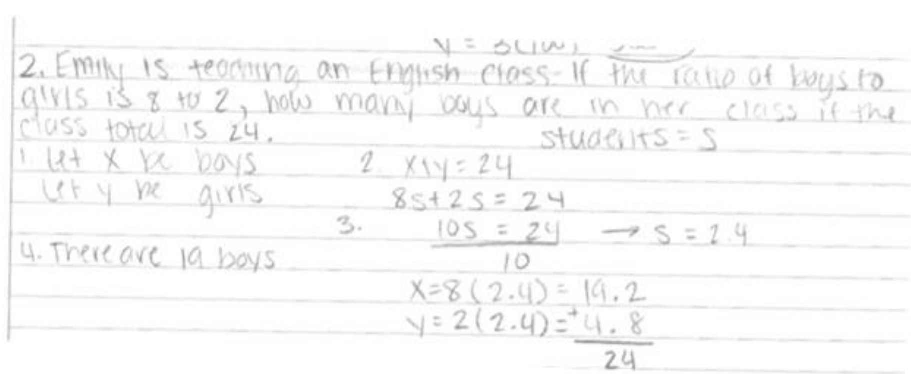


Figure 17.25: *Personalized Example 3*

In questionnaire 1, S116 stated:

> I did an independent study last year where I got to work with some of my former elementary school teachers. I went in every day at the end of my school day for 2-3 hours and helped the kids out any way she needed.

Due to the statement of interest involving working with kids and former elementary teachers, this problem was coded for personal interests and like S119's problem, represented the participants engaging with problem posing using written (as documented in questionnaire 1) personal interests.

The other form of participant engagement with problem posing with personal interests took for in discussed or non-written personal topics. For example, in Figure 17.26, represents one of S102's three posed problems based on the example involving a bridge with given values to use. Participants were asked to: *Pose a Bridge Problem. Thinking of the example from class, come up with your own bridge problems with the following equations: (x + 50) = y; y = (30 - x); x = 17 + y.* These problems were used to build from numerical statements and begin utilizing personal interests. Figure 17.26 represents one of these problems.

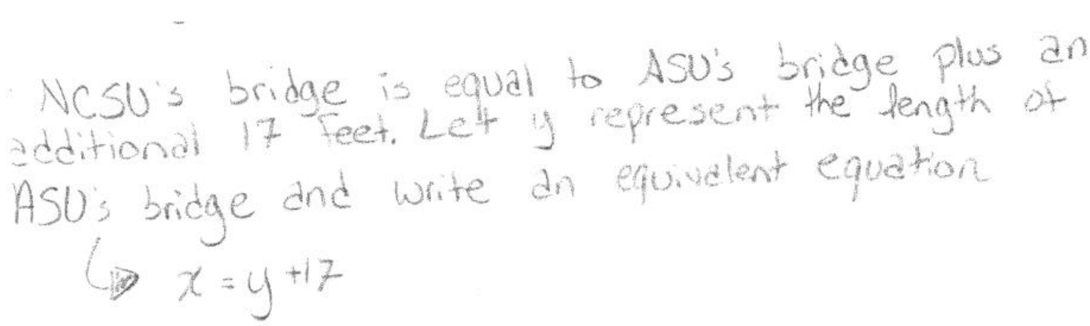
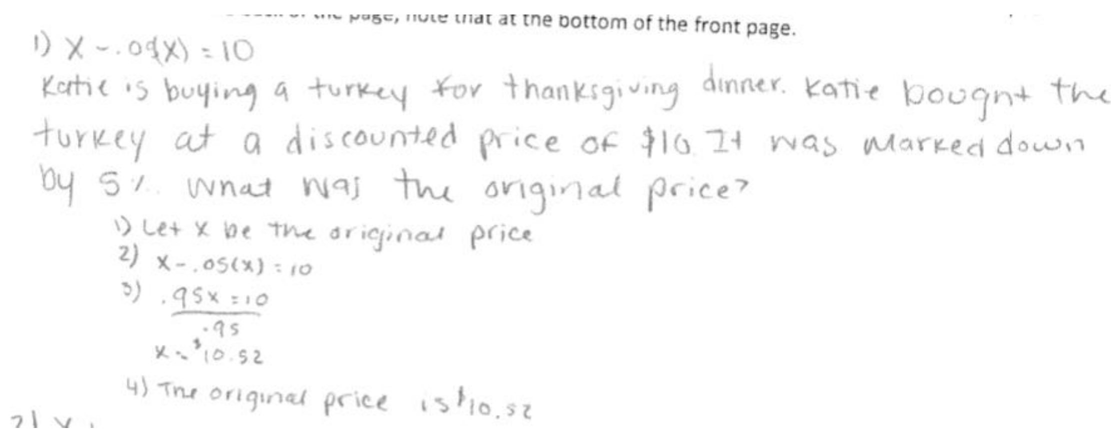


Figure 17.26: *Personalized Example 4*

S102 revealed that she had friends at NCSU and would have attended if she had not attended ASU. S102 felt like incorporating those two schools as the names of bridges. Additionally, S140 posed a problem involving a family member within the mark up mark down posed problems. Participants were given the task: *Pose Problems from the numerical statements below using money within the markup/mark down context.* Participants were given six numerical statements. Figure 17.27 represents S140's posed problem involving one of the numerical statements: $x - .05(x) = 10$.


page, note that at the bottom of the front page.

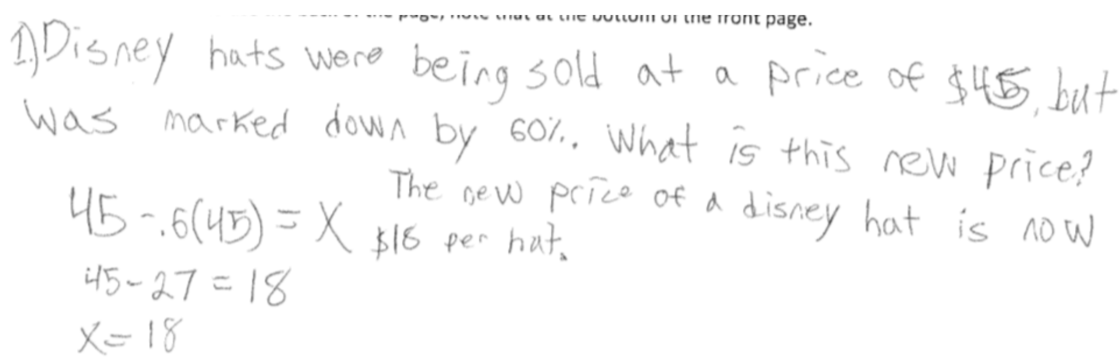
1) X - .05(X) = 10

Katie is buying a turkey for thanksgiving dinner. Katie bought the turkey at a discounted price of $10. It was marked down by 5%. What was the original price?

1) Let x be the original price
2) x - .05(x) = 10
3) .95x = 10 / .95
x ≈ $10.52
4) The original price is $10.52

Figure 17.27: *Personalized Example 5*

S140 posed this problem based the Thanksgiving holiday that took place during this unit. Additionally, S140 solved the equation and went further to note the original price of the turkey. One additional example was posed by S132. In Figure 17.28, S132 posed a question based on the task: *Create 3 statements based on the following criteria: 1) At least one must be a percent markup, 2) At least one must be a percent mark down(discount), 3) All have to have one variable, and 4) You cannot use the values used in the previous problems, even if your name is in it.*



1) Disney hats were being sold at a price of $45, but was marked down by 60%. What is this new price?

45 - .6(45) = X

45 - 27 = 18

X = 18

The new price of a disney hat is now $18 per hat.

Figure 17.28: *Personalized Example 6*

S132 drew on a personal experience of a trip he took to Disney World during the time of the study.

Student discussion about engagement with problem posing. Overall, participants preferred to pose problems that had similar contexts similar to those presented in class. As observed during the study, many participants mentioned that when they knew the context, or it was discussed in the class, and it was given as part of the problem, it was easier for them to focus on the mathematics and not worry on fitting the subject. Participants still focused on the computation and several participants mentioned that there was one less thing to worry about if they used the same context from the problem as found in semi-structured problems. S134 even noted that due to the openness of context free and numerical free was disengaging, and she needed more structure. For many of these participants, the level of engagement depended how much context was given. Two out of eight participants interviewed were challenged by context free problem posing.

Other participants discussed their level of engagement with posing numerical free problems. Participants stated that they wanted to anchor their problems using numbers that they knew would work within a context that was already given. S129 stated that

“There were only a few word problems I had issues with, the only problems I had was being able to set them up correctly. When given the numbers to use for the word problems, it was not hard at all.” Similarly, S138 stated it was harder to make a situation with his own numbers but liked the freedom to try. S116 preferred the values in the problem were given rather than coming up with them herself. She believed that coming up with her own numbers did not further her understanding of the concepts. S116 felt it took more time to write the problem and get a solution when they had to come up with the numbers. S140 alluded to this same feeling. S140 stated, “It is easy to come up with the word problem itself, but it is hard to find numbers that have valid solutions. I like creating word problems, but I don’t like trying to find numbers that work.” S120 and S138 also stated that it was preferred to have numbers given if they had to pose the problems. Participants also stated they knew the numbers worked, so felt more engaged and knew there would be a valid solution. S120 felt more engaged to pose the problems if this was the case. This was the main reason why S120 preferred structured and semi-structured posing. S132 noted he did need scaffolding and structure to build their own problems. This alludes to why less was done in numerical free and more with semi-structured and context free.

Engagement was also based on problem posing as an instructional approach. In the interviews the participants had mixed opinions about the problem posing approach the intervention. Some participants stated they liked the process, and other disliked the approach. The participants who disliked the approach stated that they preferred to engage with the traditional word problems. For example, Participants S120 and S134 preferred working through and solving word problems and not writing their own. They did not want to engage in the double load of designing and solving the problem. S120 discussed she needed more structure and routine and felt the lack of structure and openness reminded her of previous negative experiences she had in her earlier schooling. S134 would continue to discuss how it felt “backwards” and she preferred to solve the problems. S134 mentioned that she had never done problem posing before and really did not know how to do it or want to learn how to pose problems. This made her feel disengaged with problem posing and to an extent with the course itself. S108 and S123 noted on the posttest qualitative section they found it challenging and Participant 123 mentioned “I’d rather focus on how to solve them; the problems are hard enough without adding the extra work of making them as well.” Many participants discussed being disengaged during early stages of problems posing due to being asked to do something that they had never been asked to do. However, many became more “open” when they were given more freedom and became more engaged when they were not asked to complete many iterations of the same types of problems like traditional repetition.

Several participants discussed in class that it took some time to understand the process of posing and what to focus on, the context or the values. S132 noted he took many steps in working with a problem, however this helped him focus on one step in the problem-solving process and problem posing process at a time. S132 also noted that it was easier to engage with problem posing when mathematics concepts had already been covered prior working on a word problem. Several participants alluded to this point. S120 mentioned that she found useful that the course had addressed the concepts first, prior to problem posing. By covering the topics first, the participants could spend more time with designing the context of the problem. Participants S121 and S130 noted they found it easier than traditional methods and S122 stated it was their favorite section due to being a different approach to what they had experienced previously.

When asked about enjoyment within problem posing, several of the participants stated when they were engaged, found it was a fun experience, different than other math classes. Three out of the eight participants who interviewed stated that it was fun and engaging. S120 stated that "even though I did not like problem posing, it was fun to write problems." Similarly, S112 stated on their final test that:

> I found it difficult at times if I didn't completely understand something, but for the most part, it was a little fun to use a creative outlet in math. It's also fun to see your name used in word problems. I feel more confident with word problems now than I have ever before.

S132 and S138 both stated they felt problem posing was fun, useful, helpful and more engaging, if the problems were interesting to them. S132 discussed posing problems for markup/mark down problems based on his vacation and from problem from Figure 17.28. S132 stated that they became more engaged with these problems due to seeing the usefulness of them.

> I saw many of them (hats), especially the Mickey ears. So, I was like, I can write about that for sure. And it connected me back to vacation, making it more fun because I was like, oh, like I can connect it back to vacation and see how many hats. Like, you know, Disney could potentially make if they had that revenue.

Other participants also felt that once they found the problems useful and relatable, they were more engaged in learning problem posing.

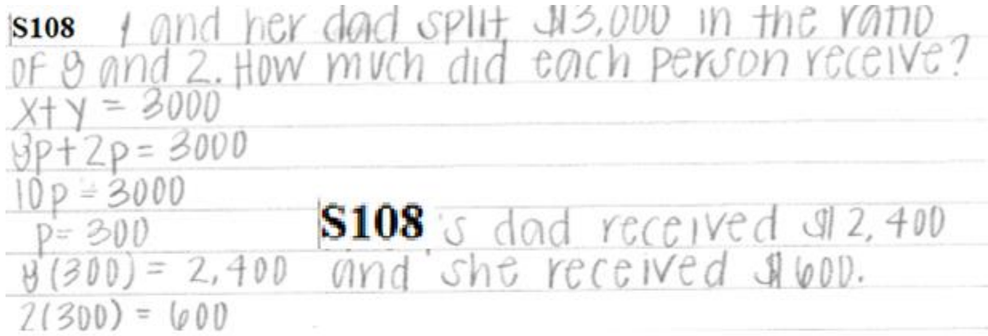
Some participants were hesitant at first to engage with the problem posing process which was a new mathematical approach. However, most of the participants began to embrace it with some practice and the opportunity to engage with their own personal interests and experiences. Participants level of engagement and personalization was influenced by the subject matter and context of the problems. This dictated what types of problems the participants posed. Many of the participants discussed how the subject and context of the problems determined the level of engagement with posing problems. If participants did not see how it was relatable, they would not engage with posing a similar problem or not look to use personal interests. Many of the problems the participants designed were based on practical and relatable life use.

Question Two: What problems do developmental math students design based on their interests?

Student designed problems. The participants were asked about their personal interests in the questionnaire. Recall that one goal of this study was to allow opportunities for the participants to use their personal interests to design problems. Reviewing all the problems the participants posed within structured, semi-structured, context free, and numerical free of the personalized problems, 299 problems of the 462 personalized problems posed involved money as the context. This represented approximately 65% of the personalized problems. The remaining 160 personalized problems reflected the varying self-reported participant interests such as family tie ins or other personal experiences occurring at that time.

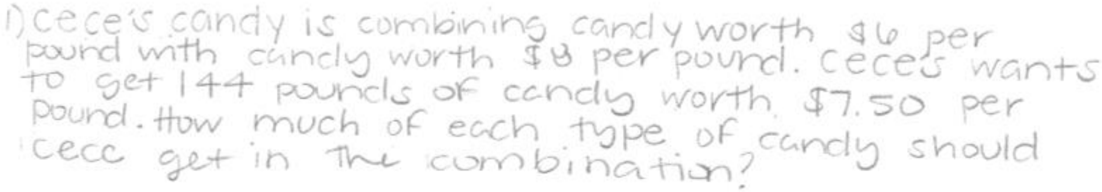
Within the interviews, the largest theme that emerged based on student responses was represented by engagement. This is understood due to most of the questions focusing on how the participants engaged with problem posing, curriculum, and the types of problems in which they engaged with the most. Much of the conversations that engagement stemmed from involved with participant interests and experiences. Participant interests and experiences came up often within the interviews and classroom discussions. During conversations about participant posed problems, most of those interviews discussed how they used their personal interests within most of the problem posing process or they did not engage at all with problem posing. Three main sub-themes that emerged from the participant interests were money, family, and personal. For some of these three subthemes, there was overlap, where participants discuss purchasing items but used family members as the subjects of the problems or participants discussed purchasing things that interested them. Examples from these are highlighted in separate sections.

Family. S108 discussed her use of family in several of the problems. Many of the subjects she used were family members, friends, and pets. S108 discussed situations with shopping with family members, dividing money between S108 and her father within a ratio problem (see Figure 17.29), systems of linear equations using pets (See Figure 17.30), friends and sisters as subjects in the problems (See Figure 17.31).



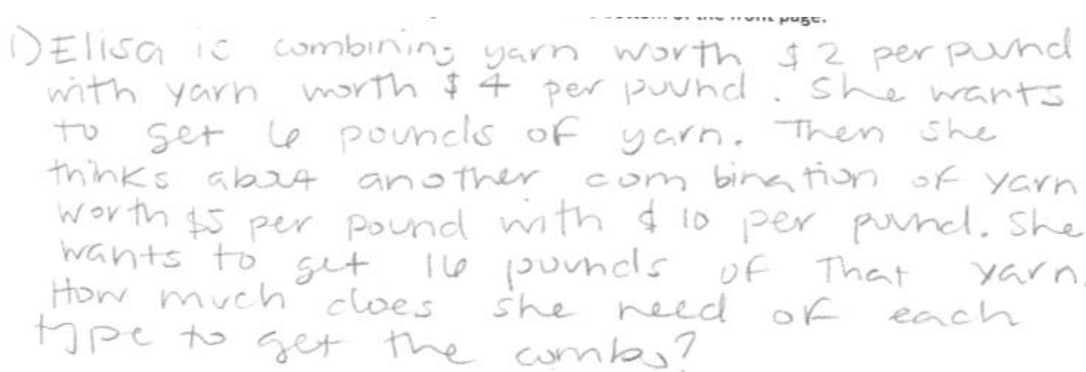
S108 (and her dad split $3,000 in the ratio of 8 and 2. How much did each person receive?
X+Y = 3000
8p+2p = 3000
10p = 3000
p = 300
8(300) = 2,400
2(300) = 600
S108's dad received $2,400 and she received $600.

Figure 17.29: *Family Example 1*



1) Cece's candy is combining candy worth $6 per pound with candy worth $8 per pound. Cece's wants to get 144 pounds of candy worth $7.50 per pound. How much of each type of candy should Cece get in the combination?

Figure 17.30: *Family Example 2*



1) Elisa is combining yarn worth $2 per pound with yarn worth $4 per pound. She wants to get 6 pounds of yarn. Then she thinks about another combination of yarn worth $5 per pound with $10 per pound. She wants to get 16 pounds of that yarn. How much does she need of each type to get the combo?

Figure 17.31: *Family Example 3*

S108 stated during class conversations that she had a large family and family was important. It was natural to use many of them in the problems. Even some the bridge problems used themes of their family (see Figure 13.72)

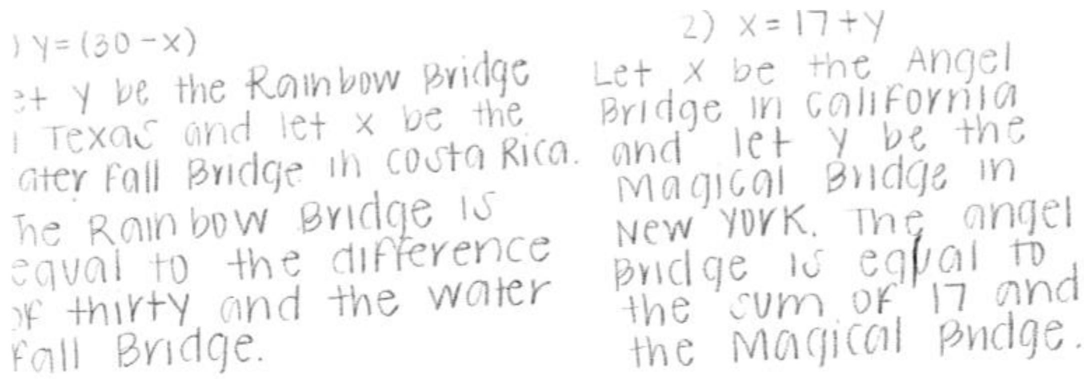


Figure 17.32: *Family Example 4*

The use of Texas, Costa Rica, California and New York all pertain to either where family had lived, or they had visited. Other participants also drew on their experiences with the family. These participants openly stated through interviews or class discussions that used family names or places they had gone on family vacations as bridge names. (See Figure 17.33, 17.34, 17.35, and 17.36). S111, S116, and S132 each explained that they had gone to several of these locations before.

S101 mentioned she wanted to go to Alaska but used a name from her family since the family wanted to go to Alaska.

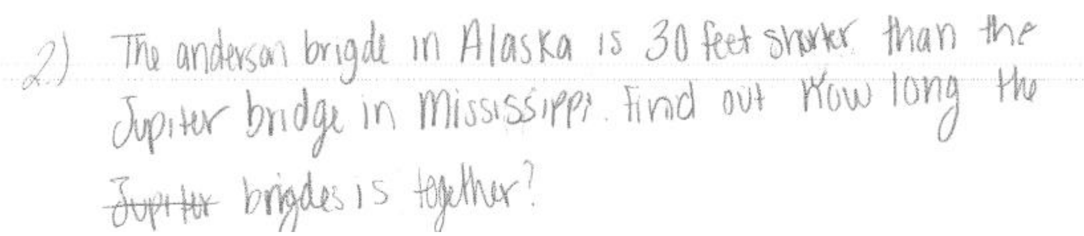
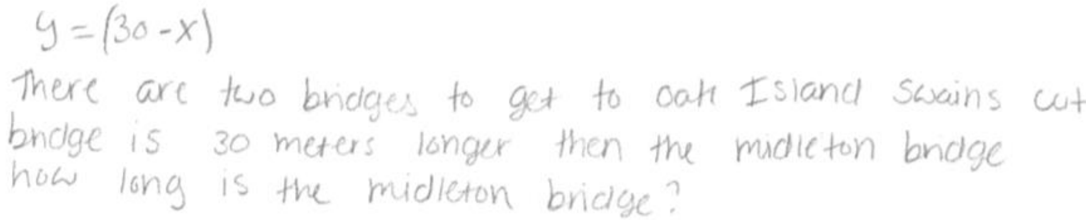


Figure 17.33: *Family Example 5*

S111 discussed in class how she would go on vacations to Oak Island.



$y = (30 - x)$

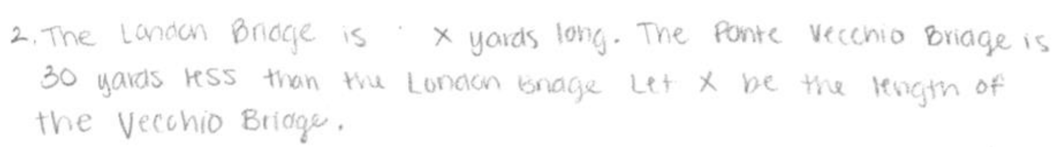
There are two bridges to get to oak Island Swains cut bridge is 30 meters longer then the midleton bridge how long is the midleton bridge?

Figure 17.34: *Family Example 6*

S116 discussed during the interview how she also went on a vacation to one the locations used with the bridge problem. S116 stated,

> “I went to London when I was like 13. Okay. With my parents were my grandparents 50th anniversary and I didn't get to see the London bridge because I decided to go see Buckingham palace that day, but my grandparents, my dad went to go see London bridge.”

This was something she utilized from previous experience. The other bridge she made up.



2. The London Bridge is x yards long. The Ponte Vecchio Bridge is 30 yards less than the London Bridge Let x be the length of the Vecchio Bridge.

Figure 17.35: *Family Example 7*

S132 noted in his interview that “Yeah, mostly I had Star Wars on my mind because I was going to Disney world before Thanksgiving and I was really thinking about Disney and like Walt Disney…” This occurred around the time these problems were assigned to be posed.

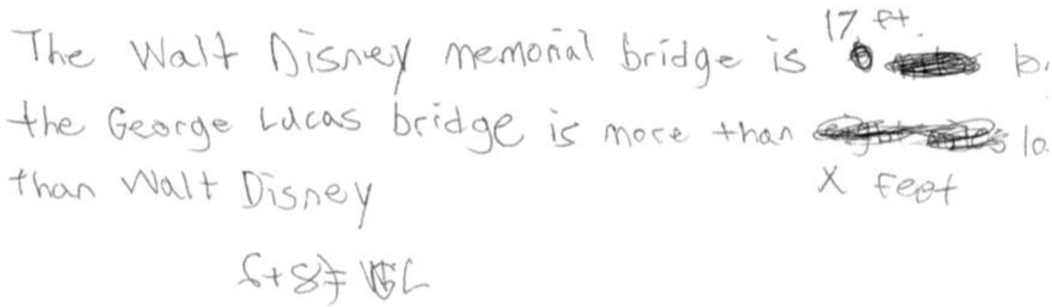


Figure 17.36: *Family Example 8*

Similarly, S116 discussed how she include subject matter that was involved in growing up. S116 discussed how their mom was involved with baking and the subject of the problem was centered around their mom and a bake sale that they had participated in (See Figure 17.37).

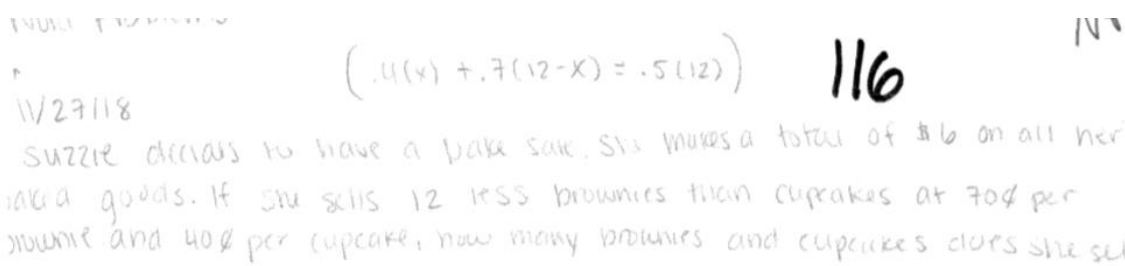


Figure 17.37: *Family Example 9*

S116 stated in the interview: “So my mom, when I was growing up, my mom was like super baker because like she, there's this place in Vermont called king Arthur flour and she took like every single baking class there was offered there and she just always made delicious things.” S116 noted in class discussion that it was similar to the problems discussed in class, but she picked it based on her experiences that seem to relate to the problem.

S132 also explained in his interview how he utilized the context of trading cards that were gifted to him by his grandfather (See Figure 17.38).

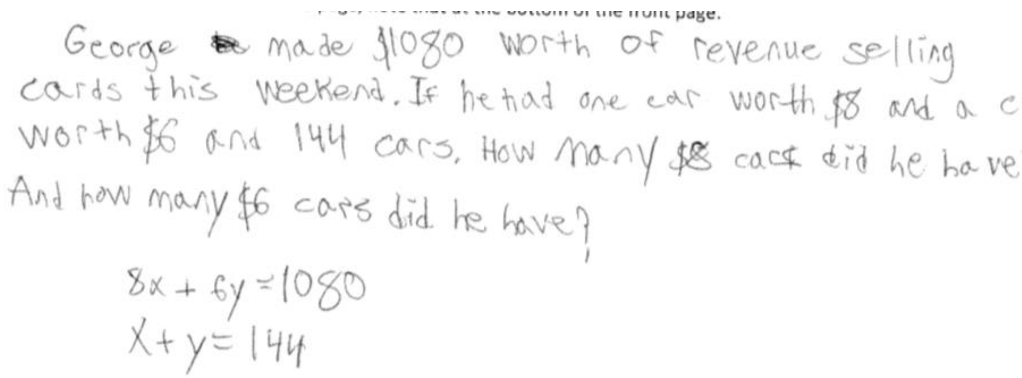


Figure 17.38: *Family Example 10*

S132 would go on to state:

> Oh, I was going to say also on the card, the trading card aspect of it. Um, that interest comes from my grandfather who was, who collected cards and I could base it based that problem around him and what his interest was because I was like, oh, I can actually see him how much he spent on cards and I can really kind of make a problem out of that.

S132 could see how that problem applied because it was something, he was familiar with. Even though S116 and 132 did not use their family within the problem, they chose an interest that was directly influenced by experiences with a family member. S138 mentioned how he also used their personal interest of music in a lot of their problems was based on family:

> Just because I've been in music since I've, well, music has always been a part of my life since as long as I can remember my, my great grandmother was the youngest music professor at the Chicago Institute for Music. My grandmother grew up in Boston with playing under her playing under the Steinway grand piano was that, that they had in their house. They have three grand pianos in their house and so her mother would play and then my grandmother would just sit under the piano and play with their toys while listening to music. And I'd always loved music. My brother, he's older than me. He, um, you started playing the trombone when you went into the sixth grade and then I remember and I just remember in elementary school in general, my favorite class was music class, you know, if even if we didn't have any instruments, just talking about music, I love, they're made sense. And then in sixth grade I started playing the saxophone and played it every day since the sixth grade. This would have been the next semester would have been the first semester that I hadn't, I want to play my saxophone every semester, but then I signed up for a concert band because I've never not played my instrument….

Like S138, many of the participants' family connection was instrumental. This created the personal dynamic and influenced his own personal interests. S138 did not pose a problem from music but noted he "listened" and "tried to pose" a problem similar to an example in class. This example was: *Katie is purchasing a new reed for her clarinet. She needs to find the cost of a box of 25 for $39.99 on sale for 20% off.* He would go on and state that felt more engaged with the instruction when this problem was discussed due to the subject. Other participants also noted that when we discussed problems in class about purchasing, they became more engaged with problems that dealt with similar interests of theirs that all referred to their family.

Personal. Some personal interests that were used in posed problems were circumstantial. S132 mentioned that he would have used some different subjects if it would have been a different time of year. When asked why he would have used different subjects in the problems, S132 stated:

> ...Possibly. It could have been hats for the New York Yankees. It could've been hats for the Carolina Panthers. It could have been many hats. But I think because I went to Disney, it was on my mind already, so I was like, hats from Disney.

Most of the problems posed by S132 built on the personal interests and contexts that were current. S102 also followed a similar pattern in her problem posing. She discussed how she would have used water sports or tubing if the problems presented themselves in a way that made her think of those interests. She mentioned that though she was interested in these activities, she did not use them in the design of the problems since it was not close to the warm season. Instead, S102 engaged with posing subjects more immediate to that time of year. This was also the case with the other participants in the study. Given that the study was around the five-day break for Thanksgiving, several students drew on this context. For example, S116 discussed how they used the interest in shopping and their interest in shopping and buy hoodies (See Figure 17.39).

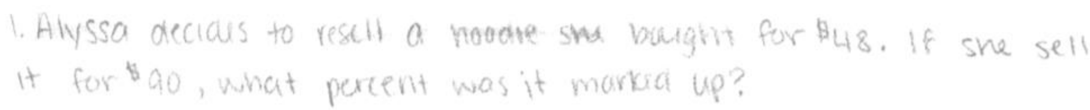

1. Alyssa decids to resell a hoodie she bought for $48. If she sell it for $90, what percent was it marked up?

Figure 17.39: *Personal Example 1*

S116 felt it fit what the context of mark up and mark down from class and that Black Friday had just occurred.

S116 and 132 also discussed how they utilized their interests in current TV shows and their perspective careers. S116 mentioned they used names of characters from their favorite show, while 132 discussed the name of their show as a subject in a posed problem. (See Figure 17.40)

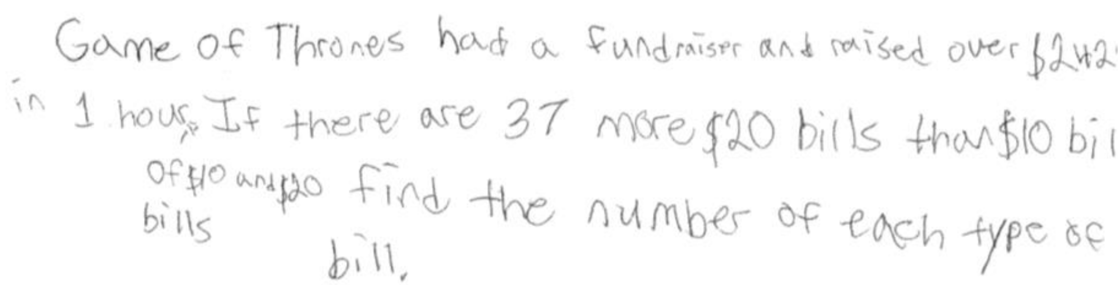

Game of Thrones had a fundraiser and raised over $242 in 1 hour. If there are 37 more $20 bills than $10 bil Of $10 and $20 bills find the number of each type of bill.

Figure 17.40: *Personal Example 2*

S132 noted that he did mimic the values for this problem, the subject was something that did interest them. These also represent circumstantial interests that were not alluded to in their personal interests' portion of the questionnaire.

Uniquely, S116 and 132 used their personal interests related to their future careers. Both participants mentioned they wanted to become teachers. S116 wanted to be an elementary teacher and S132 wanted to be a secondary social studies teacher. S116 discussed now participants were divided into groups of boys and girls in a school play (See Figure 17.41)

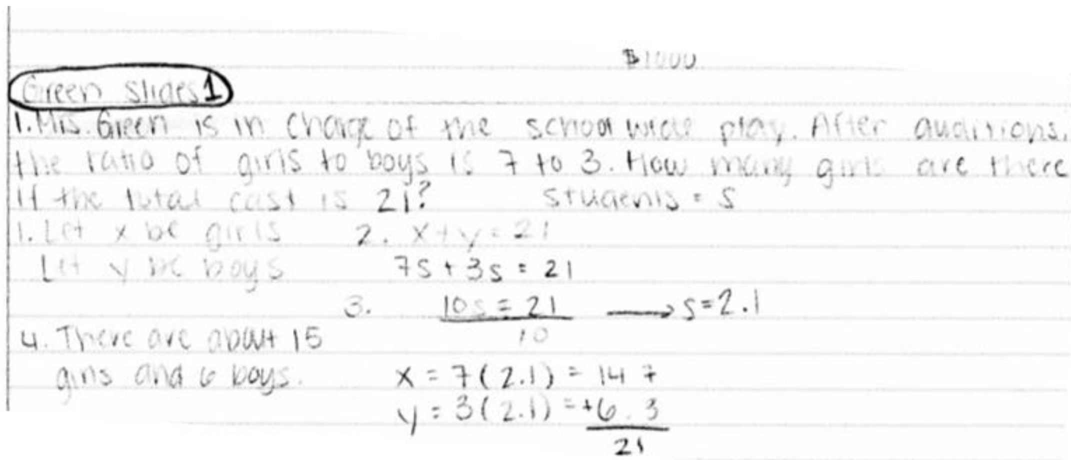


Figure 17.41: *Personal Example 3*

S132 references the United States presidents dividing troops on a field using ratios, and dividing politicians by votes. (See Figure 17.42)

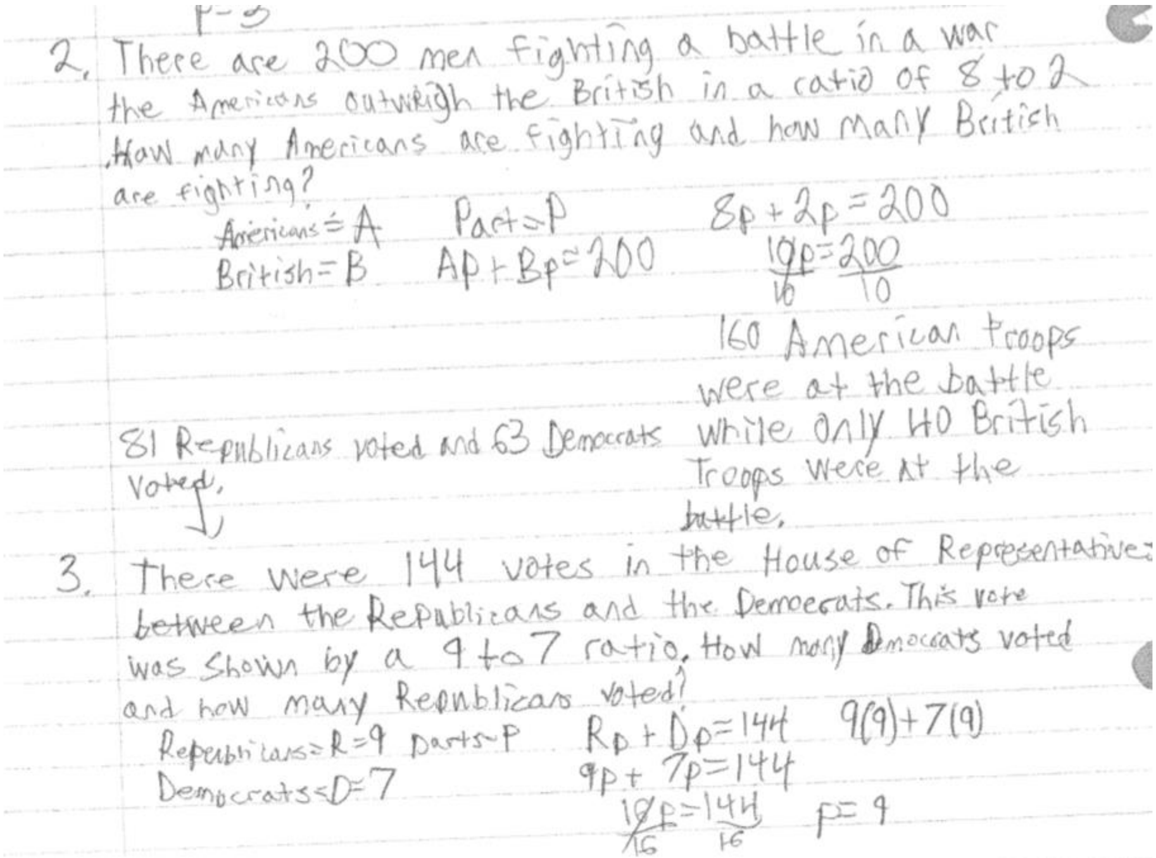


Figure 17.42: *Personal Example 4*

S132 mentions their interest within ratio problems:

> Yeah, because so my particular populations one in terms of making sense to me, the ratio problems made complete sense to me in terms of populations because I've heard it in that term before in terms of okay class has 56 people and they're divided seven to eight, like seven being men's have eight being women. How many people are in that class and how many of each denomination are in that class? That makes complete sense to me because I'm like, okay, we need to figure out how many men, how many women are in this class because one that's important to know for the

> demographics and two that, Just that's also important to know if you're doing research on the grades within that class as well. It's important to know how many of each type are in that class. So, it just. Again, it really didn't make sense to me on the population problems, especially with the one about the troops because I was doing that and I said, okay, I can probably tailor this to a battle or something because like back to world war two or something about having a battle, the battle of the bulge or something and really saying, okay, the Germans have like 100 troops on this side. The Americans have a 120 on this side together or they have 220, Americans have like a ratio of eight to the German seven. How many are like how, how this will affect or something along those lines. It just makes it tailors it to what I wanted it to be and allows me to fully see it.

Another example of personal interest involved the selling and buying tickets to a play or dance. S132 mentioned buying Hamilton tickets while S120 discussed selling tickets for their dance group routine. Even though S120 discussed that she did not feel the need to pose problems based on her interests, she discovered that certain areas were more engaging and relatable, and it was easier to pose a problem within these contexts. For example, several participants mentioned that they became more engaged to contexts of the problems related to subjects within ratios, systems of equations, and purchasing (markup mark down) problems. While most of the posed problems dealt with personal interests, many of them, like the subtheme of family, also dealt with money.

Money. A popular subject area that in several ways overlaps family and personal is money. Participants discussed posing problems involving money. For example, S108 stated “I'm more likely to try it out because like we use money every day. So, like I start like thinking of how like to approach the problem.” S108 also discussed relating the money context to understanding:

> That one's the easiest for me, like the ones that you learn like on Thursday, um, especially um, with the interest. So it was, I was like, oh my God, like, and get it but I can get through it but just a person like markup and markdown like that was the easiest for me especially because like I shop. And so, um, whenever you told us before we went onto fall break, you're like you guys are going to use this for like black Friday shopping or whatever. And I definitely saw myself like in the store, like I bought this scarf and I even used it like in a problem. Like I like said that yeah, it was like 60% off and so I'm just putting it there. So, I think it is useful, like you know what I mean, like whenever you go shopping, just stuff.

S108 posed 21 out of 48 problems with the subject and context of money. In Figure 17.43, represents the problem S108 discussed above.

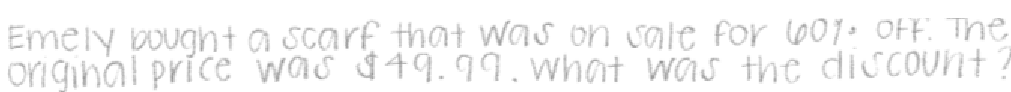

Emely bought a scarf that was on sale for 60% off. The original price was $49.99. what was the discount?

Figure 17.43: *Money Example 1*

Additionally, S102 related problems with fractions to money. She says,

> I don't know, I just feel like anytime I see a decimal I think it's a fraction of a dollar and I don't fractions Kinda freaked me out. But I mean, I'd rather have like fifty cents than a half, you know, and I feel like most people are like that because most people don't like fractions. Well,

> generally speaking, a lot of people don't like fractions so it's just whenever I see a problem that says point five or point eight, I think 80% or eight tenths, I guess.

S102 used her approach to fraction and decimal conceptual understanding to engage with the problems she posed and insure they understood how to address fractions, percentages, and decimals.

Participants 102 and 116 mentioned relating problems involving money to previous jobs as wait staff. One example is when both 102 and 116 applied a ratio structure to dividing up tips (See Figure 17.44 and 17.45).

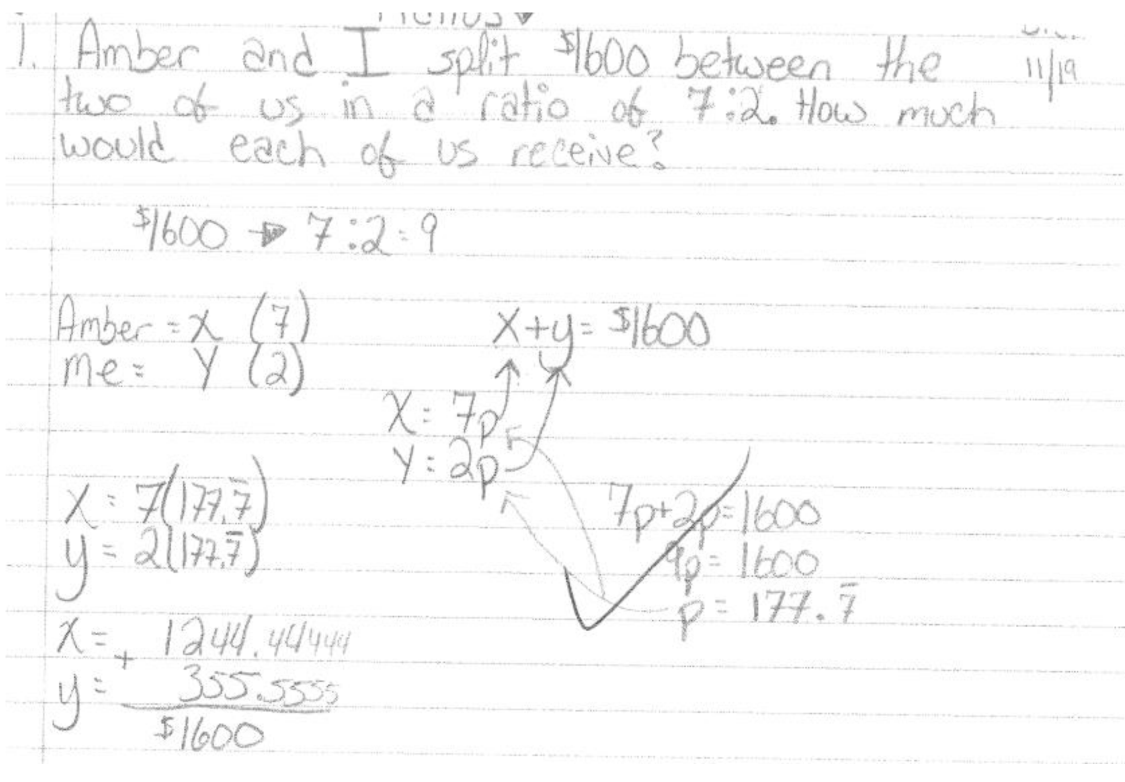


Figure 17.44: *Money Example 2*

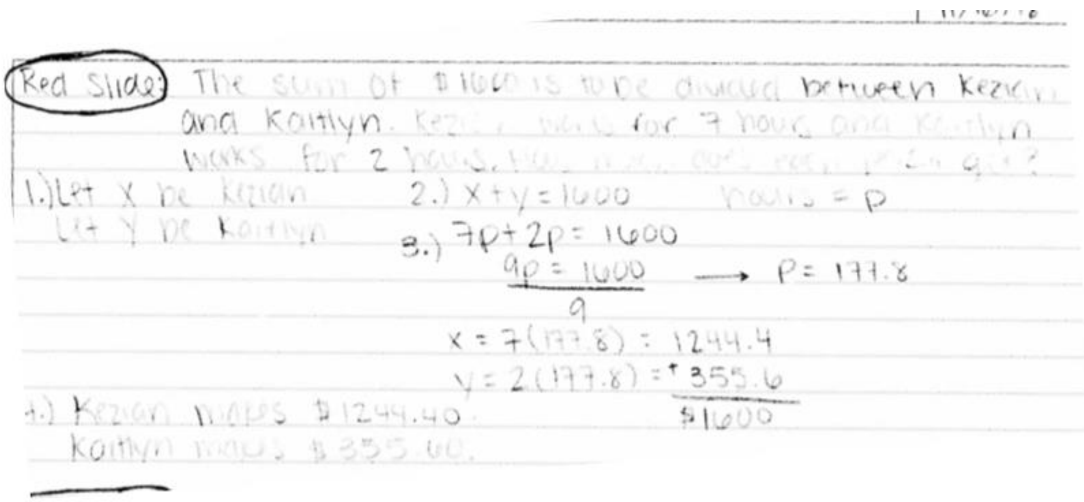


Figure 17.45: *Money Example 3*

Both S102 and S116 stated, "that's what made sense." Other participants also mentioned that they used their past experiences to draw meaning. One participant even asked if the example was similar to "splitting tips" as a waiter would at the end of the night.

S138 also discussed how his personal interests with music and applying those interests with buying a musical instrument example helped him "make sense" of the problems and numbers. He felt more engaged and could relate to the problem due to the subject matter but also because of how he was able to apply his interest of music with how he was able to understand fractions. S138 stated:

> And so, you know, like I knew you have to buy boxes of reads and reads are expensive, but then the more, the more quantity you get, you know, normally the cheaper where they are buying in bulk just in general. And then with being a cashier I just deal with money and they made sense because you can't, you can have half a dollar, fifty cents, but then you can't. That's when having fractions was okay, you know, and you can't

> have negative. Well you can't have negative money, but you can't spend a negative amount or anything.

Even when participants noted they used their personal interests, many of these interests involve purchasing their favorite items or selling items for a club event or dance. Money tied family and personal interests together and moved many participants to engage with money problems more than others. S116 noted that using money as the contest allowed her to connect more “quickly” than with something they had no background in. Most participants discussed how personal interests with family or money were used problems, even if they were not stated in the questionnaires. Where much of this engagement with theme of money was abundant, several participants noted in class where it also had to do with the time of year. The five-day break had participants discussing Black Friday shopping and several said this was convenient for them with posing these money related problems. Most of the participants that utilized family, personal interests, and money found these problems more relatable. The increased the level of engagement or disengagement was dependent on the problem context being relatable or not.

Relatability. One area to note is the occurrence of participants discussing applications to real life and finding the material relatable. Participants 102, 116, 120, 132, and 138 all discussed either relatability or applications of things that were real to them. S132 discussed how if problems did not seem realistic, they were more likely to be disengaged. S132 would go on and say, “I feel very disengaged because there'd be like that. That doesn't happen. That shouldn't happen in real life for sure.” S132 discussed the practicality of math and this helped show the practicality of the concepts by engaging with personal interests and posing problems that he thought were more relatable to his interests.

S120 mentioned she would pose problems that made sense to her because it was similar to life experiences or something, they felt they could use or related to their life outside of class. She felt more engaged with contexts that were realistic and practical. S117 noted that, “The word problem process has helped me to put mathematics in terms that give meaning. I have started thinking about things in my daily life in terms of numbers and what I can quantify.” Other participants felt this way and mentioned several examples that they believed were practical. Participants 102, 120, and 132 noted that problems reference money or prices. They stated these were contexts that made sense to them and could relate to their own experiences outside class. They felt more engaged with examples that they believed to be useful. Uniquely, S138 referenced the relatability of fractions in these problems to musical notes and how doing similar problems helped engage them with that area of interest. For these participants finding subjects and interests that they could see the practicality made it more engaging.

Overall, problems that participants posed centered on theme that they found the most relatable. This came through either posing personal situations or problems that resembled similar interests. Money, family and personal interests were the main sub themes that emerged, many were circumstantial or based on their current and immediate interests or experiences. Many participants engaged with contexts and subjects that were currently at the forefront or most convenient. The participants mentioned that they did not want to think overly about the context, so engaged in interests that were familiar. Given their focus on making the numbers and computations work, the participants did not overly engage with their deeper interests to make the contexts of the problem.

Question Three: What Impact Does Problem Posing Have on Attitudes and Beliefs?

The problem posing intervention was new to the participants in the study. As such, there was an interest in learning about the possible impact this intervention had on their beliefs and attitudes. To address the impact on students' attitudes and beliefs from problem posing, data was collected from questionnaires, interviews, pre and posttests, and the observation journal. Questionnaire 1 was given at the beginning of the term, questionnaire 2 was given before the intervention and questionnaire 3 was given at the end of the intervention. Student quantitative outcomes from each questionnaire were extracted and averaged within the control and interventions classes for comparison. Students open ended responses pertaining to attitudes and beliefs were also complied and compared between questionnaires 1, 2 and 3. Lastly, student interview responses were also analyzed for the students' attitudes and beliefs. The next sections will first examine the overall means for each item across the three questionnaires and discuss items where there were differences in the means in more detail.

Analysis of beliefs. Observing the questionnaires, participants from the Control and Intervention courses kept similar trends in their belief outcomes on most questions (See Table 12). For beliefs questions 3, 5, 8, 9 11, 13, 14, 18, and 20, participant responses differed. Questions Q1:5,8, 9, and 20 all had the Control and Intervention courses going in different directions after questionnaire 2 to 3. Question Q1:5 "*In mathematics, it is impossible to do a problem unless you've first been taught to do one like it,"* the mean scores converge before the problem posing intervention and diverge right after. This is highlighted in figure 18.1. The participants in the intervention (Intervention) are more likely to believe that it is possible to solve a problem even if they have not seen a similar example. This is an important finding for the developmental mathematics participants who have traditionally been exposed to worksheets that build on a similar example.

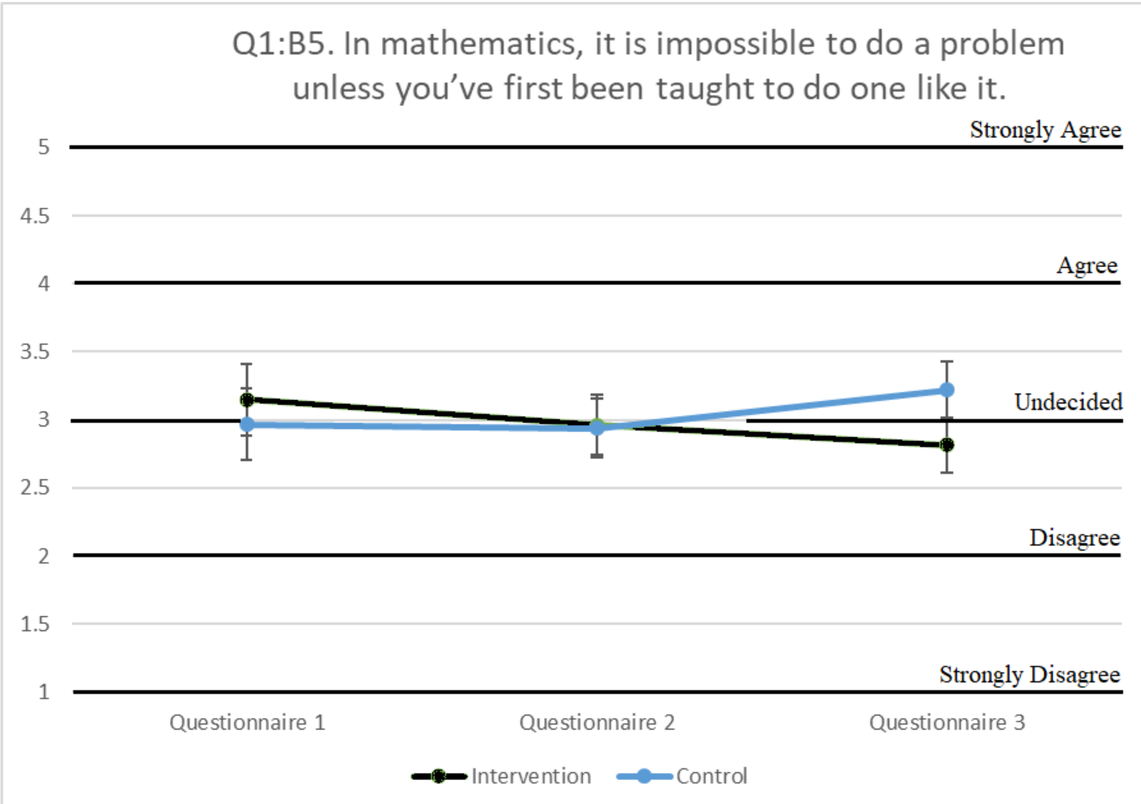


Figure 18.1: *Graph of Belief Question 5 Responses*

A better understanding for the change in the intervention course can be gleaned from the participant discussion. Several participants in the Intervention course discussed it was helpful to have observed previous examples, but it was not impossible to move forward without them. For question Q1:8, *"When I learn something new in mathematics, I often continue exploring and developing it on my own,"* the Intervention course remains increasing, but the Control course increases to a similar place as the Intervention course then diverges down again. See Figure 18.2:

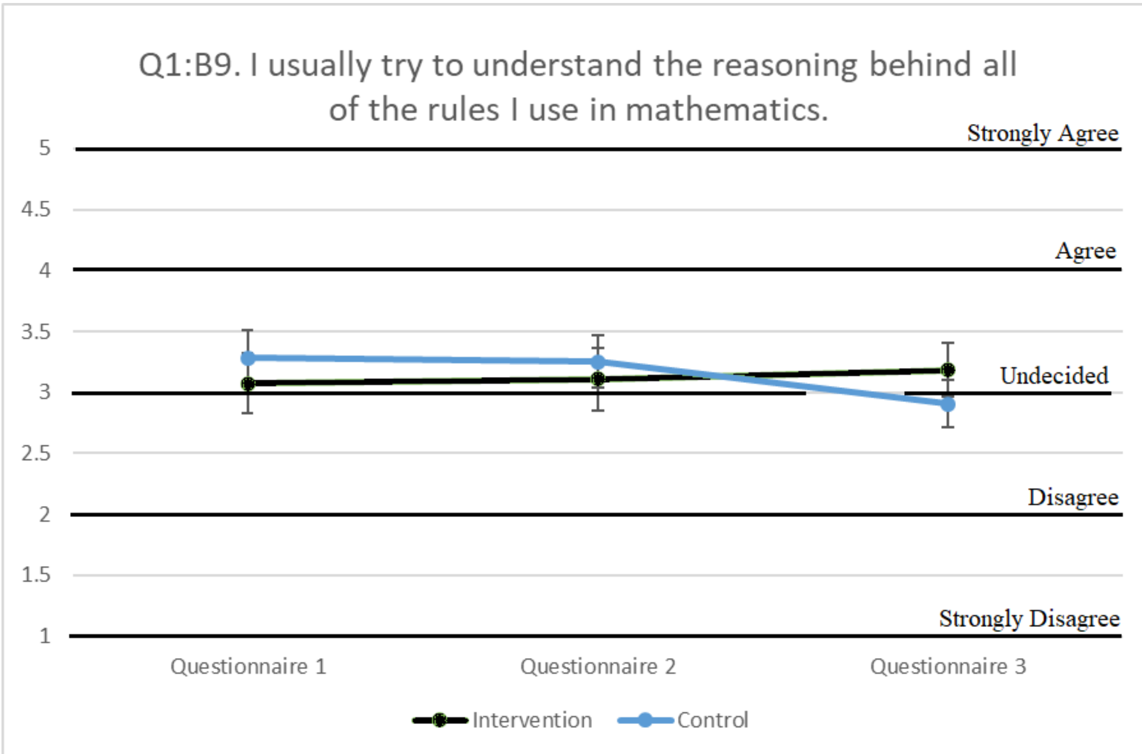


Figure 18.2: *Graph of Belief Question 9 Responses*

Where both the Control and Intervention courses are scoring as disagree, the Intervention course is trending positively where the Control course is trending negatively from questionnaire 2 to 3. This could imply that problem posing influenced participants from the Intervention course to self-discover more options in solving their word problems.

For question Q1:9 *"I usually try to understand the reasoning behind all of the rules I use in mathematics,"* both courses stated consistent from questionnaire 1 to 2;

however, the Control course diverges downward where the Intervention course continues to have a positive trend. See Figure 18.3.

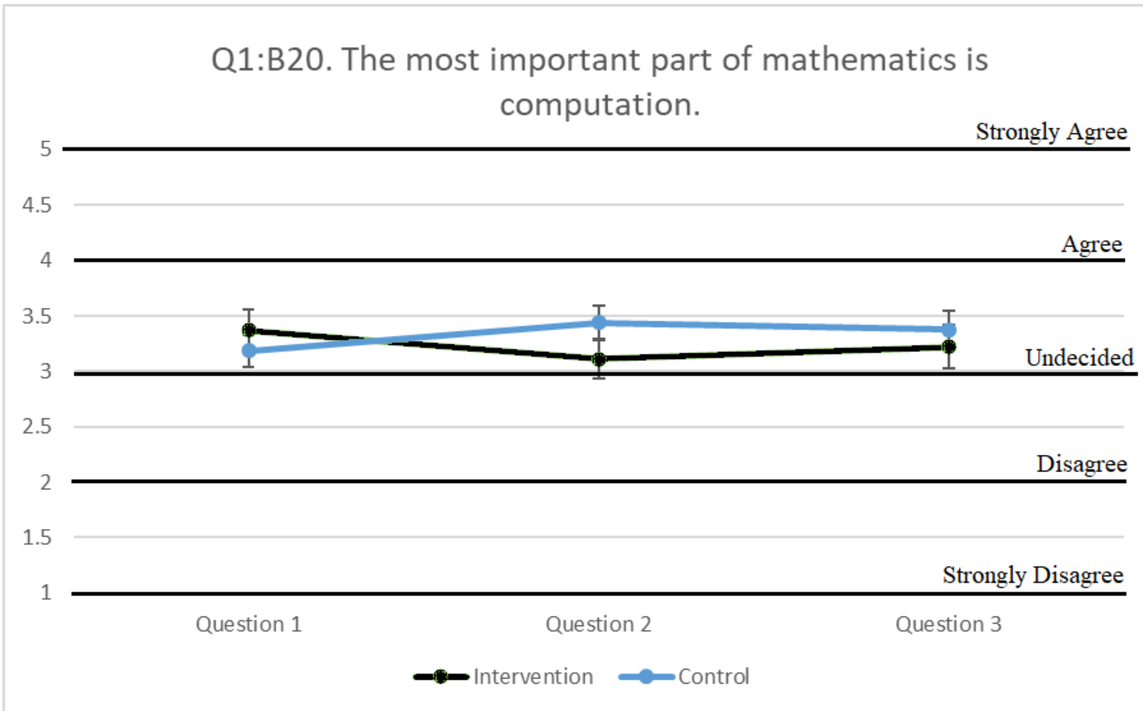


Figure 18.3: *Graph of Belief Question 20 Responses*

This may be due to the students in the Intervention course being exposed to problem posing whereas those in the Control course were not. As noted from Q1:8, participants from the Intervention course were more likely to self-discover than those in the Control course. With this likelihood of more discovery, participants from the Intervention course showed that when agreed they were more likely to try to understand reasoning behind the content.

For Q1:20, participants from the Control and Intervention courses diverged between questionnaire 1 and 2. The Intervention course then slightly increased to questionnaire 3. Where computation is still important, both fall within (3.2 to 3.4; between undecided and agree), participants from the Intervention course show change towards agreeing. See Figure 18.4.

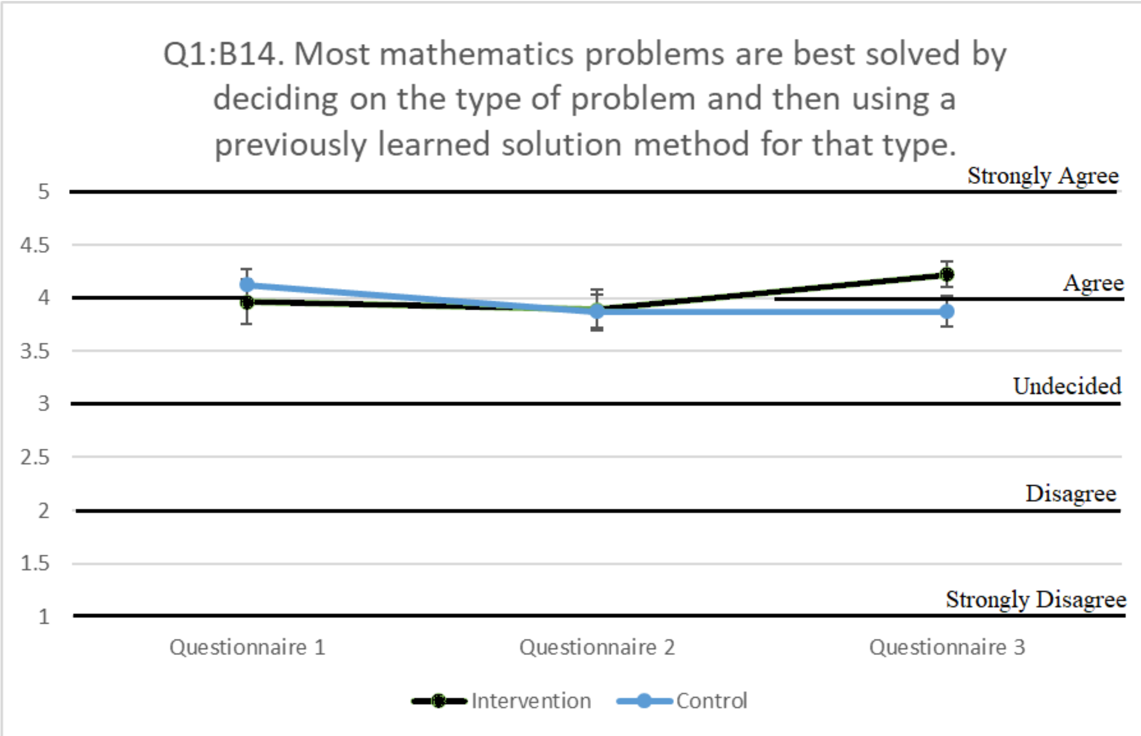


Figure 18.4: *Graph of Belief Question 14*

Of these that differed, only question Q1:14 responses for questionnaire 2 and 3 were outside the margin of standard error of one another. This is helpful to see if responses are within similar confidence intervals, which if no change has occurred, should be expected. Questions Q1:7, 12, and 17 also were outside the standard error of one another but followed similar trends and started different placements. Q1: 14 "*Most mathematics problems are best solved by deciding on the type of problem and then using a previously learned solution method for that type,*" showed the greatest divergence. the Control course began with a higher belief value of a 4.125 but decreased to 3.875 for questionnaire 2 and remained the same for questionnaire 3. The Intervention course decreased from 3.962 to 3.888 then increased to 4.222. (See Figure 18.5). This implies that participants in the Intervention course strongly believed that it was necessary to use a previous problem to know how to solve a specific problem. Recall that the participants engaged with problem posing by drawing on previous worked examples, so it is not surprising to see that this belief may have been reinforced with this experience. With no change for the Control course, they did not see a greater need to recall and review previous examples when solving word problems.

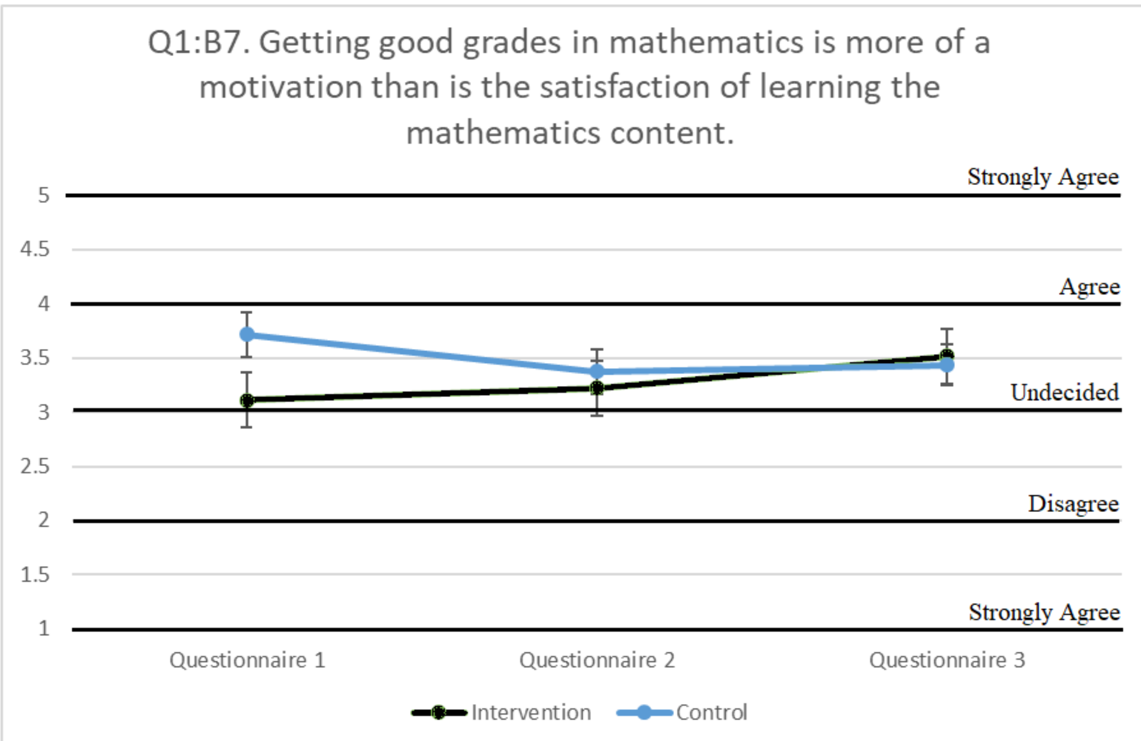


Figure 18.5: *Graph of Belief Question 7*

Though many of the beliefs remained the same for both courses, improvements in participant beliefs did occur for the Intervention course in some of the items. These improved beliefs could be attributed to the impact problem posing had on participants beliefs in the Intervention course in the short time of the study.

Analysis of attitudes. Attitudes from the 20 items in the questionnaires had similar results as the beliefs portion where little change occurred (See Table 13). Questions Q3:1,3,4,5,6, 9,10,12,15,19 and 20 all followed similar trends between both the Control and Intervention courses. Four of the questions, (Q3: 14, 16, 17, and 18) showed the two courses going in different directions form questionnaire 2 to 3. For question Q3:16, "*It makes me nervous to think about having to do a mathematics problem,"* both courses decreased from strongly agree to disagree (See Figure 18.6). The Control course maintained but the Intervention course increased to a slight agree. Thus, indicating that the experience was new to the students and they may have been nervous with the new approach of problem posing.

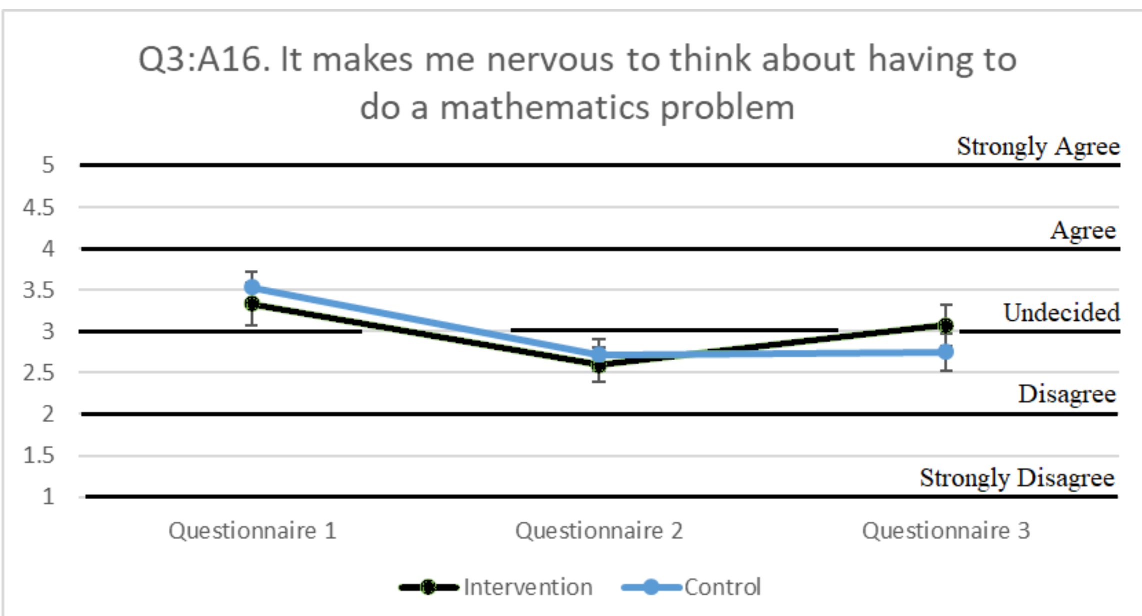


Figure 18.6: *Graph of Attitude Question 16 Responses*

For questions in Q3- 14, 17, and 18, all involved liking or disliking mathematics. the Intervention course participants presented more favorable responses than the Control course. For question Q3:14 "I *really like mathematics,"* showed both courses increasing from questionnaire 1 to 2, but the Control course decreased from questionnaires 2 to 3 and the Intervention course increased from questionnaires 2 to 3. For question Q3:17, *"I have never liked mathematics, and it is my most dreaded subject,"* both courses decrease from questionnaires 1 to 2, the Control course with a steeper decrease than the Intervention course, but as the Intervention course continues on a similar decreasing trend from questionnaires 2 to 3 where the Control course increases from questionnaires 2 to 3. For question Q3:18, *"I am happier in a mathematics class than in any other class,"* both courses increase from questionnaires 1 to 2, but the Intervention course increases at a higher rate than the Control course form questionnaires 2 to 3 (See Figure 18.7, 18.8 and 18.9). For the Intervention course, strongly disagree and degree responses decreased by 9% where strongly agree and agree responses increased by 15%. Undecided responses decreased by 9%. This shows that more participants moved from disagreeing with Q3:14 to agreeing with it.

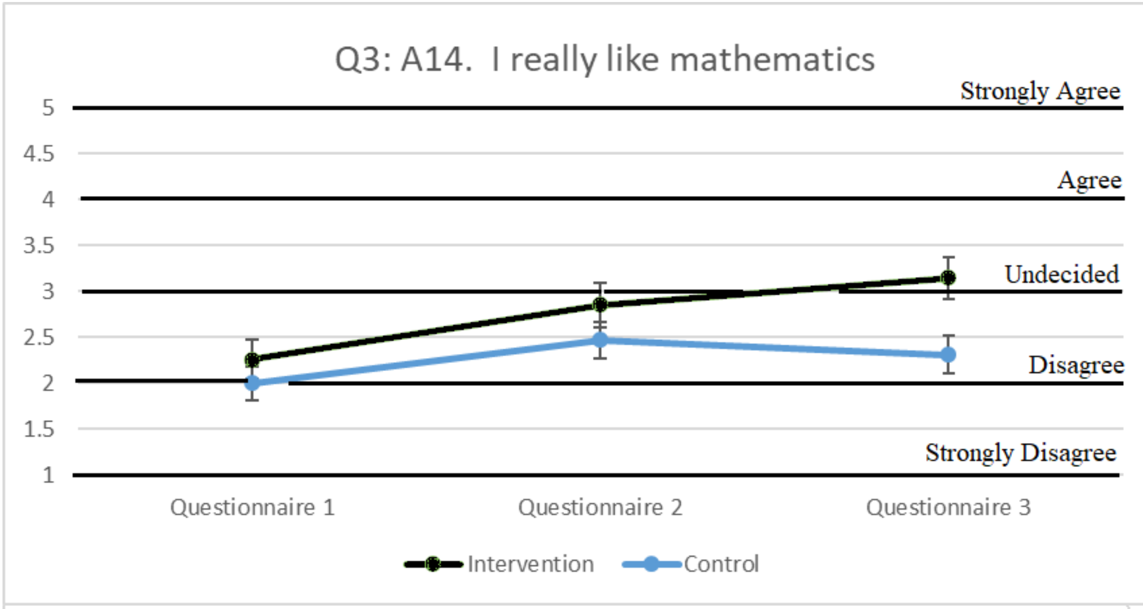


Figure 18.7: *Graph of Attitude Question 14 Responses*

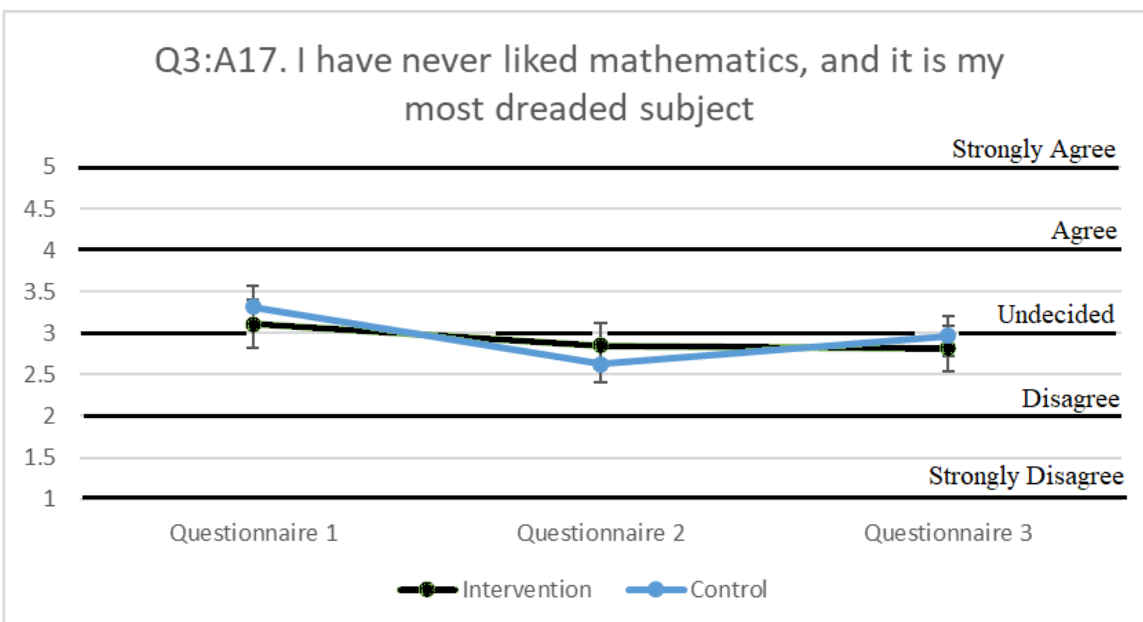


Figure 18.8: *Graph of Attitude Question 17 Responses*

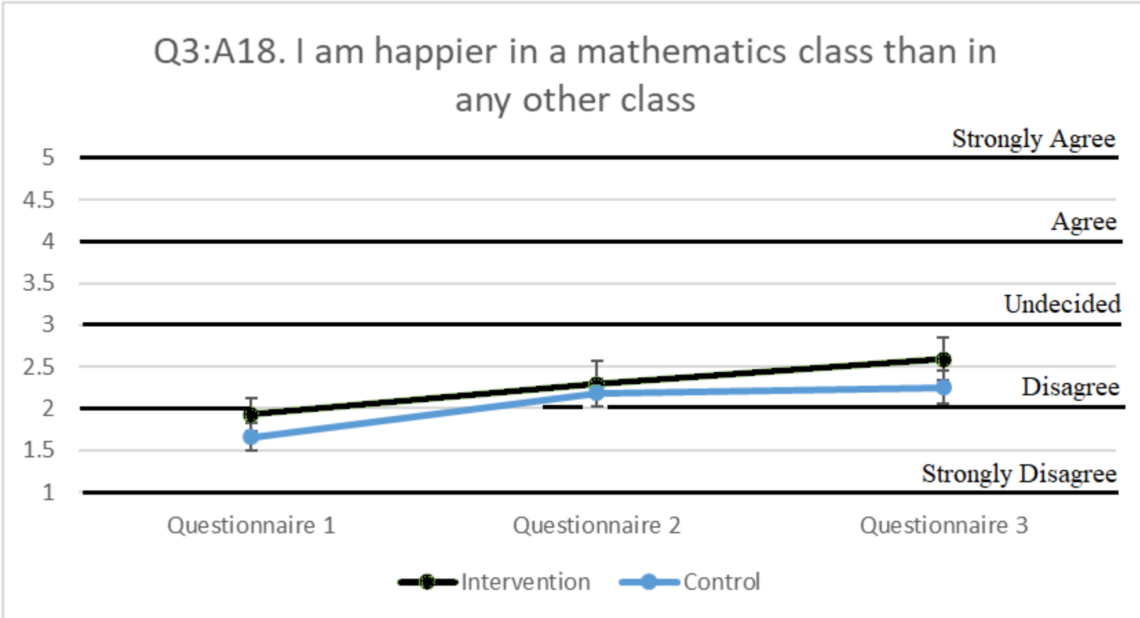


Figure 18.9: *Graph of Attitude Question 18 Responses*

For Q3:14, the positive increasing trend could be attributed to participants from the Intervention course where given more freedom in the problems they posed along with the context of the problems. Additionally, participants in the Intervention course could use their personal interest and experiences when problem posing, making it more engaging. Similar to results from Q3:14, Q3:18 shows a higher positive trend for the Intervention course as compared with the Control course. For Q3:17 it also implies that with the inclusion of personalization and incorporation of personal interests and experiences through problem posing, participants from the Intervention course are following a continued negative trend of disagreeing with the statement. With the absence of problem posing in the Control course, participants move positively to agreeing with the statement in Q3:17. Of these questions, only question Q3:14 had values outside each's standard error mean on questionnaire 3 (See Figure 18.7).

Similar to beliefs, most of the participants' attitudes in both the Control and Intervention courses followed a similar trend. The few that did differ gave insight on how problem posing might have impacted these participants perceptions on mathematics. More information was gathered from the student interviews and discussions surrounding their attitudes and beliefs.

Analysis of attitudes and beliefs from student interviews and discussion

Personal attitudes and beliefs on success. The analysis of the interview data provided more insight into possible reasons for the participants' beliefs and attitudes. Most of the participants' responses from the interviews pertaining to beliefs was about themselves. These personal beliefs varied around participants never being good at mathematics. Participants noted that they struggled with mathematics for most of their schooling. This was the reason that the students disengaged with mathematics entirely and felt stressed when they engaged with mathematics. These stressful experiences negatively affected several of the participants grades and self-expectations. The participants believed that to be successful in mathematics, they had to get good grades. For them the good grades meant that they understood the mathematics and that they would be more confident and motivated. This would propel them to better engage with the subject. Many participants from the Intervention course noted that in their previous mathematics courses, it was just about passing the class and they just had to get through it, and they did what they needed to do, it was about survival. This perception related to belief question Q1:7: "*Getting good grades in mathematics is more of a motivation than is the satisfaction of learning the mathematics content."* The Control course agree mostly with this question where the Intervention course decreased their agreement on focus on grades (See Figure 18.5). Several interviewees discussed that the success in posing the word problems made them feel more engaged and push themselves to understand the material. From this more participants stated they felt more prepared and positive about themselves with mathematics. Several participants stated that they used to do enough to "get by" but now feel having the conceptual understanding is another way of feeling successful.

Attitudes and beliefs: instructional approach. Participant beliefs and attitudes also centered around viewpoints on instruction and mathematics. Participants mentioned that they became disengaged with mathematics based on how it was taught. Participants noted that much of their current attitudes and beliefs stemmed from personal experiences at school. Many of these came from personal obstacles created from positive and negative K-12 experiences, and experiences with pervious instructor(s) and how they taught the courses. The participants noted that their high school teachers were bland, did not go into depth, and only provided examples to mimic. Some stated they would get lost because they felt there was a lot to take in. A few of the participants that interviewed noted that they if were given more options to approach mathematics, it would affect their personal beliefs in previous mathematics courses.

After taking this course and using problem posing, many participants' attitudes and beliefs changed towards the instructional approach. Several participants believed problem posing helped develop their understanding of the content at a deeper level. Those Participants noted that this was due to the openness of the task and the freedom to develop their own problems through problem posing. Problem posing also had an impact on the Intervention course participant's belief that there was only one way to approach the problem. 70% of participants in the Intervention course mostly disagreed with the question Q1:17: "*Mathematics is a rigid, uncreative subject.*" Participants noted that they no longer felt restricted within one way of approaching word problems while problem posing. This freedom helped increase participant confidence and with this increase in confidence, several interviewees stated they were more confident taking the posttest and preferred problem posing to traditional methods. Several participants from the Intervention course stated their attitudes towards mathematics changed over the course of the semester and felt they had a better understanding of the subject, felt more prepared for their next mathematics courses. Participant 120 stated they got "refreshed with mathematics during this section and it helped them with their attitude towards mathematics." Several participants did not see a change in their beliefs based on problem posing. Participants stated that they preferred traditional approach instead of problem posing. Where a few participants noted they did like writing their own scenarios in for the tasks, their attitudes and beliefs towards mathematics and their abilities did not change from the use of problem posing.

Attitudes and beliefs: enjoyment. Other participants from the Intervention course also discussed that they enjoyed material and the course. Enjoyment with mathematic s was highlight through 3 questions Q3:3, 11, and 20. Questions Q3: 15 discusses enjoyment as well but references the current mathematics course and previous courses. This is addressed in school experiences. Observing question Q3:3, *"Mathematics is very interesting to me, and I enjoy arithmetic and mathematics courses,"* participants from the Control course shows an increased across each questionnaire and participants from the Intervention course showed an increase from questionnaire 1 to questionnaire 2, however decrease from questionnaire 2 to 3. Question Q3:11, "*Mathematics is something that I enjoy a great deal,"* shows a similar trend as Q3:3. The Control and Intervention courses disagree with the statement over all three questionnaires; however, with the presences of problem posing, the Intervention course decreases and has a negative trend from questionnaire 2 to 3. Where there is an adjustment to the wording in question Q3:20, *"I feel a definite positive reaction toward mathematics; its enjoyable,"* participants in the Intervention course have a positive trend across all three questionnaires. The Intervention course shows the most change, but after increasing from questionnaires 1 to 2, it stays the same from questionnaires 2 to 3. See Figures 18.10, 18.11, 18.12 below.

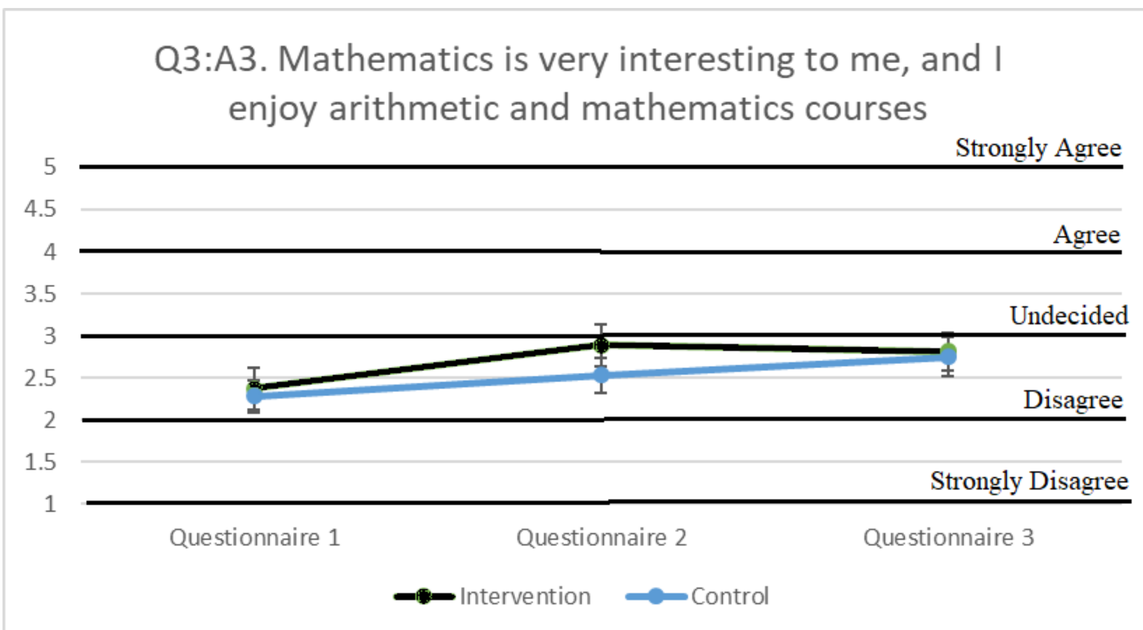


Figure 18.10: *Graph of Attitude Question 3 Responses*

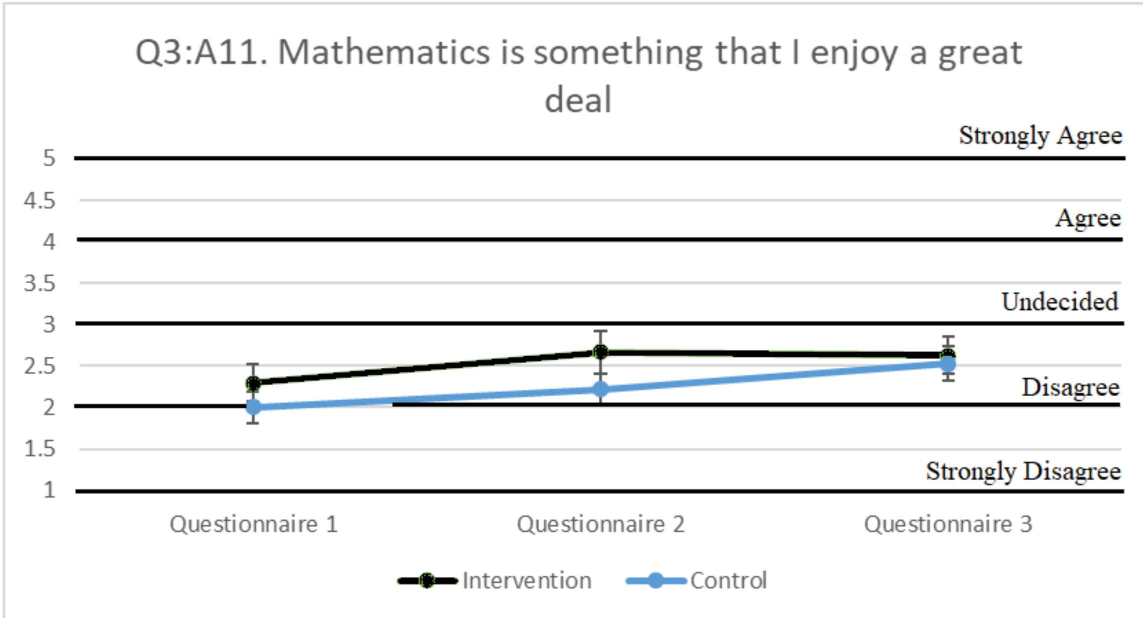


Figure 18.11: *Graph of Attitude Question 11 Responses*

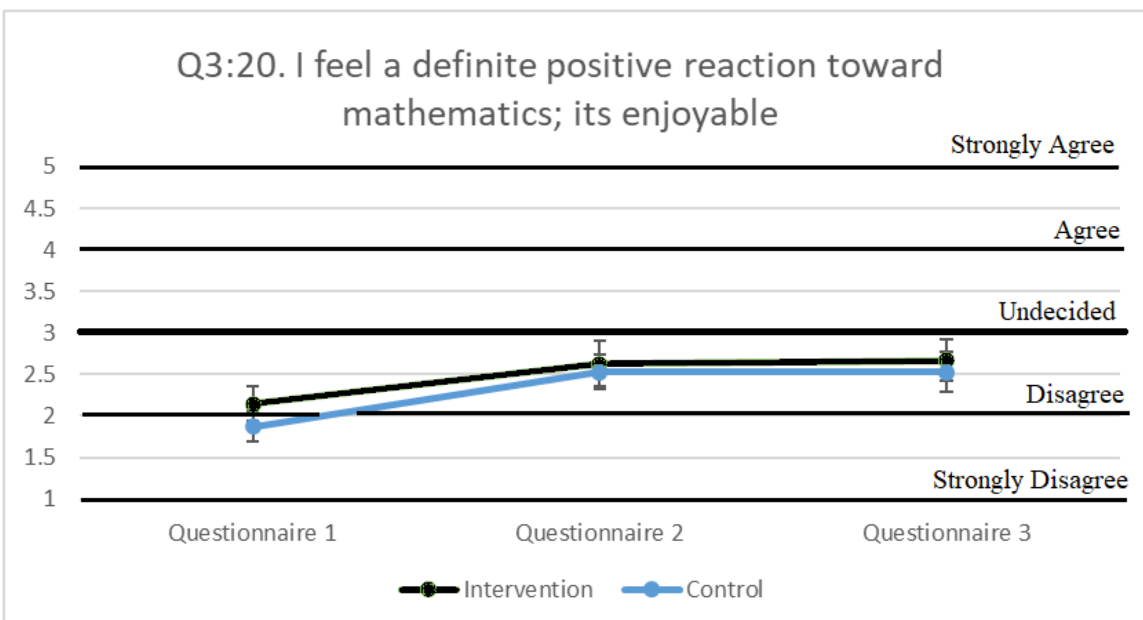


Figure 18.12: *Graph of Attitude Question 20 Responses*

Although participants noted that they enjoyed aspects of the course and problem posing, the responses to from the Intervention course's Q3: 3 and Q3:11 shows otherwise. This could be related to the participants focus on the computational aspect of word problems while incorporating personal interests and experiences in the problem posing tasks. Where participants noted that they were overwhelmed with addressing multiple items within the tasks at once, may have taken away the enjoyment of using personal interests or experiences within their own problems. This was highlighted with participant discussions about numerical free posing. That's where Q3: 20 is less absolute in the enjoyment but more positive and enjoyable at varying times, maybe not all the time. Participants were more engaged and noted more enjoyment when they were not required to pose new contextual problems with numerical statements, this question may allude to those times and representative attitudes. Other participants discussed that they never enjoyed mathematics but even though they are "warming up" to it, they will never enjoy it to the degree a mathematics major would. Where each of the participants responses from both courses are within the strongly disagree section, it is important to note that overall three questions, participants from both courses did increase over questionnaire 1 and 2, moving closer to undecided. It is also worth noting that some participants did state they enjoyed mathematics in the Intervention course at certain points of the semester and during the problem posing unit. Similar to the responses from the Intervention course, three participants noted they enjoyed mathematics on questionnaire 2 would go on and state they enjoyed mathematics and the class now (after questionnaire 2 prior to taking questionnaire 3).

Conclusion on impact on attitudes and beliefs. Overall, there were positive aspects of problem posing with the participants in the Intervention course. Participants showed that problem posing helped them explore mathematics beyond their comfort level, focus on the underlying reasoning to the rules, and engage in problems that they may not have seen before. With problem posing, several of the belief statements suggest that due to the problem posing, participants were less reliant on having traditional instruction and can continue with more self-confidence. Participants from the Intervention course also indicated that they could do a problem even if it is new and can continue exploring and understand rules for continue investigation. Where problem posing is more open ended and directly influenced by the participants' funds of knowledge, it gave them more freedom and control of their learning and ultimately their success. Where success is a positively affected, participant attitudes improve as well.

However, participants in the Intervention course also alluded to the need to using previously learned solution methods. Problem posing seemed to have an effect here and leans towards the need of the levels of posing for scaffolding. Problem posing affected the participants in a negative way where they became anxious by working through a new procedure to address algebraic word problems or had to focus on multiple steps in the same task. This is highlighted by students being overwhelmed when posing personalized problems and coming up with their own numerical statements.

In the interviews, participants noted specific items that impacted their beliefs and attitudes that may not have necessary have been contributed to problem posing. The participant attitudes and beliefs covered a vast array of influences and effects from varying points. It was highlighted that participants associated much of their beliefs about themselves and mathematics based on prior school experiences, how they had been previously been taught and influences. Where teachers were mentioned as negative experiences, much dealt with the instruction according to the participants. This manifested into a lack of conceptual understanding and poor grades. Several participants attitude towards success was dependent on their grades. Questionnaire responses and interviews for the Intervention course alluded to that the notion of success was shifting away from being dependent on grades alone but also conceptual understanding, where this was not the case for the Control course.

Question Four: Impact on Mathematical Proficiency (as measured by the pre and posttest)

Problem Posing and the impact on mathematical proficiency was observed through the pre and posttest as well as the interviews. Participants did not discuss proficiency but discussed their understanding of the material.

Student impact on proficiency was gauged based on the pre and posttests. An analysis of each test within each course was performed. Students will be referred to participants. Of the 38 participants that elected to participate in the Control course, 32 completed the pretest and 36 completed the posttest. Of the 35 participants that elected to participate in the Intervention course, 26 completed the pretest and 32 completed the posttest. All outcomes for both courses were recorded and analyzed in both pre and posttest but only participants that completed both pre and posttest were compared for analysis between courses. 31 participants from the Control course and 25 participants from the Intervention course completed both pre and posttests. Results from both courses are given in the following sections. After the results are presented, the impact of problem posing on the participants' mathematical proficiency will be discussed.

Overall results. Comparison of pre and posttest analysis is summarized in Table 14:

Table 14

Pre and Posttest Scores

	Pretest	Posttest	Difference	Std Deviation of Difference	% Change
Control	58.78	80.76	21.98	21.05	53.32
Intervention	44	79.29	35.29	14.09	63.01

Figure 19 represents the graphical comparison between average scores

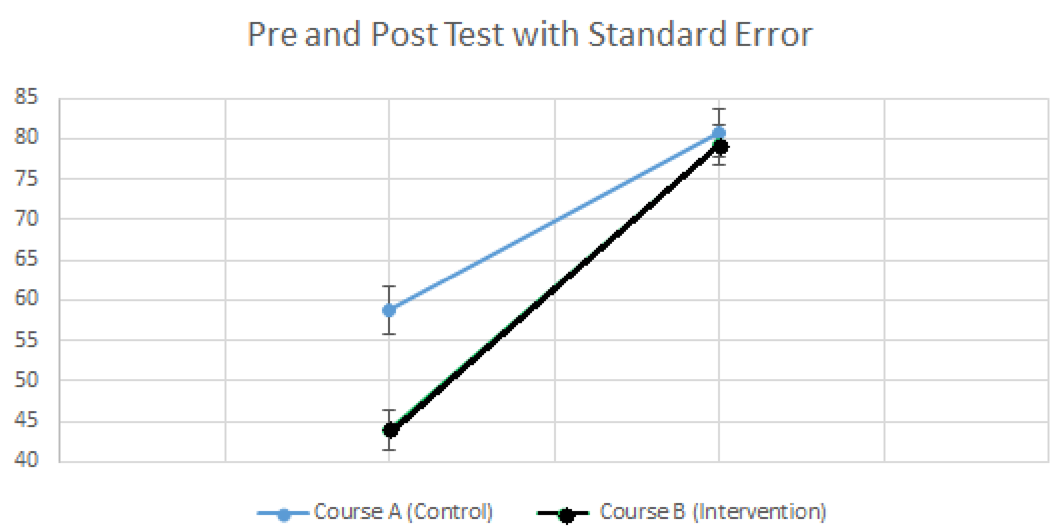


Figure 19: *Pre and Posttest with Standard Error*

Scores on the pretests lie outside of the standard error of one another while the scores of the posttest lie within the standard error of both courses. Average of the differences and their standard errors lie outside one another (See Table 15). Percent growth standard errors lie within the standard error of one another (See Table 16). Participants of the Intervention course showed more growth than those in the Control course, even though the Control course out preformed the Intervention course on both pre and posttests. Participants of the Intervention course obtained more of their potential improvement than the Control course.

An independent samples *t* test was ran to measure the level of significance between the pre and posttests, for each course. This was ran due to the small sample sizes of both courses. Analysis of the *t* test between each calculation is given in Table 17.

Table 17

T Test Analysis

	t	df	Significance (2-tailed)*
Pre-Test	3.698	54	0.000
Posttest	0.385	54	0.702
Change	2.822	54	0.007
Growth	1.524	54	0.135

Note: *Significance at $p<0.05$

Significance at the .05 level can only be observed at pretest scores and difference of pre and post-test scores. Both posttest and growth show no significant difference in means.

Pretest results. Pretest results varied between to the two courses. There pretest was made up of nine questions that came from the course materials. From the 32 participants of the Control course, this resulted into 288 responses. Of these responses from the Control course, 67 were scored as correct (23.26%), 2 were scored as partial (.69%), 57 were scored as incomplete (19.79%), 95 were scored as incorrect (32.99%), and 67 were scored as blank (23.26%). From the 26 participants from the Intervention course who took the pretest, resulted in 234 responses. Of these responses from the Intervention course, 52 were scored as correct (22.22%), 4 were scored as partial (1.71%), 40 were scored as incomplete (17.09%), 103 were scored as wrong (44.02%), and 35 was scored as blank (14.96%). Less than 25% of the questions were correct or partial correct from both the Control and Intervention courses. The Control course had a higher pretest average with 58.42 with a standard deviation of 16.42 compared to the Intervention course with an average of 43.06 with a standard deviation of 13.11.

Posttest results. Responses and averages increased for both courses. Of the 252 responses from the 36 participants who participated in the Control course, 165 were scored as correct (65.48%), 28 were scored as partial (11.11%), 18 were scored as incomplete (7.14%), 38 were scored as wrong (15.08%), and 3 were scored as blank (1.19%). Of the 224 responses from the 32 participants who participated in the Intervention course, 138 were scored as correct (61.61%), 28 were scored as partial (12.5%), 15 were scored as incomplete (6.70%), 34 were scored as wrong (15.18%), and 9 were scored as blank (4.02%). Less than 25% (23.4%) of the responses were graded incomplete, wrong, or blank for the Control course and approximately 26% (25.9%) of responses were graded incomplete, wrong, or blank for the Intervention course. The class average for the Control course improved to score of 81.15 with a standard deviation of 16.16. The class average for the Intervention course improved to a score was 78.13 with a standard deviation of 13.57.

Comparisons of Control and Intervention Scores. Scores of participants that were not present or did not participate in either or both pre or posttests were excluded from comparison between the Control and Intervention courses. Participants were compared within their respective courses and analyzed for growth between the pre- and posttests as well as compared to the other course. For the Control course, 31 participants completed both pre and posttests, while 25 participants from the Intervention course completed both pre and posttest.

Comparison of Control pre and posttest. Excluding participants that did not participate in either or both tests, the average and standard deviation of the value score on the pretest was (M = 58.78, SD = 16.56) and on the posttest (80.76,16.17), an increase of 21.98. To gauge the improvement of scores, differences of the participant pre and posttest scores were calculated, and the average and standard deviation of the differences was also calculated. The total percentage change was calculated by the participant possible improvement, see Figure 9. The average of differences in participants scores was 21.98 with a standard deviation of 21.05. Standard deviations were calculated from a non pool variance. Of the 31 participants, 26 showed growth, while 5 did not. This resulted in a 53.32% growth for the Control course.

Comparison of Intervention pre and posttest. Excluding participants that did not participate in either or both tests, the average and standard deviation of the value score on the pretest was (M = 44, SD =12.44) and on the posttest (M = 79.29, SD =12.46), an increase of 35.29. To also gauge improvement, analysis of the difference of scores and percentage growth was calculated. The average difference of participant scores was 35.29 with a standard deviation of 14.09. Of the 25 participants, all 25 increased their scores from pre to posttests. This represented a total percentage growth of 63.01%

Comparisons within the courses. In addition to examining the control and intervention courses, a detailed analysis of the mathematical proficiency of the participants in the two courses was examined by dividing the participants in each course into three groups - Low, Middle, and High, based on their scores in the pre-test. The goal was to get a sense of the improvement being made by subsets of the students and to examine if there was any impact of the problem posing experience on the students' scores. Growth was observed within each course. The group differences from the pre and posttest and averages are summarized in Table 18.

Comparing the highest participants to the lowest participants within each course, participants in the lowest in group in the Control course showed a greater increase in score than the high group as well as almost double the percentage obtainable growth than that of the highest group. This is similar for the Intervention course, where the lowest group obtained a higher change in score, but both the highest and lowest group increased over 50% of their perspective obtainable growth. Outcomes of Posttest, and percentage Growth all lie within the standard error of each course. Both differences of the Control and Intervention courses lie outside the standard error.

Comparing the highest groups and lowest groups from both courses, participants from the highest group in the Control course improved their scores by only 6.55% whereas participants in the Intervention course improved their scores by 22%. This showed an average growth of 30.48% and 57.43% respectively. The Intervention course showed greater percentage of obtainable gain than the Control course. For the lower groups within the Control and Intervention courses, participants improved by 36.36% and 42.38%, where the Intervention course's lowest participants showed greater percentage obtainable growth (63.7%) compared to the Control course's lowest (62.5%). Outcomes of the posttest, differences and percentage Growth lie within the standard error of each comparison excluding difference between the high groups of the Control and Intervention courses.

When observing which course made the largest gains when comparing all groups, (See Table 19) the highest percentage growth obtainable increase was for the middle group of the Intervention course, who showed 68.2% growth. The Intervention course's lowest group showed the next highest gains, followed by the lowest group from the Control course. The Intervention course's highest group showed close to 14% more gain than the Control course's middle group and close to 27% more than the Control course's highest group. Participants from the Intervention course showed more percentage growth in all groups excluding the lowest group for the Control course.

Problem posing and understanding. The participant interviews provide some insight into the possible reasons for the observed growth from the pre- to the post-test. Participants in the interviews also noted areas of understanding or the lack thereof. Several participants noted in class that they felt they did not know how to solve the word problems until they knew what mathematical concept the theme of the problem was. This was highlighted by several of the interviewees as well. One of the interviewees was Participant 108, who was also within the Middle (Intervention) group and was one of the participants that showed the most growth. Participant 108 mentioned they did understand the concepts of the equations and understood the setup of mark up and mark down problems due to being more engaged with problems that involved money and family. Participant 108 had some the most diverse posed problems. She also was also one the participants that produced the most personalized posed problems. Participant 108 noted that having personalized problems helped with understanding specific concepts that she had struggled with previously. Areas where she did not engage with problem posing, she stated that she continued to struggle. For example, Participant 108 noted she struggled with the quadratic formula. Due to time, the course did not have the opportunity to be exposed to posing problems that were quadratic. Participant 108 might have been able to understand the quadratic formula more if she had the opportunity to pose problems based on those concepts with her own personalized topics.

Participants also noted understanding from types of problems they posed. By mimicking and trying their own numbers, several participants noted they were able to make sure their numbers were valid or not through the outcomes. Some would make sure the equations and solutions worked prior to writing the problem. Participant 116 was ranked in the high group but was on the periphery of being in the middle group. She approached posing problems in a similar light when she validated solutions prior to personalizing the problem. Participant 116 stated they made sure the numbers worked first, if it did make sense, they switched them. When numbers came out incorrect, she would address the equations. This was difficult for most participants, including Participant 116. For example, Participant 116 discussed when they were working with systems of linear equations (noted mixtures), they once got a negative quantity. For this example and referencing previous examples from class, they knew that there could not be a negative quantity. Because of this, they did not know what to do at first, since as a class, we had never discussed or posed a similar problem with this situation. Once discussed, Participant 116 noted they would double check their problems, which made a big difference in understanding of the concepts. If a similar situation came up with a negative number, Participant 116 found a way to adjust the other variable so that the variable would valid and not be a negative value. Participant 108 had a similar approach. They looked to make numbers that fit and avoid quantities that they felt would become negative. Participant 108 stated that once they found the solutions were not negative, writing the problem was easy. Most of the understanding statements stemmed from involving understanding correct solutions within the word problems. Participant 108 in one situation stated, "you can have negative numbers, they have to be common sense." And Participant 120 discussed with some problems, they had to figure out the numbers by substituting them in.

Where mimicking did help with some of the problem posing and for some finding valid solutions, others did not find understanding in the concepts from problem posing. Where those who did, they noted they understood the material better because they knew what to look for in their solutions and how the problems were set up. Several even mentioned they notice "the patterns" in the set ups with linear word problems and constant slope and made the connection to what slope represented in the context of the problem. Several participants made this observation about the posing and understanding from the class.

Conclusion of analysis on impact on proficiency. Problem posing did impact participant performance on the posttests. Participants that took both pre and posttest from the Intervention course, all showed positive growth, whereas this was not the case for the Control course. The Control course showed a higher percentage obtainable growth than the Intervention course. When observing the standard deviation and standard error of both courses, the Intervention course performed closer to the average, showing there was less variation in the data. This made the Intervention course more predictable in their averages and growth. There was statistical significance for difference in means for the difference in pre and posttests for the Control and Intervention courses. Additionally, where all performance courses increased from pre to posttest, the Intervention course showed the most growth with the highest and middle reaching above 80% as compared to only the highest of the Control course. the Control course's lowest group was close to obtaining the 80% on the posttest (79.55%). the Control course's middle group and Intervention's lowest group both scored above 75% with 76.49% and 75.71% respectively.

However, observing the overall averages for both the Control and Intervention courses posttests, both courses averages were close to the Intervention course average (Control course difference of 2.24% and Intervention course difference of 3.71%). This very close to the lower bound of the Intervention course average. Both courses were under. Where addressing if problem posing impacted proficiency, participants from the Intervention course did not show statistical significance in impact when compared to the Control course. This is mostly due to the small sizes of both courses. Where there was influence on participant performance based on the problem posing, there is not enough evidence to conclude statistical significance.

Participant understanding was important but may be viewed as procedural understanding and knowing how to pose problems. Not until the end of the study did participants openly see that they in fact conceptually understood the material better than they had previously thought. Much of this could be based on how the varying participants engaged with problem posing and how in depth they pose the problems. For Participants 108 and 116, the level of posing and validating their solutions to their personalized problems helped them build a higher conceptual understanding. For others who did not engage in developing their own value in numerical free, still engaged with other levels of posing but may not have benefited as much as those who engaged with numerical free. Those participants sought to validate, which moved them to a deeper understanding. However, there is some argument to be made for participants from the Intervention course and their conceptual understanding when compared to the Control course. Participants in the Intervention course showed more growth than the Control course, implying understanding of the material.

CHAPTER FIVE: CONCLUSION

Overview

This chapter will discuss the results of the study. Recall, that the research questions guiding the study were “how do developmental mathematics students engage with problem posing? More specifically, what problems do developmental mathematics students design based on their personal experiences? Further, what impact does problem posing have on their mathematics proficiency, and beliefs and attitudes about mathematics?

The quantitative and qualitative analysis revealed the impact that the intervention of problem posing had on the students in the developmental mathematics course. The key results within each result will be highlighted and discussed with respect to previous studies.

How did students engage with problem posing and what types of problems did they pose? The students in the course were experiencing problem posing for the first time. Their level of engagement was found to depend on multiple features. These included the level of problem posing, context of the problem, involvement of the task, concept of the problem, and posing as its own instructional approach. Each one of these items will be highlighted below.

Level of posing. The levels of problem posing in this study were structured, semi-structured, and free. Free was viewed in two categories, context free and numerical free. Note that a scaffolded approach was taken to problem posing where the authority to design the problems was gradually released to the students in the Intervention course. The participants engaged with context free and semi-structured problems more than any other level of posing. Based on the participant work and discussions, participants felt they had more support for their thinking when they engaged with semi-structured problem posing. Further, they noted that there was more freedom within the context free problem posing. The underlying connection to these two levels was that participants were given the numerical statements or values. Most participants engaged and felt more likely to be successful when they knew the statements were correct and values were valid. The participants were always concerned that if they were given the freedom to choose the values for the problem, their answers would not work out or be reasonable within the context (e.g. getting a negative cost of a clothing item). By having the values, the participants mentioned that this freed them up to be innovative in the context that was requested. There was less cognitive load dedicated to the feasibility of the answers. This concern was reflected in the low engagement in the numerical free problem posing. Participants felt overwhelmed when trying to come up with numerical statements and values that fit the given context, and many chose not to participate or attempt these tasks. The participants also did not engage extensively in structured problems. Participants noted that structured problem posing was too constraining and felt it did not have any freedom to personalize. Thus, the participants found semi-structured and context free more engaging; both required less cognitive load to perform the task. This explains a high level of engagement and return of original problems. There was less involvement in what the tasks required, but more freedom for the participants. This provided an opportunity for participants to try to pose more in-depth problems due to not feeling overburdened with multiple items for them to consider, allowing participants to engage more openly to posing problems more personal to them.

Context of the problem. Participant engagement also depended on the contexts of the problems, when these were provided. Depending on the subjects of the problems, participants felt more inclined to participate or not if they found the topic relatable. Participants were more likely to engage and pose problems that they found relatable to them and controlled what the topics were in the problems. Problems that were posed and personalized related to participants' personal interests and experiences that they felt could be adapted to the tasks being presented. If this was not the case, then they picked random topics or mimicked from the class examples. Personalization also depended on the level of involvement of the task as well as the constraints. Participants were more likely to personalize problems within semi-structured problems due to the tasks of posing being less involved. Participants were already given the statements and an overall general context, many incorporated personal experiences or changed to subjects to make it more personal. Participants were less likely to personalize posed problems within the numerical free level of posing due to the existing cognitive load of trying to come up with their own values or numerical statements. If participants personalized the numerical free problems, they shifted their focus from problems that had valid solutions to a personalized problem without a solution.

The results showed that participants did not use interests or experiences they had documented in the questionnaires. Many participants used situational interests that were relevant to that specific time of the tasks. With the study conducted around the time of Thanksgiving and Black Friday, many of the participants posed problems on the topics of shopping, travel, families, and other activities occurring during that time of year. Money was one of the largest subjects within the personalized problems along with family.

Students felt more comfortable with posing problems about money and family because they found those topics and individuals more relatable and familiar. In addition to problems with money or family, other topics of interests that came up were current television shows, majors or careers they aspired to go into also came through in posed problems. Participants engaged with problems that they found more relatable to previous, current, or future life experiences.

Instructional approach. Engagement for several participants depended on how they accepted the new instructional approach of problem posing. At first, many participants were not willing to engage in a new instructional method. Some disengaged due to this being a different approach to learning mathematics. Though some participants felt disengaged, most became more open to problem posing with engaging slowly and methodically. Several participants discussed that moving through the various levels helped with learning how to pose a problem and alleviated some doubt of not being successful. Others also noted that some of their first posing tasks were less involved and allowed them more freedom and control to pose problems with their own wording. Most of the original problems were posed during this time. Participants felt more successful and relinquished some of the fears of a new instructional approach. When less scaffolding was used, some participants mimicked class examples to ensure they were still correct but continued to engage with problem posing.

Although the problem posing was a new experience for the students in the developmental mathematics course, the placement of the intervention during the last five weeks of the course meant that the participants worked with concepts that they had studied earlier in the semester. Thus, the participants felt some level of comfort with posing problems. Several participants discussed how it was nice to not try to pose problems based on tasks they were currently trying to learn. Many felt that it would be too challenging to adapt to a new teaching approach and learn a new mathematical concept at the same time. Most of the participants were open to the use of problem posing as a way for them to review old material in the course as they prepared for the final exam at the end of the course. Similarly, participant engagement also alluded to topics that students continue to struggle with based on their level of engagement. Participants engaged less in posing problems based on tasks that involved ratios and proportions. With the lowest return, these tasks showed students less willing to pose problems about ratios. Much of this may be due to the cognitive demand on the participants to pose a problem on concepts that they had previously struggled with, therefore choosing to disengage altogether.

Even though participants engaged with problem posing, computation was still their biggest focus. Many continued to revert to the belief that there was a single answer to a mathematics, and it was important for the student to get the correct answer to a problem. Thus, the participants made the extra effort of solving the problem they designed, even when they were not explicitly asked to do so. Thus, many of the participants preferred semi-structured and context free posing. It reassured them to know that when they posed the problem, it was solvable. This was not the case for many for numerical free posing. Participants omitted the personalization of a problem with personal interests or experiences to ensure the problem was mathematically accurate.

In summary, it was found that students are more engaged with areas of their personal interests as noted by Rellsensmann and Schukajlow (2017). These interests affected the engagements and connection to the mathematical activity of problem posing and the given tasks within. Participants from the study were either disinterested from the subjects of the problems or either problem posing as an instructional approach, became more disengaged with the course. Additionally, based on the requirements of the participants, it was found that a higher cognitive load produced minimal engagement and lack of deeper personalization of posed problems, where students reverted back to focusing on the computation with little reflection on the topics themselves (Mji & Glencross, 1999; Schoenfeld, 1989). Participants were provider more scaffolding, it decreased the cognitive load, and provided a deeper focus on relationships within the problems and a heightened level of engagement (Mji & Glencross, 1999; Ramsden, Martin, & Bowden, 1989) and higher likelihood to related to previous concepts and personal experience (Mji & Glencross, 1999; Watkins & Regmi, 1995).

Participants from the study engaged in problem posing where they felt more open and had the freedom to pose based on what they felt was more relatable to them. They felt in more control, which was a different feeling that many had not experienced in a mathematics course prior to this experience. Many participants were hesitant at first but felt more comfortable and engaged more due to having a scaffolding of constraints that assisted them in their posing of the tasks. Participants still focused on the worry of not getting the right solution or valid solution so disengaged with posing tasks that made them question their own conceptual understanding of the topic or concept being posed. When asked to solve and personalize, it was too much of a cognitive load for some and they chose to either focus on either the creation of the numerical statements or personalization separately or disengage from problem posing entirely. However, when participants were reassured that the statements and values given were valid and had solutions, participants were more willing to engage with problem posing and use their own personal interests and experiences and look beyond the numbers of the problem and focus on the context.

How did problem posing affect students' attitudes and beliefs? Attitudes and beliefs did have an influence on how the Control course and Intervention course engaged with the mathematics. This was observed through the first questionnaire. As the participants progressed in both courses, there was slight changes to some of the attitudes and beliefs of both courses. Upon implementing problem posing with the Intervention course, there were several instances where the Control and Intervention courses had different outcomes in attitudes and beliefs on the third questionnaire.

The participants in the Intervention course showed an increased willingness to explore mathematics beyond the traditional approach and were willing to engage with tasks that participants may not have engaged with previously. Most of this willingness to explore and try new tasks stemmed from having a solid foundation of conceptual understanding and being able to rely on previously learned solution methods, as well as freedom to use their own personal interests or experiences. Participants improved their attitudes of self-exploration; however, they also had difficulty disconnecting from their beliefs of needing to have a template or reference to review if they were to struggle. If problems did not resemble previously done tasks or familiar context, several participants would not engage with that task. This echoed the notion made by Pajares (1992) where depending on the participant's attitude, is their willingness to attempt new and advanced problems and will avoid conflicting the previously deep seeded beliefs and not engage with a task.

Freedom to use personal interests and experiences helped improve participants attitudes, but also negatively affected participants with being overly anxious. Much of this was based on engaging with a new way of addressing word problems and focusing on multiple items within the same task. Participants believed they could perform the task and find a solution, if they were not asked too much. For example, participants' attitudes towards numerical free were more negative than semi-structured and context free posing. More participants became frustrated when they had to personalize a problem and find numerical statements that also had a valid solution. Participants had more positive attitudes towards how they could perform if they were given the numerical statement. The larger cognitive load impacted the attitudes of the participants and dictated the progression of many of them. Only if participants could observe foreseeable success, would they move beyond negative beliefs about their success. Participants felt that if they had a better chance of being successful, this attitude affected their overall confidence of getting a better grade. Where participants' focus was still on being successful, much of this success was shown to shift from grades alone to also having conceptual understanding.

How did problem posing affect students' proficiency? When comparing the Control and Intervention courses, there was no statistically significant difference in post-test score means or growth within each course. Problem posing did in fact have an impact on individual participants from Intervention. For these individual participants, problem posing impacted each differently based on their engagement. When participants were divided into thirds based on their pretest scores, the Intervention course participants from the middle third and lower third showed greater growth than those in the highest group in the Intervention course and all the groups from the Control course. When this was discussed with participants from the Intervention course, more insight was given based on where the participants began with the pretest scored and finished with the post-test score. Additionally, it was also based on how those participants engaged with the levels of problem posing. Several participants from the middle and lower groups in the Intervention course mentioned that they focused on the outcomes of the problems first, then personalized the problem. The focus was also based on the validity of the solution. The students who checked their solutions showed the most growth. Those students would check their solutions for validity and algebraic correctness and had the highest increase from pre to posttests. Problem posing engaged the participants with the content. The participants who went beyond just posing with personalized content and validated their solutions and thus benefitted the most. This helped participants achieve a deeper conceptual understanding.

Comparison to Previous Studies

This study draws on and reiterates similar findings of how problem posing impacts student outcomes and understanding. As found in previous studies, word problems persist to be difficult for students (De Corte, Verschaffel, & De Winn, 1985; Ku and Sullivan, 2000; Vicente, Orrantia, & Verschaffel, 2007; Walkington, Clinton, & Shivraj, 2018; Walkington & Bernacki, 2015). Participants from both courses noted that they struggled with word problems, and for the Control course, took little interest in solving word problems. As found in similar studies (Powell, 2011), participants from the

Control course found themselves disassociated with word problems based on the context. However, participants from the Intervention course gravitated towards word problems based on the contexts that they could incorporate. As found by Yee and Bostic (2014), those in a rich problem solving environment had better problem solving skills than those in a traditional environment, specifically participants in the Intervention course showed they were more engaged to solve the problems and as the study progressed as opposed to participants in the Control course with the absence of problem posing.

Much in part due to problem posing, participants from the Intervention course found themselves more motivated to solve the word problems based upon the personalized context of their posed problems. Like the studies performed by Ku and Sullivan (2000) and López & Sullivan (1992), participants from the Intervention course were more motivated and engaged more with problem solving of word problems due to the personalized nature of the problems they posed, even if participants found it challenging. With problem posing, the Intervention course participants transitioned into active learners and had the opportunity to navigate the problems they posed within their areas of interest (Goldenberg, 1993; Lavy & Bershadsky, 2003; Moses, Bjork, & Goldenberg, 1990). Problem posing allowed participants from the Intervention course to be more open to explore alternative approaches to challenging problems, as highlighted in the Intervention course's questionnaires.

Where participants from the Intervention course were more likely to explore multiple approaches, they kept to only utilizing a few. Many chose to not approach multiple approaches and disengaged with problem-solving based on the level of posing. Similar to the study conducted by Arikan and Unal (2015), the Intervention course participants found it difficult to pose and use different problem-solving approaches. Due to this, many of the participants only used one or two approaches. For the Intervention course, most of this was due to posing numerical free problems where they not only had to develop values and numerical statements, but also personalize the given context. This proved to be too heavy of a cognitive load for participants in Arikan and Unal's (2015) study and participants in Intervention. Even with personalizing the problems, it did not lessen the cognitive load as found by Ku and Sullivan (2000). Participants from the Intervention course still had difficulty solving the tasks. Furthermore, participants in the Intervention course needed additional scaffolding and were more likely to engage with problem posing that only had the numerical statement given. This lessened the cognitive load and allowed participants in the Intervention course to focus on either solving the given numerical statements or personalizing the problem.

Where more scaffolding of posing was in place, such as in semi-structured, participants posed more problems because it required less cognitive load to answer and personalize. More contextual information was given in the problem. This level of posing still provided the openness to include personal interests and experiences into the problems. Similarly, as Kontorovich, Koichu, Leikin, and Berman (2012) found with 16 high achieving high school students, due to participants having the flexibility of using personal interests but with infrastructure, participants were able to pose unique problems and solutions to the given tasks. Participants continued to have scaffolding in the structured level and additional freedom in the context free level of posing.

Participants openly engaged with each level of posing and many were successful at posing at each level. For participants that have self-professed being bad at mathematics and enrolling in developmental mathematics, contradicts the notion that only upper level students can problem pose. Arikan and Unal (2000) notes that non gifted mathematics students did not engage has much with problem posing as gifted mathematics students. Similarly, Lavy and Bershadsky (2003) also alluded in their study that only students who have been previously exposed to higher level of mathematics. This study supports that lower achieving mathematics students could also engage with problem posing and improve their problem solving of word problems. Arikan and Unal (2000) did note that their non-gifted students found problem posing enjoyable, useful, and necessary, a similar reaction as the Intervention participants.

Achievement and understanding also were impacted by problem posing. Similar to a study performed by Ross and Anand (1987) where it was found that personalized context within instruction and tasks increased achievement, the Intervention course participants showed greater growth on their achievement from the pre to posttest. Most participants improved their conceptual understanding mainly due to being engaged with problems that were similar to their own personal interests. Problems posed by the participants drew on their own knowledge and made it relatable to their own daily activity. As noted by Walkington and Bernacki (2015) and Lesh and Zawojewski (2007), this implementation of relatable mathematics into daily activity not only improved understanding but also showed to improve attitudes towards themselves and mathematics.

Implications of Current Study

Where much research has been conducted about problem posing, very little has been conducted with lower level students at the post-secondary level. Where it has been implied that lower performing students could not handle problem posing, this study shows otherwise. These participants illustrated that they were capable of engaging with problem posing while utilizing personal interests and experiences to build meaningful and relatable word problems. Several participants would continue to improve their problem-solving skills as a product of engaging with problem posing. Where research has noted that higher performing students do not see the need in problem posing (Arikan and Unal, 2000), lower achieving students did see the need for problem posing and were more likely to engage. Problem posing with this population of college/university students could provide insight to how these students address word problems and how could other instructors work with students to become more active problem solvers.

Limitations of Study

Both courses that were selected had students self-enroll prior to the start of the semester. This did not insure of a similar class demographic makeup. Enrollment was also limited to a fix number of students. The sample of 45 was the largest that either section could hold. With attrition of students based on electing to participant in the study, samples decreased even more. This created unparallel sample sizes for each course. Additionally, where participants had elected to participant, some were absent or did not complete other measurement items, therefore could not be used in analysis of those items. This decreased the samples and varied the sample size from the data instruments. Where these small and varied samples from each course did not impact the qualitative artifacts, it did impact the strength of the quantitative data.

The study was planned to run for 17 days, during the semester. Due to course interruptions due to inclement weather, the study was shortened to 12 days. These unexpected changes affected the instruction and the researcher had to adjust lessons accordingly. Missing artifacts could be attributed to in part to the missed instruction days. Additionally, a major holiday also occurred during the study which affected participant artifact return. The holiday was considered during the planning of the study, but due the inclement weather and cancellation of face to face meetings, impacted the instruction and artifact return.

This change in schedule also adjusted the type of problem posing tasks given to the participants. The premise was to scaffold through structured, semi-structured and free. However, several posing within each posing level, mostly in structured, were removed for curriculum to be covered, as per the expectation of the goals of the course.

Conclusions

This study was designed to investigate how developmental mathematics students engage with problem posing and more specifically, what problems do developmental mathematics students design based on their personal experiences. Further, it was also observed what impact does problem posing have on their mathematics proficiency, and beliefs and attitudes about mathematics. Based on the study, the following conclusions were made:

1. Developmental Mathematics students were able to engage with each level of problem posing.
2. Developmental Mathematics students engaged with problem posing by utilizing areas of personal interest or experiences that they found relatable to their everyday lives.

3. Developmental Mathematics students are more willing to engage with problem posing due to having the freedom to incorporate their personal interests and or experiences.
4. Problem posing impacted student attitudes on self-exploration and success but was limited to their beliefs on instructional needs and scaffolding.
5. Developmental Mathematics students found the cognitive load too high when engaging with numerical free posing.
6. For those developmental mathematics students who did engage with numerical free posing, were more likely to have a deeper understanding of the content due to addressing the validity of the posed numerical statements prior to personalizing the problems.
7. Students enjoyed participating in problem posing if they found the contexts of the problems relatable and useful to their everyday lives.

Recommendations for Future Research

Due to the study being conducted over a 17-day period, a study should be conducted that allocates more time to allow for students to have more opportunities to engage with problem posing as a new instructional method. This would allow for more scaffolding with structured, semi-structured, and free posing and more emersion into the new instructional method.

This study investigated the impact problem posing had on attitudes and beliefs of the students. There appeared to be some level of impact, future studies should incorporate more problem posing over a longer period to see if immersing students in problem posing for the longer period had greater impacts on student attitudes and beliefs.

While this study did focus on proficiency, the samples for comparison were too small to provide any generalizable outcomes to be addressed. Future studies should be conducted with larger sample sizes that would allow for power in the statistical analysis. Additionally, where developmental mathematics is focused to improve student proficiency and understanding for their college mathematics courses, future longitudinal studies could be conducted to address if developmental mathematics students perform equally to their peers that do not take developmental mathematics

Implications for Practice

Elementary, middle, and high school instructors should utilize problem posing as an additional instructional method. As noted by Abu-Elwan (1999), problem posing can be an essential fifth step in Pólya’s four step problem solving process. Problem posing can allow for students from varying backgrounds and mathematical capabilities to be more engaged have more opportunities to be successful. For those students who have begun to disconnect themselves from mathematics due to negative schooling experiences, lack of early success, low confidence, and negative attitudes can be given this alternative approach to help deter this negative change and lack of engagement. Many studies have shown effectiveness with problem posing at early ages but mostly with stronger or gifted students. This study illustrated that those students who are not as strong or not as gifted can still benefit from problem posing early on. This may improve early success, build confidence in themselves and create the beliefs that they in fact can be successful and in addition created positive attitudes so that moving forward, allows the student to be more likely prepared for college/university mathematics.

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Tables

Table 1

Examples of problem posing phases

Problem Posing Phases	Example: Given	Student Task
Structured	A student has a jar containing 65 coins, all of which are either nickels or dimes. The total value of the coins is $5.30.	Create as many problems using the same subject matter and values but with different individuals.
Semi-structured	Consider the statements: x + y =65 and .05x + .10y =5.30.	Create as many problems using personal interests involving currency
Free	Consider the statements: x + y =65 and .05x + .10y =5.30.	Create as many problems using personal interests based on the given constraints
	Consider the subject matter, (distance, area, markup/mark down, etc)	Create as many problems using personal interests based on the given subject matter.

Table 2

Pilot Study Beliefs Pre and Post Questionnaire Results

Question	Pre-Average	Post Average	Difference
1.Doing mathematics consists mainly of using rules.	4.2	4.1	-0.10
2.Learning mathematics mainly involves memorizing procedures and formulas.	4	4.2	0.20
3.Mathematics involves relating many different ideas.	3.7	4	0.30
4.Getting the right answer is the most important part of mathematics.	3.8	4.1	0.30
5.In mathematics, it is impossible to do a problem unless you've first been taught to do one like it.	3.2	3.8	0.60
6.One reason learning mathematics is so much work is that you need to learn a different method for each new class of problems.	3.4	3.5	0.10
7.Getting good grades in mathematics is more of a motivation than is the satisfaction of learning the mathematics content.	3.7	3.7	0.00
8. When I learn something new in mathematics, I often continue exploring and developing it on my own.	2.5	2.5	0.00
9.I usually try to understand the reasoning behind all of the rules I use in mathematics.	3.4	3.5	0.10
10.Being able to successfully use a rule or formula in mathematics is more important to me than understanding how and why it works.	3.7	3	-0.70
11.A common difficulty with taking quizzes and exams in mathematics is that if you forget relevant formulas and rules you are lost.	4.4	4.1	-0.30
12.It is difficult to talk about mathematical ideas because all you can really do is explain how to do specific problems.	3.2	3.5	0.30
13.Solving mathematics problems frequently involves exploration.	3.6	3.7	0.10
14.Most mathematics problems are best solved by deciding on the type of problem and then using a previously learned solution method for that type.	3.9	3.6	-0.30
15.I forget most of the mathematics I learn in a course soon after the course is over.	3.6	3.5	-0.10
16.Mathematics consists of many unrelated topics.	2.6	2.6	0.00
17.Mathematics is a rigid, uncreative subject.	2.7	2.7	0.00
18. In mathematics there is always a rule to follow.	4.4	4.1	-0.30
19. I get frustrated if I don't understand what I am studying in mathematics.	4.4	4.3	-0.10
20. The most important part of mathematics is computation.	3.3	3.5	0.20

Table 3

Pilot Study Attitudes Pre and Post Questionnaire Results

Question	Pre-Average	Post Average	Difference
1. I am always under a terrible strain in mathematics class	3.4	3.7	0.3
2. I do not like mathematics, and it scares me to take it	3.4	3.7	0.3
3. Mathematics is very interesting to me, and I enjoy arithmetic and mathematics courses	2.1	2.6	0.5
4. Mathematics is fascinating and fun	2.0	2.5	0.5
5. Mathematics makes me feel secure, and at the same time it is stimulating	2.3	2.3	0.0
6. My mind goes blank and I am unable to think clearly when working mathematics	2.7	3.3	0.6
7. I feel a sense of insecurity when attempting mathematics	3.5	3.8	0.3
8. Mathematics makes me feel uncomfortable, restless, irritable, and impatient	3.4	3.6	0.2
9. The feeling that I have toward mathematics is a good feeling	2.4	2.9	0.5
10. Mathematics makes me feel as though I'm lost in a jungle of numbers and can't find my way out	3.4	3.8	0.4
11. Mathematics is something that I enjoy a great deal	2.6	2.1	-0.5
12. When I hear the word mathematics, I have a feeling of dislike.	3.1	3.8	0.7
13. I approach mathematics with a feeling of hesitation, resulting from a fear of not begin able to do mathematics	3.7	3.5	-0.2
14. I really like mathematics	1.8	2.3	0.5
15. Mathematics is a course in school that I have always enjoyed studying	2.2	2.5	0.3
16. It makes me nervous to think about having to do a mathematics problem	3.4	3.4	0.0
17. I have never liked mathematics, and it is my most dreaded subject	3.9	3.1	-0.8
18. I am happier in a mathematics class than in any other class	2.1	2.3	0.2
19. I feel at ease in mathematics, and I like it very much	2.0	2.2	0.2
20. I feel a definite positive reaction toward mathematics; its enjoyable	2.0	2.2	0.2

Table 4

Criteria of Problem Posing Matrix: Color Coded

Categories of Posed Problems	Color	Criteria of Categories
Personalized (Written)	Green	Personal Interest Used (Based on Written Interest in Q1 and Q3)
Personalized (Not Written)	Yellow	Localized Interest- Includes class, instructor, location, and discussed interests during the course. (Was not given by student in Q1 or Q3 and not given in a problem by instructor)
Not Personalized	Red	Posed questions but did not use personal interests, written or stated otherwise, but was different than class examples.
Mimic	Blue	Similar or exact problems from the class examples. (All structured posing baseline will use example from class or instruction.)
Original (Not given option of personalization)	Orange	Original problems that were different than problems presented in class but did not use personal interest. Material was not given as an option to be personalized.
Not Available	Purple	Problems requested by instructor, but students did not turn in problem or assignment.

Table 5

Examples of problem posing phases

Problem Posing Phases	Example: Given	Student Task
Structured	A student has a jar containing 65 coins, all of which are either nickels or dimes. The total value of the coins is $5.30.	Create as many problems using the same subject matter and values but with different individuals.
Semi-structured	Consider the statements: x + y =65 and .05x + .10y =5.30.	Create as many problems using personal interests involving currency
Context Free	Consider the statements: x + y =65 and .05x + .10y =5.30.	Create as many problems using personal interests based on the given constraints
Numerical Free	Consider the subject matter, (distance, area, markup/mark down, etc)	Create as many problems using personal interests based on the given subject matter.

Table 9

Problem Posing Matrix Outcomes: Totals of Assigned and Return Within Each Level of Posing

Levels of Posing	# of Problems Assigned	# of Returned Pose Problems	Ratio of Returned to Assigned
Structure	1	14	14
Semi-Structure	15	270	18
Context Free	27	399	14.77
Numerical Free	10	192	19.12
Total	53	875	16.50

Note: Each assignment based on 35 students and returned is the number of returned problems from the assignments.

Table 10

Problem Posing Matrix Outcomes

Categories of Student Posed Problems	Totals within each category	Mean Return Rate
Personalized (Written)	83	2.37
Personalized (Not Written)	233	6.66
Not Personalized	146	4.17
Mimic	40	1.14
Original	373	10.66
Not Available	1007	28.77

Table 11

Problem Posing Matrix Outcomes: Totals Within Each Level of Posing

Categories of Student Posed Problems	Structured	Semi-Structured	Context Free	Numerical Free	Total Per Category
Mimicked	3	21	10	6	40
Original	0	61	232	80	373
Personalized	11	188	157	106	462
Total Per Level	14	270	399	192	875

Table 12

Comparison of Beliefs Averages with Standard Error

		Averages		Standard Error of Mean	
Question	Questionnaires	Control	Intervention	Control	Intervention
Q1:1	Questionnaire 1	4.094	4.222	0.158	0.145
	Questionnaire 2	3.969	4.148	0.177	0.166
	Questionnaire 3	3.844	3.852	0.163	0.190
Q1:2	Questionnaire 1	4.344	4.222	0.139	0.209
	Questionnaire 2	3.813	3.852	0.171	0.166
	Questionnaire 3	3.844	3.852	0.175	0.190
Q1:3	Questionnaire 1	4.000	4.185	0.180	0.169
	Questionnaire 2	4.156	4.111	0.150	0.172
	Questionnaire 3	4.094	4.111	0.151	0.123
Q1:4	Questionnaire 1	3.406	3.074	0.215	0.213
	Questionnaire 2	3.063	2.741	0.229	0.189
	Questionnaire 3	3.000	2.926	0.180	0.232
Q1:5	Questionnaire 1	2.969	3.148	0.260	0.260
	Questionnaire 2	2.938	2.963	0.215	0.223
	Questionnaire 3	3.219	2.815	0.209	0.200
Q1:6	Questionnaire 1	3.563	3.704	0.200	0.191
	Questionnaire 2	3.188	3.222	0.182	0.229
	Questionnaire 3	3.313	3.296	0.188	0.244
Q1:7	Questionnaire 1	3.719	3.111	0.207	**0.252**
	Questionnaire 2	3.375	3.222	0.209	0.252
	Questionnaire 3	3.438	3.519	0.185	0.252
Q1:8	Questionnaire 1	2.094	2.407	0.158	0.215
	Questionnaire 2	2.406	2.407	0.190	0.215
	Questionnaire 3	2.219	2.481	0.204	0.222
Q1:9	Questionnaire 1	3.281	3.074	0.230	0.244
	Questionnaire 2	3.250	3.111	0.215	0.258
	Questionnaire 3	2.906	3.185	0.192	0.220
Q1:10	Questionnaire 1	3.094	3.074	0.226	0.256
	Questionnaire 2	2.969	2.963	0.182	0.264
	Questionnaire 3	3.219	3.074	0.184	0.232
Q1:11	Questionnaire 1	4.469	4.333	0.135	0.160
	Questionnaire 2	4.094	4.370	0.164	0.152
	Questionnaire 3	3.969	4.222	0.165	0.163
Q1:12	Questionnaire 1	3.656	3.222	0.153	**0.202**
	Questionnaire 2	3.281	2.815	0.192	**0.177**
	Questionnaire 3	3.219	3.259	0.178	0.230
Q1:13	Questionnaire 1	3.656	3.444	0.153	0.202
	Questionnaire 2	3.594	3.667	0.173	0.151
	Questionnaire 3	3.563	3.481	0.168	0.195

		Averages		Standard Error of Mean	
Q1:14	Questionnaire 1	4.125	3.963	0.147	0.210
	Questionnaire 2	3.875	3.889	0.160	0.187
	Questionnaire 3	3.875	4.222	0.147	**0.123**
Q1:15	Questionnaire 1	4.000	3.778	0.215	0.216
	Questionnaire 2	3.531	3.519	0.215	0.216
	Questionnaire 3	3.500	3.444	0.229	0.258
Q1:16	Questionnaire 1	2.375	2.704	0.200	0.225
	Questionnaire 2	2.250	2.148	0.196	0.205
	Questionnaire 3	2.406	2.556	0.210	0.209
Q1:17	Questionnaire 1	3.063	2.630	0.210	0.262
	Questionnaire 2	2.625	2.074	0.205	**0.206**
	Questionnaire 3	2.719	2.185	0.202	**0.220**
Q1:18	Questionnaire 1	4.063	4.074	0.155	0.159
	Questionnaire 2	3.969	4.185	0.198	0.160
	Questionnaire 3	3.813	3.815	0.176	0.169
Q1:19	Questionnaire 1	4.625	4.519	0.133	0.163
	Questionnaire 2	4.219	4.407	0.194	0.171
	Questionnaire 3	4.000	3.741	0.201	0.224
Q1:20	Questionnaire 1	3.188	3.370	0.145	0.186
	Questionnaire 2	3.438	3.111	0.155	0.180
	Questionnaire 3	3.375	3.222	0.172	0.195

Note: Bolded values represent standard error of means that do not overlap.

Table 13

Comparison of Attitudes Averages with Standard Error

		Averages		Standard Error of Means	
Question	Questionnaires	Control	Intervention	Control	Intervention
Q3:1	Questionnaire 1	3.656	3.407	0.194	0.252
	Questionnaire 2	2.750	2.889	0.201	0.263
	Questionnaire 3	2.875	2.852	0.237	0.254
Q3:2	Questionnaire 1	3.500	2.926	0.215	**0.311**
	Questionnaire 2	2.750	3.000	0.238	0.261
	Questionnaire 3	2.813	2.926	0.226	0.256
Q3:3	Questionnaire 1	2.281	2.370	0.192	0.245
	Questionnaire 2	2.531	2.889	0.211	0.252
	Questionnaire 3	2.750	2.815	0.233	0.227
Q3:4	Questionnaire 1	2.031	2.481	0.193	**0.247**
	Questionnaire 2	2.344	2.630	0.188	0.234
	Questionnaire 3	2.531	2.519	0.211	0.222
Q3:5	Questionnaire 1	2.188	2.000	0.203	0.239
	Questionnaire 2	2.375	2.519	0.194	0.241
	Questionnaire 3	2.594	2.667	0.237	0.207
Q3:6	Questionnaire 1	3.594	3.556	0.205	0.209
	Questionnaire 2	2.875	3.037	0.214	0.247
	Questionnaire 3	3.063	3.111	0.246	0.252
Q3:7	Questionnaire 1	3.906	3.667	0.203	0.233
	Questionnaire 2	3.000	3.444	0.196	**0.247**
	Questionnaire 3	3.094	3.148	0.235	0.231
Q3:8	Questionnaire 1	3.656	3.111	0.218	**0.258**
	Questionnaire 2	2.781	3.000	0.219	0.233
	Questionnaire 3	3.000	2.815	0.238	0.231
Q3:9	Questionnaire 1	2.125	2.519	0.189	0.247
	Questionnaire 2	2.875	2.926	0.178	0.261
	Questionnaire 3	2.844	3.000	0.225	0.233
Q3:10	Questionnaire 1	3.750	3.481	0.196	0.235
	Questionnaire 2	2.688	2.889	0.231	0.235
	Questionnaire 3	2.813	2.778	0.231	0.241
Q3:11	Questionnaire 1	2.000	2.296	0.191	0.225
	Questionnaire 2	2.219	2.667	0.189	**0.256**
	Questionnaire 3	2.531	2.630	0.215	0.227
Q3:12	Questionnaire 1	3.563	3.111	0.200	0.263
	Questionnaire 2	2.750	2.815	0.196	0.251
	Questionnaire 3	3.063	2.889	0.210	0.258
Q3:13	Questionnaire 1	3.844	3.667	0.180	0.214
	Questionnaire 2	2.938	3.444	0.215	**0.241**
	Questionnaire 3	3.031	3.074	0.203	0.250

		Averages		Standard Error of Means	
Q3:14	Questionnaire 1	2.000	2.259	0.180	0.217
	Questionnaire 2	2.469	2.852	0.201	0.243
	Questionnaire 3	2.313	3.148	0.208	**0.231**
Q3:15	Questionnaire 1	1.969	2.148	0.208	0.212
	Questionnaire 2	1.938	2.185	0.195	0.220
	Questionnaire 3	2.156	2.296	0.211	0.225
Q3:16	Questionnaire 1	3.531	3.333	0.190	0.256
	Questionnaire 2	2.719	2.593	0.192	0.209
	Questionnaire 3	2.750	3.074	0.220	0.244
Q3:17	Questionnaire 1	3.313	3.111	0.256	0.284
	Questionnaire 2	2.625	2.852	0.219	0.276
	Questionnaire 3	2.969	2.815	0.240	0.278
Q3:18	Questionnaire 1	1.656	1.926	0.166	0.199
	Questionnaire 2	2.188	2.296	0.165	0.266
	Questionnaire 3	2.250	2.593	0.201	0.257
Q3:19	Questionnaire 1	1.688	1.926	0.171	0.192
	Questionnaire 2	2.219	2.519	0.166	0.247
	Questionnaire 3	2.375	2.704	0.200	0.266
Q3:20	Questionnaire 1	1.875	2.148	0.184	0.205
	Questionnaire 2	2.531	2.630	0.211	0.268
	Questionnaire 3	2.531	2.667	0.238	0.250

Note: Bolded values represent standard error of means that do not overlap.

Table 15

Mean Difference in Pre and Posttest Course Mean and Standard Error

Course	Mean Difference (SE)	Lower Bound	Upper Bound
Control	21.98 (3.78)	18.2	25.76
Intervention	35.29 (2.82)	32.47	38.11

Table 16

Mean of Percentage Growth in Pre and Posttest Course Mean and Standard Error

Course	Mean % Growth (SE)	Lower Bound	Upper Bound
Control	53.32 (9.96)	43.36	63.28
Intervention	63.01(4.33)	58.68	67.34

Table 18

Comparison of Groups Within Each Course

Group	Pre-Test Mean (SE)	Post Test Mean (SE)	Difference Mean (SE)	% Growth Mean (SE)
Control				
High	82.29 (3.10)	88.84 (5.42)	6.55 (5.63)	30.48 (32.22)
Middle	57.41 (1.34)	76.49 (4.49)	19.08 (4.91)	43.46 (11.99)
Low	43.18(1.73)	79.55 (5.03)	36.36 (6.07)	62.50 (9.59)
Intervention				
High	59.13 (4.01)	81.12 (4.46)	22.00 (3.33)	57.43 (9.66)
Middle	44.10 (0.97)	82.14 (4.82)	38.05 (4.73)	68.20 (8.50)
Low	33.33 (1.66)	75.71 (3.91)	42.38 (3.72)	63.77 (5.61)

Table 19

Groups Ranked by Percentage Growth

Groups	Pretest	Posttest	Difference	% Growth
Middle (Intervention)	44.10	82.14	38.05	68.20
Low (Intervention)	33.33	75.71	42.38	63.70
Low (Control)	43.18	79.55	36.36	62.50
High (Intervention)	59.13	81.12	22.00	57.43
Middle (Control)	57.41	76.49	19.08	43.46
High (Control)	82.29	88.84	6.55	30.48

Figures

PILOT STUDY SECHEDULE

MAT 0010 Summer 2 2018 Semester Schedule - Subject to Change - Instructor:						
Meeting Number	**Date**	**Day**	**Content 12:40-1:35**	**Content 1:40-2:35**	**Lab 2:40-3:40**	**Notes**
1	7/5/2018	Thursday	**Intro/Fractions**	**Fractions**		
2	7/6/2018	Friday	**Fractions**	**Fractions**	**TEST 1**	
3	7/9/2018	Monday	Chapter 1	Chapter 2		
4	7/10/2018	Tuesday	Chapter 2	Chapter 2		
5	7/11/2018	Wednesday	Chapter 3	Chapter 3		
6	7/12/2018	Thursday	Chapter 3	Chapter 4		
7	7/13/2018	Friday	Chapter 4	Chapter 4	TEST 2	
8	7/16/2018	Monday	Chapter 5	Chapter5		
9	7/17/2018	Tuesday	Chapter 5	Chapter 6		
10	7/18/2018	Wednesday	Chapter 6	Chapter 6		
11	7/19/2018	Thursday	Chapter 7	Chapter 7		
12	7/20/2018	Friday	Chapter 7	Chapter 7	TEST 3	
13	7/23/2018	Monday	Chapter 8	Chapter 8		
14	7/24/2018	Tuesday	Chapter 8	Chapter 8		
15	7/25/2018	Wednesday	Chapter 9	Chapter 9		
16	7/26/2018	Thursday	Chapter 9	Chapter 10		
17	7/27/2018	Friday	Chapter 10	Chapter 10	TEST 4	Pre Survey Conducted
18	7/30/2018	Monday				
19	7/31/2018	Tuesday				
20	8/1/2018	Wednesday	Word Problems- See Word Problem Schedule			Data Collection: See Word Problem Schedule
21	8/2/2018	Thursday				
22	8/3/2018	Friday			TEST 5	
23	8/6/2018	Monday	REVIEW			
24	8/7/2018	Tuesday		FINAL		Post Survey Collected

Figure 1. Pilot Schedule given to Participants.

Date	Day	12:40-1:35	1:40-2:35	2:40-3:40
7/30/2018	Monday: Content	Unit 1 Strategies in Translating and Solving: Focus Single Variable Translation	Unit 1 Strategies in Translating and Solving: Focus Single Variable Translation	Unit 1 Strategies in Translating and Solving: Consecutive Integers
Posing Type		Structured	Structured	Semi Strucutured
7/31/2018	Tuesday: Content	Unit 1 Strategies in Translating and Solving: Reciprocals and Quotients	Unit 2: Ratios and Precent Word Problems: Focus Ratios and Proportions	Unit 2: Ratios and Precent Word Problems: Pecent Increase and Decrease Problems
Posing Type		Structured	Structured	Semi Strucutured
8/1/2018	Wednesday: Content	Unit 2: Ratios and Precent Word Problems: Pecent Increase and Decrease Problems	Unit 3: Linear Equations. Focus One or two equations/One Unknown	Unit 3: Linear Equations. Focus One or two equations/One Unknown
Posing Type		Structured	Structured	Semi Strucutured
8/2/2018	Thursday: Content	Unit 3: Linear Equations. Focus One or two equations/One Unknown	Unit 4: Higher Power Single Variable Problems	Unit 5: Two Variable Word Problems: Linear
Posing Type		Semi Strucutured	Semi Strucutured	Free
8/3/2018	Friday: Content	Unit 5: Two Variable Word Problems: Linear	Unit 5: Two Variable Word Problems: Quadratic	TEST 5
Posing Type		Free	Semi Strucutured	Free

Figure 2. Lesson plan with problem posing levels for pilot study.

Date	Day	12:40-1:35	1:40-2:35	2:40-3:40
7/30/2018	Monday: Content	Unit 1 Strategies in Translating and Solving: Focus Single Variable Translation	Unit 1 Strategies in Translating and Solving: Focus Single Variable Translation	Unit 1 Strategies in Translating and Solving: Consecutive Integers
Posing Type		Structured	Structured	Semi Strucutured
7/31/2018	Tuesday: Content	Unit 1 Strategies in Translating and Solving: Reciprocals and Quotients	Unit 2: Ratios and Precent Word Problems: Focus Ratios and Proportions	Unit 2: Ratios and Precent Word Problems: Pecent Increase and Decrease Problems
Posing Type		Structured	**Semi Strucutured**	**Free**
8/1/2018	Wednesday: Content	Unit 2: Ratios and Precent Word Problems: Pecent Increase and Decrease Problems	Unit 3: Linear Equations. Focus One or two equations/One Unknown	Unit 3: Linear Equations. Focus One or two equations/One Unknown
Posing Type		**Sturctured and Semi Strucutured**	**Semi Strucutured**	**Free**
8/2/2018	Thursday: Content	Unit 3: Linear Equations. Focus One or two equations/One Unknown	Unit 3: Linear Equations. Focus One or two equations/One Unknown	Unit 5: Two Variable Word Problems: Linear
Posing Type		Structured/Semi Strucutured	**Free**	**Free**
8/3/2018	Friday: Content	Unit 5: Two Variable Word Problems: Linear	Unit 5: Two Variable Word Problems: Linear	TEST 5
Posing Type		**Free**	**Free**	Free

Figure 3. Lesson plan with conducted problem posing levels.

Day	Topics	Instructional Focus	Data Collected
18	NOT INCLUDED IN STUDY		Pre Survey
19	Unit 1 Strategies in Translating and Solving: Focus Single Variable	Structured Problem Posing (2 sections) Semi Structured (1 Section)	Student Comments from Discussion and Student Work. Instructor Notes
20	Unit 1 Strategies in Translating and Solving: Reciprocals and Quotients and Unit 2: Ratios and Precent Word Problems: Pecent Increase and Decrease Problems	Structured Problem Posing (1 section) Semi Structured Posing (1 Section) Free Posing (1 Section)	Student Work and Instructor Notes
21	Unit 2: Ratios and Precent Word Problems: Pecent Increase and Decrease Problems & Unit 3: Linear Equations. Focus One or two equations/One Unknown	Sturctured Posing (1 Section) Semi Structured Posing (2 Section) Free Posing (1 Section)	Student Work and reflections from student discussion. Instructor Notes
22	Unit 5: Two Variable Word Problems: Linear	Semi Structure (1 Section) Free Posing (2 Sections)	Student Work and reflections from student discussion. Instructor Notes
23	Unit 5: Two Variable Word Problems: Linear	Semi Structure (1 Section) Free Posing (2 Sections)	Post Survey and Test

Figure 4. Lesson Plan with Problem Posing Levels and Data Collection Methods

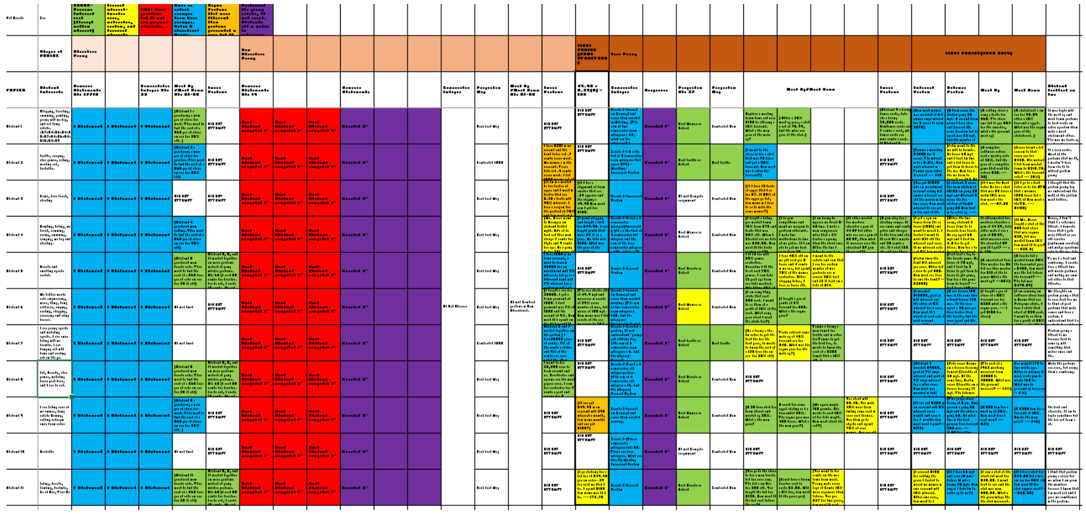

Figure 5. Problems were colored coded based on criteria from Table 4

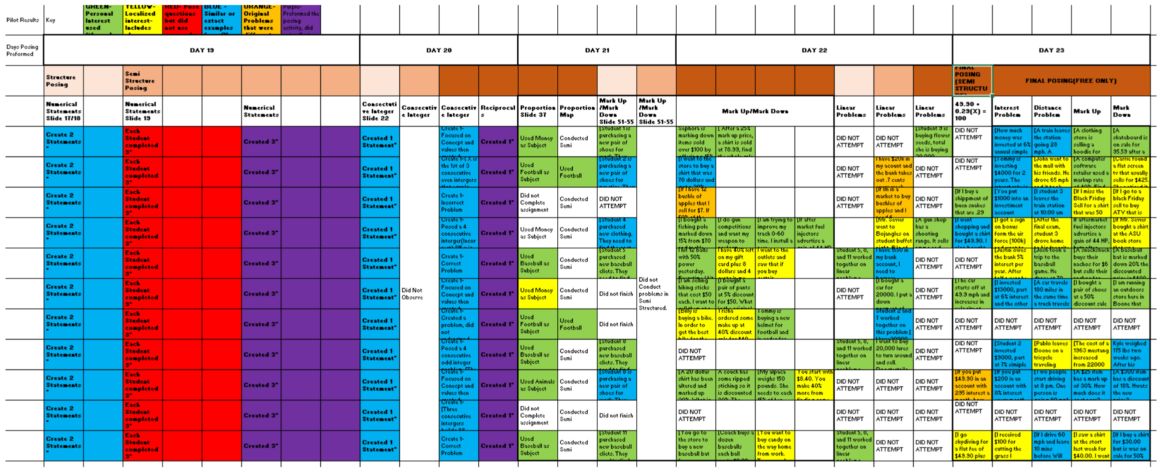

Figure 6. Coded Posed Problems from Pilot by Day and were colored coded based on criteria from Table 4

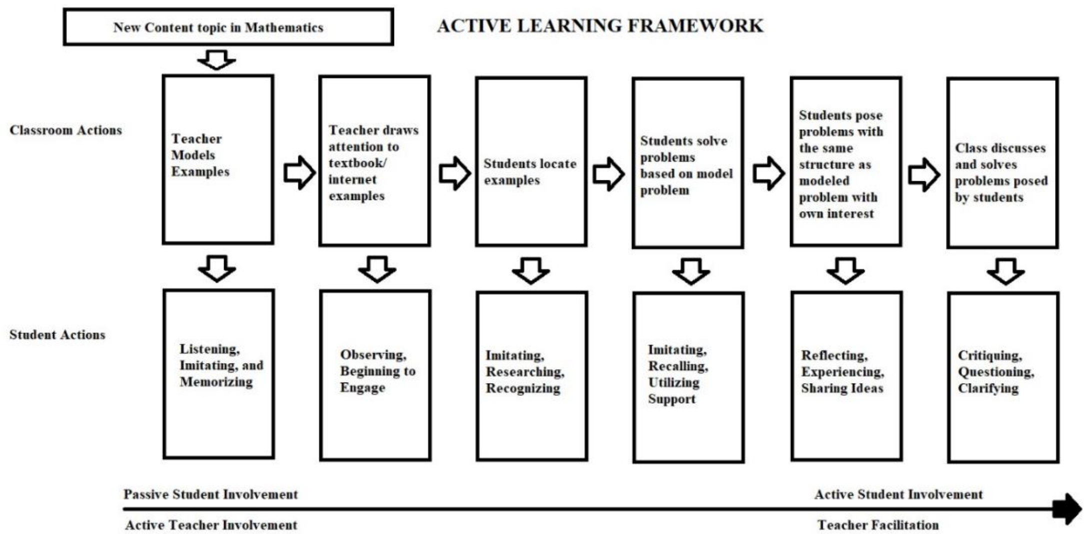

Figure 7. Adapting Active Learning framework from Ellerton (2013)

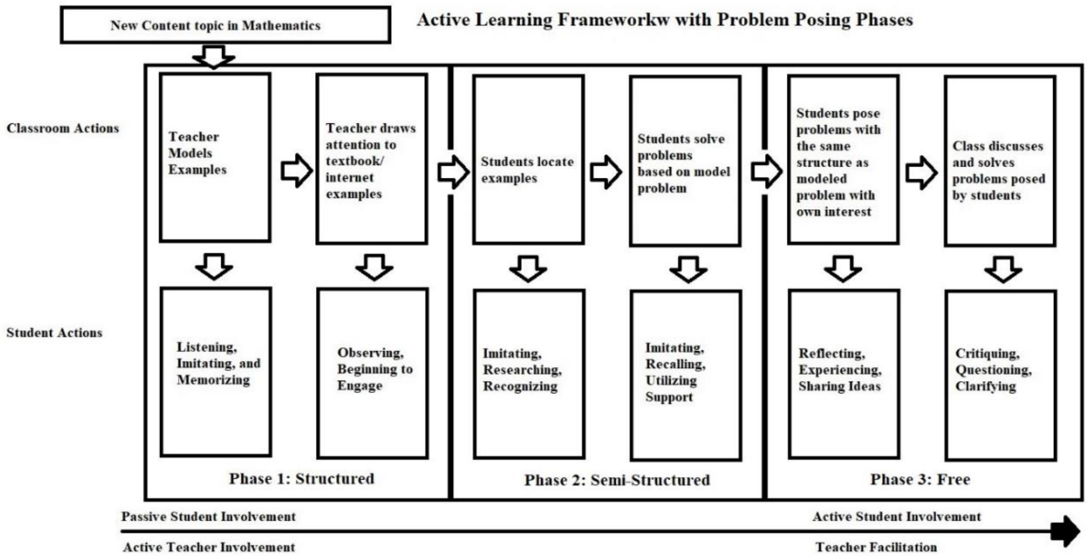

Figure 8. Ellerton (2013) Active Learning Framework with Problem Posing Phases

Writing Phrases as Algebraic Expressions

Addition (+)	Subtraction (-)	Multiplication (·)	Division (÷)	Equal Sign
Sum	Difference of	Product	Quotient	Equals
Plus	Minus	Times	Divide	Gives
Added to	subtracted from	Multiply	Into	Is/was/ should be
More than	Less than	Twice	Ratio	Yields
Increased by	Decreased by	Of	Divided by	Amounts to
Total	Less			Represents
				Is the same as

Figure 9. Word list to introduce numerical statements from *Beginning Algebra (*Martin-Gay)

Date	Duration	COURSE A- CONTROL	Assessment/Data Collection	Duration	COURSE B- INTERVENTION	Assessment/Data Collection
8/21/2018	75 mins	First Day of Class-Syllabus and Explanation of Study	Consent forms	75 mins	First Day of Class-Syllabus and Explanation of Study	Consent forms
8/22/2018	50 mins	Questionaire1	File for Review after Grades Posted	50 mins	Questionaire1	File for Review after Grades Posted
8/23/2018-11/4/2018		Chapters 1 -9			Chapters 1 -9	
11/5/2018	50 mins	Questionaire2		50 mins	Questionaire2	
11/6/2018	75 mins	Pretest	Review and Grade	75 mins	Pretest	Review and Grade
11/7/2018	50 mins	Section 1.4		50 mins	Introduction to Problem Posing	Video/Collect Student work
11/8/2018	75 mins	Section 1.5		75 mins	Implement Instruction-**Structured** Problem Posing	
11/12/2018	50 mins	1.4 and 1.5 Lab		50 mins	Implemented Instruction- **Semi Structued** and **Free**	
11/13/2018	75 mins	Section 2.2-2.3		75 mins	Implement Instruction-**Structured** Problem Posing	
11/14/2018	50 mins	Section 2.2 2.3 Lab	Lecture/Lab	50 mins	Implemented Instruction- **Semi Structued** and **Free**	
11/15/2018	75 mins	2.5, 2.6	Lecture	75 mins	Implement Instruction-**Structured** Problem Posing	
11/16/2018		NO Cource Meeting-Compare Pretest of Both Groups				
11/19/2018	50 mins	2.5, 2.6 Lab	Lab	50 mins	Implemented Instruction- **Semi Structued** and **Free**	Video/Collect Student work/Interview
11/20/2018	75 mins	2.7, 2.8	Lecture	75 mins	Implement Instruction-**Semi Structured** Problem	
11/21/2018		No Classes Thanksgiving	Assigned Word Problems		No Classes Thanksgiving	Assigned Problem Posing
11/22/2018		No Classes Thanksgiving			No Classes Thanksgiving	
11/23/2018		No Classes Thanksgiving			No Classes Thanksgiving	
11/26/2018	50 mins	2.5-2.8 Lab	Lab	50 mins	Implemented Instruction- **Semi Structued** and **Free**	Video/Collect Student work/Interview
11/27/2018	75 mins	4.4	Lecture/Lab	75 mins	Implement Instruction-**Structured** Problem Posing	
11/28/2018	50 mins	6.7	Lecture/Lab	50 mins	Implemented Instruction- **Semi Structued** and **Free**	
11/29/2018	75 mins	8.6	Lecture/Lab	75 mins	Implement Instruction-**Structured** Problem Posing	
12/3/2018	50 mins	9.3	Lecture/Lab	50 mins	Implemented Instruction- **Semi Structued** and **Free**	
12/4/2018	75 mins	Post-Test		75 mins	Post-Test	
12/5/2018	50 mins	Study Ends- Questionaire3	Review and Grade	50 mins	Study Ends- Questionaire3	Review and Grade
12/6/2018	Day			Day	Conduct Interviews	
Spring 2019						
	Compare	Control Pretest toTreatment Pretest		Compare	Review Questionnaires	
		Control Posttest to Treatment Posttest			Review Video/Interviews	Create Transript/Review
		Control Pretest to Control Posttest				Review for Student Work
		Treatment Pretest to Treatmen Posttest				Statistical Analysis
					Compare questionaires to video	

Figure 10 Course Schedule.

Date/Time			Task	
11/6/2018	75 mins		Pretest	
11/7/2018	50 mins	Statements	Introduction to Word Problems and Problem Posing Unit 1	
11/8/2018	75 mins	Statements	Instruction Unit 1 (50 mins) and Intro to Posing	
11/12/2018	50 mins	Ratios/Proportions	Instruction Unit 2 (50 mins)	
11/13/2018	75 mins	Ratios/Proportions (FREE 10 mins)---Mark Up /Down	Structure Posing (25 mins)	Semi Structure Posing (25 mins
11/14/2018	50 mins	Ratios/Proportions/Mark Up /Down	Free Posing (50 mins)	
11/15/2018	75 mins	Linear (two equation two unknown)	Instruction Unit 3 (50 mins)	Structure Posing (25 mins)
11/19/2018	50 mins	Linear (two equation two unknown)	Semi Structure Posing (25 mins	Free Posing (25 mins)
11/20/2018	75 mins	Interest (Linear)	Instruction Unit 3 (50 mins)	Structure Posing (25 mins)
11/21/2018			No Class- Free Posing Assignment	
11/22/2018				
11/23/2018				
11/26/2018	50 mins	Interest (Linear)	Instruction Unit 3 (50 mins)	Structure Posing (25 mins)
11/27/2018	75 mins	Distance (Linear)	Semi Structure Posing (25 mins	Free Posing (25 mins)
11/28/2018	50 mins	Distance (Linear)	Semi Structure Posing (25 mins	Free Posing (25 mins)
11/29/2018	75 mins	Linear (two equation two unknown)	Instruction Unit 5 (50 mins)	Structure Posing (25 mins)
12/3/2018	50 mins	Linear (two equation two unknown)	Semi Structure Posing (25 mins	Free Posing (25 mins)
12/4/2018	75 mins		Post Test	
12/5/2018	50 mins		Questionnaire 3	

Figure 12. Daily schedule with detail instruction and posing.

Fall 2018 Section A Schedule is Subject to Change					
Date	**Class Activity**	**Research Objectives**	**Date**	**Class Activity**	**Research Objectives**
8/21/2018	First Day of Class	Syllabus/Disucssion of Study	10/16/2018	Instruction/Labs	Chapter 7
8/22/2018	Instruction/Labs	Questionaire 1	10/17/2018	Lab	Chapter 7
8/23/2018	Instruction/Labs	Chapter 1	10/18/2018	Instruction/Labs	Chapter 7
8/27/2018	Lab	Chapter 1	10/22/2018	Lab	Chapter 7
8/28/2018	Instruction/Labs	Chapter 1	10/23/2018	Instruction/Labs	Chapter 8
8/29/2018	Lab	Chapter 1	10/24/2018	Lab	Chapter 8
8/30/2018	Instruction/Labs	Chapter 2	10/25/2018	Instruction/Labs	Chapter 8
9/3/2018	Lab	Chapter 2	10/29/2018	Lab	Chapter 8
9/4/2018	Instruction/Labs	Chapter 2	10/30/2018	Instruction/Labs	Chapter 8
9/5/2018	Lab	Chapter 2	10/31/2018	Instruction/Labs	Chapter 9
9/6/2018	Instruction/Labs	Chapter 2	11/1/2018	Lab	TEST
9/10/2018	Lab	Chapter 3	11/5/2018	Instruction/Labs	Questionaire 2
9/11/2018	Instruction/Labs	Chapter 3	11/6/2018	Instruction/Labs	Study Begins- Pretest
9/12/2018	Lab	Chapter 3	11/7/2018	Lab	Word Problems
9/13/2018	Instruction/Labs	Chapter 3	11/8/2018	Instruction/Labs	Word Problems
9/17/2018	Lab	Chapter 4	11/12/2018	Instruction/Labs	Word Problems
9/18/2018	Instruction/Labs	Chapter 4	11/13/2018	**Instruction/Labs**	Word Problems
9/19/2018	Lab	Chapter 4	11/14/2018	Instruction/Labs	Word Problems
9/20/2018	Instruction/Labs	Chapter 4	11/15/2018	**Instruction/Labs**	Word Problems
9/24/2018	Lab	TEST	11/19/2018	Instruction/Labs	Word Problems
9/25/2018	Instruction/Labs	Chapter 5	11/20/2018	**Instruction/Labs**	Word Problems
9/26/2018	Lab	Chapter 5	11/21/2018	No Classes Thanksgiving	
9/27/2018	Instruction/Labs	Chapter 5	11/22/2018	No Classes Thanksgiving	
10/1/2018	Lab	Chapter 5	11/23/2018	No Classes Thanksgiving	
10/2/2018	Instruction/Labs	Chapter 5	11/26/2018	Instruction/Labs	Word Problems
10/3/2018	Lab	Chapter 6	11/27/2018	**Instruction/Labs**	Word Problems
10/4/2018	Instruction/Labs	Chapter 6	11/28/2018	Instruction/Labs	Word Problems
10/8/2018	Lab	Chapter 6	11/29/2018	**Instruction/Labs**	Word Problems
10/9/2018	Instruction/Labs	Chapter 6	12/3/2018	Instruction/Labs	Word Problems
10/10/2018	Lab	TEST	12/4/2018	**Instruction/Labs**	Post Test
10/11/2018	NO CLASSES FALL BREAK		12/5/2018	Problem Solving Assesment	Study Ends- Questionaire 3
10/12/2018	NO CLASSES FALL BREAK		12/6/2018	Reading Day	NO CLASS Meeting
10/15/2018	Lab	Chapter 7	12/xxx/2018	Final Exam	Date TBD by University

Figure 14. Schedule given to participants at the beginning of the semester.

Fall 2018 Course B Schedule is Subject to Change					
Date	**Class Activity**	**Research Objectives**	**Date**	**Class Activity**	**Research Objectives**
8/21/2018	First Day of Class	Syllabus/Disucssion of Study	10/16/2018	Instruction/Labs	Chapter 7
8/22/2018	Instruction/Labs	Questionaire 1	10/17/2018	Lab	Chapter 7
8/23/2018	Instruction/Labs	Chapter 1	10/18/2018	Instruction/Labs	Chapter 7
8/27/2018	Lab	Chapter 1	10/22/2018	Lab	Chapter 7
8/28/2018	Instruction/Labs	Chapter 1	10/23/2018	Instruction/Labs	Chapter 8
8/29/2018	Lab	Chapter 1	10/24/2018	Lab	Chapter 8
8/30/2018	Instruction/Labs	Chapter 2	10/25/2018	Instruction/Labs	Chapter 8
9/3/2018	Lab	Chapter 2	10/29/2018	Lab	Chapter 8
9/4/2018	Instruction/Labs	Chapter 2	10/30/2018	Instruction/Labs	Chapter 8
9/5/2018	Lab	Chapter 2	10/31/2018	Instruction/Labs	Chapter 9
9/6/2018	Instruction/Labs	Chapter 2	11/1/2018	Lab	Chapter 9 Test
9/10/2018	Lab	Chapter 3	11/5/2018	Instruction/Labs	Study Begins-Questionaire2
9/11/2018	Instruction/Labs	Chapter 3	11/6/2018	Instruction/Labs	Pretest
9/12/2018	Lab	Chapter 3	11/7/2018	Lab	Introduction to Problem Posing
9/13/2018	Instruction/Labs	Chapter 3	11/8/2018	Instruction/Labs	Implement Instruction-**Structured** Problem Posing
9/17/2018	Lab	Chapter 4	11/12/2018	Instruction/Labs	Implemented Instruction- **Semi Structued** and **Free Posing**
9/18/2018	Instruction/Labs	Chapter 4	11/13/2018	**Instruction/Labs**	Implement Instruction-**Structured** Problem Posing
9/19/2018	Lab	Chapter 4	11/14/2018	Instruction/Labs	Implemented Instruction- **Semi Structued** and **Free Posing**
9/20/2018	Instruction/Labs	Chapter 4	11/15/2018	**Instruction/Labs**	Implement Instruction-**Structured** Problem Posing
9/24/2018	Lab	TEST	11/19/2018	Instruction/Labs	Implemented Instruction- **Semi Structued** and **Free Posing**
9/25/2018	Instruction/Labs	Chapter 5	11/20/2018	**Instruction/Labs**	Implement Instruction-**Semi Structured** Problem Posing
9/26/2018	Lab	Chapter 5	11/21/2018	No Classes University Break	
9/27/2018	Instruction/Labs	Chapter 5	11/22/2018	No Classes University Break	
10/1/2018	Lab	Chapter 5	11/23/2018	No Classes University Break	
10/2/2018	Instruction/Labs	Chapter 5	11/26/2018	Instruction/Labs	Implemented Instruction- **Semi Structued** and **Free Posing**
10/3/2018	Lab	Chapter 6	11/27/2018	**Instruction/Labs**	Implement Instruction-**Structured** Problem Posing
10/4/2018	Instruction/Labs	Chapter 6	11/28/2018	Instruction/Labs	Implemented Instruction- **Semi Structued** and **Free Posing**
10/8/2018	Lab	Chapter 6	11/29/2018	**Instruction/Labs**	Implement Instruction-**Structured** Problem Posing
10/9/2018	Instruction/Labs	Chapter 6	12/3/2018	Instruction/Labs	Implemented Instruction- **Semi Structued** and **Free Posing**
10/10/2018	Lab	TEST	12/4/2018	**Instruction/Labs**	Post-Test
10/11/2018	NO CLASSES FALL BREAK		12/5/2018	Problem Solving Assesment	Study Ends- Questionaire 3
10/12/2018	NO CLASSES FALL BREAK		12/6/2018	Reading Day	NO CLASS Meeting
10/15/2018	Lab	Chapter 7	12/xxx/2018	Final Exam	Date TBD by University

Figure 15. Semester Schedule for Course B with Levels of Posing. Schedule was not given to students.

11/1/2018	75 mins	Chapter 9		75 mins	Chapter 9	
11/4/2018	50 mins	TEST		50 mins	TEST	
11/5/2018	75 mins	Questionaire2		75 mins	Questionaire2	
11/6/2018	50 mins	Pretest	Review and Grade	50 mins	Pretest	Review and Grade
11/7/2018	75 mins	Word Problems		75 mins	Introduction to Problem Posing	
11/8/2018	50 mins	Word Problems		50 mins	**Structured** Problem Posing	
11/12/2018	75 mins	Word Problems		75 mins	**Semi Structued** and **Free Posing**	
11/13/2018	50 mins	Word Problems		50 mins	**Structured** Problem Posing	Video/Collect Student work/Interview
11/14/2018	75 mins	Word Problems	Lecture/Lab	75 mins	**Semi Structued** and **Free Posing**	
11/15/2018	50 mins	Word Problems	Lecture	50 mins	**Structured** Problem Posing	
11/19/2018	50 mins	Word Problems	Lab	50 mins	**Semi Structued** and **Free Posing**	
11/20/2018	75 mins	Word Problems	Lecture	75 mins	**Semi Structured** Problem Posing	
11/21/2018		No Classes Thanksgiving	Assigned Word Problems		No Classes Thanksgiving	Assigned Problem Posing
11/22/2018		No Classes Thanksgiving			No Classes Thanksgiving	
11/23/2018		No Classes Thanksgiving			No Classes Thanksgiving	
11/26/2018	50 mins	Word Problems	Lab	50 mins	**Semi Structued** and **Free Posing**	
11/27/2018	75 mins	Word Problems	Lecture/Lab	75 mins	**Structured** Problem Posing	
11/28/2018	50 mins	Word Problems	Lecture/Lab	50 mins	**Semi Structued** and **Free Posing**	Video/Collect Student work/Interview
11/29/2018	75 mins	Word Problems	Lecture/Lab	75 mins	**Structured** Problem Posing	
12/3/2018	50 mins	Word Problems	Lecture/Lab	50 mins	**Semi Structued** and **Free Posing**	
12/4/2018	75 mins	Post-Test		75 mins	Post-Test	
12/5/2018	50 mins	Study Ends- Questionaire3	Review and Grade	50 mins	Study Ends- Questionaire3	Review and Grade
12/6/2018	Reading Day			Reading Day	Conduct Interviews	

Figure 16. Comparison of Study for Control and Intervention

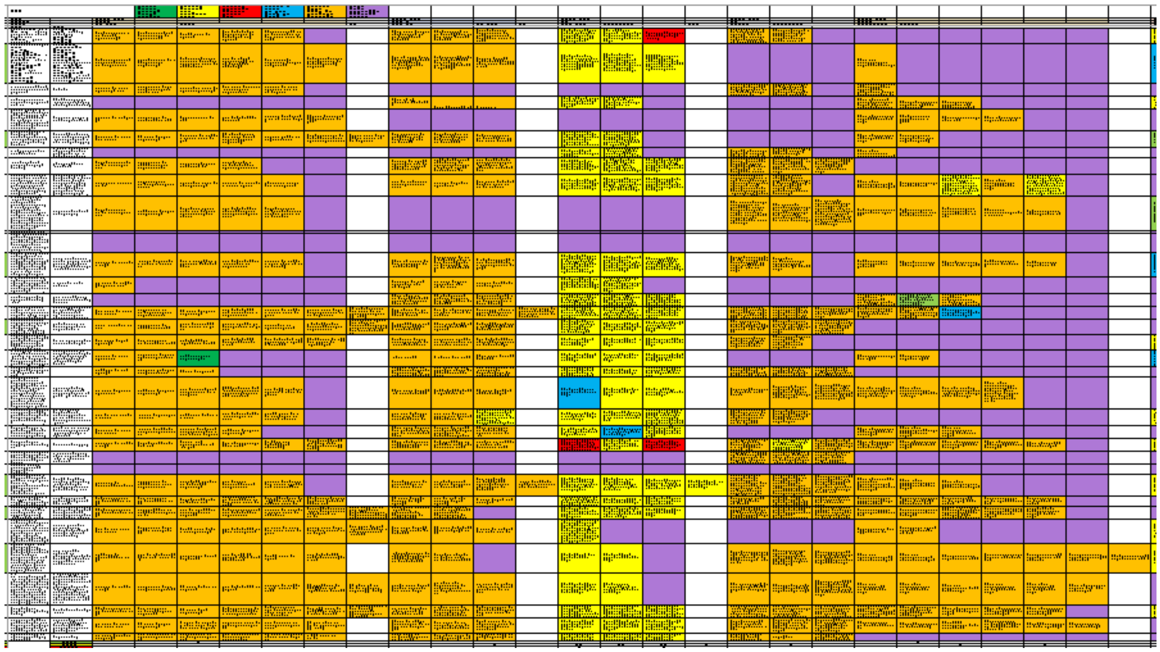

Figure 20.1 Coding for student work (Nov 8th-Nov 14th)

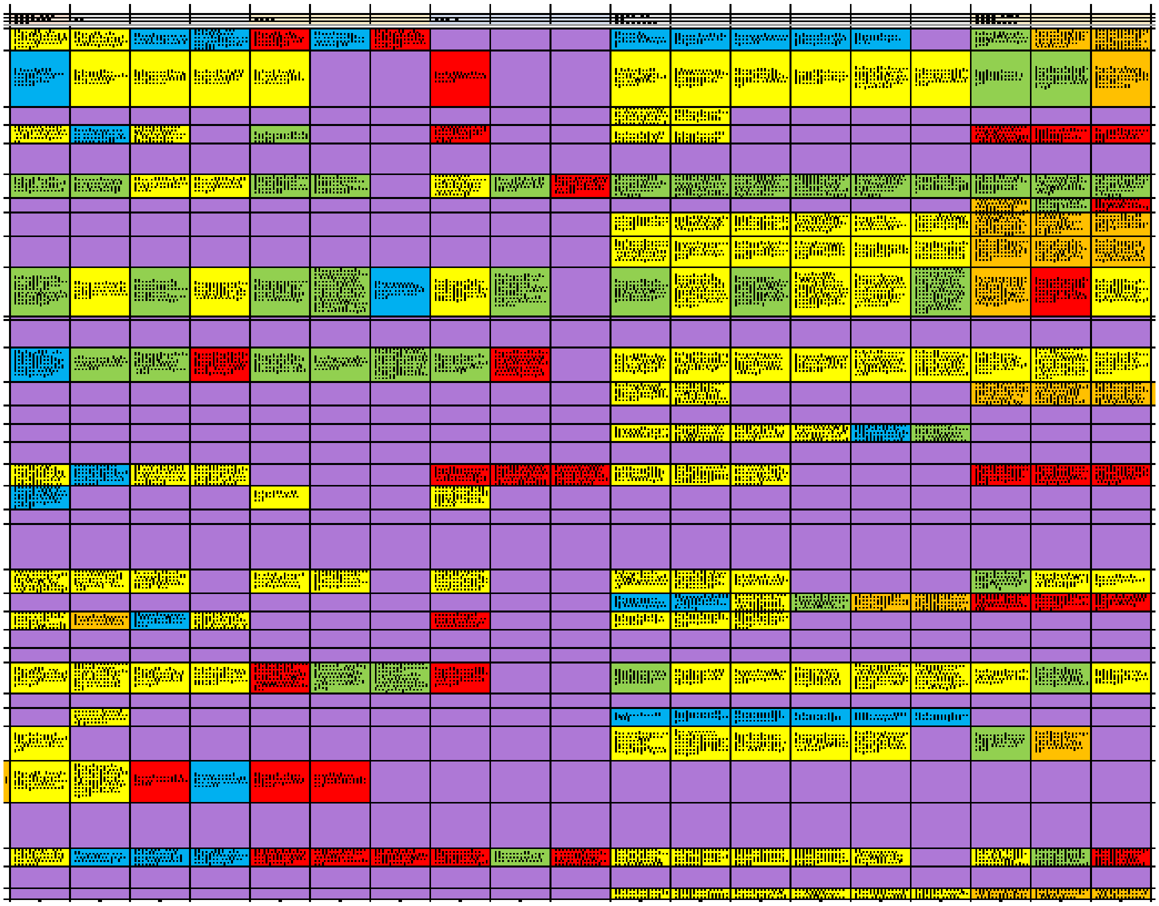

Figure 20.2. Coding for student work from (Nov 17th-Nov 20th)

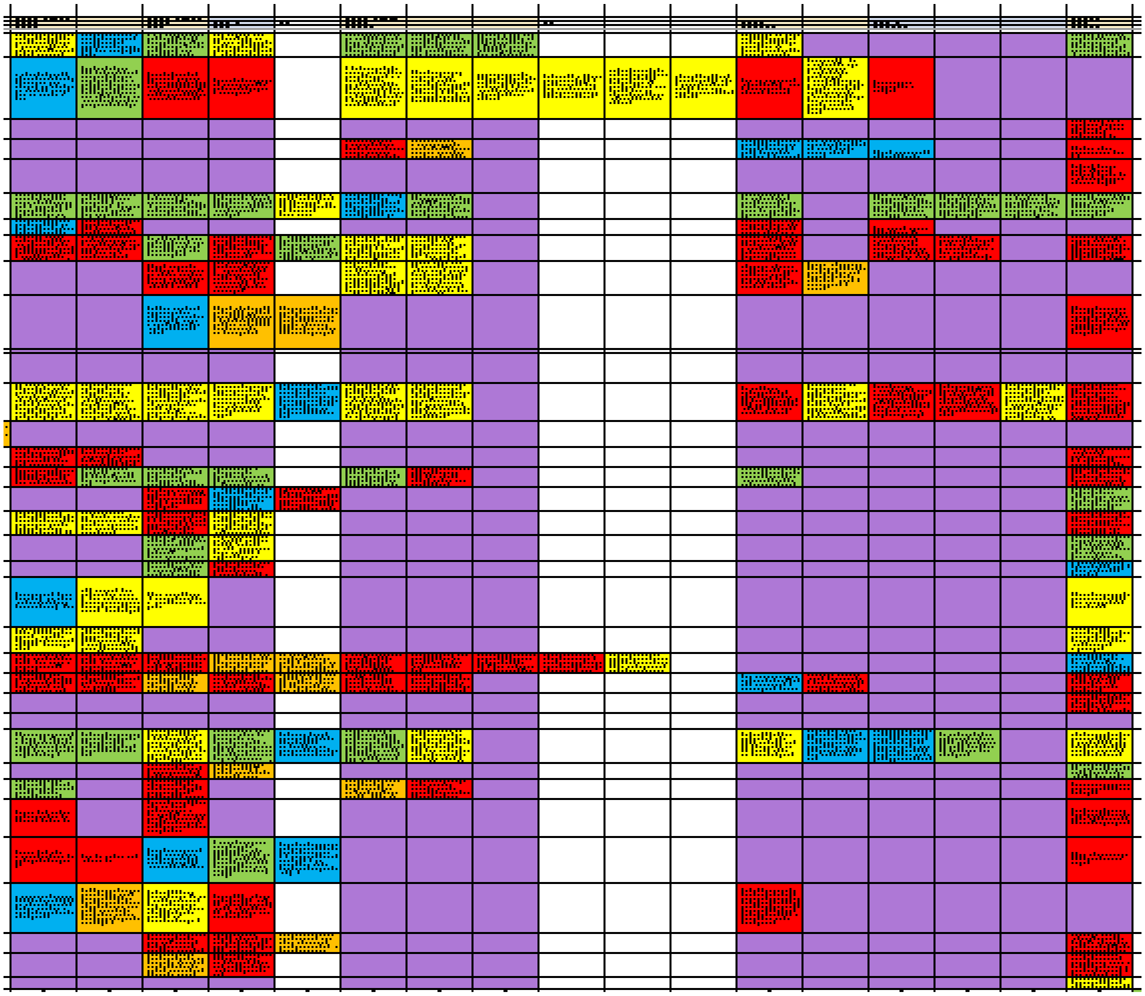

Figure 20.3. Coding for student work (Nov 26th-Dec 3rd)

Appendix A: Questionnaire 1

Developmental Survey 1

Page 1

1 * Schoenfeld (1998) defines beliefs as "mental constructs that represent the arrangement of people's experiences and understanding.

Additionally, beliefs can be viewed as something that is accepted, considered to be true, or held as an opinion : something believed

Mathematical Beliefs

Please answer in the following format:

1 Strongly Disagree

2 Disagree

3 Undecided

4 Agree

5 Strongly Agree

		1	2	3	4	5
1.Doing mathematics consists mainly of using rules.	*	○	○	○	○	○
2.Learning mathematics mainly involves memorizing procedures and formulas.	*	○	○	○	○	○
3.Mathematics involves relating many different ideas.	*	○	○	○	○	○
4.Getting the right answer is the most important part of mathematics.	*	○	○	○	○	○
5.In mathematics, it is impossible to do a problem unless you've first been taught to do one like it.	*	○	○	○	○	○
6.One reason learning mathematics is so much work is that you need to learn a different method for each new class of problems.	*	○	○	○	○	○
7.Getting good grades in mathematics is more of a motivation than is the satisfaction of learning the mathematics content.	*	○	○	○	○	○
8. When I learn something new in mathematics, I often continue exploring and developing it on my own.	*	○	○	○	○	○
9.I usually try to understand the reasoning behind all of the rules I use in mathematics.	*	○	○	○	○	○
10.Being able to successfully use a rule or formula in mathematics is more important to me than understanding how and why it works.	*	○	○	○	○	○
11.A common difficulty with taking quizzes and exams in mathematics is that if you forget relevant formulas and rules you are lost.	*	○	○	○	○	○
12.It is difficult to talk about mathematical ideas because all you can really do is explain how to do specific problems.	*	○	○	○	○	○
13.Solving mathematics problems frequently involves exploration.	*	○	○	○	○	○

14.Most mathematics problems are best solved by deciding on the type of problem and then using a previously learned solution method for that type.

15.I forget most of the mathematics I learn in a course soon after the course is over.

16.Mathematics consists of many unrelated topics.

17.Mathematics is a rigid, uncreative subject.

18. In mathematics there is always a rule to follow.

19. I get frustrated if I don't understand what I am studying in mathematics.

20. The most important part of mathematics is computation.

2 * Please describe your beliefs about you in the subject of Mathematics.

Page 2

3 * Neale (1969) defines mathematical attitudes as "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless"

Attitudes can be defined as: "a settled way of thinking or feeling about someone or something, typically one that is reflected in a person's behavior"

Please answer in the following format:

1 Strongly Disagree

2 Disagree

3 Undecided

4 Agree

5 Strongly Agree

	1	2	3	4	5
1. I am always under a terrible strain in mathematics class					
2. I do not like mathematics, and it scares me to take it					

3. Mathematics is very interesting to me, and I enjoy arithmetic and mathematics courses

4. Mathematics is fascinating and fun

5. Mathematics makes me feel secure, and at the same time it is stimulating

6. My mind goes blank and I am unable to think clearly when working mathematics

7. I feel a sense of insecurity when attempting mathematics

8. Mathematics makes me feel uncomfortable, restless, irritable, and impatient

9. The feeling that I have toward mathematics is a good feeling

10. Mathematics makes me feel as though I'm lost in a jungle of numbers and can't find my way out

11. Mathematics is something that I enjoy a great deal

12. When I hear the word mathematics, I have a feeling of dislike.

13. I approach mathematics with a feeling of hesitation, resulting form a fear of not begin able to do mathematics

14. I really like mathematics

15. Mathematics is a course in school that I have always enjoyed studying

16. It makes me nervous to think about having to do a mathematics problem

17. I have never liked mathematics, and it is my most dreaded subject

18. I am happier in a mathematics class than in any other class

19. I feel at ease in mathematics, and I like it very much

20. I feel a definite positive reaction toward mathematics; its enjoyable

4 * Briefly describe your attitude towards Mathematics. How does this affect your behavior?

Page 3

5 * Please list your areas of interests and what engages you. This list can include but not be limited to hobbies, past times, major or career aspirations.

6 * Please state what your intended major or career aspiration

7 * Do you see yourself perusing a career in a Math or Science field?

Yes No

Close this window

Appendix B: Questionnaire 2

Developmental Survey 2

Page 1

1 * Schoenfeld (1998) defines beliefs as "mental constructs that represent the arrangement of people's experiences and understanding.

Mathematical Beliefs

Please answer in the following format:

1 Strongly Disagree

2 Disagree

3 Undecided

4 Agree

5 Strongly Agree

		1	2	3	4	5
1.Doing mathematics consists mainly of using rules.	◉	○	○	○	○	○
2.Learning mathematics mainly involves memorizing procedures and formulas.	◉	○	○	○	○	○
3.Mathematics involves relating many different ideas.	◉	○	○	○	○	○
4.Getting the right answer is the most important part of mathematics.	◉	○	○	○	○	○
5.In mathematics, it is impossible to do a problem unless you've first been taught to do one like it.	◉	○	○	○	○	○
6.One reason learning mathematics is so much work is that you need to learn a different method for each new class of problems.	◉	○	○	○	○	○
7.Getting good grades in mathematics is more of a motivation than is the satisfaction of learning the mathematics content.	◉	○	○	○	○	○
8. When I learn something new in mathematics, I often continue exploring and developing it on my own.	◉	○	○	○	○	○
9.I usually try to understand the reasoning behind all of the rules I use in mathematics.	◉	○	○	○	○	○
10.Being able to successfully use a rule or formula in mathematics is more important to me than understanding how and why it works.	◉	○	○	○	○	○
11.A common difficulty with taking quizzes and exams in mathematics is that if you forget relevant formulas and rules you are lost.	◉	○	○	○	○	○
12.It is difficult to talk about mathematical ideas because all you can really do is explain how to do specific problems.	◉	○	○	○	○	○
13.Solving mathematics problems frequently involves exploration.	◉	○	○	○	○	○

14.Most mathematics problems are best solved by deciding on the type of problem and then using a previously learned solution method for that type.					
15.I forget most of the mathematics I learn in a course soon after the course is over.					
16.Mathematics consists of many unrelated topics.					
17.Mathematics is a rigid, uncreative subject.					
18. In mathematics there is always a rule to follow.					
19. I get frustrated if I don't understand what I am studying in mathematics.					
20. The most important part of mathematics is computation.					

2 Please describe your beliefs about you in the subject of Mathematics.

Page 2

3 Neale (1969) defines mathematical attitudes as "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless"

Attitudes can be defined as: "a settled way of thinking or feeling about someone or something, typically one that is reflected in a person's behavior"

Please answer in the following format:

1 Strongly Disagree

2 Disagree

3 Undecided

4 Agree

5 Strongly Agree

	1	2	3	4	5
1. I am always under a terrible strain in mathematics class					
2. I do not like mathematics, and it scares me to take it					

3. Mathematics is very interesting to me, and I enjoy arithmetic and mathematics courses

4. Mathematics is fascinating and fun

5. Mathematics makes me feel secure, and at the same time it is stimulating

6. My mind goes blank and I am unable to think clearly when working mathematics

7. I feel a sense of insecurity when attempting mathematics

8. Mathematics makes me feel uncomfortable, restless, irritable, and impatient

9. The feeling that I have toward mathematics is a good feeling

10. Mathematics makes me feel as though I'm lost in a jungle of numbers and can't find my way out

11. Mathematics is something that I enjoy a great deal

12. When I hear the word mathematics, I have a feeling of dislike.

13. I approach mathematics with a feeling of hesitation, resulting form a fear of not begin able to do mathematics

14. I really like mathematics

15. Mathematics is a course in school that I have always enjoyed studying

16. It makes me nervous to think about having to do a mathematics problem

17. I have never liked mathematics, and it is my most dreaded subject

18. I am happier in a mathematics class than in any other class

19. I feel at ease in mathematics, and I like it very much

20. I feel a definite positive reaction toward mathematics; its enjoyable

4 * Briefly describe your attitude towards Mathematics. How does this affect your behavior?

Appendix C: Questionnaire 3

Developmental Survey 3

Page 1

1 * Schoenfeld (1998) defines beliefs as "mental constructs that represent the arrangement of people's experiences and understanding.

Mathematical Beliefs

Please answer in the following format:

1 Strongly Disagree

2 Disagree

3 Undecided

4 Agree

5 Strongly Agree

		1	2	3	4	5
1.Doing mathematics consists mainly of using rules.	*	○	○	○	○	○
2.Learning mathematics mainly involves memorizing procedures and formulas.	*	○	○	○	○	○
3.Mathematics involves relating many different ideas.	*	○	○	○	○	○
4.Getting the right answer is the most important part of mathematics.	*	○	○	○	○	○
5.In mathematics, it is impossible to do a problem unless you've first been taught to do one like it.	*	○	○	○	○	○
6.One reason learning mathematics is so much work is that you need to learn a different method for each new class of problems.	*	○	○	○	○	○
7.Getting good grades in mathematics is more of a motivation than is the satisfaction of learning the mathematics content.	*	○	○	○	○	○
8. When I learn something new in mathematics, I often continue exploring and developing it on my own.	*	○	○	○	○	○
9.I usually try to understand the reasoning behind all of the rules I use in mathematics.	*	○	○	○	○	○
10.Being able to successfully use a rule or formula in mathematics is more important to me than understanding how and why it works.	*	○	○	○	○	○
11.A common difficulty with taking quizzes and exams in mathematics is that if you forget relevant formulas and rules you are lost.	*	○	○	○	○	○
12.It is difficult to talk about mathematical ideas because all you can really do is explain how to do specific problems.	*	○	○	○	○	○
13.Solving mathematics problems frequently involves exploration.	*	○	○	○	○	○

14.Most mathematics problems are best solved by deciding on the type of problem and then using a previously learned solution method for that type.	*	○	○	○	○	○
15.I forget most of the mathematics I learn in a course soon after the course is over.	*	○	○	○	○	○
16.Mathematics consists of many unrelated topics.	*	○	○	○	○	○
17.Mathematics is a rigid, uncreative subject.	*	○	○	○	○	○
18. In mathematics there is always a rule to follow.	*	○	○	○	○	○
19. I get frustrated if I don't understand what I am studying in mathematics.	*	○	○	○	○	○
20. The most important part of mathematics is computation.	*	○	○	○	○	○

2 * Please describe your beliefs about you in the subject of Mathematics.

Page 2

3 *

Neale (1969) defines mathematical attitudes as "a liking or disliking of mathematics, a tendency to engage in or avoid mathematical activities, a belief that one is good or bad at mathematics, and a belief that mathematics is useful or useless"

Attitudes can be defined as: "a settled way of thinking or feeling about someone or something, typically one that is reflected in a person's behavior"

Please answer in the following format:

1 Strongly Disagree

2 Disagree

3 Undecided

4 Agree

5 Strongly Agree

		1	2	3	4	5
1. I am always under a terrible strain in mathematics class	*	○	○	○	○	○
2. I do not like mathematics, and it scares me to take it	*	○	○	○	○	○

3. Mathematics is very interesting to me, and I enjoy arithmetic and mathematics courses

4. Mathematics is fascinating and fun

5. Mathematics makes me feel secure, and at the same time it is stimulating

6. My mind goes blank and I am unable to think clearly when working mathematics

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15. Mathematics is a course in school that I have always enjoyed studying

16. It makes me nervous to think about having to do a mathematics problem

17. I have never liked mathematics, and it is my most dreaded subject

18. I am happier in a mathematics class than in any other class

19. I feel at ease in mathematics, and I like it very much

20. I feel a definite positive reaction toward mathematics; its enjoyable

4 * Briefly describe your attitude towards Mathematics. How does this affect your behavior?

Page 3

5 * Please discuss your interests. This could represent what you do in your past time, hobbies, other course work you enjoy. Give as much detail or as many examples as possible.

6 * Please state you age.

7 * Please state your Gender

- Male
- Female

8 * Please state your Race.

- White
- Black or African American
- American Indian or Alaska Native
- Asian Indian
- Chinese
- Filipino
- Japanese
- Korean
- Vietnamese
- Native Hawaiian
- Other

9 * How many years has it been since you have taken a mathematics course. Please answer in the form of years. Example: 1 semester = .5 years

10 * Please state if you are a traditional or non traditional Student. Traditional is a student directly right out of high school. Non traditional represents students who are not directly out of high school.

- Traditional
- Non Traditional

11 * Do you include Math in your daily life? If so, in what way?

12 * Do you see yourself considering a career in Math or Science?

Yes No

Close this window

Appendix D: Pretest

1. If you can feed 152 birds for a month for \$8.80, how many birds could you feed for a month for \$70?

2. A cyclist leaves a checkpoint and travels at an average of 14 mph. A second cyclist leaves one half hour later and averages 18 mph. How long does it take the second cyclist to overtake the first?

3. The sum of two integers is 85. Ten less than three times the smaller of the integers is equal to twenty more than twice the larger integer. Find the two integers.

4. A grocer mixes 4 lbs of nuts, costing \$9 per pound, with 16 lbs of nuts, costing \$4 per pound. What price per pound is the mixture worth?

5. How many liters of a 10% saline solution must be mixed with 20 liters of a 15% saline solution to make a 12% saline solution?

6. A child's bank contains \$9.45 in dimes and quarters. If there are 48 coins in all, how many of each type of coin are there?

7. The height of a triangle is 3 less than the base. The area of the triangle is 14 square feet. Find the base and height of the triangle.

8. If three times a number is subtracted from twice its reciprocal, the result is -1. Find the number.

9. If the square of the larger or two consecutive integers is reduced by 3 times the smaller, the result is the sum of the two integers. Find the integers.

Appendix E: Posttest

1. Mr. Sevier is buying candy for his Mat 0010 classes. He goes to Mast General Store to pick two kinds of Candy. When he arrived, he decided to get M&Ms and Skittles. They charged him ten cents per pound of M&Ms and twenty-five cents per pound of Skittles. How many pounds of each candy did he purchase if he bought forty-eight pounds of candy for $9.45?

2. Shelton writes a problem to try to stump everyone in the band. His problem is "The sum of four consecutive whole numbers is thirty." Shelton wants to know what the whole numbers are.

3. A triangle has an angle that is 20 times the smallest angle. The second angle is 10 times the smallest angle plus 25. What are the measures of the three angles?

4. The sum of $1500 is divided between David and Jules with a ratio of 7 to 8. How much does each one get?

5. Alec was given sum of six hundred dollars. He decides to invest his money in two accounts paying 7% and 9% simple interest. After one year, he made fifty dollars in total interest from both accounts. How much did Alec invest into both accounts?

6. Kina decides he wants to purchase new shoes. She finds a pair that that have been marked down to fifty dollars. The tag on the box says they are 43% off. What was the original price of the shoes?

7. Drew is mixing Kool Aid together to create the ultimate flavor. He has decided to mix Pina-Pineapple and Lemon-Lime. The Kool Aid packets are measured in level of sweetness. 0% is not sweet and 100% is the highest sweetness level. This represents the amount of sugar in each pack. Both types are at different sweetness levels. Pina-Pineapple is the sweetest and has a sweetness level is 75%. Lemon-Lime is not as sweet and is 33%. If he wants to put both together and have 120 oz at a sweetness level of 50%, how many oz of each Kool Aid will he need to make before mixing it?

Appendix F: Interview Questions

INTERVIEW QUESTIONS and POINTS OF DISCUSSION

1. Describe your Mathematics experiences from school prior to this course.
    a. What was it like,
    b. did you like or dislike math?
        i. Why and can you provide some examples?
        ii. Can you think of a good one, a bad one, etc?

2. What is your attitude towards Mathematics?
    a. follow up with other areas such as when attitudes began, beliefs, interests
    b. Give examples if you can

3. Describe your thoughts and experiences with problem posing and creating you own problems.
    a. Follow up questions will pertain to, engagement, problem choice, interests, understanding, and using their own work. **Main focus is on how they engaged with the process**

4. Explain your thought process for the following situation (Student Work)
    a. Will show a work and give the context of the problems posed. This may be several artifacts depending on the discussion. Follow up questions will be based back on attitudes and beliefs, interests, problem posing, etc

5. What are your overall thoughts about problems based on using problem posing?
    a. What did you like?
    b. What did you find challenging?
        i. discuss problem creation, solving, and understanding. Main focus is proficiency and engagement

6. Questions about problems posed- Look at specifics about the problems posed.

Appendix G: Problem Posing Worksheet

Name____Date________________

Lesson_________________________________Topic____________________________

SLIDE NUMBER and COLOR___________________

Instructions: Please write and show all work below. Show all steps and circle your final solution. If you need to use the back of the page, note that at the bottom of the front page.

Appendix H: Student Consent Form Control

Consent to be Part of a Research Study

Title of the Project: Problem Posing and Student Engagement in a University Developmental Mathematics Course.
Principal Investigator: John Sevier, MA, Instructor at Appalachian State University; PhD Student of University of North Carolina at Charlotte.
Faculty Advisor: Anthony Fernandes, PhD, Associate Professor of Mathematics Education at University of North Carolina at Charlotte

Dear Student:
You are invited to participate in a research study of Developmental Education. The intent of this research is to investigate instructional strategies to better support students' success and understanding in developmental mathematics. Participation in this research study is voluntary. The information provided is to help you decide whether to participate.

Important Information You Need to Know

- The purpose of this study is to investigate how developmental mathematics students engage in problem posing. Further, how does engaging in problem posing affect students beliefs and attitudes in mathematics.
- You will be asked to complete three questionnaires at the beginning, middle and end of the semester, a pre and posttest within the word problem solving unit conducted at the end of the semester
- If you choose to participate it will require your attendance in your course throughout the semester with no required or additional meeting outside of class hours.
- There are no foreseeable risks during this study.
- If you choose to participate, you will be contributing to research to better course and to help improve instruction and curriculum for developmental mathematics students.

Why am I doing this study?
The purpose of this study is to investigate how developmental mathematics students engage in problem posing. Further, how does engaging in problem posing affect students beliefs and attitudes in mathematics. It is the goal of this study to find other instructional approaches in working with this course to better prepare students for college mathematics. As part of the study you will engage in problem posing activities as part of your regular coursework. This will not involve any extra instructional time outside the regular class times. The problem posing activities will also be tied to the topics in the course.
Why are you being asked to be in this research study.
You are being asked to be in this study because you have enrolled in your course based on your placement, transfer, and or SAT/ACT scores.
What will happen if I take part in this study?

You will be providing profound information and data to better assist the instruction in improving methods of mathematical delivery to better serve the students of this course.
If you choose to participate in this study, you will be attending regular classes throughout the semester as part of the course. On three separate days you will be asked to complete a questionnaire. This will occur on the second day of the semester, beginning of the problem solving/word problem unit, and the conclusion of the semester. You will also be asked to complete an in-class pretest prior to the start of the problem solving/word problem unit and at the conclusion of the word problem unit. Test will be graded but this is already a part of the course curriculum. Timeline of events are attached to this document and the semester calendar.
You time commitment will be about 20 hours of your regular scheduled course meeting times. This time commitment will take place during regularly scheduled course meetings; therefore, no additional time will be required of you for this course.
I will also collect demographical data including placement testing results, SAT math and ACT math results in the last questionnaire of the semester. Names and identifiers will not be included or connected to any demographic data.

What benefits might I experience?

Benefits experienced may include a stronger understanding of the content, and better preparation and readiness for the next mathematics course.
You may not benefit directly from being in this study. However, others might benefit because/by investigating this data, the instructor will be allowed to assess, re organized and adjust instructional methods for the next developmental mathematics courses.

What risks might I experience?

The only foreseeable risks are breach of confidentiality.

How will my information be protected?

The instructor will use pseudonyms for data collected from participants. All documentation will be kept confidential and the instructor will delete, erase and remove all identifying marks and coding to which only the instructor has record of.
I plan to publish the results of this study. To protect your privacy, I will not provide names or school identification numbers or course identifiers. I will protect the confidentiality of the data by collecting all information and placing in a locked facility. Coding will be kept at a separate electronic location password lock through a different university system. This information will only be housed on one stationary computer with password entry within a locked room. Other instructors will be working with me throughout this process, but only final results of the class will be shared. All individual results will only be observed by myself. Individuals who will be assisting will professors working at Appalachian State, UNC Charlotte, and other agencies as required by law or allowed by federal regulations.

How will my information be used after the study is over?

Upon completion and use of data, all records will be destroyed. This includes identifiers, coding, and protocols.

Will I be paid for taking part in this study?

Participants will not be compensated for study.

What are the costs of taking part in this study?
There are no additional costs of the study beyond the university and course requirements. You will spend some time participating in the activities like the pre and posttests, and questionnaires, but all are a part of the regular curriculum and semester schedule.

What other choices do I have if I don't take part in this study?
Your participation in this study is voluntary and will not in any way affect the outcomes of the course. It is up to you to decide to be in this research study. Even if you decide to be part of the study now, you may change your mind and stop at any time. You do not have to answer any questions you do not want to answer. If you choose not to take part in study at any time, your results from the questionnaires, pre and post tests will not be used. If you decided not to participate during the semester, all your data will be removed from the data collection and destroyed at the end of the semester. Your choice not to participate will not affect your grades or outcome of the course.

Who can answer my questions about this study and my rights as a participant?
For questions about this research, you may contact John Sevier at sevierjn@appstate.edu or Dr. Anthony Fernandes at Anthony.Fernandes@uncc.edu. If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Office of Research Compliance at 704-687-1871 or uncc-irb@uncc.edu.

Consent to Participate
I hope you are willing to participate in this study to help improve developmental mathematics. Please indicate your willingness to participate in this research study by signing below and returning to John Sevier. You will receive a signed copy upon request for your records.

Thank you,

John Sevier, Doctoral Candidate
College of Education
UNC Charlotte

PERSONALIZATION OF PROBLEM SOLVING IN DEVELOPMENTAL MATHEMATICS CONSENT FORM

PLEASE READ THE STATEMENT BELOW AND SIGN AT THE BOTTOM, IF YOU ARE WILLING TO PARTICIPATE IN THIS STUDY:

By signing this document, you are agreeing to be in this study. Make sure you understand what the study is about before you sign. You will receive a copy of this document for your records upon request. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

I understand what the study is about, and my questions so far have been answered. I agree to take part in this study.

____
Name (PRINT)

____
Signature Date

____

Name and Signature of person obtaining consent Date

Appendix I: Student Consent Form Intervention

Consent to be Part of a Research Study

Title of the Project: Problem Posing and Student Engagement in a University Developmental Mathematics Course.
Principal Investigator: John Sevier, MA, Instructor at Appalachian State University; PhD Student of University of North Carolina at Charlotte.
Faculty Advisor: Anthony Fernandes, PhD, Associate Professor of Mathematics Education at University of North Carolina at Charlotte

Dear Student:
You are invited to participate in a research study of Developmental Education. The intent of this research is to investigate instructional strategies to better support students' success and understanding in developmental mathematics. Participation in this research study is voluntary. The information provided is to help you decide whether to participate.

<u>Important Information You Need to Know</u>

- The purpose of this study is to investigate how developmental mathematics students engage in problem posing. Further, how does engaging in problem posing affect students beliefs and attitudes in mathematics.
- You will be asked to complete three questionnaires at the beginning, middle and end of the semester, a pre and posttest within the word problem solving unit conducted at the end of the semester, and potentially participate in an interview after the conclusion of the semester. Participation in the interview will be requested by invitation upon completion of the course and final grades posted.
- f you choose to participate it will require your attendance in your course throughout the semester with no required or additional meeting outside of class hours. Course work will be video recorded during the unit of study
- There are no foreseeable risks during this study.
- If you choose to participate, you will be contributing to research to better course and to help improve instruction and curriculum for developmental mathematics students.

<u>Why am I doing this study?</u>
The purpose of this study is to investigate how developmental mathematics students engage in problem posing. Further, how does engaging in problem posing affect students beliefs and attitudes in mathematics. It is the goal of this study to find other instructional approaches in working with this course to better prepare students for college mathematics. As part of the study you will engage in problem posing activities as part of your regular coursework. This will not involve any extra instructional time outside the regular class times. The problem posing activities will also be tied to the topics in the course.
<u>Why are you being asked to be in this research study.</u>
You are being asked to be in this study because you have enrolled in your course based on your placement, transfer, and or SAT/ACT scores.

What will happen if I take part in this study?

You will be providing profound information and data to better assist the instruction in improving methods of mathematical delivery to better serve the students of this course. If you choose to participate in this study, you will be attending regular classes throughout the semester as part of the course. On three separate days you will be asked to complete a questionnaire. This will occur on the second day of the semester, beginning of the problem solving/word problem unit, and the conclusion of the semester. You will also be asked to complete an in-class pretest prior to the start of the problem solving/word problem unit and at the conclusion of the word problem unit. Test will be graded but this is already a part of the course curriculum. Some of you will be asked to participate in interviews in the following spring semester. The interviews will be audio recorded and will be directed at collecting student responses about their engagement with the material, process used, and instruction procedure. Interview duration will depend on the student responses. This participation will be on request and not required of everyone. Timeline of events are attached to this document and the semester calendar.

You time commitment will be about 20 hours of your regular scheduled course meeting times. This time commitment will take place during regularly scheduled course meetings; therefore, no additional time will be required of you for this course.

I will also collect demographical data including placement testing results, SAT math and ACT math results in the last questionnaire of the semester.

What benefits might I experience?

Benefits experienced may include a stronger understanding of the content, and better preparation and readiness for the next mathematics course.

You may not benefit directly from being in this study. However, others might benefit because/by investigating this data, the instructor will be allowed to assess, re organized and adjust instructional methods for the next developmental mathematics courses.

What risks might I experience?

The only foreseeable risks are breach of confidentiality.

How will my information be protected?

The instructor will use pseudonyms for data collected from participants. All documentation will be kept confidential and the instructor will delete, erase and remove all identifying marks and coding to which only the instructor has record of.

I plan to publish the results of this study. To protect your privacy, I will not provide names or school identification numbers or course identifiers. I will protect the confidentiality of the data by collecting all information and placing in a locked facility. Coding will be kept at a separate electronic location password lock through a different university system. This information will only be housed on one stationary computer with password entry within a locked room. Other instructors will be working with me throughout this process, but only final results of the class will be shared. All individual results will only be observed by myself. Individuals who will be assisting will professors working at Appalachian State, UNC Charlotte, and other agencies as required by law or allowed by federal regulations.

How will my information be used after the study is over?

Upon completion and use of data, all records will be destroyed. This includes identifiers, coding, transcripts, videos, and protocols.

Will I be paid for taking part in this study?
Participants will not be compensated for study.

What are the costs of taking part in this study?
There are no additional costs of the study beyond the university and course requirements. You will spend some time participating in the activities like the pre and posttests, and questionnaires, but all are a part of the regular curriculum and semester schedule.

What other choices do I have if I don't take part in this study?
Your participation in this study is voluntary and will not in any way affect the outcomes of the course. It is up to you to decide to be in this research study. Even if you decide to be part of the study now, you may change your mind and stop at any time. You do not have to answer any questions you do not want to answer. If you choose not to take part in study at any time, your results from the questionnaires, pre and post tests will not be used, and you will not be asked for an interview. If you decided not to participate during the semester, all your data will be removed from the data collection and destroyed at the end of the semester. Your choice not to participate will not affect your grades or outcome of the course.

Who can answer my questions about this study and my rights as a participant?
For questions about this research, you may contact John Sevier at sevierjn@appstate.edu. If you have questions about your rights as a research participant, or wish to obtain information, ask questions, or discuss any concerns about this study with someone other than the researcher(s), please contact the Office of Research Compliance at 704-687-1871 or uncc-irb@uncc.edu.

Consent to Participate
I hope you are willing to participate in this study to help improve developmental mathematics. Please indicate your willingness to participate in this research study by signing below and returning to John Sevier. You will receive a signed copy upon request for your records.

Thank you,

John Sevier, Doctoral Candidate
College of Education
UNC Charlotte

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By signing this document, you are agreeing to be in this study. Make sure you understand what the study is about before you sign. You will receive a copy of this document for your records upon request. If you have any questions about the study after you sign this document, you can contact the study team using the information provided above.

I understand what the study is about, and my questions so far have been answered. I agree to take part in this study.

____

Name (PRINT)

____

Signature Date

____

Name and Signature of person obtaining consent Date