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# A Case Study: Students' Mathematics-Related Beliefs From Integrated STEM Model-Eliciting Activities

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A CASE STUDY: STUDENTS' MATHEMATICS-RELATED BELIEFS FROM INTEGRATED STEM MODEL-ELICITING ACTIVITIES

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**Abstract**

This case study examines the mathematics-related beliefs of fourth and fifth grade students who participated in an after-school integrated science, technology, engineering and mathematics (STEM) program where participants completed four Model-Eliciting Activities. The research questions addressed by this study are, What is the nature of the change in mathematics-related beliefs of students who participate in an after-school MEA program? In particular, what is the difference, if any, of the nature of the change in beliefs across varying ability levels? The framework used to describe these beliefs was developed by Kloosterman and includes beliefs about the nature of mathematics and mathematics learning. The rich description of the participants' mathematics-related beliefs in this study provides a rationale for why mathematics-related beliefs are important and how they can affect students' abilities to solve non-routine problems like MEAs.

Data collected included a pre and post-questionnaire, six individual interviews selected so that there were two high-, two middle- and two low-ability students and focus groups. Interviews and focus groups were collected before and after the after-school program as well as after the completion of each MEA.

Overall, the participants' mathematics- related beliefs were found to slightly change as a result of participating in the MEAs. For the high-ability level students who participated in the interviews there was no change in their mathematics-related beliefs. The middle-ability level students were able to better connect mathematics to their other classes and to the world around them as a result of completing the MEAs. For the low-ability level students there was no consistent change in their mathematics-related beliefs. However one of the low-ability level students indicated that MEAs would be good motivational activities. One middle-ability level

student and one low-ability student reported changes in their beliefs about mathematics after every activity except the last one.

Focus group participants also reported some change in their mathematics-related beliefs. Two high-level participants suggested that they could learn mathematics when problem solving like engineers. Completing the MEAs caused two high-ability level students to think that doing mathematics was fun and also to understand that there is more to mathematics than just solving problems on paper.

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# Chapter 1: Introduction

Our society is increasingly more dependent on science, technology, engineering and mathematics (STEM) disciplines. The United States Bureau of Labor Statistics (BLS) (2009) defined STEM fields as fields where individuals logically solve problems using mathematics and science. The BLS (2009) reported that in 2018 over 8.5 million jobs will be in STEM fields and 80% of the jobs in the future will require technology and there is no evidence to suggest that this trend will change. Even if an individual does not pursue a STEM career, they need to have some degree of STEM literacy, including mathematics literacy, to participate in society. Being able to understand and apply mathematics is essential for the other STEM subjects. This is seen in that individuals can gain knowledge of new technology through their understanding of mathematics and science (Moses, 1994). Moses (1994) also said that the "hidden culture of the computer is math" (p. 13). In addition, mathematics is often referred to as the language of science (Lemke, 2004). The mathematics that is necessary to be successful in everyday life is different from the mathematics that is currently taught in schools (Lesh & Doerr, 2003; NAS, 2014). In order to better prepare students for the mathematics that they will use later in life, the way that mathematics is taught in school needs to change. For this change to be successful students' beliefs about the nature of mathematics and how mathematics is learned must be examined.

## Statement of the Problem

The purpose of this case study was to describe the mathematics-related beliefs of fourth and fifth grade students at a Title I Elementary School in a large Southwestern school district. For the purposes of this research, mathematics-related beliefs will be generally defined as students' beliefs about the nature of mathematics and mathematics learning (Kloosterman, 1996). These beliefs affect students' problem solving behaviors and are shaped by school mathematics

curriculum and instruction as well as the socio-mathematical norms that students encounter (Yackel & Rasmussen, 2002).

## Definitions

### Integrated STEM Education

Being able to apply mathematics, science and technology to the real world is important because our society is so dependent on technology. Despite this importance there continues to be some disagreement on the definition of integrated STEM education (National Academies, 2014). STEM education could refer to the integration of science and mathematics (Bybee, 2010b). While for others integrated STEM means there should be an increased focus on technology (Bybee, 2010a). Bybee (2010a) stated STEM education needed to include engineering because of its focus on problem solving. There is agreement, though, that the implementation of integrated STEM education is student centered with the teacher serving as the facilitator of learning (Hung, Jonassen & Liu, 2012; Verma & Dickerson, 2011).

For the purpose of this dissertation, integrated STEM education is defined as the combination of three of the STEM fields that are naturally connected and integrated into an activity. For example, in one of the activities in the study participants were asked to design a shelter that can withstand wind and rain. For this activity participants are introduced to the scientific concepts of evaporation and transpiration that occur in tropical rain forests. Participants are then asked to design a scale model of a shelter that can withstand simulated wind and rain as well as hold three participants. Participants use the engineering design process to design and test their model as they build it. This activity and the others used in this study are called (MEAs).

**Model-Eliciting Activities**

MEAs are student-centered activities in which students use mathematical modeling to solve complex, real-life problems (Maiorca & Stohlmann, In Press). In the mathematical modeling cycle students are given a problem they need to solve, then students identify what variables they think are important and formulate a plan or model using these variables, then students will build either a physical model or a mathematical model and test and revise this model until they have determined what they believe to be a satisfactory solution to the problem. The final step is to share what was learned and the models that were developed. Students will often complete several iterations of this cyclical process while they complete a MEA. Figure 1 illustrates the mathematical modeling cycle (CCSSM, 2012).

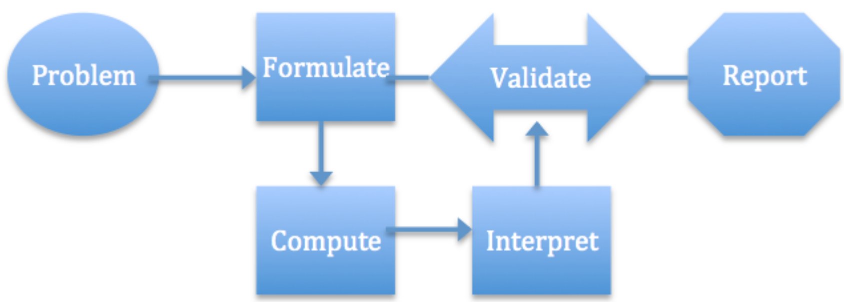



*Figure 1.* Mathematical Modeling Cycle

MEAs are implemented in a structured format. The first step to implementing an MEA in the classroom is the opening activity. This activity provides context for the students to solve the MEA. In this activity students are given either a short article or a video to watch. This is followed by readiness questions. The readiness questions are 4 to 5 questions that ask students about the opening activity and start the students thinking about the problem. The readiness questions should first be answered individually and then as a whole group. Both the opening activity and readiness questions should take approximately 15 to 20 minutes of class time to

complete. If the teacher wants to save time then the opening activity and readiness questions can be sent home for the students to answer individually and the next class can begin with the whole-group discussion.

The problem statement follows the readiness questions. For younger students it is beneficial for the group to read the problem statement out loud to clarify any vocabulary before having students begin working on it. Next, students are given time to work in groups on developing their models (solutions). After students have developed their model it is important to provide the students with an opportunity to share their results with their class and then to decide if they would make any changes based on their classmates' work. When students have completed this, they then write a letter to the client explaining why their model is the best, how they built it and any changes they might make in the future. Depending on how polished the teacher wants the solution to be it takes 45 – 90 minutes for students to complete a MEA.

**Mathematics-Related Beliefs**

The mathematics-related beliefs that will be examined in this study include beliefs about the nature of mathematics and mathematics learning (Kloosterman, 1996). The first category describes the beliefs that students have of mathematics as a discipline and include perceptions of problems in mathematics, the usefulness of mathematics and the connectedness of mathematics to other subjects. The second category examines the beliefs that students hold about the nature of mathematics learning and include beliefs about word problems and mathematical modeling as well as the social context in which students learn mathematics, the role of the teacher, and also the students' view of self and ability in mathematics.

## Rationale for the Study

This case study is necessary and important for several reasons. First, the mathematics that students need to know to be successful later in life has changed. Students no longer need to be able to simply use algorithms; students need to be able to apply mathematics to the real world. Integrated STEM MEAs are one way to teach students how to model mathematically. For the purpose of this study, integrated STEM MEAs are open-ended, client-driven activities that require students to use a combination of three or more organically connected subjects in science, technology, engineering or mathematics to solve a problem. Students' mathematics-related beliefs influence students' success in solving these non-routine problems. For example, students who believe that mathematics is based on following rules and memorization may struggle and be less motivated to solve MEAs. This is true because MEAs require students to conceptually understand mathematics so that they may apply it in a real-life scenario. When students only memorize equations they do not necessarily understand the context where these equations are applicable. This could lead to frustration when students solve MEAs because they are not told what mathematical content that they should use to solve a given MEA. Students who believe that mathematics problems can be solved using step-by-step procedures may also struggle with MEAs because there is no one procedure that can be used to solve these types of problems. Second, there is a gap in the research literature concerning students' mathematics-related beliefs and integrated STEM MEAs. Third, this study will add new knowledge about students' mathematics- related beliefs and will provide information to mathematics instructors to better understand how students' mathematics-related beliefs will affect the implementation of mathematical modeling and students' problem-solving abilities.

## Theoretical Perspective

My theoretical lens is one of social constructivism because I believe that reality is socially constructed through interactions with others and influenced by our personal experiences (Creswell, 2013). Integrated STEM MEAs are based on the models and modeling perspective, an extension of constructivism. Mathematics-related beliefs are constructed individually using personal experiences and further constructed socially through student interaction during MEAs. The framework that is predominantly used to describe mathematics-related beliefs is Kloosterman's (1996). Kloosterman (1996) alleged that the mathematics-related beliefs of students could be separated into two main categories: beliefs about the nature of mathematics and beliefs about mathematics learning. Beliefs about the nature of mathematics included beliefs that mathematics is useful, not solely computational or integrated with other subjects. Beliefs about mathematics learning included beliefs about learning mathematics and the role of the teacher.

## Research Questions

The main research question that this study addresses is focused on the mathematics-related beliefs of fourth and fifth grade students before and after participating in an after-school MEA program. The research question is as follows:

What is the nature of the change in mathematics-related beliefs of students who participate in an after-school MEA program? In particular, what is the difference, if any, of the nature of the change in beliefs across varying ability levels?

## Organization of the Study

This study is organized into five chapters. Chapter 1 contains the introduction, rationale, purpose statement and the research questions. In chapter 2 the relevant literature is reviewed for

integrated STEM, MEAs and mathematics-related beliefs. Also included in this chapter is the theoretical framework for mathematics-related beliefs. In chapter 3 the research methods are explained. Chapter 4 includes the analysis of data and findings. Chapter 5 contains a discussion of the findings and their implications, the limitations of the study, the significance of the study as well as recommendations for future research.

## Chapter 2: Review of the Literature

The purpose of this section is to provide a review of the literature. First integrated STEM will be reviewed. This will be followed by a literature review for MEAs and beliefs. This section will close with a discussion on why it is important to study beliefs using integrated STEM MEAs.

### Integrated STEM

As society becomes more advanced, science, technology, engineering and mathematics (STEM) are becoming more prevalent. New knowledge in STEM fields is rarely composed of just a single content area because STEM fields are highly inter-related (Stohlmann, Moore, & Roehrig, 2012). The National Academy of Sciences (NAS) (2014) described this inter-relatedness,

> Scientists use technological tools to conduct experiments and mathematics and statistics to interpret the data produced by those experiments; engineers draw on scientific knowledge and mathematical reasoning to develop and model potential design inventions and solutions; technologists who build and maintain the products and systems designed by engineers must understand the scientific and mathematical principles governing their operation. (p. 20)

Even if individuals will not be working in a STEM field, it is important for them to receive an authentic education that includes integrated STEM because students need to develop the life skills necessary to succeed in a society that is strongly dependent on the many applications of integrated STEM.

**Definition of Integrated STEM**

Although there has been increased focus on STEM education, there remains some disagreement as to what exactly STEM or the integration of STEM education is (National Academies, 2014). One of the reasons for this disagreement is the lack of an agreed upon definition for the individual subjects in STEM education (Bybee, 2010; National Academies, 2014; Roehrig, Moore, Wang, & Park, 2012; Williams, 2009).

STEM education is an amalgamation of the individual STEM content areas. In order to better understand what integrated STEM education encompasses, the individual components of STEM education need to be more clearly defined. The National Academy of Sciences has specific definitions for each of the components of STEM (see Appendix A).

According to the National Academy of Sciences (2014), integrated STEM education is complex and not just limited to K-12 education. Integrated STEM education can also be incorporated in after-school or summer programs. Integrated STEM education will provide students with the opportunities to learn in real-world situations, unlike traditional methods that are used to teach mathematics and science where students learn the subjects separately and then have to combine their knowledge on their own at a later time (Tsupros, Kohler, & Hallinen, 2009).

Stohlmann, Moore and Roehrig (2012) defined integrated STEM education as combining science, technology, engineering, and mathematics by using engineering as the real-world context that connects them. For the purpose of this paper integrated STEM education will be defined as the combination of three of the STEM fields that are organically connected and integrated into an activity, unit or lesson that can take place in the classroom or in a after-school type program.

## Goals of STEM Education

The purpose of this section is to discuss the goals of integrated STEM education. These include future STEM employment, STEM literacy and 21st century competencies.

**STEM and the Economy.** A goal for STEM education is to prepare students for post-secondary education and the workforce (Moses, 1994; NRC, 2012; ITEA, 2007; Common Core State Standards [CCSS], 2010). According to the U.S. Department of Commerce Economic and Statistics, individuals in STEM fields have a lower rate of joblessness than those employed in non-STEM fields. STEM workers get higher wages than non-STEM field workers and individuals who have post-secondary degrees in STEM fields have higher incomes than those who do not, even if they are working in non-STEM fields (Langdon, McKittrick, Beede, Khan & Doms, 2011). While STEM fields are vital for the success of our economy, the U.S. Department of Commerce Economics and Statistics reported that STEM jobs represent only a small portion of employment in the United States (Langdon et al.,, 2011). The Center on Education and the Workforce at Georgetown University (2011) reported that only 5% of all jobs in 2018 would be in STEM fields. Despite the small portion of jobs that are available in the STEM fields, STEM is vital for the United States economy. Innovations and technological advancements would not be possible without STEM (Bybee, 2010b; Moses, 1994; NAS, 2014).

**STEM Literacy.** The economy is not the only reason that integrated STEM education is important. Another goal of integrated STEM education is to create students with some level of STEM literacy. Just like STEM education, there is not a universal definition for STEM literacy (NAS, 2014). According to Bybee (2010a), there needs to be a clear definition of STEM literacy in order to advance STEM education.

***Mathematics Literacy.*** Mathematical literacy is an essential skill for participation in today's society. Mathematical literacy provides students with the knowledge to apply mathematics in other content areas. The Programme for International Student Assessment (PISA) defined mathematical literacy as students' ability to use mathematics in their personal, private lives outside of the mathematics classroom (as cited in Kaiser & Willander, 2005).

***Science Literacy.*** There are two different, competing viewpoints on what constitutes scientific literacy. The first refers to individuals' knowledge about science and the second refers to the usefulness of science in today's rapidly changing society (Holbrook & Rannikmae, 2008). The American Association for the Advancement of Science (as cited in Sanfeliz, & Stalzer, 1998) defined science literacy as,

> Scientific literacy, which encompasses mathematics and technology as well as the natural and social sciences, has many facets. These include being familiar with the natural world and respecting its unity; being aware of some of the important ways in which mathematics, technology, and the sciences depend upon one another; having a capacity for scientific ways of thinking; knowing that science, mathematics, and technology are human enterprises and knowing what that implies about their strengths and limitations; and being able to use scientific knowledge and ways of thinking for personal and social purposes. Thus scientific, mathematical, and technological processes are important factors in improving society, along with thinking skills and scientific knowledge. (p. 20)

This definition reflects how science, technology and mathematics are interconnected. However, the National Research Council (NRC) (2012) defined science literacy as students having

> some appreciation of the beauty and wonder of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful

> consumers of scientific and technological information related to their everyday lives; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering, and technology. (p. 1)

The NRC (2012) used this definition to develop the framework for K-12 science education.

***Technology Literacy.*** Being able to use, understand and develop technology is vital to our society. Technology means  "the act of making or crafting, but more generally it refers to the diverse collection of processes and knowledge that people use to extend human abilities and to satisfy human needs and wants" (International Technology Education Association [ITEA], 2007, p.2). Bybee (2010) suggested, "there are very few other things that influence our everyday existence more and about which citizens know less" (p. 30). Technology literacy is essential in enhancing the education of other subjects, vital for individuals to gain and maintain employment as well as being able to participate in our ever-changing technological society.

***Science, Technology, Engineering and Math (STEM) Literacy***. Our society is dependent on technology and because of this dependence it is increasingly more important to have citizens who are STEM literate. Moses (1994) believed that technology is the direct application of science and mathematics; it is through mathematics and science that individuals gained access to new technological advances.  Moses (1994) also stated that the computer was "the visible manifestation of the technological shift [in society], the hidden culture of the computer is math" (p. 13). Some scientists refer to mathematics as the language of science (Lemke, 2004).

Science, technology and mathematics are similar to each other because they all address problem solving. For technology this is the design process where students design problems,

create solutions and evaluate designs by considering its effects on other technology (ITEA, 2007). Problem solving occurs in the scientific inquiry process when students formulate hypotheses, design and conduct experiments, make arguments with scientific evidence, consider alternate hypotheses and interpret the results (NRC, 2012). In mathematics, problem solving consists of students making conjectures, exploring, being able to justify conclusions with counter examples and evaluating the reasonableness of their results (CCSS, 2010).

Real-world applications of science, mathematics and technology are important to all the content areas. In mathematics, students need to be able to use statistics to model and describe real world situations (CCSS, 2010). Students also need to be able to interpret mathematical solutions in a real-life context. Engineering is the application of mathematics and science in the real world. Engineers use applied mathematics and science to design new technologies. Because our society is a technological one, all technology has real-world applications. A basic understanding of all of these subjects is necessary in order for individuals to participate fully in society. Bybee (2010a) defined STEM literacy as,

> Acquiring scientific, technological, engineering, and mathematical knowledge and using that knowledge to identify issues, acquire new knowledge, and apply the knowledge to STEM-related issues. Understanding the characteristic features of STEM disciplines as forms of human endeavors that include the processes of inquiry, design, and analysis. Recognizing how STEM disciplines shape our material, intellectual, and cultural world. Engaging in STEM-related issues and with the ideas of science, technology, engineering, and mathematics as concerned, affective, and constructive citizens (p. 31).

This provides a context that can be used to evaluate the influences of STEM literacy and its impact on society. In general, STEM literacy is a challenging goal to measure (NAS, 2014) and

at this time there is no way of directly assessing it. However, the knowledge of how STEM influences the world and students' understanding of specific concepts can be measured.

**21st Century Competencies.** As our society becomes more dependent on technology, the skills that students need to be successful in it are different from those that were necessary in the past. The New York Times reported that 65% of future jobs do not exist today (Heffernan, 2011). Reich (as cited in Voogt & Roblin, 2010) argued that routine jobs like those involving repetitive tasks would be replaced by technology. He also stated that the jobs that are not replaced by technology would be heavily technologically dependent. Not only will the kinds of jobs change in the future but also most jobs do not even exist yet.

Students are being trained for jobs that do not exist; the "skills" that they need to be successful are more ambiguous because it is not known exactly what skills students will need. The National Research Council (2012) referred to 21st century skills as "competencies" because of this ambiguity. According to the National Academies of Sciences (2014), these competencies are "a blend of cognitive, interpersonal and intrapersonal characteristics, that may support deeper learning and knowledge transfer. Cognitive competencies include critical thinking and innovation; interpersonal attributes include communication, collaboration and responsibility; and intrapersonal traits include flexibility, initiative and metacognition" (p. 35). Lesh (2000) proposed that representational fluency, reasoning, reflection and responsibility should be added to the traditional curriculum. Not only are educators responsible for educating students for future jobs, they also need to teach individuals how to understand the world around them (Burkhardt, 2006).

## Implementation of Integrated STEM Education

The purpose of this section is to discuss the implementation of integrated STEM education. This will be accomplished by discussing two different methods; project-based learning and problem-based learning that can be used to include integrated STEM education in the curriculum.

**Project-Based Learning.** One way to implement integrated STEM education into the curriculum is through project-based learning (NAS, 2014). Just like integrated STEM education, project-based learning can have many different meanings (David, 2008).

In general, project-based learning is a student-centered model with authentic, real-life problems that occur over a period of time, allowing students to solve complex problems and produce realistic solutions (Thomas, 2000). In project-based learning, the problems are question-centered and require students to use the scientific inquiry process to solve them (Hmelo-Silver, 2004). Project-based learning prepares students to work collaboratively and develops the skills that are necessary to succeed in the workplace (David, 2008). Project-based learning also "bridges the gap" between academia and the workplace (Verma & Dickerson, 2011).

Using project-based learning to teach science, technology and mathematics emphasizes a realistic application of these content areas that highlights problem solving, critical thinking skills, content knowledge and integrates these content areas (Lou, Liu, Shih, & Tseng, 2011). Andrade (2013) found that project-based learning enabled students to improve their knowledge and understanding of subjects by presenting a global picture of them. Verma and Dickerson (2011) found that students enjoyed project-based learning and that it provided students with the opportunity to think creatively and collaboratively.

**Problem-Based Learning.** Another way to implement integrated STEM education is by using problem-based learning (NAS, 2014). Problem-based learning is similar to project-based learning because it is also a student-centered model in which the teacher serves as a facilitator and the students work collaboratively to find a solution to a real-life problem that has more than one possible solution (Hmelo-Silver, 2004; Thomas, 2000). The problem-solving process begins with the presentation of a real-life problem that students solve in a cyclical nature (Hmelo-Silver, 2004). The problem solving process entails the identification of relevant information that is needed to solve the problem, generation of possible solutions, recognizing any deficiencies of a solution and the creation of new knowledge that is then used to enhance solutions. The problem solving cycle is repeated until a "final" solution is attained.

The purpose of this section was to discuss problem-based and project-based learning. Both are student-centered methods where the teacher serves as the facilitator while students work collaboratively to "solve their problems." Project-based and problem-based learning are both based on constructivist-learning principles (Hung, Jonassen & Liu, 2012;Verma & Dickerson, 2011).

### Implications for Math Education

The way the teachers apply integrated STEM education in the classroom will effect mathematics education. The Common Core State Standards for Mathematics (CCSSM) would suggest students be able to connect and use mathematics in other contexts, such as engineering and science (NAS, 2014).

One goal of the CCSSM is to provide students with the skills and knowledge to succeed in our technological society and the ability to compete in a global economy. The CCSSM standards for mathematical practice include: the ability to make sense of problems and persevere

in solving them; abstract and quantitative reasoning; construct and critique arguments; mathematical modeling; use suitable mathematical tools; attend to precision; the ability to identify and use patterns and structures; and identify and use repeated reasoning (CCSSM, 2012). There is a new emphasis on mathematical modeling and the ability to apply these skills to nonmathematical concepts. The CCSSM emphasize a more student-centered teaching approach rather than the teacher-centered approach used in traditional mathematics education.

The CCSSM will provide students the opportunity to explore mathematics curriculum and develop higher-level thinking skills (CCSS, 2012). The interaction with other students through collaboration will provide students with the social context necessary to develop a deep understanding of mathematics and the ability to work in teams.

**Implications for Science Education**

In science education, integrated STEM will also have an impact on the science classroom. In the Next Generation Science Standards (NGSS), engineering, technology and the applications of science is one of the four core disciplinary ideas because it is important for individuals to understand the world around them (National Academy of Science [NAS], 2012).

According to the National Academy of Sciences (2012) the major goal of the NGSS is to ensure,

> all students have some appreciation of the beauty and wonders of science; possess sufficient knowledge of science and engineering to engage in public discussions on related issues; are careful consumers of scientific and technological information related to their everyday lies; are able to continue to learn about science outside school; and have the skills to enter careers of their choice, including (but not limited to) careers in science, engineering and technology. (p. 1)

Integration of STEM concepts is important for science education. An important practice in science is modeling. Students use models of phenomena and also conduct mathematical modeling in order to better make sense of science concepts. Engineering and technology are applications of science and the engineering design process is an important element of science education (NAS, 2012).

**Benefits of Integrated STEM Education**

Although there are few quantitative studies that examined integrates STEM education, Becker and Park (2011) conducted a meta-analysis to examine the effects of integrated STEM education. Becker and Park (2011) found that teaching integrated STEM had a positive effect on student achievement, where as students who were taught using the traditional teaching methods had no such effect. The researchers also found that integrated STEM education was a more effective teaching strategy than separately teaching the subjects. Becker and Park (2011) indicated **“**due to the lack of a comprehensive review regarding the effects of integrative approaches among STEM subjects on academic achievement, many teachers are unaware of the benefits of the integrative approaches for student learning” (p. 23). Becker and Park (2011) also found that “various types of integrative approaches could serve as bridges between the theoretical learning of mathematics and science and the practical learning of technology and engineering” (p. 32).

Elliot, McArthur and Clark (2001) conducted a study that compared a traditional college algebra course to an interdisciplinary mathematics course. The researchers found there to be no significant difference in problem solving skills between the two groups. However, they did find that students in the interdisciplinary class had more positive attitudes towards mathematics and increased critical thinking skills compared to the students in a traditional college algebra course.

Venville, Wallace, Rennie and Malone (2012) conducted a qualitative research study that described the implementation of integrated science, technology and mathematics in a school environment where these subjects were taught in separate classes. The researchers wanted to know what this would do to student learning. Participants were separately introduced to concepts in their mathematics, technology and science classes and in an after-school program the researcher used technology-based projects to integrate mathematics and science concepts. The researchers found that although it was challenging, teachers with subject-specific backgrounds could work together to provide students with opportunities to learn in an integrated setting (Venville et al., 2012). The researcher also found that student learning was enhanced when students were able to apply the knowledge they learned in their separate classes together.

One way to implement integrated STEM education is through the use of MEAs. Students use the STEM disciplines to solve MEAs.  Math and science concepts are developed through the engineering design process and technology can be used as a tool to solve MEAs.

**Model-Eliciting Activities**

MEAs are defined as open-ended problems where students have to answer to a client and create complex solutions that are generalizable to different situations (Lesh & Doerr, 2003; Lesh & Zawojewski, 2007). Hamilton, Lesh, Lester, and Brilleslyper (2008) described the characteristics of MEAs:

> include a capacity to function in complex design or other task settings with competing constraints that frequently are unrelated to underlying science or technology but instead involve human preferences, values, and social dynamics; a pragmatism that welcomes multiple approaches in designing and testing solutions rather than rigid adherence to a single paradigm; and an ethos of continuous field-testing and improvement cycles. (p. 2)

Lesh and Doerr (2003) described MEAs as "products that students produce that go beyond short answers to modifiable and reusable conceptual tools (e.g., models) for constructing, describing, explaining, manipulating, predicting or controlling mathematically significant systems" (p. 3). In MEAs, the process that students use to find their solutions is more important than the solution itself (Hamilton, et al., 2008). Lesh and Doerr (2003) further state that the most important component of students' solutions to MEAs is the process that they used to find their solutions (see Figure 2).


*Figure 2*.Graphical Representation of Product on MEA

MEAs are designed using six design principles: (a) the model construction principle, (b) the reality principle, (c) self-assessment principle, (d) model construction principle, (e) model documentation principle, (f) generalizability principle and prototype principle (English, 2010; Lesh, Hoover, Hole, Kelly & Post, 2000; Lesh et al., 2003; Yoon, Dreyfus, & Thomas, 2010;). To satisfy the model construction principle the problem requires the student to develop a model to interpret the given situation. The second principle, the reality principle, means that the problem should occur in real life and be personally meaningful to students. The self-assessment principle refers to whether the task allows the students the ability to determine if their response meets the needs of the client. The generalizability principle requires that the solution of a MEA needs to be sharable with others and can be modified to apply to other situations. The model

documentation principle requires that students need to be able to show their thinking process used to determine their solution. The simple prototype principle requires that the solution of MEAs can be used to interpret other situations and connects to big mathematical ideas.

**Mathematical Modeling Cycle**

Mathematical modeling is cyclical in nature (Lane, & Harkness, 2012; Lesh et al. 2003; Lieven & De Corte, 1997; Maher, 2005). MEAs are problems where individuals create models to represent different situations. Some models are designed to represent complex mathematical situations using technology to represent the solutions; others may be simpler representations of more complex situations or could consist of spoken language (Lesh & Doerr, 2003). While there are several different kinds of models, all of these models can be solved using a four-step process illustrated in Figure 3 (Lesh, Doerr, Carmona, & Hjalmarson, 2003).

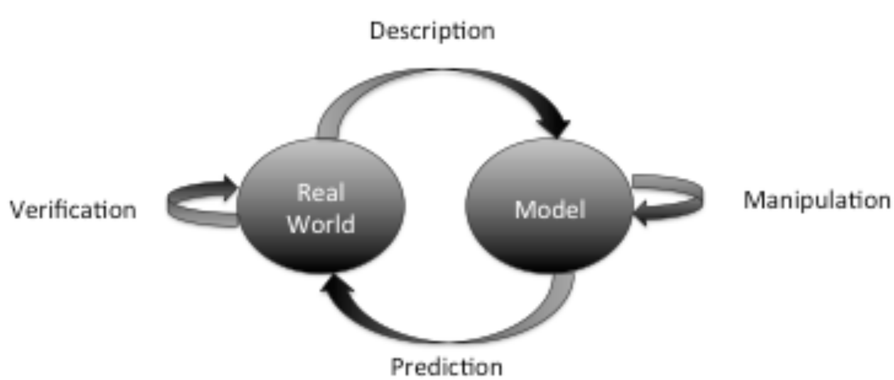



Figure 3. *The four steps in the mathematical modeling cycle*

Lesh and Doerr (2003) describe these steps:

(a) *description*: that establishes a mapping to the model world from the real (or imagined) world, (b) *manipulation*: of the model in order to generate predictions or actions related to the original problem solving situation, (c) *translation* (or prediction) carting relevant results back into the real (or imagined) world, and (d) *verification* concerning the usefulness of actions and predictions. (p. 17)

In order to solve a MEA, students will complete several iterations of this process and will often refine, revise and extend powerful math constructs that would not ordinarily be taught in the traditional classroom setting (Hamilton et al. 2008; Lesh, & Doerr, 2003).

**Problem Solving**

The models and modeling perspective is an alternate way to view mathematics teaching and learning--specifically the nature of reality, mathematical knowledge, how knowledge is developed, what drives the development of knowledge, the connection between generalizability and context, problem solving, teachers' knowledge and the knowledge of what activities add to the development of children's' knowledge (Lesh, et at., 2003). In this perspective, problem solving is approached using MEAs.

Problem solving is approached differently than in a traditional mathematics course in this perspective (Lesh & Doerr, 2003). Applied problems are considered to be more difficult and a subset of problem solving in the traditional view of mathematics. In the traditional view of mathematics mathematical skills are first learned in the abstract with no real life context, then students are taught general problem solving strategies and if there is time students might work problems in real world setting. However, in the models and modeling perspective solving real-world problems is assumed to be less difficult than solving an abstract problem with no context and students are given "real life "problems that are more meaningful and require students to

develop a deep understanding of mathematics and problem solving in traditional sense is considered a subset of these more meaningful problems see Figure 4 (Lesh & Doerr, 2003).

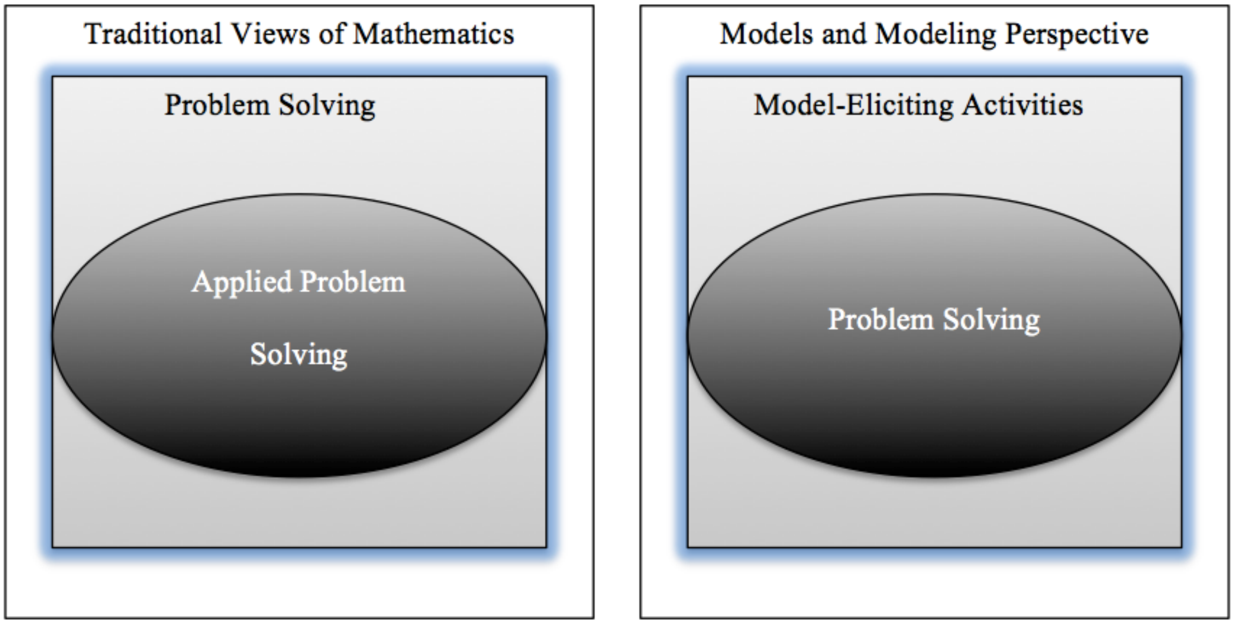



*Figure 4.* Traditional versus models and modeling perspective view of problem solving.

In MEAs, students use the mathematics that is similar to the mathematics that is often required to solve real-life problems (Lesh & Doerr, 2003). In order to solve MEAs it is necessary for students to mathematize or interpret real-world situations (Lesh et al., 2000) thus developing higher-order thinking skills (Stohlmann, Maiorca, & Olson, 2015). According to Lesh and Doerr (2003), mathematizing is the process of "quantifying, dimensionalizing, coordinatizing, categorizing, algebratizing, and systematizing relevant objects, relationships, actions, patterns, and regularities" (p. 5). Hamilton et al. (2008) described MEAs as focusing "less on notions such as ill-defined problems, problem-solving strategies, and rubrics and more on drawing out and changing the conceptual models that underlie strategies and on structuring problems to optimize that modeling process" (p. 8).

## Engineering Design Process

An important component to MEAs is the engineering design process (Maiorca & Stohlmann, in press). In fact, Gainsburg (2013) described MEAs as "the most thoroughly developed modeling initiative in engineering education" (p. 262). The engineering design process is similar to the mathematical modeling cycle because it too is cyclical in nature and more than one solution is possible (NAE, 2009). In MEAs students participate in the engineering design process as they plan, test and revise models (English, 2010).

## Implementation of MEAs

MEAs can be implemented either before or after instruction (Yoon, et al.,, 2010). The effectiveness of MEAs is mostly due to when they are implemented (Lesh, Yoon, & Zawojewski, 2007). The two possible ways that Lesh and colleagues (2007) described that MEAs could be implemented was what they called "making mathematics practical and making practice mathematical." When an MEA is implemented before instruction it is intended to encourage students to solve problem by mathematizing and to develop their own personal knowledge and therefore is an example of making practice mathematical (Yoon et al., 2010). An example of making mathematics practical is when MEAs are used at the end of a unit. In this situation MEAs are designed to facilitate student application of content knowledge but also to practice mathematizing topics. In a research study conducted by Yoon and colleagues (2010), the claim that MEAs enhanced conceptual understanding of mathematics was investigated. This is an example of how MEAs are implemented in a way that made mathematics practical. Yoon and colleagues (2010) were able to generalize that MEAs, implemented after instruction, lead to a deeper conceptual understanding of mathematics. Yoon and colleagues also found that there were severe limitations in the conceptual understanding of their participants, though, in regards

to generalizability. The participants were unable to use integration to solve their problem because they did not recognize the application of integration outside of the context in which it was learned. The researchers did find, though, that the participants were provided an opportunity to improve their conceptual understanding through the iterative modeling process used in MEAs.

English (2010) conducted a qualitative research study that examined how to make practice mathematical. In this study a variety of mathematical models created by fourth graders were examined. English found that the mathematical concepts the students developed to solve the MEAs were far more advanced than what they would have been taught in a traditional fourth grade classroom and that the students' conceptual understanding of mathematics increased.

There are many advantages to using MEAs in the classroom.  One advantage is due to the nature of MEAs themselves. MEAs were problems that were originally developed for mathematical research so student reasoning can easily be observed throughout the problem-solving process (Hamilton et al. 2008; Yoon et al., 2010).  MEAs are non-traditional problems that address the diverse learning styles of students. Many students who typically do not perform well on traditional standardized tests performed perform well on MEAs (Lesh & Zawojewski, 2007). Lesh and Doerr (2003) found in their study that low-level students performed better on MEAs than they did in the traditional classroom. When MEAs are used in the classroom, teachers are better able to understand how students develop their understanding of important mathematical concepts (Lesh & Caylor, 2007).

When teachers implement MEAs in the mathematics classroom it is possible to address all of the Standards of Mathematical Practice (SMPs) in the Common Core State Standards (CCSS) (see Table 1).

*Table 1. Possible SMPs Addressed in MEAs*

| Standards of Mathematical Practice | How it can occur in MEAs |
| --- | --- |

| | |
|---|---|
| 1. Make sense of problems and persevere in solving them. | As participants work through iterations of their models they continue to gain new insights into ways to use mathematics to develop their models. The structure of MEAs allows for participants to stay engaged and to have sustained problem-solving experiences. |
| 2. Reason abstractly and quantitatively. | MEAs allow participants to both contextualize, by focusing on the real world context of the situation, and decontextualize by representing a situation symbolically. |
| 3. Construct viable arguments and critique the reasoning of others. | Throughout MEAs while groups are working and presenting their models. |
| 4. Model with mathematics. | This is the essential focus of MEAs; for participants to apply the mathematics that they know to solve problems in everyday life, society, or the workplace. This is done through the mathematical modeling process. |
| 5. Use appropriate tools strategically. | Materials are made available for groups as they work on MEAs. |
| 6. Attend to precision. | Precise communication is essential in MEAs. Participants develop the ability to communicate their mathematical understanding through different representations. |
| 7. Look for and make use of structure. | Participants in MEAs can use their knowledge of mathematical properties and algebraic expressions to develop their solutions. |
| 8. Look for and express regularity in repeated reasoning | As participants notice patterns that can assist in their model development |

(Stohlmann, et al., 2015)

MEAs are open-ended client driven problems that are designed using six design principles, which require students to use the modeling cycle to solve them and have generalizable solutions. For the purpose of this study integrated STEM MEAs are MEAs that require students to use a combination of three or more organically connected STEM fields to solve them. Mathematics and science content will be developed in a real-world context. The

engineering design process will be used to solve the problem. Technology may be used as a tool to aide the problem-solving process.

## Beliefs

Mathematical-related beliefs are important to study because beliefs can be used to explain students' behaviors in numerous mathematical settings (Underhill, 1988). Schoenfeld (1983) argued that in order to fully understand students' mathematical performance researchers need to understand students' mathematics-related beliefs including beliefs about self, mathematical tasks, social context of mathematical learning, facts, problem-solving procedures and strategies.

Beliefs have been studied in numerous fields using a large variety of definitions (Leder, Pehkonen, & Törner, 2002). As a result, studying beliefs can be challenging. Despite this challenge, Op't Eynde, De Corte, and Verschaffel (2002) suggest that future research is necessary to fully understand how students' beliefs influence mathematical learning and problem solving.

Op't Eynde and colleagues (2002) stated that, "students' mathematics-related beliefs are implicitly or explicitly held subjective conceptions students hold to be true, that influence their mathematical learning and problem solving" (p. 24). Op't Eynde and colleagues (2002) also asserted that beliefs and knowledge are connected because "students' problem-solving behavior is always directed by what they believe to be true, referring to knowledge as well as beliefs" (p. 23). Although beliefs and knowledge are interrelated epistemologically they are different. According to Op't Eynde et al. (2002) knowledge is a social construct whose truth can be verified by others and beliefs are an individual construct in which the truthfulness resides in the individual. This is similar to Yackel and Rasmussen's (2002) belief that beliefs develop from

socio-mathematical norms, often developed in the mathematics classroom. Underhill (1988) described knowledge as a belief when he stated,

> knowing is believing, and then learning is the process of developing new beliefs and of altering old beliefs. New beliefs will result from our interpretations of empirical data, our interpretations of rational argumentation, and our instinctive need to resolve the unexplained. (p. 64)

Beliefs, attitudes and emotions articulate the affective responses that occur in the problem solving process (McLeod, 1989; McLeod, 1992). Beliefs, attitudes and emotions are documented in order of decreasing cognitive influence and an increasing affective influence (McLeod, 1989). For the most part, beliefs are cognitive in nature and develop over time. Attitudes and beliefs are considered to be stable and difficult to change (McLeod, 1989). Emotions are important because students will experience both positive and negative emotions as they learn mathematics. Emotions seem to appear and disappear quickly as a response to a stimulus and have very little to do with cognition. As students participate in new mathematical activities emotions may be especially noticeable (McLeod, 1992). Arguably, because MEAs are new mathematical activities students' emotions may also be very noticeable. Despite the fact that researchers agree that mathematics-related beliefs influences mathematics learning there is not a clear conceptual framework used to study beliefs (Furinghetti & Pehkonen, 2002).

The National Assessment of Educational Progress (NAEP) measured beliefs about mathematics as well as student performance on mathematics and it was administered to students in the third, seventh, and eleventh grades (Brown, Carpenter, Kouba, Lindquist, Silver & Swafford, 1988; Kouba, Brown, Carpenter, Lindquist, Silver & Swafford, 1988). Four categories of beliefs were assessed at the middle school and secondary level: (a) mathematics and oneself,

(b) mathematics and society, (c) mathematics in school and (d) mathematics as a discipline. Only the categories, *mathematics and oneself* and *mathematics and society* were administered to the students in the third grade.

Students at the seventh and eleventh grade were also asked items to determine their beliefs about mathematics as a subject and how it compared to other subjects they studied in school (Brown et al., 1988). Researchers found that students in both grades believed mathematics to be the most important subject. For seventh grade students, mathematics was viewed as the easiest subject while the eleventh grade students believed that it was more challenging than the other subjects they studied in school.

Kouba and colleagues (1988) found that third grade students had a positive attitude towards themselves and mathematics. At least 80% of the third grade students who were tested said they were prepared to work hard to do well in mathematics and had a positive attitude towards school mathematics. This trend remained the same for the seventh and eleventh grade students with 85% of seventh grade students and at least 80% of the eleventh grade students who were tested also had a positive attitude towards themselves and mathematics (Brown et al., 1988).

Kouba and colleagues (1988) also found that the majority of seventh graders felt that they understood the mathematics they were being taught and also thought mathematics was difficult. Similarly a transition would be helpful here Brown et al. (1988) found 70% of eleventh grade students believed that they understood mathematics and approximately two-thirds thought they were good at mathematics. There were a similar percentage of students who thought that mathematics was difficult.

All students were also tested to access their beliefs about the usefulness of mathematics in their everyday life and their future careers (Brown et al., 1988; Kouba et al., 1988). Researchers found that less than half the students in the seventh and eleventh grades and 40% of students in the third grade thought they would need mathematics in their future careers; however, it is important to note that 25% of the third grade student participants were not sure about how mathematics might be used on the job. The researchers found that students at all grade levels did not think that mathematics was important at the individual level but was important for society.

Students in the seventh and eleventh grades were asked about their beliefs about the discipline of mathematics; specifically students were asked if they viewed mathematics as a process versus rule based, the perceptions of mathematics as a static versus dynamic subject, and beliefs about mathematics as a formal discipline (Brown et al., 1988). Researchers found that students did not understand mathematics was a dynamic discipline or what mathematicians did. Students had conflicting perceptions of mathematics as a subject. Eighty percent of the students believed that the process used to solve a problem is as important as the solution. However, students also held the belief that mathematics was rule based and mostly memorizing.

**Empirical Frameworks and Studies**

There are many different frameworks that have been used to analyze beliefs in mathematics education. Most of the research is situated in motivational, affective or cognitive practices (Op't Eynde et al., 2002). The empirical frameworks that were used by McLeod (1992), Underhill (1988) and Kloosterman (1996) will be used to develop the definition for and the beliefs model that will be used for this study.

**McLeod's framework.** McLeod (1989;1992) believed that mathematics researchers needed to include affective issues in research so that the effect instruction has on student learning

could be maximized. The affective domain, considered different from pure cognition, consists of an extensive range of moods and feelings (McLeod, 1989). Including the affective domain in research is important,

> if students are going to be active learners of mathematics who willingly attach non-routine problems, their affective responses to mathematics are going to be much more intense than if they are merely expected to achieve satisfactory levels of performance in low-level computational skills (McLeod, 1992, p. 575)

Mathematics students are most influenced by their beliefs about mathematics and their selves and how they relate to mathematics as a field (McLeod, 1989). Both students' beliefs about mathematics and how students relate to mathematics have a significant part in the development of affective responses in mathematics (McLeod, 1992).

Although there is very little affect involved in students' beliefs about the nature of mathematics, "these beliefs form an important part of the context in which affect develops" (McLeod, 1989, p. 246). It has been shown that most often students believe mathematics to be based on rules and difficult to learn (McLeod, 1989). Schoenfeld (as cited in McLeod, 1992) argued that this kind of belief would impact how students approach mathematical tasks and weaken students' abilities to solve non-routine problems. I believe that this belief will also impact students' abilities to solve MEAs.

Affect plays a more important role in the development of students' beliefs about themselves in relationship to mathematics because this category includes student beliefs about their success and failure in mathematics, their self-concept and confidence in mathematics (McLeod, 1989). Most research in this area has been on gender-differences. Research shows that

females, even though they outperform males, tend to be less confident. There is a direct relationship between confidence and performance on non-routine problems (McLeod, 1989).

Teachers' beliefs about mathematics instruction also influence student performance, especially on non-routine problems (McLeod, 1989;1992). If teachers believe that mathematics consists of memorizing rules and using algorithms then this belief is passed on to the students and "if students believe that mathematical problems should always be completed in five minutes or less, they may be unwilling to persist in trying to solve problems that may take substantially longer" (McLeod, 1992, p. 579). There has been little research concerning students' beliefs about the role of the mathematics teacher.

The final category addresses the social context of mathematics learning. Students' beliefs about the culture of their mathematics classrooms influence their problem-solving abilities (McLeod, 1989; 1992). Students' responses to non-routine problems are profoundly affected by their views of their role and the teacher's role in the classroom (McLeod, 1989). For example, students who believe that the teacher's role in the classroom is to transfer knowledge to students and it is the student's responsibility to receive it will struggle solving non-routine problems. In MEAs the role of the teacher is to facilitate learning and the student needs to construct their solution independently of the teacher (Lesh & Doerr, 2003). In this setting students might initially struggle because their beliefs about mathematics classroom culture are being challenged.

Very little research that has been conducted extends beyond the individual to examine the social culture of the classroom. The majority of research that has been conducted has examined gender differences. However, Cobb, Yackel and Wood (1991) examined social norms in the classroom and found the affective reactions that students expressed were influenced by the social norms that were taught to them in class.

The purpose of this section was to examine McLeod's framework for mathematical-related beliefs. The four categories of this framework included beliefs about mathematics, belief about self, beliefs about mathematics teaching and beliefs about the social context.

**Underhill's framework.** Underhill (1988) also developed a framework to examine mathematics-related beliefs. This framework is grounded in constructivist principles and has four main categories: (a) beliefs about mathematics as a discipline, (b) beliefs about mathematics learning, (c) beliefs about teaching mathematics and (d) beliefs about the social context of mathematics.

Underhill's (1988) category, beliefs about mathematics, denotes students' beliefs about the nature of mathematics as a discipline (Op't Eynde et al., 2002). What students believe about the nature of mathematics affects how they approach specific math content, problem solving and even learning mathematics (Underhill, 1988). Underhill stated that "what learners know and what they believe are often indiscernable" and for some students "their beliefs permit them to 'know' mathematics through memorization and algorithms. Their beliefs do not foster integration and relational learning" (Underhill, 1988, p. 58). If students believe that they learn mathematics to understand mathematics by being able to perform procedures and memorize equations, then they think that mathematical knowledge is transmitted to them and is not theirs. Underhill (1988) suggested,

> if mathematics cannot be transmitted because the conceptualization leads us to the problems that we are presently experiencing, perhaps we can begin to look at teaching more in a facilitating, resource-directing manner. Then learners can use resources to create or construct their meaning, meaning which is relational. (p. 58)

What students believe about the nature of mathematics will influence their beliefs about how mathematics is learned.

Beliefs about mathematics learning include students' beliefs about learning strategies in mathematics education. These strategies include what students believe to be productive and non-productive strategies; "for example learning mathematics is mainly memorizing" (Op't Eynde et al., 2002, p. 18). Typically students are exposed to the transmission model of education (Underhill, 1988). Underhill believed we should no longer use this model and instead approach teaching and learning from a constructivist perspective.

In constructivism, learners actively construct knowledge using their own experiences and create knowledge through their actions and reflections (Lerman, 1989). In other words, "Teaching and learning are viewed as complementary parts of a (re) construction process" (Underhill, 1988, p. 59). Although these parts are considered to be complementary, the learning process begins with the student not the teacher (Lerman, 1989). Teachers should not present content to the students as they understand it because "children cannot construct [the teachers'] knowledge, because our knowledge is essentially inaccessible to them. The best they can do is to modify their own knowledge as a result of interacting with us" (Steffe & Tzur, 1994, p. 12). Underhill (1988) believed that "knowledge which is constructed is more functional to learners, especially because of the reversibility they gain and the ability to generalize" (p. 59).

Underhill's (1988) third category was used to describe beliefs about the teaching of mathematics. This category describes students' beliefs about good teaching strategies in mathematics (Op't Eynde et al.,, 2002). An example of this could be that mathematics teaching is about teaching computations and not facilitating investigations. For Underhill, beliefs about the

nature of mathematics, mathematics learning and mathematics teaching were difficult to separate (Underhill, 1988; Op't Eynde et al., 2002).

Underhill (1988) also believed that there was a significant affective component to students' beliefs about learning and teaching, especially the students' beliefs about motivation and their self, which Underhill believed to be inseparable. Underhill did not separate beliefs about motivation and the self into a separate category because he believed that they were highly connected to beliefs about teaching and learning (Op't Eynde et al., 2002).

The final category in Underhill's (1988) framework is the belief about the social context of mathematical learning considers students' behaviors and the social nature of beliefs (Op't Eynde et al., 2002). Group norms of the classroom influence students' learning and what is considered to be appropriate classroom behavior (Underhill, 1988). In turn this influences students' beliefs about the teaching and learning of mathematics as well as their beliefs about the nature of mathematics.

The purpose of this section was to describe Underhill's (1988) framework that was used to categorize beliefs. These categories included students' beliefs about the nature of mathematics, beliefs about the learning of mathematics, beliefs about teaching mathematics and beliefs about the social context of mathematics. Also discussed was how Underhill connected his framework to constructivism.

**Kloosterman.** Kloosterman developed a model of beliefs that was designed to explain students' motivational decisions in mathematics (Op't Eynde et al., 2002). The two categories used in this model are beliefs about mathematics and beliefs about mathematics learning in Figure 5 (Kloosterman, 1996).

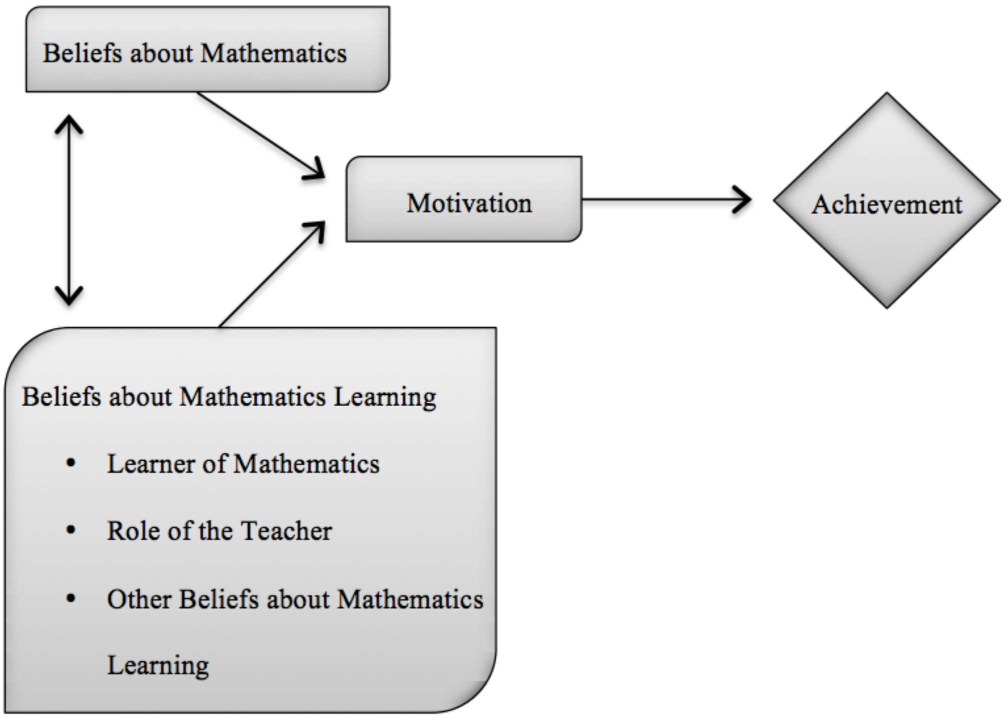



*Figure 5*. Kloosterman's model of beliefs/motivation/achievement

The category beliefs about learning mathematics was very similar to McLeod's category, beliefs about mathematics (Kloosterman, 1996). However, unlike McLeod, Kloosterman does not include students' beliefs about learning mathematics in this category (Op't Eynde et al., 2002). Kloosterman (1996) believed that this category was important to include in his model because "perceptions of the discipline of mathematics can have substantial influence on what students feel is important to study and how they study it" (p. 133).

If students believe that mathematics consists of procedures and rules then they are not concerned with making connections with mathematical topics or to understanding any underlying concepts (Kloosterman, 1996). They will be motivated to memorize the rules and procedures. Students also believe that "mathematical thinking consists of being able to learn, remember and apply facts, rules, formulas and procedures" (Garofalo, 1989, p. 503).

Most curriculum for elementary and middle school focuses on math computations (Kloosterman, 1996). This emphasis influences what students believe about the nature of mathematics. Students often believe that mathematics is about being able to do computations quickly and efficiently. Students with this belief are often interested in problems that cannot be solved quickly using a straightforward computational procedure.

The idea that mathematics is useful has become common rhetoric in the mathematics classroom (Kloosterman, 1996). However, Kloosterman's (1996),

> concern is that students have been told that mathematics is useful enough times to 'believe' it, but have little knowledge of how mathematics is used in the workplace or at home…Few children see patterns as an important aspect of mathematics or to understand the applicability of mathematical thinking to real world situation. (p. 136)

What is perceived as being useful in mathematics varies by topic and if students are shown that mathematics is useful they are usually open to learning it (Kloosterman, 1996). The more useful students view mathematics to be, the more likely students will try to learn different mathematical ideas. Similarly, students who view mathematics as integrated will be motivated to remember earlier topics so that they can connect these topics to new ones.

Kloosterman's second category was beliefs about learning mathematics, included in this category are three subgroups: (a) beliefs about oneself as a learner, (b) beliefs about the role of the teacher, and (c) other beliefs about mathematics (Kloosterman, 1996; Op't Eynde et al., 2002). Kloosterman's model focuses on beliefs from the students' perspectives. As a result, McLeod's categories belief about self, beliefs about mathematics teaching and beliefs about the social context, are all included in Kloosterman's beliefs about learning mathematics category (Kloosterman, 1996).

The first subcategory, belief about oneself as a learner, is similar to McLeod's category beliefs about self. Kloosterman (1996) argued, "beliefs about self are important influences on motivation because, in essence, students who feel they are not capable of learning mathematics see little reason to even try" (p. 133). Self-confidence is an important component of students' motivation to solve non-routine problems. Not only do students need to be confident in their ability to solve routine problems but also in their ability to solve non-routine problems. Students, who lack confidence in solving routine problems might not be motivated to solve non-routine problems, like MEAs, because students do not want to learn the higher-order skills necessary to solve them.

For Kloosterman (1996), the role of the teacher was examined from the students' perspectives so it was also included in beliefs about mathematics learning. The traditional view of a teacher is a lecturer and the person who provides correct answers. Kloosterman (1996) taught a class to fourth grade students on non-routine problem solving. In this course, Kloosterman did not give students the correct answers because the author wanted to develop the students' own intuition and skills. The author found that the students' beliefs about the role of the teacher was violated. This led to student dissatisfaction and some students' refusal to work in this class. Kloosterman (1996) stated that students who believe the teachers' role in the classroom is to transmit knowledge might be less motivated to learn when they are in a classroom where they are required to construct their own mathematical knowledge.

In the third subcategory other beliefs about mathematics are considered. McLeod's (1992) category, beliefs about the social context, would be included in this category because social context, viewed through the eyes of the students, is a component of students' beliefs about learning mathematics (Kloosterman, 1996; Op't Eynde et al., 2002). Other examples of items

that might also be included in this category are students' beliefs about the importance of memorization in mathematics, students' beliefs about mistakes and students' beliefs about the use of manipulatives.

**Kloosterman's study on students' beliefs and implications for motivation.** Using the previously mentioned empirical framework, Kloosterman conducted a research study that examined students' beliefs and the implication of these beliefs on motivation (Kloosterman, 1996). The researcher followed elementary students for three years and conducted interviews with them about their mathematical beliefs. The participants were asked numerous questions about mathematics including how much they liked math, how confident they felt in math, and how they learn mathematics. The participants were also asked to decide if certain problems were mathematical, to solve mathematical problems and describe their previous mathematical experience. The participants were asked, "How do you go about learning a new mathematics topic?" (Kloosterman, 1996, p. 144). This was followed up with questions about the role of the student, teacher and textbook (Kloosterman, 1996). The researcher found that most students believed that the role of the teacher was to transmit knowledge and provide students with the answers.

The researchers also asked the students questions associated with the nature of mathematics. These questions included, "I'd like you to think about doing math in school and out of school. How do you know when someone is doing math? Tell me in as many words as you can think of to describe when someone is doing math" (Kloosterman, 1996, p. 145). Most participants believed that mathematics was computational. However, there were a few participants who believed mathematics was more than just computations.

Participants in Kloosterman's (1996) study were asked "what does it mean to be a good math student and how do you know who is the best students in the class are? (p. 145). The majority of the participants believed that good math students get good grades. A few of the participants indicated that good students were those who could do math quickly, those who turned in all of their homework or those who made few mistakes. Kloosterman (1996) found that the participants had trouble describing beliefs that they were not often questioned about. For example, students were not able to talk about their beliefs about the nature of mathematics or their beliefs about cooperative learning but were able to tell the researcher whether or not they liked mathematics or found it useful.

**Kloosterman study on secondary math students.** Kloosterman conducted a qualitative research study that examined secondary students' beliefs (Kloosterman, 2002). The researcher assumed that beliefs had a significant affect on motivation and that the goal of instruction was to motivate students to learn. Fifty-six students completed a 51-question interview, the Indiana Mathematics Beliefs Scale and the Fennema-Sherman Usefulness Scale developed by Kloosterman and Stage (1992). The Indiana Mathematics Beliefs Scale measured five beliefs about mathematics: *(a) I can solve time-consuming mathematics problems; (b)* there are word problems that cannot be solve with simple, step-by-step procedures; (c) understanding concepts is important in mathematics, (d) word problems are important in mathematics and (f) effort can increase mathematical ability (Kloosterman & Stage, 1992). The Fennema-Sherman Usefulness scale measured the students' perceived usefulness of mathematics. The interview questions included some background information of the students, feelings about school and mathematics, effort in mathematics, non-school influences on motivation, self-confidence in mathematics,

natural ability in mathematics, goal orientation and effort, study habits in mathematics, mathematics content, assessment practices and students' expectations of teachers.

Kloosterman (2002) found that there was significant variability in what the students had to say in their interviews. The researcher found that students who were taking lower-level mathematics classes tended to have very little to say about their likes and dislikes of their mathematics courses. The researcher found that the social norms that the students accepted were whatever the teacher asked them to do without questioning. Kloosterman also found that the majority of students felt that the role of the teacher was to clearly explain whatever task the students were required to perform. Kloosterman (2002) also found that students interpreted that question about the nature of mathematics to mean the nature of their mathematics classroom. The researcher hypothesized that because the students were not regularly asked the nature of mathematics they didn't have an opinion regarding it.

In summary, Kloosterman (2002) found that students rarely thought about the nature of mathematics. The researcher also found that most students believed that memorization was an important part of mathematics. Despite this belief, the researcher found that these students also thought they didn't need to be able to easily memorize facts to be successful in mathematics. Additionally, the researcher found that students had trouble separating activities that they did in the mathematics classroom from their beliefs about mathematics as a discipline.

**Greer, Verschaffel and De Corte's study on beliefs and word problems.** Greer, Verschaffel and De Corte (2002) conducted a research study that examined how students and teachers responded to word problems. The researchers argued that word problems exemplify how school mathematics is influenced by beliefs of not only the students but by society as well.

Greer and colleagues (2002) defined word problems as “a text (typically containing quantitative information) that describes a situation assumed familiar to the reader and poses quantitative question, an answer which is derived by mathematical operations performed on the data in the text or otherwise inferred” (p. 271). The researchers believed that word problems had two main purposes. First, word problems reflected the belief that the purpose of mathematics was to draw inferences and describe reality and were used to practice applying mathematics to the physical and social realm. The second purpose of word problems, using real-world stories that were often not believable, was to serve as a mechanism for thinking about the structure of mathematics. Greer et al. (2002) focused this study on the first purpose of word problems because these,

> application problems may be considered as exercises in mathematical modeling, the core elements of which the process are the translation of the situation into mathematics relationships, the manipulation of those relationships to yield derivations, and the interpretation of those derivations within the original context. (p. 273).

The researchers also stated that mathematical modeling was important because it “raises fundamental questions about the relationship between the real world and mathematics” (p. 273). Yackel and Rasmussen’s (2002) and Op’t Eynde and colleagues’ (2002) definition of beliefs was used in this study. The researchers connected these two definitions of beliefs when they stated

> students’ beliefs develop from their perceptions and interpretations of the socio-mathematical norms that determine- explicitly to some extent, but mainly implicitly- how to behave in a mathematics class, how to think, how to communicate with the teacher, and so on. (p. 274)

Greer and colleagues (2002) also stated that students' beliefs about word problems include that word problems make sense and are solvable, word problems have one correct answer, the numbers necessary to solve word problems will be in the text of the problem, word problems can be solved using customary mathematical procedures, the text of a word problem has all the information necessary to solve the problem and that students can ignore the real world while solving word problems.

Greer et al. (2002) provided participants problematic questions that required the participants to use their knowledge about the real world and standard problems that resembled traditional word problems, meaning the calculations necessary to solve them should be straightforward. Participants included students and student teachers. Greer, Verschaffel and De Corte (2002) found that the student participants answered few questions realistically. The researchers found that the teachers' beliefs about word problems were most influential on their students' performance on word problems.

Greer and researchers (2002) propose that in order to implement modeling in the classroom there needs to be a change in socio-mathematical norms in the classroom. The researchers argue that mathematical modeling, which could be used to connect mathematical structure and the real world, is ignored in school mathematics. Greer et al. (2002) also stated that students would have more balanced beliefs about the nature of mathematics if word problems were taught using the modeling perspective.

**Presmeg's study about the nature of mathematics.** Presmeg (2002) conducted a qualitative research study that examined the beliefs of high school students. The researcher considered beliefs to have both affective and cognitive components as well as influence

behaviors. The researcher not only asked participants about their beliefs but also observed the participants to determine if their professed beliefs corresponded with their actions.

The goal of this study was to determine if the students' lived experiences could be used to assist the learning of school mathematics (Presmeg, 2002). Participants were interviewed during the fall and spring semesters and were asked questions about the nature of math and whether it was used in their lived experiences. The researcher found that the participants' beliefs did change but these changes were only superficial. At the end of the study, participants were able to make connections between their school mathematics and their lived experiences. The researcher also determined that in order to change the practices in the classroom both the teachers' and the students' beliefs about the nature of mathematics needed to change.

## Framework for this Study

The purpose of this section is to define beliefs and explain the framework that will be used to examine beliefs in this study. First this will be accomplished by defining beliefs. Next, a description will be provided of the framework and the categories that will be examined in this study.

### Definition of Mathematics-Related Beliefs

For the purpose of this study beliefs are defined as "knowledge" constructed by the individual. This "knowledge" is not verifiable by others, and the *truthfulness* of this "knowledge" is only demonstrable within the individual (Op't Eynde et al, 2002). Students' beliefs impact their problem-solving behaviors. School mathematics and socio-mathematical norms that students encounter in their mathematical classes influence their beliefs (Yackel & Rasmussen, 2002).

**Framework Used to Study Mathematics-related Beliefs**

The framework that will be used to analyze beliefs has two main categories including beliefs about the nature of mathematics and beliefs about learning mathematics (Kloosterman, 1996; Op't Eynde et al., 2002). However, the subcategories are different than those used by Kloosterman. The framework that is used to analyze beliefs is presented in Table 2.

In the first category the three subcategories that will be examined are beliefs about mathematical modeling, the usefulness of mathematics and how mathematics is connected to other disciplines. In the second category beliefs about mathematical word problems, the social context that mathematics is learned, the role of the teacher and the self in mathematics will be examined. All of these beliefs will be examined from the view of the student.

*Table 2.* Framework for Mathematics-Related Beliefs

| **Category**<br>**Belief** |
| --- |
| **Category 1: Beliefs about the Nature of Mathematics (Kloosterman, 1996; McLeod, 1989; Underhill, 1988,)** |
| Belief 1: Perceptions of problems in mathematics (Kloosterman, 1996; McLeod, 1989) |
| Belief 2: Mathematics is useful. (Kloosterman, 1996; McLeod, 1989; Underhill, 1988) |
| Belief 3: Mathematics is connected to other subjects. (Kloosterman, 1996; McLeod, 1989; Underhill, 1988;) |
| **Category 2: Beliefs about Learning Mathematics (Kloosterman, 1996; Underhill, 1988)** |
| Belief 4: Mathematical word problems and mathematical modeling (Kloosterman & Stage 1996; Presmeg, 2002) |
| Belief 5: Social context in which mathematics is learned (McLeod, 1989; Underhill, 1988) |
| Belief 6: Role of the teacher (Kloosterman, 1996) |
| Belief 7: View of self and ability in mathematics. (Kloosterman, 1996) |

## Discussion

The mathematics and mathematics-related beliefs that have been cultivated in the traditional classroom setting need to change in order for students to fully participate in the age of information. In this new age, mathematical thinking is no longer just computations, it is also the ability to construct, describe and explain phenomena, i.e., modeling (Lesh & Doerr, 2003). Without the modeling perspective, Greer et al. (2002) state that maladaptive beliefs about mathematics are strengthened. Greer et al. (2002) also state that the modeling perspective "offers a way of introducing students early to this fundamental aspect of mathematics and thereby fostering more balanced beliefs about the nature of mathematics as both an abstract construction and a way of modeling physical and social phenomena" (p. 289). One way to incorporate mathematical modeling in the classroom is through integrated STEM MEAs that emphasize higher-level thinking skills and not rote memorization. Students' beliefs about the nature of mathematics and mathematics learning will influence how students solve non-routine mathematical tasks like MEAs.

## Chapter 3: Research Methodology

In order to study the mathematics-related beliefs of fourth and fifth grade students a qualitative case study was conducted. In this chapter the research methods are discussed. This includes both the rationale for conducting a mainly qualitative study and using the case study design. Included in this section is the description of the setting and participants who participated in this study. Also included are the procedures and the sources that were used to collect data, which comprises focus groups, interviews, observations and a questionnaire.

### Rationale for Qualitative Methods

The purpose of qualitative research is to explore, understand or explain a problem or phenomena (Marshall & Rossman, 2011). Creswell (2013) defined qualitative research,

> begins with assumptions and the use of interpretive/theoretical frameworks that inform the study of research problems addressing meaning individuals or groups ascribe to a social or human problem. To study this problem, qualitative researchers use an emerging qualitative approach to inquiry, the collection of data in a natural setting sensitive to the people and places under study, and the data analysis that is both inductive and deductive and establishes patterns or themes. The final written report or presentation includes voices of the participants, the reflexivity of the researcher, a complex description and interpretation of the problem, and its contributions to the literature or a call for change. (p. 44)

Bernard and Ryan (2010) indicated that the goals of qualitative research are to explore, describe, compare and test different models. Bernard and Ryan (2010) also indicated that qualitative research should be used when the purpose of the study is to understand a behavior or action and that quantitative research should be used when measuring how much a behavior

occurs. The purpose of this study was to describe participants' mathematics-related beliefs and therefore is a qualitative study. Marshall and Rallis (as cited in Marshall & Rossman, 2011) described qualitative research as emergent in nature, occurring in the natural world, and using multiple interactive and humanistic methods. This study is qualitative because it interpreted the participants' perspectives, occurred in an after-school setting, and used multiple forms of data collection.

## Rationale for Design

Yin (2014) defined a case study as "an empirical inquiry that investigates a contemporary phenomenon (the 'case') in depth and within its real world context, especially when the boundaries between phenomenon and context may not be clearly evident" (p. 16). According to Bernard and Ryan (2010), "the goal of a case study is to get an in-depth understanding of something" (p. 43). The purpose of this study was to understand the mathematics-related beliefs of fourth and fifth grade students. Case studies are bounded by time and place (Creswell, 2013). This study was bounded in time by six weeks; it was defined by place because all participants were sampled from the same school.

## Participants and Setting

### The School

The school was purposefully sampled because it was a Title I elementary school with a diverse student population in a large, Southwestern school district. Access was then negotiated with a gatekeeper at the school. The school district where the elementary school was located serves approximately 320,000 students from diverse backgrounds, 72% of the students are from minority populations and 58% of the district's students receive free and reduced lunches. The elementary school serves approximately 840 students with a 24 to 1 student/teacher ratio (see

Table 3)Seventy-seven percent of the students attending the school receive free and reduced lunch and approximately 24% of the students are classified as English Learners.

*Table 3.* Demographic and Student Information for School

| Demographics Information | | Percent |
|---|---|---|
| Ethnicity | | |
| | American Indian/ Alaskan Native | 0.47% |
| | Asian | 10.60% |
| | Hispanic | 44.7% |
| | Black | 15.78 |
| | White | 18.8 % |
| | Pacific Islander | 1.57% |
| | Two or More Races | 8.31% |
| Gender | | |
| | Male | 51.57% |
| | Female | 48.43% |
| Special Populations | | |
| | Students with Disabilities | 11.69% |
| | English Language Learners | 22.77% |
| | Free and Reduced Lunch | 77.23% |

**The Participants**

Twenty-four participants were sampled from the overall fourth and fifth grade populations. There were 11 fourth grade students, 4 boys and 7 girls, and 13 fifth grade students, 6 boys and 7 girls. Eight students identified themselves as white, nine Latino, two Asian, two black, one Pacific Islander and two as bi-racial. Eighteen students received free and reduced lunch, five students were labeled as English Learners (ELs) and one student was on an Individualized Education Program (IEP).

Participants were recruited using flyers that were passed out in class and classroom announcements (Appendix B). Six participants were purposefully sampled to participate in the semi-structured interviews. These students were selected based upon ability level so that there were two high-, two middle- and two low-ability level students. The Criterion Referenced Test (CRT) scores were collected for all participants. The CRT is a standards-based test that is used to

measure specific skills that students should have for third through eighth grades (Great schools, 2014). The CRT scores are separated into the categories *exceeds the standard* for scores greater than 400*, meets the standard* for scores between 300 and 400, and *approaching the standard* for scores that were less than 300. The students' previous CRT scores were used to determine the ability levels of students so that all ability levels were represented in the semi-structured interviews. All other participants were invited to participate in the focus groups. Nine participants were classified as high-ability because their CRT scores were identified as *exceeds standards* or *meeting the standard* with a score greater than 350. Eight participants were classified as middle-ability because their CRT scores were *meets the standard* with scores between 300 and 350. Four participants were classified as low-ability because their CRT scores were *approaching the standard* and two participants were classified as no score because they did not have CRT scores from the previous year (see Table 4).

*Table 4.* Classification of Participants by Ability Level

| Ability Level | High | Middle | Low | No Score Available |
|---|---|---|---|---|
| | Chris | Wyatt | Ashley | Robbie |
| | James | Becka | Dawn Marie | Mike |
| | Katie | Mitchell | David | |
| | Zach | Beth | Jakob | |
| | Jennifer | Amy | | |
| | Kelly | Mia | | |
| | Elizabeth | Francesca | | |
| | Joseph | Piper | | |
| | Chloe | | | |

Note: Pseudonyms have been used to protect the identity of the participants

**The After-School Program**

The program met after-school on Tuesdays in a classroom at the elementary school for five weeks. Each session was 2.5 hours long and the participants were provided a snack at the beginning of each session. There were 24 participants who were grouped in fours at six tables for

each of the activities. The facilitators included a teacher from the elementary school, the researcher and occasionally another graduate student.

## Research Context

The purpose of this section is to describe the daily activities of the research participants. Including a brief description of the Model-Eliciting Activities (MEAs) that will be completed on each day.

### Day 1

During the first session participants completed the questionnaire and the Marshmallow Challenge (C). The Marshmallow Challenge was used as the first activity because it introduced the participants to the engineering design process and working in groups. In the Marshmallow Challenge participants are given 20 pieces of spaghetti, a yard of string, a yard of tape and a marshmallow. Using only the given supplies, participants are given 20 minutes to build the tallest freestanding structure with the marshmallow on top. After students have completed the Marshmallow Challenge they were introduced to the engineering design process and then were given an opportunity to rebuild their marshmallow structures.

### Day 2

On the second day participants completed the Survivor MEA (Appendix C). In this MEA students were asked to design a shelter that was sturdy, water resistant, and spacious enough for people to survive while stranded on an island. The mathematical topics that this MEA focused on were estimation and mathematical reasoning, proportional reasoning, and problem solving. Students had to work in dissimilar measurement scales and convert between scales. Students also had to make decisions about whether or not a solution meets the needs of a client.

First students were given a video to introduce some science content and set the context for the MEA (FlowMathematics, 2013). Then the students were asked to individually answer the readiness questions that were shared as a whole group. Students were then given the problem statement and given time to build their models. The models were tested to see if they could withstand wind and rain. Students then wrote their letters to the client, shared out their solutions with the rest of the group and completed the student reflection forms.

**Day 3**

On day 3 students completed the Rocket MEA (Appendix D), adapted from Try Engineering's Water Rocket Launch Activity (2010). In this MEA participants were asked to design a water rocket for Virgin Galactic using everyday materials. This MEA addressed the engineering design process, numerous science standards and the Common Core Standards of Mathematical Practice: make sense of problems and persevere in solving them, construct viable arguments and critique the reasoning of others, model with mathematics, use appropriate tools strategically and attend to precision (CCSS, 2012). Students had to make decisions about whether or not a solution met the needs of a client.

Students were given the background article and took turns reading it aloud to the whole group. Then they answered the readiness questions. Students then were given the problem statement that was read aloud as a whole group and were given time to build their models. After participants built their models, the rockets were taken outside and launched. The participants then returned inside, shared their thoughts on their modeling process with the rest of the participants, wrote their letters to the client, and then completed the student reflection forms.

**Day 4**

On day four students participated in the Mars Rover MEA (Appendix E)The Mars Rover MEA was adapted from NASA's Mars Pathfinders Egg Drop Challenge. Students were asked to design a capsule that protected its payload when dropped from a ladder. This MEA focused on mathematical reasoning and problem solving. Students demonstrated an understanding of the challenges of soft landing a spacecraft on Mars, made decisions about whether or not a solution met the needs of a client, and communicated the solution clearly to the client.

The students first watched a short video that established the context for the problem. Students then answered the readiness questions and as a whole group read out loud the problem statement. Students were then given the remaining time that day to build their models. Initially students were provided a basket that had samples of the materials they could use to build their rovers. Before students were able to begin building the rovers they had to determine what materials they could use that were within the allowed $300 budget. Participants then purchased their items from the classroom teacher. Participants were allowed to buy additional items if their budget permitted but were not allowed to return any items that were already purchased. During the next meeting of the after-school program the rovers were dropped from the roof of the elementary school

**Day 5**

The last day of the program began with the participants testing the Mars Rovers that were designed during the previous session. The researcher dropped the rovers off the roof of the elementary school while the participants observed from the ground below and timed how long it took for each rover to fall from the roof to the ground. After all of the rovers were dropped the participants returned to the classroom and then used the data collected to calculate the rate the different rovers were traveling while they fell to the ground using the *distance=rate*time*

formula. Each group then wrote a letter to their client, shared their strategies with the rest of the participants, and completed the student reflection forms.

After the Mars Rover MEA was completed the participants completed the Freighter MEA (Appendix F), adapted from Lee's (2014) Tinkering with Buoyancy Activity. In this MEA participants were asked to design a boat that could hold the most freight with the least expense to the boat-building company. The mathematical topics that this MEA addressed were estimation and mathematical reasoning, as well as problem solving. Students also had to make decisions about whether or not a solution met the needs of a client.

In this MEA students watched a video to introduce the context of the problem, answered readiness questions, and then as a whole group read the problem statement out loud. Participants were then given time to design and test their model and write their client letter. After participants completed the Freighter MEA they completed the post-questionnaire survey.

## Data Collection

In case studies it is important to collect documents, artifacts, interviews and observations (Bernard & Ryan, 2010; Creswell, 2013; Marshall & Rossman, 2010; Yin, 2014). The purpose of this section is to describe the questionnaire, interviews, focus groups and classroom observation that will be used in this study.

### Instruments

**Questionnaire.** The questionnaire was developed by modifying the Indiana Mathematics Beliefs Scales (Kloosterman & Stage, 1992). The Indiana Beliefs Scale was originally developed to measure the mathematics beliefs that were "related to motivation and thus achievement on mathematical problem-solving" (Kloosterman & Stage, 1992, p. 109) of secondary and college-age students. Kloosterman and Stage (1992) stated, "each scale should be measured separately

and there is no overall scale" (p. 114). The original survey was aligned to all seven of the beliefs in the framework used to describe mathematics-related beliefs (Appendix G). The original questions that were prepared were initially given to three mathematics educators at the collegiate level, including Kloosterman, to determine if the questions were related to the beliefs that they were supposed to measure. Kloosterman suggested that questions regarding the category, *the social context in which mathematics is learned*, be removed because elementary aged students would provide inconsistent answers for what it means to do group work. Therefore the questions that related to this belief were removed from the survey. The modified survey was given to two elementary schoolteachers to determine if the wording was developmentally appropriate for the students. After the wording was determined developmentally appropriate the survey was piloted with 91 fifth grade students to determine the validity of the instrument. Crohnbach's Alpha is used to determine the internal consistency of an instrument (Tavakol & Dennick, 2011). According to Tavakol and Dennick acceptable values of Crohnbach's alpha range from 0.7 to 0.9. For this instrument a Crohnbach's alpha of 0.71 was calculated.

All students in the after-school STEM program completed the questionnaire that consisted of 24, five-point Likert-scale items and three open-ended questions that measured their mathematics-related beliefs (Appendix H). This questionnaire was completed on the first and last day of the after-school program. Students were given 20 to 30 minutes to individually read and answer the questionnaire.

Kloosterman (2003) stated that Likert-scale items provide a baseline measurement of students' mathematics-related beliefs. Likert-scale items on this survey were both positively and negatively written. Examples of positively written items are, "Mathematics is useful outside of school" and, "Mathematics is a necessary subject to know." Examples of negatively written

items are, “I never use mathematics outside of school” and, “Studying mathematics is a waste of time.”

Open-ended questions were used to discover participants’ beliefs and attitudes (Bernard & Ryan, 2010). Kloosterman and Stage (1992) believed that interview questions were more effective than just Likert-scale items, “More open-ended measures might pick up on factors not mentioned in this instrument [Likert-scale items] but such measures also have the risk of not getting to some of the key factors mentioned in the literature” (p. 262). Examples of the open-ended questions that were used are, “How do you use math outside of your math classroom?” “What do you want to do when you grow up?” and “How will you use math doing this job?”

**Interviews.** Bernard and Ryan (2010) stated that semi-structured interviews are a useful tool to interview children. Semi-structured interviews produce a lot of qualitative data (Creswell, 2013; Marshall & Rossman, 2011). Semi-structured interviews were conducted before and after the six-week program, as well as after each activity. Participants at high-, medium- and low-ability levels were purposefully sampled from all students participating in the after-school program. These semi-structured interviews were audio taped and conducted before the school day began. Example questions from the pre and post semi-structured interviews included, “What do you think doing math looks like outside of school?” and “Do you use math when you study other subjects?” (Appendix I). Example questions from the semi-structured interviews that were conducted after each activity included, “What math did you use to solve the problem?” and “Did this activity change the way you think about mathematics?” (Appendix J). Non-scripted follow-up questions were used as necessary to provide the researcher with more details.

**Focus Groups.** According to Bernard and Ryan (2010), focus groups provide a sense of a group’s dynamic; allow students’ responses to build off of each other; and provide the researcher

with rich data. Marshall and Rossman (2011) thought that beliefs and attitudes were socially constructed and that participants needed to listen to other peoples' beliefs in order to better form their own. Participants who might not be able or willing to comment about their mathematical beliefs would feel safe in the focus groups to disclose their feelings.

Focus groups were conducted before the interviews and after-school program as well as throughout the program. Focus groups ranged in size from four to 12 participants. Marshall and Rossman (2011) stated that one of the challenges to successfully implementing focus groups is the issue of power dynamic. All focus groups were video taped and occurred before or after-school. Example questions on the focus group interview protocol included, "How is mathematics used in your everyday life?", "How is math connected to other subjects?", "Describe mathematical modeling," "How is mathematics learned?", and, "Describe what the role of a math teacher is" (Appendix K). The focus groups were conducted after each activity and used the same questions as the interviews that were conducted after each activity.

**Observations.** Observation is a vital component of qualitative research (Bernard & Ryan, 2011; Creswell, 2013; Marshall & Rossman, 2010). Beliefs influence students' behaviors and actions so observing students is one way to examine their beliefs (Yackel & Rasmussen, 2003). Yackel and Rasmussen (2003) also believed that beliefs are influenced by the socio-mathematical norms that exist in the students' classroom.

Two of the beliefs about mathematics learning that were examined for this study were beliefs about the social context in which mathematics is learned and beliefs about the role of the teacher. To better explain the change (or not) in these beliefs, the math classes of the students who participated in the after-school program were observed. Only the participants who were in my study were observed; this included interactions with other students and their teacher. One

classroom observation was made for three teachers that lasted the entire instructional period, which ranged from 30 to 70 minutes. During these observations only written notes were taken.

## Data Analysis

An inductive approach was taken when analyzing the qualitative data (Bernard & Ryan, 2010). Grounded theory was selected as the method of analysis because, according to Bernard and Ryan (2010), the purpose of grounded theory, "is to let understanding emerge from the close study of the texts" (p. 288).

However, because I was interested in understanding rather than explaining, Charmaz's constructivist grounded theory was more appropriate for my data analysis than the grounded theory used by Strauss and Corbin (Creswell, 2013). According to Charmaz (2008) the objective of grounded theory is to understand a phenomenon rather than to explain a new theory. Data were coded inductively from the bottom up using open, axial and selective coding.

## Methodological Rigor

There are eight strategies that can be used to validate a qualitative research study: (a) prolonged engagement and persistent observation, (b) triangulation, (c) peer review and debriefing, (d) clarifying research bias, (e) negative case analysis, (f) member checking, (g) rich, thick description, and (i) external audits (Creswell, 2013; Maxwell, 2013). Creswell (2013) recommended that researchers use at least two of these procedures to ensure validity. To ensure validity for this study, rich data were collected and multiple data sources were used to triangulate the findings.

### Rich Data

Maxwell (2013) stated, "Such data generally require verbatim transcripts of the interviews, not just notes on what you felt was significant. For observation, rich data are the

product of detailed descriptive note taking (or videotaping and transcribing) of specific, concrete events that you observe" (p. 126). The interviews and focus groups were recorded and transcribed in their entirety. During classroom observations detailed field notes were taken.

According to Yin (2014), the reliability of a case study is increased when the data are organized and analyzed using a computer assisted qualitative analysis software. NVivo was used to analyze the interviews and focus groups. This allowed the researcher to better observe themes that might not have be visible without the use of the software.

### Triangulation

Triangulation was defined by Yin (2014) to be the merging of multiple data sources to establish the consistency of findings. Multiple forms of data such as focus groups, questionnaires, interviews and observations were used to triangulate the data.

## Conclusion

In this section the research methodology that was used to study the mathematics-related beliefs of fourth and fifth grade students was discussed. The rationale for using a qualitative case study design was also provided. Also included in this section were the descriptions of the setting, participants, procedures and the sources that were used to collect data; focus groups, interviews, observations and a questionnaire.

## Chapter 4: Data Analysis and Results

The purpose of this single case study was to examine the mathematics-related beliefs of students who participated in an after-school MEA program. This chapter presents the key findings obtained by a pre and post-questionnaire as well as 12 individual interviews and six focus groups that were analyzed using grounded theory.

### Data Analysis

#### Questionnaire

A nonparametric Sign test was conducted to compare the pre and post scores for beliefs (Table 5). There was a significant sign change between the pre ($M$= 2.022, $SD$ = 0.674) and post ($M$=1.902, $SD$ = 0.665) questionnaire scores for students' beliefs about mathematical word problems and mathematical modeling ($p < .10$). On the post-questionnaire students had a more negative view towards mathematical word problems and mathematical modeling than on the pre-questionnaire.

*Table 5.* Means and Standard Deviations for Framework Beliefs

| **Beliefs** | **Pre** | | **Post** | | |
|---|---|---|---|---|---|
| | M | SD | M | SD | P-value |
| Belief 1: perceptions of problems in mathematics | | | | | |
| | 3.18 | 0.565 | 3.076 | 0.479 | 0.503 |
| Belief 2: mathematics is useful | | | | | |
| | 4.693 | 0.429 | 4.533 | 0.484 | 0.549 |
| Belief 3: mathematics is connected to other subjects | | | | | |
| | 4.076 | 0.535 | 4.141 | 0.726 | 1.000 |
| Belief 4: Mathematical word problems and mathematical modeling | | | | | |
| | 2.022 | 0.674 | 1.902 | 0.665 | 0.096 |
| Belief 6: role of the teacher | | | | | |
| | 3.522 | 0.657 | 3.554 | 0.589 | 1.000 |
| Belief 7: view of self and ability in mathematics | | | | | |
| | 4.185 | 0.981 | 3.967 | 0.850 | 1.000 |

Although there was no quantitative analysis performed on the individual questions in the survey, there were some changes in the participants' responses. The researcher defined this

change as an increase or decrease of four or more participants in a category such as no opinion to the categories disagree a little or disagree a lot.

The summary tables for the statements in the questionnaire that measured students' beliefs about mathematical word problems and mathematical modeling are presented in Table 6.

*Table 6.* Belief 4: Mathematical Word Problems and Mathematical Modeling

| Question | No Answer | Disagree a lot | Disagree a little | No Opinion | Agree a little | Agree a lot |
|---|---|---|---|---|---|---|
| There are some problems that can not be solved following a predetermined sequence of steps | | | | | | |
| Pre | | 4 | | 11 | 6 | 2 |
| | | (17.4%) | | (47.8) | (26.1%) | (8.7%) |
| Post | | 7 | 1 | 13 | | 2 |
| | | (30.4%) | (4.3%) | (56.5%) | | (8.7%) |
| Word problems can be solved without remembering formulas | | | | | | |
| Pre | | 10 | 3 | 4 | 2 | 4 |
| | | (43.5%) | (13%) | (17.4%) | (8.7%) | (17.4%) |
| Post | | 10 | 4 | 4 | 3 | 2 |
| | | (43.5%) | (17.4%) | (17.4%) | (13%) | (8.7%) |
| Any problem can be solved if you remember the right steps to follow | | | | | | |
| Pre | | | 1 | | 3 | 19 |
| | | | (4.3%) | | (13%) | (82.6%) |
| Post | | | | 2 | 3 | 18 |
| | | | | (8.7%) | (13%) | (78.3%) |
| Most word problems can be solved using the correct step-by-step procedures | | | | | | |
| Pre | 1 | | | 2 | 1 | 20 |
| | (4.3%) | | | (8.7%) | (4.3%) | (87%) |
| Post | | | 1 | 2 | 5 | 15 |
| | | | (4.3%) | (8.7%) | (21.7%) | (65.2) |

On the pre-questionnaire 17.4% of the participants disagreed with the statement *there are math problems that cannot be solved by following a predetermined sequence of steps*. On the post- questionnaire 34.7% of the participants disagreed with this statement. For this question 47.8% and 56.5% of the participants on the pre and post questionnaires marked no opinion for this item. There was little to no change for the statements *word problems can be solved without remembering formulas* and any problem can be solved if you remember the right steps to follow.

On the pre-questionnaire 87% of the participants strongly agreed that *most word problems can be solved using the correct step-by-step procedures* while on the post-questionnaire only 65% strongly agreed with this statement.

The summary table for the statements in the questionnaire that measured students' beliefs about perceptions of problems in mathematics is presented in Table 7.

*Table 7.* Belief 1: Perceptions of Problems in Mathematics

| Question | No Answer | Disagree a lot | Disagree a little | No Opinion | Agree a little | Agree a lot |
|---|---|---|---|---|---|---|
| Math is about exploring new ideas | | | | | | |
| Pre | | 2 (8.7%) | 2 (8.7%) | 3 (8.7%) | 10 (43.5%) | 6 (26.1%) |
| Post | | 2 (8.7%) | | 6 (26.1%) | 6 (26.1%) | 9 (39.1%) |
| Math is more than doing operations like adding, subtracting, multiplying and dividing | | | | | | |
| Pre | | | 1 (4.3%) | 1 (4.3%) | | 21 (91.3%) |
| Post | | 1 (4.3%) | | 2 (8.7%) | 2 (8.7%) | 18 (78.3%) |
| Math is memorizing | | | | | | |
| Pre | | 1 (4.3%) | | 3 (13%) | 7 (30.4%) | 11 (47.8%) |
| Post | | | | 1 (4.3%) | 8 (34.8%) | 14 (60.9%) |
| Math is about following rules | | | | | | |
| Pre | | 3 (13%) | 2 (8.7%) | 3 (13%) | 7 (30.4%) | 8 (34.8%) |
| Post | | 2 (8.7%) | 3 (13%) | 8 (34.8%) | 5 (21.7%) | 5 (21.7%) |

Fewer students disagreed with the statement *mathematics is about exploring new ideas* on the post-questionnaire than on the pre- questionnaire and more students answered no opinion on the post questionnaire. There was little to no change for the statements *math is more than doing operations like adding, subtracting, multiplying and dividing* and *math is memorizing*. Approximately 65% of the participants on the pre-questionnaire agreed with the statement *math*

*is about following rules* while only 43.4% agreed with this statement in the post-questionnaire. Thirteen percent of the participants marked no opinion on the pre-questionnaire while 34.8% did so on the post-questionnaire.

The summary table for the statements in the questionnaire that measured students' beliefs about the usefulness of mathematics is presented in Table 8.

*Table8.* Belief 2: Usefulness of Mathematics

| Question | | No Answer | Disagree a lot | Disagree a little | No Opinion | Agree a little | Agree a lot |
|---|---|---|---|---|---|---|---|
| Math is useful outside of school | | | | | | | |
| | Pre | | | | 1 (4.3%) | 3 (13%) | 19 (82.6%) |
| | Post | | 1 (4.3%) | | 2 (8.7%) | 1 (4.3%) | 19 (82.6%) |
| Math is a worthwhile and necessary subject to know | | | | | | | |
| | Pre | | | | | 5 (21.7%) | 18 (78%) |
| | Post | | | | 1 (4.3%) | 4 (17.4%) | 18 (78%) |
| I never use math outside of the school | | | | | | | |
| | Pre | | 16 (69.6) | 3 (13%) | 2 (8.7%) | 1 (4.3%) | 1 (4.3%) |
| | Post | | 12 (52.2%) | 5 (21.7%) | 2 (8.7%) | 4 (17.4%) | |
| Studying math is a waste of time | | | | | | | |
| | Pre | | 21 (87.5%) | 1 (4.3%) | 1 (4.3%) | | |
| | Post | | 18 (78.3%) | 4 (17.4%) | | 1 (4.3%) | |

There was little to no change in the statement *math is useful outside of school* and *math is a worthwhile and necessary subject to know*. Approximately 83% of the participants strongly disagreed or somewhat disagreed with the statement *I never use mathematics outside of* school on the pre-questionnaire while approximately 74% of the participants strongly disagreed or somewhat disagreed with the statement. The also was little to no change in the participants' answers to the statement *studying math is a waste of time*.

The summary table for the statements in the questionnaire that measured students' beliefs about mathematics being connected to other subjects presented in Table 9. There was little to no change for the statements *I use math is my science class*, *math is used to create the technology I use everyday* and *math is not used in my other classes*. On the pre-questionnaire approximately 65% of the participants strongly disagreed with the statement *I don't use math in my everyday life* but on the post-questionnaire 48% strongly disagreed and 13% disagreed a little with this statement.

*Table 9.* Belief 3: Mathematics is connected to Other Subjects.

| Question | No Answer | Disagree a lot | Disagree a little | No Opinion | Agree a little | Agree a lot |
|---|---|---|---|---|---|---|
| I use math in my science class | | | | | | |
| Pre | | | | 4 (17.4%) | 7 (30.4%) | 12 (50%) |
| Post | | | | 3 (13%) | 6 (26.1%) | 14 (60.9%) |
| Math is used to create the technology I use everyday | | | | | | |
| Pre | | 1 (4.3%) | 3 (13%) | 1 (4.3%) | 7 (30.4%) | 11 (47.8%) |
| Post | | | 2 (8.7%) | 3 (13%) | 4 (17.4%) | 14 (60.1%) |
| Math is not used in my other classes | | | | | | |
| Pre | | 1 (4.3%) | | 3 (13%) | 7 (30.4%) | 11 (47.8%) |
| Post | | | | 1 (4.3%) | 8 (34.8%) | 14 (60.9%) |
| I don't use math in my everyday life | | | | | | |
| Pre | | 15 (65.2%) | | 2 (8.7%) | 3 (13%) | 3 (13%) |
| Post | | 11 (47.8%) | 3 (13%) | 5 (21.7%) | 3 (13%) | 1 (4.3%) |

For *the role of the teacher is to facilitate learning* 78.2% and 56.5% of the participants agreed with this statement on the pre and post questionnaire, respectively. However, on the post-questionnaire 39.1% participants had no opinion versus the 17.4% on the pre-questionnaire. There was little to know change for the statement *the teacher lets students figure*

*things out for themselves*. On the pre-questionnaire, approximately 35% of the participants either somewhat agreed or strongly agreed with the statement *the role of the teacher is to provide answers to problems* but on the post-questionnaire only 8.7% of the participants only somewhat agreed with this statement. It is important to note, 17.4% of the participants on the pre-questionnaire neither agreed nor disagreed with the statement *the role of the teacher is to provide answers to problems* but on the post questionnaire this number increased to 48% on the post-questionnaire. For the statement *all knowledge comes from the teacher* only 33.7% of the participants disagreed with this statement on the pre –questionnaire while 43.4% of the participants disagreed with this statement on the post-questionnaire. The summary table for the statements in the questionnaire that measured students' beliefs about the role of the teacher is presented in Table 10.

*Table 10.* Belief 6: The Role of the Teacher

| Question | | No Answer | Disagree a lot | Disagree a little | No Opinion | Agree a little | Agree a lot |
|---|---|---|---|---|---|---|---|
| The role of the teacher is to facilitate learning | | | | | | | |
| | Pre | 1 (4.3%) | | | 4 (17.4%) | 6 (26.1%) | 12 (50%) |
| | Post | 1 (4.3%) | | 1 (4.3%) | 9 (39.1%) | 6 (26.1%) | 7 (30.4%) |
| The teacher lets students figure things out for themselves | | | | | | | |
| | Pre | | 1 (4.3%) | 4 (17.4%) | 3 (13%) | 8 (34.8%) | 7 (30.4%) |
| | Post | | 2 (8.7%) | 3 (13%) | 2 (8.7%) | 9 (39.1%) | 7 (30.4%) |
| The role of the teacher is to provide answers to problems | | | | | | | |
| | Pre | | 9 (39.1%) | 2 (8.7%) | 4 (17.4%) | 3 (13%) | 5 (21.7%) |
| | Post | | 7 (30.4%) | 3 (13%) | 11 (47.8%) | 2 (8.7%) | |
| All knowledge comes from the teacher | | | | | | | |
| | Pre | | 3 (13%) | 5 (21.7%) | 4 (17.4%) | 4 (17.4%) | 7 (30.4%) |
| | Post | | 3 (13%) | 7 (30.4%) | 6 (26.1%) | 5 (21.7%) | 2 (8.7%) |

The summary table for the statements in the questionnaire that measured students' view of self and ability in mathematics is presented in Table 11.

*Table11.*. Belief 7: Self and Ability in Mathematics

| Question | | No Answer | Disagree a lot | Disagree a little | No Opinion | Agree a little | Agree a lot |
|---|---|---|---|---|---|---|---|
| I usually do well in math | | | | | | | |
| | Pre | | 1 (4.3%) | 1 (4.3%) | | 6 (26.1%) | 15 (65.2%) |
| | Post | | | | 2 (8.7%) | 5 (21.7%) | 16 (69.6%) |
| Mathematics makes sense to me | | | | | | | |
| | Pre | | | 3 (13%) | | 6 (26.1%) | 14 (60.9%) |
| | Post | | 2 (8.7%) | 2 (8.7%) | 1 (4.3%) | 6 (26.1%) | 12 (56.5%) |
| Math is hard | | | | | | | |
| | Pre | | 14 (60.9%) | 4 (17.4%) | 3 (13%) | 1 (4.3%) | 1 (4.3%) |
| | Post | | 9 (39.1%) | 4 (17.4%) | 2 (8.7%) | 6 (26.1%) | 2 (8.7%) |
| Math makes me confused | | | | | | | |
| | Pre | | 12 (52.5%) | 3 (13%) | 2 (8.7%) | 5 (21.7%) | 1 (4.3) |
| | Post | | 11 (47.8%) | 2 (8.7%) | 2 (8.7%) | 8 (34.8%) | |

There was little to no change for the statement *I usually do well in math*, *mathematics makes sense to me* and *math makes me confused*. On the pre-questionnaire 78% of the participants either disagreed a little or disagreed a lot with the statement *mathematics is hard* while on the post-questionnaire only 56% of the participants disagreed a little or a lot with this statement.

**Interviews and Focus Groups**

Grounded theory was selected as the method of analysis because, according to Bernard and Ryan (2010), the purpose of grounded theory "is to let understanding emerge from the close study of the texts" (p. 288). Charmaz (2006) stated that researchers should "avoid imposing a

forced framework (p. 66)" so data was coded inductively. In the initial stages of open coding 561 items were coded into 253 units (see Appendix L).

According to Creswell (2013), Charmaz used the codes found in open coding to "sift through large amounts of data, analyzing for syntheses and larger explanations" (p. 196). During the axial stage of coding there were 33 larger themes that were revealed (see Appendix M). According to Charmaz (2006) the objective of grounded theory is to understand a phenomenon rather than to explain a new theory. In the final stages of coding, there were themes that were connected to the beliefs framework and several emergent themes were revealed (see Table 12).

*Table 12.* Selective Coding

| Framework Codes | Emergent Codes |
|---|---|
| Perceptions of problems in mathematics | Teamwork |
| Mathematics is useful | Student opinions of activities |
| Math is connected to other subjects | Math identified in each activity |
| Word problems and mathematical modeling | |
| Social context in which mathematics is learned | |
| Role of the teacher | |
| View of self and ability in mathematics | |

These codes were then grouped into the two major categories of the framework (see Table 13).

*Table 13.* Categories for the Framework of Mathematics-Related Beliefs

| Category<br>Themes from Coding |
|---|
| Beliefs about the Nature of Mathematics (Kloosterman, 1996; McLeod, 1989; Underhill, 1988) |
| Perceptions of problems in mathematics |
| Mathematics is useful |
| Math is connected to other subjects |
| Mathematics identified in each activity |
| Beliefs about Learning Mathematics (Kloosterman, 1996; Underhill, 1988) |
| Word problems and mathematical modeling |
| Social context in which mathematics is learned |
| Role of the teacher |
| View of self and ability in mathematics |
| Teamwork |
| Student opinions of the activities |

## Beliefs about the Nature of Mathematics

**Perceptions of problems in mathematics.** The category, *Perceptions of problems in mathematics*, was one of the categories in the belief framework. The themes that were observed in this category were the *definition of mathematics*, *beliefs after each activity*, and *mathematics outside of school*. Throughout the presentation of the results students have a designation of High (H), Medium (M), and Low (L) provided by their name. This provides their mathematics ability level that was determined by the Criterion Referenced Test (CRT) from the previous year. If a participant has a designation of (N) that means there was no score on the CRT available.

***Definition of mathematics.*** In the first focus group the 13 participants were asked to define mathematics. One participant defined mathematics to be part of science. Becka (M) said, "I think it's a part of a science. Science and other stuff to get you're mind building." When asked to clarify what she meant by it being part of science the participant said that math and science had the same symbols. Another participant said that mathematics was used in science for measurement. A third participant said that mathematics was a tool that was used in science:

> *Interviewer: Now you said it was part of science. What do you mean by part of science?*
>
> *Becka (M): Math and science have the same symbols and sometimes you have to use a calculator for math and science to figure out the problems that you're having trouble with.*
>
> *Interviewer: That's good. Anyone else? Yes?*
>
> *Mike (N): Maybe measurement, like for metric units to measure the measuring of liquids.*
>
> *Interviewer: Anyone else have an idea? Yes.*

*Kelly (H): In science, like say you're building a rocket and like the corner like that (gestures with hands making an angle) had to be a perfect 120-degree angle. If it wasn't that you might just get fired.*

*Interviewer: That's true.*

*Kelly (H): (inaudible) and angles are a part of math, so that would help out with your math.*

In the first focus group, participants believed that mathematics was part of science because it was a tool that they used to help them in science.

After the Mars Rover MEA four participants reported that the activity made them think that mathematics was fun.

*Joseph (H): Yeah. You can have fun.*

*Interviewer: How? You said?*

*Joseph (H): You can have fun.*

*Interviewer: You can have fun doing math? What about you Becka (M)?*

*Becka (M): It can be fun doing math.*

*Interviewer: Again, fun doing math?*

*Chloe (H): It could be fun.*

*Interviewer: Fun? I'm sensing a theme here. What about you?*

*Becka (M): I think it's the same thing*

*Interviewer: It makes math fun?*

*Jennifer (H): I thought math was kind of boring because but then like we got to do different things with math.*

*Interviewer: It wasn't just a straight here's a problem you do math but it was like- (interruption) Here's math, but you get to use it. Apply it.*

*Group: Yeah*

After the completion of the Mar Rover MEA the focus group participants' beliefs about mathematics went from boring to fun because they were able to do different things with mathematics.

In the last focus group Jennifer (H) defined mathematics to be measuring and counting. Mike (N) stated that mathematics is numbers.

*Mike (N): How many books are in the library.*

*Jennifer (H): That's not actually like math, math.*

*Joseph (H): But you have to count them.*

*Mike (N): You have to count 10 by 10*

*Jennifer (H): Math is like measuring and counting*

*Mike (N): Numbers have to do with math.*

In the first focus group three participants defined mathematics as a tool to be used in science. After the third MEA participants saw mathematics a more than just a tool for science and began to see that mathematics can be more than just what they do in the classroom. In the last focus group mathematics participants defined mathematics not just as a tool for science but the participants began to see mathematics was connected to their everyday lives.

***Beliefs after each activity.*** *Beliefs after each activity* were measured after students completed each MEA and asked if their belief or opinion of mathematics had changed. The results in this section are reported in the order that the participants completed the Model-Eliciting Activities (MEAs).

*Survivor MEA.* After completing the Survivor MEA there was a mixture of changed and unchanged beliefs. Four students' beliefs remained the same. Piper (M) said, "Umm… not exactly [belief about mathematics] is the same. When we do homework it has lines we have to measure and give the right answer." However, other students thought that this kind of activity made learning mathematics more fun.

*Interviewer: Did it make you change the way you think about math?*

*David (L): Yeah a little.*

*Interviewer: How?*

*David (L): Like not all the time it's always going… to me like everything is the same thing repeated and repeated. Now it's just like different.*

*Interviewer: It's different?*

*David (L): (nods head yes)*

*Interviewer: How is it different?*

*David (L): Like it's starting to get a little bit more fun.*

For one participant this activity made him realize that mathematics is more than just doing pencil and paper problems in their mathematics class. Amy (M) said, "Earlier I think that math is just like addition and multiplication but it's also measuring and doing and like using calculators and not just doing it with pencil and paper."

After the Survivor MEA there was a mixture of changed and unchanged beliefs. Some participants' beliefs remained unchanged while others began to think of mathematics as fun and not just pencil and paper problems.

*Rocket MEA.* After completing the Rocket MEA there was some change in the participants' beliefs about mathematics connected to engineering. However, four participants

reported no change in their beliefs about mathematics. One participant reported that his beliefs didn't change because he still had a good grade in his mathematics class. Mike (N) said, "Not exactly, I still have an A or a B in math." Two other participants reported that their beliefs didn't change because they still liked mathematics. One participant reported that he didn't use mathematics to complete the activity. Two other participants reported that they believed they could use or learn mathematics as an engineer:

*Interviewer: Did it change your opinion on how you could use math or you could learn math?*

*Mike (N): Not really.*

*Joseph (H): As an engineer, yes.*

*Interviewer: As an engineer, okay.*

*Elizabeth (H): Yeah, same as Joseph (H).*

Not all participants' beliefs about mathematics changed after the Rocket MEA. Some participants did not see that they used mathematics in the activity and one participant's beliefs about mathematics were connected to his grade in his mathematics class. Other participants' beliefs did not change because they were either good at mathematics or still enjoyed it. Two participants thought that activities like the Rocket MEA, where they worked as engineers helped them learn mathematics.

*Mars Rover MEA.* After completing the Mars Rover MEA students were asked if their beliefs about mathematics had changed. Four of the participants reported no change in their beliefs about mathematics. Three participants reported that they believed that doing mathematics was fun. Jennifer (H) said," I thought math was kind of boring but then like we got to do different things with math." One participant reported that he now believed that there could be

more than one way to do mathematics. He also said that these kinds of hands-on activities motivate him to learn mathematics.

*Interviewer: So did this activity change your opinion about mathematics?*

*David (L): A little*

*Interviewer: How?*

*David (L): Like there's always like you like don't always have to think about it this way there is always another way.*

*Interviewer: And so what do you mean by like math that way?*

*David (L): Umm… like if you have like a math problem and you don't get it like try and like to like say something like remember this and try and compare it to that and if it is the same thing just remember that.*

*Interviewer: Okay.*

*David (L): Remember the fun things you did so you won't get bored.*

*Interviewer: And so it these keep you from getting bored these activities?*

*David (L): (shakes head yes)*

After the Mars Rover MEA four participants reported no change in their beliefs about mathematics. Three participants reported that they believed mathematics could be fun. After participating in the Mars Rover MEA one participant began to see that there is more than one way to solve mathematics problems.

*Freighter MEA.* The last activity that the participants completed was the Freighter MEA. For this activity no participants reported that this activity changed their beliefs about mathematics. Four participants reported that they didn't use mathematics in this activity After the Freighter MEA no participants reported that their beliefs about mathematics changed.

***Mathematics outside of school.*** Another theme that was uncovered was *mathematics outside of school*. The purpose of this section is to describe the participants' beliefs about mathematics outside of school. In the pre-interviews two participants said that mathematics outside of school was paying bills. David (L) said, "Umm… just like a bunch of things on paper that you have to pay the bills or something," and James (H) said, "umm… mostly like money and checks and like reading like how much to pay when you buy stuff."

Another participant thought that mathematics outside of school was connected to work. Piper (M) said,

> *Umm I think math outside of school is pretty much what you need to work… cause when you work you need … you'll need… cause when you're cash registering you need to make sure how you know much money you have and how much change you need to give back.*

Two other participants thought that mathematics outside of school was exactly like the mathematics that they do in their classrooms. Chris (H) thought that mathematics outside of school was exactly like the mathematics that he did in the classroom.

> *Interviewer: What do you think math looks like outside of school?*
>
> *Chris (H): The same.*
>
> *Interviewer: Like what do you mean?*
>
> *Chris (H): When you see it in school it looks the same outside.*
>
> *Interviewer: So do you get problems like you do in class or how would you know to do math?*
>
> *Chris (H): Like what do you mean?*
>
> *Interviewer: So umm what does math look like in school?*
>
> *Chris (H): Easy.*

*Interviewer: So are you given problems like written down?*

*Chris (H): Yeah.*

*Interviewer: Okay*

*Chris (H): Like on my homework.*

*Interviewer: Yeah, so outside of school do you think it's going to be the same?*

*Chris (H): Yeah.*

*Interviewer: Like when you are asked to do it they are going to give you problems like that?*

*Chris (H): yeah.*

However, Amy (M) thought that mathematics outside of school was doing calculations:

*Interviewer: So what do you think math looks like outside of school?*

*Amy (M): Like just answering a word problem or doing long division.*

*Interviewer: Okay, is there anything else you think it might look like?*

*Amy (M): Like just up and down multiplication and addition.*

In the pre-interview the final participant said that mathematics outside of school was scientific. Ashley (L) said, "I think that it is very scientific kind of like how it is not really boring but it can be fun." In her post-interview she described mathematics outside of school to be the same as the mathematics that she does for homework. Ashley (L) said,

> *I think it looks like as if so if you are outside of school it will be pretty much on your homework cause sometime you do it in class and sometimes you don't… It's homework and sometimes its magazines how they have the games you need to multiply and subtract that's how I could find it pretty much outside of school.*

In Piper's (M) pre-interview she said that mathematics outside of school was connected to work. In her post-interview she said that mathematics outside of school was connected to money.

*Interviewer: So what do you think math looks like outside of school?*

*Piper (M): Umm… Like when you are at the store you have to count your money the exact…*

*Interviewer: Okay*

*Piper (M): You could have a few extra changes.*

In David (L) and James (H)'s pre-interviews both participants said that mathematics outside of school was connected to bills. In David's (L) post-interview he still said that mathematics outside of school was connected to bills. David (L) said, "Umm… just a bunch of things on paper that you have to pay" which was almost verbatim to his answer on the pre-interview. On James (H)'s post-interview he said that mathematics outside of school was related to jobs, shopping and money. James (H) said, "Uh, probably like…. I don't know…. Like for like jobs or like to estimate how much money for like if you are going out shopping for how much money you are going to spend."

In the pre-interview Chris (H) said that mathematics outside of school is the same as the mathematics that he did in school. In the post-interview he also said that mathematics outside of school is the same as school mathematics.

*Interviewer: So what do you think math looks like outside of school?*

*Chris (H): The same.*

*Interviewer: The same, like what do you mean?*

*Chris (H): In school like you have like word problems and then like if you go to the store you could make it into a word problem.*

*Interviewer: Okay.*

*Chris (H): so it would like be the same thing.*

In Amy's (M) pre-interview she said that mathematics outside of school was word problems that used the basic operations of mathematics. In her post- interview she described mathematics outside of school as more general problem solving. Amy (M) said, "Umm… like may… still like addition and subtraction and umm… other types like figuring out how long it takes you to go run from one side of the park to the other side of the park... so like measuring time."

In the pre- interviews two participants said mathematics outside of school was connected to bills, one work, two said it was the same as the mathematics they used in their classes, one described it as calculations and one participant described it as scientific. In the post- interview two participants' beliefs about mathematics outside of school remained the same. These beliefs were that mathematics is the same as school mathematics and bills. One participant described mathematics outside of the classroom to be general problem solving, while another described it to be homework. One participant described mathematics outside of school to be associated with money and another participant said it was related to jobs, money and shopping. Participants' beliefs about mathematics outside of school didn't really change from the pre to post-interviews. Participants did not really see how mathematics was connected to life outside of school.

**Mathematics is useful.** *Mathematics is useful* explored the belief that students held about mathematics being useful. The purpose of this section is to describe how the participants thought

mathematics was used in their everyday lives. In the first focus group three participants said that mathematics was useful when they were playing games. One of these students said,

> *When I play Monopoly, and sometimes I don't have enough money to buy something I really want like Board Walk. Lots of times that happens. Then sometimes I just forget about it, saving some money and just try to buy again, that's how I earn money.*

Two students said that mathematics was useful when buying something or using money. Mike (N) said, “You need it to count your money spend it on the right kind; the exact same amount of money you had.”

Two students said that mathematics was useful when they cooked. Becka (M) said, “For cooking you need the exact measurement for like a cup of oil or of water.” While another student reported that you could use mathematics at a job. Another student reported that he used mathematics when he did homework. Zach (H) answered,

> *Zach (H): When you're doing your homework.*
>
> *Interviewer: For just math or you use it in math and science and history and English?*
>
> *Zach (H): You use it in mostly just math but sometimes in science.*

One student reported that she used mathematics to measure time. Kelly (H) said,

> *We have to know what time it is and then what time it would be later, so like how much time there would be we need like (inaudible) will from 12:00 to 4:00, so it could be 4 hours more.*

In the last focus group five students said mathematics was useful for money or taxes, one for baking, one for dividing time and two for measuring. Focus group participants were able to see that mathematics was useful in a variety of settings, including school and some activities from their everyday lives.

Zach (H) reported that mathematics was useful for dividing time,

*Sometimes I divide my time to see ... Put 30 minutes I want to do this and for the other 30 minutes, I'm going to do this. Like I plan like I divide my time so that I have enough time to do everything.*

The same student who reported mathematics was useful for cooking in the first focus group also reported that it was useful in the last focus group.

*Becka (M): Baking.*

*Interviewer: Baking? How do you use it in baking?*

*Becka (M): So I can know how much oil or milk or water to use.*

Joseph (H) reported that he used math when he measured the amount of water he drinks every day. Joseph (H) said, "I use math in how many ounces of water I drink every day."

Five of the students stated the mathematics was useful with money and taxes,

*Interviewer: Do you guys think math is useful?*

*Joseph (H): Yes, very much.*

*(3 other members in the group nod yes)*

*Interviewer: Very much how?*

*Joseph (H): The money part. Say you went into a restaurant and you have to pay 20 dollars and umm no you pay 29.99 and you give 30 dollars and the cents is ... The change is 1 dollar and they give you no change. That's it.*

*Mike (N): You have to add taxes.*

*Jennifer (H): We learned how to do taxes. The teacher explained us what taxes are.*

*Zach (H): I hate taxes.*

*Becka (M): I don't like taxes. They don't give you money back.*

*Chloe (H): I know.*

*Interviewer: So you use it for taxes?*

*(Joseph [H] nods yes)*

Mathematics was reported as useful in the interviews as well.

In Ashley's (L) pre-interview she reported that mathematics was useful in school,

*I think it's useful because like when it comes to high school you are going to need to use math to see if you could get good grades… cause if you get bad grades you are not going to make it*.

Ashley (L) was unable to think of any other way that mathematics was useful. In her post-interview she said that mathematics would be useful in her future career but when asked if mathematics was useful again she only gave school as an example.

*Interviewer: What about… what was the job that you said you wanted to do on your questionnaire yesterday?*

*Ashley (L): Oh to be a vet to help animals and go to the military and help save people*

*Interviewer: Do you think you're going to use math there?*

*Ashley (L): Umm… probably not… I don't know …*

*Interviewer: Okay.*

*Ashley (L): For a vet probably yeah cause you need to know how… cause how you are going to give them shots you are going to use the little needle and you see how much you need put in them*

*Interviewer: Mmmhuh*

*Ashley (L): Cause you don't want to put too much.*

However, when asked if mathematics is useful, Ashley (L) responded, "*Umm... I think it's very useful because through your like you are going to have to be using math even through high school, outside of school and your work, on papers*."

Another individual who was interviewed said that mathematics was useful for measuring. Piper (M) said, "Math is useful for everything... like how big is a table … how long is your hair… how much pages are in a book." In her post-interview she again reported that mathematics was useful for measuring,

*Interviewer: Okay so do you think math is useful?*

*Piper (M): Yeah it's… Math is useful because it pretty much is in everything.*

*Interviewer: In everything?*

*Piper (M): Yeah like how much wood do we need, how much glass do we need… rubber for a phone case.*

But when she was asked how she would use mathematics in her dream job she was unable to give any specific examples of how a teacher would use measurement.

*Interviewer: So if you could be anything in the world?*

*Piper (M): I think I would… if I could be anything in the world I would want to be a teacher.*

*Interviewer: A teacher? Do you think you would use math as a teacher?*

*Piper (M): Of course.*

*Interviewer: How?*

*Piper (M): Umm like if you are a math teacher you pretty much use math for everything.*

Another participant in the pre-interview also reported that mathematics was useful for school. Amy (M) said, “When… like you’re in college or high school or any other grade it will help you like answering like difficult questions.”

In the post-interview, Amy (M) said that mathematics was useful but was unable to give an example except for being a teacher. Amy (M) reported, “It can help you with many things and if you grow up to be a teacher it will be easy for you to learn it because you teach it.”

In her post-interview she was asked if she would use mathematics in her future occupations, which were a singer and an artist. Initially, she said that she wouldn’t use any mathematics as a singer or an artist but after some prompting by the researcher she said that she would use measurement as an artist:

*Interviewer: Okay, now on your survey what jobs did you put down that you wanted to do?*

*Amy (M): Singing and being an artist.*

*Interviewer: Being an artist. Do you think you are going to use math in either of those?*

*Amy (M): (shakes no)*

*Interviewer: So you are not you are not going to use math in art?*

*Amy (M): Well, yeah in art because we have to use a ruler to make sure that the perimeter of the painting is perfect*

*Interviewer: Okay, that makes sense. Are there any other ways you might use it?*

*Amy (M): Not that I can think of.*

Another participant reported that mathematics was useful when trying to determine how much you needed to spend in the store to use a coupon and determining how many items were in cartons. Chris (H) said,

*Interviewer: Okay, do you think math is useful?*

*Chris (H): Yeah.*

*Interviewer: How?*

*Chris (H): Because like if you need like for a coupon for the store you need to buy a certain amount.*

*Interviewer: Okay.*

*Chris (H): And you can like multiply it out.*

*Interviewer: Okay, is there any other way that you think it might be useful?*

*Chris (H): Like a carton of eggs you can like multiply the two sides and see how many are in there.*

In Chris's (H) post-interview he was unable to think of how mathematics was useful as a TV producer--the career he wanted to pursue when he gets out of school.

Another participant said that math was useful to count money and determine how much people owe you. David (L) reported,

*David (L): Well, you want to know what to do, you want to know ….umm how much money you need to pay and everything.*

*Interviewer: Any other ways?*

*David (L):  If somebody owes you money you have to be sure that they give you… like you have to multiply like if they give you 200 and 20 dollar bills or something you have to know what to multiply so that it doesn't take that long to count.*

In his post-interview David (L) still used money as an example of how mathematics was useful and when prompted by the researcher he was unable to think of a different example of how mathematics was useful.

*David (L): If you owe someone money you like owe them $100 don't give $70 just saying it's a hundred.*

*Interviewer: Can you think of any other way besides with money that you think math is useful?*

*David (L): Umm… when you're like umm… I couldn't.*

The last participant who was interviewed also said that mathematics was useful for determining how much was needed to buy items at the store and for paying bills. James (H) said, "it helps you again by figuring out how much money you need to pay for all your stuff. It's also good for writing checks and stuff." After being prompted by the interviewer he said, "Umm… sometimes like for if you have like stuff and you want to divide it up into friends… you can use division to do that and that's all I can really think of."

In his post-interview James (H) said that mathematics was useful "later on in life with like shopping and doing work and stuff." When asked whether he would use mathematics in his future career he was able to give non-specific examples of how mathematics might be used.

*Interviewer: Okay, now do you remember what job you said you wanted to do?*

*James (H): Umm... Uh… a video game designer.*

*Interviewer: How do you think you are going to use math there?*

*James (H): Probably like coding and like doing that.*

In the pre-interviews and the first focus group, two students reported that they used mathematics for cooking. One reported that mathematics was useful when she measured objects while another said that mathematics was useful when he measured time. One participant reported that mathematics was useful to count items. Four participants said that mathematics was useful

when they counted money, and one participant said that mathematics was useful when she played games.

In the post-interviews and the last focus group one participant was unable to provide an example of how mathematics was useful. Seven participants said that mathematics was useful when they needed to determine the amount of money that they had or needed. Three participants reported that mathematics was useful for measuring; two reported general measurements and the other reported measuring specifically related to cooking.  Two reported that mathematics was useful to teachers and one reported that mathematics was useful when trying to determine the time to spend on activities. When participants in the post-interviews were specifically asked what mathematics they would use in their future jobs, three participants were able to connect mathematics with their future careers and three were unable to see how they would use mathematics in these professions.

**Mathematics identified in each activity.** Another theme that emerged from the data was *mathematics identified in each activity.* This is an important theme because integrated STEM activities like MEAs are often used a motivational activities to encourage students to pursue careers in one of the STEM fields.

***Survivor MEA.*** There were 20 instances that were coded as *mathematics in the Survivor MEA*.  In the Survivor MEA 6 participants said that they used measurement to build their shelters. Mia (M) said, “We had to measure and calculate how much of everything we needed and we had to just like we had to calculate everything.” While Chris (H) said, “Yeah cause you had to see how many centimeters would go and fit inside the tarp cause we had to have three people so we measured in centimeters like the inside of it and how tall it would be.” Two participants reported that they used area, perimeter and volume to design their shelters.

The original design for one group was too large and they were unable to build a complete structure so they had to redesign their shelter. Two participants in this group reported that they used fractions to redesign their shelter.

*Interviewer: Did you guys use any math when you built your shelter?*

*Mia (M): Fractions, because we were saying we should use 1/4 of the regular house to split it and make it as our own house.*

One of the unexpected challenges for participants in this MEA was the difficulty that students had cutting the materials that the participants needed to build their shelters. All four participants in the focus group reported that cutting the materials was a challenge.

***Rocket MEA.*** For the Rocket MEA there were 19 items that were coded as *Math in the Rocket MEA***.** For one group, one participant thought that they used no mathematics to build their rocket while another member in his group did:

*Interviewer: What math did you guys use?*

*Mike (N): I didn't really use any math.*

*Jennifer (H): Actually yeah. We measured a tape, how much we needed to put down and make the paper toilet rolls stay down so we had to measure.*

Two participants thought they didn't use mathematics but then stated that they did. One of these students initially stated no math was used but then said that they used measurement. James (H) said, "I didn't really use any math beside like length and kind of which like tape to use." Another participant, in a different group, initially thought his group didn't use any mathematics but then stated that he used estimation:

*Interviewer: What about you guys? Did you guys use math?*

*Joseph (H): I don't think so.*

*Interviewer: Did you measure anything?*

*Joseph (H): Not that much we just estimated it.*

Two participants used measurement. Piper (M) said, "We had to use measuring ...well we had to make sure that we had the right room for everything."

Two participants didn't think that they used any mathematics at all. Ashley (L) said, "umm... no not really but we only didn't use the ball because we recognized that if we added it with the other stuff it's going to make it to heavy and it's going to make it fall faster."

***Mars Rover MEA.*** There were 20 units that were coded as *Math* in the *Mars Rover MEA*. After completing the Mars Rover MEA twelve participants were asked if they used any mathematics to complete their rover. Eleven of the participants said they used mathematics and only one participant said that they did not.

Five students were interviewed and, of the five, four said that they used mathematics to calculate their budget. David (L) said, "Adding cause like when we had to add up to see like umm you know how you gave us the budget we added up all the numbers and we get exactly $300." Chris (H) another student interviewed said, "Yeah, we used math to add up the total of the money." The other participant said that she didn't use any mathematics.

There were two focus groups where students were asked if they used mathematics to build their rovers. In the first focus group four of the participants said that they used mathematics to calculate their budget.

*Interviewer: What math did you use?*

*Joseph (H): Money!*

*Interviewer: Money?*

*Jennifer (H): Yeah, money, yeah.*

*Interviewer: You guys had to do a budget right?*

*Jennifer (H): Yeah.*

*Interviewer: Is that the only math that you used?*

*Joseph (H): Subtraction and addition.*

*Interviewer: Okay. Anyone else?*

*Becka (M): Multiplication.*

*Jennifer (H): Yeah. When we had to try to multiply the money amount times how many things we were going to get.*

*Joseph (H): Estimation.*

*Interviewer: How did you do estimation?*

*Joseph (H): Because we didn't really know if we were going to need all those balloons, but we did.*

*Interviewer: When you were building it, besides the budget, did you use any math?*

*Becka (M): I don't think we did.*

*Interviewer: No geometry or anything like that?*

*Group: (nod heads no)*

In the second focus group two new members were asked if they used mathematics to build their rover. One of the new members indicated that he used a budget and, at first, the other member said that he did not do any mathematics but after prompting from the researcher realized he did.

*Zach (H): …For the rover we didn't.*

*Interviewer: Yeah, for the rover, but you measured time outside, didn't you?*

*Group: Oh yeah. We did.*

*Interviewer: What did you guys do with that time?*

*Mike (N): We see how fast it went down.*

*Interviewer: Okay, so we calculated rate. Was that math?*

*Group: Yeah.*

And then he stated that, "We do math when we're learning and don't even know it."

***Freighter MEA.*** In the last activity that the students completed, four students did not think that they used any mathematics to complete the activity while two students said that they used counting. David (L) said, "We counted all up the pennies that we did used to like put in the boat." Six students reported that they used estimation to complete the activity. Amy (M) said, "Yeah, we had to… like we had to also figure out how much pennies we had to use before we tested it to make sure it didn't sink."

In the Survivor MEA six participants reported using mathematics to build their shelters; two reported using measurement; two area and perimeter; and two reported using fractions. In the Rocket MEA six participants reported using measurement, three reported not using any mathematics, and one reported using estimation. For the Mars Rover MEA, five participants reported using mathematics to calculate their budget and one reported using mathematics to measure the time it took their capsule to drop to the ground. After the Mars Rover MEA one participant realized that he often used mathematics to learn while being completely unaware that he was using it. In the Freighter MEA four participants reported using no mathematics, two reported using counting, and six participants reported using estimation.

**Mathematics is connected to other subjects.**

***Pre-interviews and focus group.*** Two participants in the pre-interviews and focus group said that mathematics was connected to writing.

*Interviewer: Okay, do you use math when you study other subjects?*

*Piper (M): Yes.*

*Interviewer: How?*

*Piper (M): Because when I do writing she says how much paragraphs, sentences and so yeah I always count them just to make sure.*

After prompting, Piper (M) did say that mathematics was connected to science.

*Interviewer: Okay, do you use it in any other subjects?*

*Piper (M): Umm. No I don't think so. That's pretty much it… like in the subjects.*

*Interviewer: Okay, what about in science or umm history?*

*Piper (M): Oh yeah, cause you can use it when you are doing an experiment.*

Amy (M) also made connections to writing when she said, "like for writing it can like ask me like a word problem and it's like with the writing ... I like and like my second teacher… she does writing and math and some math is in the writing and some writing is in the math." When Amy (M) was asked a follow up question about science she replied that she used very little mathematics in science.

*Interviewer: What about science?*

*Amy (M): Like how I like it?*

*Interviewer: Do you use math in science?*

*Amy (M): not that much.*

*Interviewer: Not that much, can you think of a case where you did?*

*Amy (M): No.*

Three participants said that mathematics was connected to other subjects but initially gave no specific example. Kelly (H) said that mathematics was connected to other subjects but

did not give an example of how it was connected. Kelly (H) said, “Yes it is because you need to know what to do, how much. If there’s an angle in it …like how much degrees are in it.” Chris (H) also thought that mathematics was connected to other subjects but could not give an example until prompted. After prompting Chris (H) said that mathematics was a tool to be used in science but said that it was not something that he currently used in school.

*Interviewer: Do you use math when you study other subjects?*

*Chris (H): What kind of other subjects?*

*Interviewer: Like if you do history, science or English?*

*Chris (H): Sometimes yes.*

*Interviewer: Can you think of an example?*

*Chris (H):(silence)*

*Interviewer: Do you use it in science?*

*Chris (H): We don’t really do science that much… right now*

*Interviewer: Have you ever?*

*Chris (H): Yeah but like in second or third grade.*

*Interviewer: Did you ever add and subtract things to do your science labs?*

*Chris (H): Yeah like when you fill a beaker you have to subtract a certain amount to another cup.*

David (L) did not think of a specific example until after he was asked if he used mathematics in science.

*Interviewer: ….So do you use math when you study other subjects?*

*David (L): Umm… not all the time.*

*Interviewer: Not all the time? Can you think of a time when you do… it's not all the time but when?*

*David (L): Umm*

*Interviewer: Like a specific example?*

*David (L): Umm… I can't think of one.*

*Interviewer: What about in science?*

*David (L): In science, well, if you are going to do something that runs on oil you have to make sure that everything is going to be right… like you have to know your fractions… you have to know like how many how much you need to put in it.*

Two participants thought that mathematics was connected to history. Kelly (H) said, "In history if you ever … everyone needs to know what time it is and how much that is." Becka (M) agreed with her when she said," I was going to say what she just said."

Four participants said that mathematics was connected to science. James (H) said that mathematics was a tool that he used in science when he said, "Like sometimes when we are doing science umm… I do like umm…I need to use like math in order to like read the … umm… how much water I need for beaker or something." Ashley (L) said that she used mathematics for homework when she said, "Like on my homework if I needed like if it's a scientific homework that I need for science and yeah I would have to use it." When asked if mathematics was connected to other subjects Zach (H) said, "You use it in mostly just math but sometimes in science." Jakob (L) believed that there were mathematics problems in science, "Math is connected to science in a couple of ways, because in science you need to do math problems."

***Post-interview and focus group.*** In the last interviews and the last focus group participants were asked if they thought that mathematics was connected to other subjects. When

asked how mathematics was connected to other subjects, one participant did not describe what mathematics was connected to but instead how mathematics was used in other subjects. Chloe (H) said, "You count and you figure the time and that stuff."

Two interview participants said that mathematics was connected to other subjects at school but were unable to provide an example.

*Interviewer: Okay, umm… so when we talk about other subjects that you look at in school do you use math when you're studying other subjects?*

*David (L): Umm… sometimes math, sometimes like reading I think.*

*Interviewer: So you use math in reading? Do you use it anywhere else?*

*David (L): Umm… no I don't think so.*

When prompted about science, David (L) was unable to see a connection between mathematics and science.

*Interviewer: What about science?*

*David (L): Umm… Not really. We do that much in science.*

David (L) was further prompted about an activity that the researcher had observed in his classroom where the teacher had students explore the concepts of theoretical and experimental probability. In this activity the students drew chips from a brown paper bag and recorded their results, then based on their empirical evidence they were supposed to predict the number and color of chips that were in their bag.

*Interviewer: In class I noticed that probability activity was that math or science?*

*David (L): Umm… I think it was a little bit of both.*

*Interviewer: Yeah, How was it science? What about and the math… how was it math?*

*David (L): Umm… I can't.*

The other participant that said mathematics was connected to other subjects said that mathematics was connected to English.

*Interviewer: Okay, umm… so do you use math when you study other subjects?*

*Ashley (L): Umm… sometimes, sometimes not.*

*Interviewer: Which one can you think of?*

*Ashley (L): Pretty much… I want to say like on working so like how in class you get papers to work on…*

*Interviewer: Mmhuh [affirmative]*

*Ashley (L): Yeah I want to say pretty much that.*

But when Ashley (L) was prompted further she was unable to provide an example of how she used mathematics in English.

*Interviewer: So which like umm… is it in English or science that you use it the most?*

*Ashley (L): It's pretty much in English.*

*Interviewer: In English? So can you give me an example of how you would use it in English?*

*Ashley (L): Umm… I'm trying to think of one…I can't really think of one right now. Remember…. I just I think it had a little bit of math and science.*

Two participants in the interviews stated that mathematics was connected to science. Chris (H) said that mathematics was connected to science and then gave two specific examples of how he used mathematics in his science class.

*Chris (H): Yeah because for science we have to like if you put like… we did if you put the pie pads and how many drops of water you could get and then you had to like and find the mean for it, so yeah.*

*Interviewer: Now you're talking about the desalinization project you guys did?*

*Chris (H): Yeah and we also did another one where you had to put however many drops you could put on a penny.*

James (H) also said that he used mathematics in science.

*Interviewer: Umm… so do you use math when you study other subjects?*

*James (H): Oh, yes in science.*

*Interviewer: Okay, can you think of an example?*

*James (H): Umm for measuring how much stuff to put on a beaker for stuff like that.*

When asked if mathematics was connected to other subjects the six participants in the focus group responded unanimously "science." In a discussion among the members of the focus group participants responded that mathematics was connected to art, science, music, library and history.

*Interviewer: What about you?*

*Joseph (H): Art, science, reading.*

*Interviewer: How? [crosstalk]*

*Joseph (H): Music, library, history.*

*Becka (M): Music*

*Interviewer: You see it as connected to everything?*

*Joseph (H): Yeah.*

*Becka (M): Except for library because there's no math.*

*Joseph (H): You use math to count how many books you get.*

*Jennifer (H): And in music you count how many notes.*

*Mike (N): How many pages it has.*

*Becka (M): And how much it weighs.*

When asked to provide an example, two participants provided an example of how science is connected to mathematics.

*Interviewer: What about you guys, you said science? Let's raise our hands and then I'll call, okay?*

*Jennifer (H): Science.*

*Interviewer: How?*

*Jennifer (H): Because let's say we're doing an experiment and we have water or we're doing baking soda and we're supposed to*

*Mike (N): Baking soda volcano.*

*Jennifer (H): We're supposed to get how much we actually need or else it makes a huge mess.*

The participants in the focus group were able to see they used counting and measuring in their everyday lives. The participants were able to see how mathematics was connected to music, science and history. Joseph (H) also provided an example of how he used mathematics in science.

*Joseph (H): Science because last year we had to measure how many eggs we had and how much that is that what is that wheat called.*

*Becka (M): Bread*

*[Interruption]*

*Joseph (H): No, we made pancakes and eggs last year. I forgot what it was called… We had to measure it and how much we might use and how many eggs we had to have and yeah*

Another participant said history and provided an example of how mathematics was used to measure time. Zach (H) said,  "History because when you're seeing how many years in between like 1951 to 1965 and how many years are in between is what happened each day. If something's started when did it end." Zach was able to see that mathematics was used to measure and calculate time in when he studied history.

Mike (N) replied mathematics was used to determine how many books are in the library. This started a discussion of what the participants thought was really mathematics.

*Mike (N): How many books are in the library?*

*Jennifer (H): That's not actually like math, math.*

*Joseph (H): But you have to count them.*

*Mike (N): You have to count 10 by 10.*

*Jennifer (H): Math is like measuring and counting.*

*Mike (N): Numbers have to do with math.*

When asked how mathematics was connected to other subjects, one participant said that it was connected to music.

*Becka (M): Music.*

*Interviewer: Music? How is it connected to music?*

*Becka (M): To count how many beats are in a measure.*

*Interviewer: That's really good. Yeah.*

In the pre-interviews and the first focus group four participants said that mathematics was connected to science without prompting. Two participants reported mathematics was connected to writing. After prompting one of these participants said that mathematics was connected to science while the other saw little connection between the two content areas. Three participants

reported mathematics was connected to other subjects but were initially unable to provide an example. After prompting, two of these participants reported that mathematics was somewhat related to science. Two participants reported that mathematics was connected to history.

In the last focus group and the post-interviews eight participants reported that mathematics was used in science. Two participants in the interviews were unable to provide examples of how mathematics was connected to other subjects and one participant reported that mathematics was not connected to science. One participant reported that mathematics was connected to English but, when prompted, was unable to provide any examples. During the last focus group the participants described mathematics as being connected to art, science, music, library and history. One of these participants provided an example of how mathematics was used in other subjects but not a specific subject.

## Beliefs about Learning Mathematics

**Word problems and mathematical modeling.** There were three themes that were observed in this category. One theme was *word problems* and in this theme students described what they believed word problems were in their mathematics classroom. The second theme that was observed was *mathematical modeling.* Instances that were coded under this theme included the participants' beliefs about mathematical modeling. The final theme in this category was *math word problems and modeling are different.* This category includes the participants' beliefs about how mathematical modeling and word problems are different.

***Word problems.***

*Pre-interviews and focus group.* Five participants who were interviewed reported that word problems in mathematics were sentences. Three of the participants gave examples that were all addition problems. Piper's (M) example was, "Umm... sometimes they look like how

much does David have or like David has 16 marbles and Emily has 17 then how much are there in all? So something like that." James (H) said, "Umm… A word problem would be … umm… kind of like so a name and then had 2 of like 2 apples and the other name had 1 apple how many apples are all together it would be like that." One participant gave an example of a problem that used fractions. Chris (H) said, "Like you… could put like 1/8th fraction of pie is shared with four people." The last participant was unable to give an example of what a word problem was in mathematics.

*Interviewer: What do you think word problems look like in a math class?*

*David (L): Umm… can't think of that one either.*

*Interviewer: Could you think of like maybe an example?*

*David (L): Something like a sentence compared to writing.*

*Interviewer: Can you think of a sentence like make one up? It could be anything?*

*David (L): The dog ran away.*

*Interviewer: Mmhuh. So what else… like if you were going to write a word problem about a dog running away what would you say maybe?*

*David (L): The dog started at 5 mile per hour then went to 20 … umm…multiply… How do you get to …umm… 4 to 20?*

One of the participants who was interviewed was unable to give an example of a word problem in her interview. However, this participant also came to the focus group and in the focus groups she described word problems as sentences. Ashley (L) said, "Word problems are like math problems with the end of sentences of saying like, Joe had one apple and then he ate three more. No, he had three more." Ashley was not able to provide the researcher with an example or a description of a word problem because she does not understand mathematics enough to apply

it. In the traditional mathematics classroom word problems are given to students at the end of a section or an assignment so if a students is struggling in mathematics like Ashley they will often not complete these problems and miss out on the opportunity to better understand the mathematics content being studied.

Five of the participants who were interviewed thought that word problems were either easy or quick to solve. Chris (H) said that word problems were sometimes easy and if they were not easy "you can just ask the teacher to help you." James (H) said word problems were sometimes easy. When he was asked what he did when word problems were hard he replied, "I usually try my best on it and if I don't get it right then I know what I did wrong and I can fix it." In Ashley's (L) interview she replied that word problems should be quick to solve and if they were not easy then she said, "if you can't solve it right away then that's means like you weren't really listening or something so that means you didn't really know the problem." One participant reported that word problems were easy if you looked for keywords.

*Interviewer: Okay…umm... do you think that word problems are easy to solve?*

*David (L): Yeah if you highlight the key words.*

One participant believed that word problems were not always straightforward because the problems require multiple steps to solve them and that her teacher might require her to work it using a specific strategy.

*Interviewer: Do you think that they are always straightforward to work?*

*Piper (M): Not always.*

*Interviewer: Not always?*

*Piper (M): Cause sometimes it can be long and difficult and maybe there's like three things that you need to do.*

*Interviewer: Do you umm … so they can take a while to solve?*

*Piper (M): Mmhuh [yes]. Sometimes.*

*Interviewer: Now? How is that … does it take you a while to figure out how you want to answer it or actually work the problem?*

*Piper (M): Sometimes your teacher says you need to answer it in this way and so usually sometimes it takes a while to answer it.*

*Post-interviews and focus group.* Two participants who were interviewed described word problems as containing key words. Chris (H) described word problems as having phrases like "however many more" and like "altogether." Another participant described word problems as sentences. Amy (M) said, "Tim has 5 doughnuts. His friend had 4. How many doughnuts does Tim have more?"

One interview participant said that if word problems were challenging and took longer than 20 minutes he would go to the teacher for help.

*Interviewer: So what happens if you get a problem that takes more than a minute to solve?*

*Chris (H): Like usually I think about it more and then if it takes longer then you can go up and ask the teacher.*

*Interviewer: Do you ever get frustrated and just give up?*

*Chris (H): (Shakes head no)*

*Interviewer: But you'll go ask the teacher?*

*Chris (H): (shakes head yes)*

*Interviewer: What if you had a word problem that took half an hour to solve?*

*Chris (H): I'd go get the teacher*

*Interviewer: You'd go get the teacher okay. But how long would it take before you decided go get the teacher?*

*Chris (H): 20 minutes*

When the participants in the last focus group were asked to describe a word problem, they described them to be sentences with numbers and letters.

*Interviewer: All right. Let me ask you a question. Can you tell me what word problems look like?*

*Chloe (H): They have numbers.*

*Zach (H): They are a bunch of words and they have numbers and letters.*

*Interviewer: Oh my goodness. Okay. Really?*

*Katie (H): Sometimes when they give you a math problem and then they'll give you numbers and then they're going to be missing numbers that have a letter and then you have to add it up.*

One participant described word problems as puzzles. Joseph (H) said, " *It's a whole bunch of words and involves a puzzle. You need to do measuring, subtracting, addition, multiplication, or divisio*n."

When participants in the focus group were asked what they would do if they could not figure out a problem right away they also said that they would go to the teacher for help and that most problems took only a few minutes to solve.

Interviewer: *What happens if you get to a word problem that you can't figure out right away?*

*Joseph (H): I take it to the teacher.*

*Interviewer: You just go to the teacher right away? How long?*

*[Interruption]*

*Interviewer: How long do you wait before you go to the teacher?*

*Zach (H): 5 minutes.*

*[Interruption]*

*Becka (M): Like 15 or 10 to 15 minutes.*

*Joseph (H): At least try to do it.*

*Jennifer (H): The teacher tells us to try it. Try to figure it out. If you can't find the answer, then come to class.*

*Zach (H): The lines are long too.*

*Interviewer: To go to the teacher? What happens if you get to a problem that takes 20 minutes to work?*

*Group: Oh.*

*Mike (N): Usually they just take 1 or 2 minutes.*

*Joseph (H): Yeah.*

In the last focus group and post-interviews, two participants described word problems as containing key words; one of these participants also described word problems as sentences. One participant described word problems as containing numbers and words. Five participants reported that if word problems were challenging they would take it to the teacher for help. One participant described word problems as puzzles.

**Mathematical modeling and word problems are different.** The purpose of this section is to describe how the participants understood mathematical modeling. Also described in this section is the belief that mathematical modeling and word problems were different.

During the first focus group, participants were asked what mathematical modeling was. Only one participant answered this question.

*Interviewer: Can you describe that to me? What do you think of mathematical modeling?*

*Katie (H): Like… You help me too (looks at Kelly [H])*

*Kelly (H): When you draw a model for a math problem, like you do division, you might have a couple of equal this and like every dot in it.*

Katie was unable to describe the process of mathematical modeling. Katie believed that mathematical modeling referred only drawing models to drawing pictures to represent mathematical operations. During the last focus group three participants also described mathematical modeling as a picture.

*Interviewer: What does mathematical modeling look like?*

*Joseph (H): Models are like that. (Points to the posters on the classroom wall that described perimeter and area as well as circumference and volume)*

*Interviewer: Oh, so like a picture? Okay. Yes?*

*Becka (M): Yeah*

*Interviewer: Yes?*

Another participant also said that mathematical modeling was like pictures. Jennifer (H) said, “I'm thinking of a model as like an area model. Like when we have to count the things inside of the picture.” The participants in the focus group were unable to describe the mathematics modeling process but were able to successfully use the mathematical modeling process to solve the MEAs in the after school program. So the participants were able to engage in the modeling process before they were able to describe mathematical modeling.

Chris (H) also thought that mathematical modeling was making graphs.

*Interviewer: So think about word problems or mathematical modeling problems, what do they look like?*

*Chris (H): Graphs*

*Interviewer: Graphs?*

*Chris (H): Like we make the tally marks and umm… trying to think of the other graph part… I can't think of the other part… There is like two graphs that help us with tally marks and you have to count how many of these chose this and like add it to like a chart*

*Interviewer: So like a bar graph?*

*Chris (H): Mmhuh (yes)*

When prompted to describe mathematical modeling and word problems Chris (H) described them as different. For Chris (H), mathematical modeling was making graphs while word problems used key words.

*Interviewer: So when you think about math modeling and word problems do they look like anything else?*

*Chris (H): [silence]*

*Interviewer: Are they two very different things for you?*

*Chris (H): Yes.*

*Interviewer: Okay so you have modeling problems, which are like making graphs?*

*Chris (H): Yeah.*

*Interviewer: And then what does a word problem look like for you?*

*Chris (H): Like I just take out the numbers like "however many more" and like "altogether"*

Piper (M) described mathematical modeling and word problems as being similar. Piper also described how word problems were solved using key words.

*Interviewer: Okay, so like when you think of like word problems or math modeling problems do they look the same or different?*

*Piper (M): Probably a little same.*

*Interviewer: A little same?*

*Piper (M): Like for a math problem like a math problem I would take a highlighter and highlight all the things I need.*

*Interviewer: So you look for key words in problems?*

*Piper (M): Mmmhuh (yes)*

But when Piper (M) was asked how she solved problems that did not have any keywords she was unable to describe how she would solve them.

*Interviewer: What if there aren't any key words in the problem?*

*Piper (M): I'd try to read it three times to make sure I got it down.*

When Amy (M) was asked what word problems or mathematical modeling problems look like in math she said, "For example like Tim has 5 doughnuts his friend had 4 how many doughnuts does Tim have more?." When she was asked if this was a word problem or a mathematical modeling problem she described it as a word problem. When asked if it was a mathematical modeling problem it was clear that she did not know what mathematical modeling meant.

*Interviewer: Is that a word problem or modeling?*

*Amy (M): Word problem.*

*Interview: What about modeling?*

*Amy (M): What's modeling?*

In the first focus group two participants described mathematical modeling as pictures that were used to solve area problems. In the post-interviews and focus group three participants described mathematical modeling as pictures and one participant described mathematical modeling as graphs. Two participants stated that word problems and mathematical modeling were different, but one of these participants was unclear what the term modeling meant. One participant described word problems and mathematical modeling as similar.

**Social context in which mathematics is learned.** To determine how students believed that mathematics was learned, participants were asked in the pre and post-interviews and focus groups "how they thought mathematics was learned." The participants interpreted the meaning of this question differently and when students were asked how they learned mathematics they often discussed behaviors of their teacher. Although these behaviors were classified as *the role of the teacher* they were included in this section.

***Pre-interviews and focus groups.*** In this section of the paper the results from the pre-interviews and the first focus group are presented. Two participants said that flashcards helped them learn mathematics. Chris (H) said, "When you were just learning we used to get like flash cards to help you study it." Chris (H) also said that after he learns something he just reviews it before a test.

*Interviewer: Okay, what do you do now?*

*Chris (H): I just go over the stuff the day before the test.*

*Interviewer: Okay, why do you think that helps you?*

*Chris (H): Because you get it fresh in your brain again.*

Chris was unable to describe activities that helped him learn mathematics. One participant said writing her math facts helped her learn mathematics. Piper (M) reported, “ every now and then I just write the multiplication facts or division.”

There were two participants who initially could not think of an activity that helped them learn mathematics but after prompting from the researcher they were able to come up with an activity. One of these participants said her teacher helped her learn mathematics,

*Interviewer: What activities help you learn math?*

*Amy (M): Umm… I don’t know.*

*Interviewer: So what do you do if you are trying to learn something new? What’s the best way for you to do it?*

*Amy (M): I like to ask my teacher for help on how to do it.*

Amy believed that her teacher helped her learn mathematics. This is an example of her belief that the teacher is the source of knowledge. The other participant said that doing different mathematical activities on paper helped him learn mathematics. David (L) said,

*Interviewer: All right so umm what kinds of activities help you learn math?*

*David (L): Umm… counting… umm…umm…. Like easier ways to do it and yeah.*

*Interviewer: Why do you think… so what example…. So if you were asked to multiply what kinds of activities would help you learn to multiply?*

*David (L): Umm… repeated addition or multiplication (mumbling).*

*Interviewer: So would it be like doing it on paper or looking at it on a multiplication chart?*

*David (L): Doing it on paper.*

One participant reported that there was no specific activity that helped him to learn mathematics and that he learned mathematics by just completing problems.

*Interviewer: Okay…umm… What activities help you learn math?*

*James (H): Umm… Mostly like ugh nothing really helps me I just like I help myself through it but there is no activity that I do to help me.*

*Interviewer: So what do you do when you are working with yourself to try to learn math?*

*James (H): Like analyze the either word problem or umm normal problem and try to work out how I'm going to solve it.*

*Interviewer: Do you work by yourself or with others?*

*James (H): Sometimes by myself and sometimes with others.*

In the first focus group there were six participants who answered the question, "How do you learn mathematics?" Only two of these participants were able to describe ways that they believed mathematics was learned without the teacher. One of these participants described the process that a student might use to learn how to add. Dawn Marie (L) said, "If you're learning how to add stuff, what you need is your fingers and then start memorizing the problems." The other participant described how mathematics was learned with and without the teacher. First Kelly (H) said that you learn mathematics, "with numbers, symbols, sometimes words in word problems." Then she said that her teacher helped her learn mathematics by using math jokes.

The other four participants who answered this question said that their teachers helped them learn mathematics. One participant said that the teacher shows them how to do something and then has them to try it on their own. Mike (N) said, "She shows us how to do it first and then she tells us to try it on our own." Zach (H) said, "She only teaches math and sometimes science too." Another participant said that her teacher tried to make learning math fun:

*Katie (H): She'll try to mix it with a little bit of fun so it won't get boring for us and then she makes it a lot of fun to remember. And she's trying to prepare us for the SBAC test*

*Interviewer: Okay. What does she do that's fun?*

*Katie (H): She'll like make her own math sentences and then in her sentences she'll put something funny and then she'll be like, "Do you guys get it?" and then we'll be like, "Oh yeah," and then we all start laughing.*

Another participant said that her teacher provided her examples of how to do the problem but then allowed them to do it their own way. Mia (M) said, "She will make it easier by telling us how other people would do it but she will tell us how we should do it our own style."

In the pre-interviews and focus group when participants were asked what helped them to learn mathematics two participants reported flashcards, one said reviewing by himself, one said math facts, three reported doing mathematics, five said the teacher, one said nothing, and one said jokes. This suggests that the majority of participants initially held the belief that their teachers are the source of knowledge because most of these activities are teacher driven.

***Post-interviews and focus group.*** The purpose of this section of the paper is to present the findings from the post-interviews and the last focus group. In the pre-interviews, Ashley (L) said that using flash cards helped her learn mathematics but in the post-interview she responded that the teacher helped her learn mathematics.

*Interviewer: Okay, umm… so when you're learning math what activities help you the most?*

*Ashley (L): Umm… when I'm learning math what activities help me the most…*

*Interviewer: Mmhuh … like how do you learn math?*

*Ashley (L): Well usually I learn math by listening to the teacher because they are going to instruct you on how you are going to do this and that. But if I didn't learn math then I wouldn't be able to know on how to solve for … for example dividing if I didn't listen to the teacher on knowing how to divide in high school you are going to have to divide even more than you think you would. I wouldn't know how to do that and I would not pass.*

Ashley described listening to her teacher, as an activity that helped her learn mathematics and her teacher was the source of knowledge. Ashley was also unable to describe how mathematics was used outside of school. The only consequence she described for not learning mathematics was failure in her future academic career.

In the pre-interview Piper (M) said writing her math facts helped her learn mathematics. In the post-interview Piper (M) said that practicing mathematics helped her learn it.

*Interviewer: Okay, umm so what activities help you learn math?*

*Piper (M): Maybe like you know when kids are little they count sheep.*

*Interviewer: Okay.*

*Piper (M): Probably like that.*

*Interviewer: Is there anything else that helps you learn math?*

*Piper (M): Umm…. Count everything in the room…. And plus it all up.*

When Piper (M) was asked if hands-on activities helped her learn mathematics, she said that games did. When she was asked why games helped her learn mathematics she replied that she used it to play some games,

*Interviewer: Okay, umm… do hands-on activities help you learn math?*

*Piper (M): Yeah, kind of like games.*

*Interviewer: K… Umm. Why do you think they do… why do you think they help you?*

*Piper (M): Umm… probably because in a certain game that I play I forgot the name of it … but when you play it you have to buy certain things to finish a quest.*

In the pre-interview Amy (M) said that her teacher helped her learn mathematics. In the post-interview she said that games helped her learn mathematics.

*Interviewer: When you are learning math what kinds of activities help you learn math?*

*Amy (M): Umm... we do like in our class like sometimes multiplication and division bingo.*

*Interviewer: Oh okay, oh yeah I saw those.*

In the classroom observation of Amy's (M) teacher she had her students complete several timed tests that covered multiplication and division on both days that she was observed. Amy (M) was also asked if hands-on activities helped her learn math. Amy (M) said that they did but was unable to say why she thought these might help her learn mathematics,

*Interviewer: Do hands-on activities help you learn math at all?*

*Amy (M): Umm… kind of.*

*Interviewer: Yeah?*

*Amy (M): Yeah.*

*Interviewer: So…. Do you know why they might help you?*

*Amy (M): Umm… (shakes no)*

When Amy (M) was asked why she thought that bingo helped her learn mathematics she replied, "Umm... cause it will help like you remember to…. It will let you remember your division and multiplication and it pushes you to get like all five in a row." Amy's beliefs about mathematics were influenced by the activities in her mathematics classroom.

In the pre-interview Chris (H) said that flashcards helped him learn a new concept and just reviewing a concept in his head helped him learn it. In his post-interview Chris (H) said that worksheets and help from the teacher were activities that helped him learn mathematics. Chris (H) said, “Oh, Ms. XXXX prints practice sheet for us like so we can take home and check it the next day and see what we got right and if you don’t get it right then she lets you come in at lunch for tutoring.” After some prompting from the researcher he also said that hands-on activities helped him learn mathematics.

*Interviewer: So do hands-on things help you learn math?*

*Chris (H): Like what do you mean?*

*Interviewer: Well, like drawing the chips [an activity from his class] and some of the stuff that we did in here? Did that help you learn math?*

*Chris (H): Oh yeah.*

*Interviewer: Is there one that sticks out to you more than others?*

*Chris (H): the one where we did on the board. Last week when we did the rate = time ….distance uh*

While Chris still believed that his teacher helped him to learn mathematics he also believed that hands-on activities, including MEAs, helped him learn mathematics. In his pre-interview Chris only believed that his teacher helped him learn mathematics. Now he holds both the belief his teacher helps him learn mathematics and also that hands-on activities help him learn mathematics. His beliefs are in transition from the belief that teacher is the source of knowledge and that knowledge is constructed through hands-on activities.

In the pre-interview James (H) said that there were no activities that helped him learn mathematics. In his post-interview James (H) said that completing worksheets helped him learn

mathematics. James (H) said, “umm... usually… like not really sure of what activities help me learn math. I guess kind of like getting worksheets and doing them.” When the researcher asked James (H) if hands-on activities helped him learn mathematics he said “yes” but did not give any examples of an activity. James still holds the belief that he learns from doing abstract mathematics problems.

In the final focus, group when participants were asked how they learned mathematics one participant reported that the teacher helped him learn mathematics.

*Interviewer: Let's look at the next one. How do you learn math?*

*Joseph (H): Teachers.*

*Interviewer: By teachers? What activities help you learn math?*

*Joseph (H): Getting teached by the teacher.*

*Interviewer: The teacher? Okay.*

Another participant said that games and flashcards helped her to learn mathematics. Katie (H) said, “You said games and games where we learn math or maybe like flashcards. Cause you practice them everyday and you get used to them.” Another participant also said that flashcards helped her to learn mathematics. Becka (M) said, “Me and my dad practice math by using flashcards.”

When asked if hands on activities helped them learn mathematics two participants gave examples of hands-on activities.

*Interviewer: Can you guys give me an example of one?*

*Joseph (H): The rocket. Yeah I mean the capsule.*

*Interviewer: The capsule helped you learn math.*

*Joseph (H): What was it? Speed and height with distance.*

*Interviewer: Distance equals rate times time? Okay. Yes?*

After the Rocket MEA Joseph (H) and Elizabeth (H) said that they could learn mathematics as engineers,

*Interviewer: Okay, that works. Did it change your opinion on how you could use math or you could learn math?*

*Mike (N): Not exactly.*

*Joseph (H): As an engineer, yes.*

*Interviewer: As an engineer, okay.*

*Elizabeth (H): Yeah, same as Joseph (H).*

Elizabeth and Joseph were beginning to see that they could learn mathematics by completing activities like the MEAs. The other participant gave an example that he did in his mathematics class that was not observed by the researcher.

*Mike (N): Surface tension.*

*Interviewer: For the foil activity?*

*Mike (N): No I mean like a math activity our teacher did. With the pennies. It was awesome.*

In the post-interviews and the final focus group there were two participants who said they learned mathematics through their teachers, one said they learned mathematics by doing mathematics, one said they used mathematics by using flashcards, two said they used worksheets, three reported games, five participants said that hands-on activities helped them learn mathematics, and two said that they learn mathematics as engineers. Participants' beliefs about mathematics changed as a result of participating in the after school program. Before the program the majority of participants thought that the teacher helped them learn mathematics but

after participating in the MEAs some participants' beliefs changed and they began to think that hands-on activities helped them learn mathematics.

**Role of the teacher.** The *role of the teacher* was a belief in the framework developed by Kloosterman (1996). Participants were asked if there were times where teachers should let students figure out problems or whether teachers should explain them first.

***Pre-interviews and focus group.*** Seven participants reported that the teacher should always explain new concepts first. James (H) said, "She should explain it first and then let us try and figure out how we are going to do it"; and Jennifer (H) said, "she teaches us the lesson and then we do some problems with her and then she lets us do some problems on our own."

Three participants said that there were times when their teachers should explain concepts and there were also times when their teachers should let them figure things out first. James (H) said, "Umm… there should be some times where they should just let us figure it out and also some times when they should explain stuff." Amy (M) said, "It's a little bit of like half and half… Some days she knows we can do it by ourselves and some days… when we are learning something new she teaches it."

Three participants reported that their teachers let them try problems first and then explain the problems. David (L) said his teacher lets him "figure out and then she explains what you did wrong and everything." Katie (H) said, "She always lets us figure it out first, and then if we don't get it, she'll try to help us but she won't give it all away."

When asked what the teacher should do when students were being taught a new concept, three participants said that the teacher needed to explain the content first,

*Interviewer: If you are introduced to something new should the teacher explain it first or should they let you figure it out?*

*James (H): She should explain it first and then let us try and figure out how we are going to do it.*

*Interviewer: And what happens if you get to a point where you are stuck and you don't understand?*

*James (H): I usually go up to the teacher and ask her for help.*

*Interviewer: Okay*

*James (H): Or I ask… umm… a friend for help.*

Jennifer (H) said, "she teaches us the lesson and then we do some problems with her and then she lets us do some problems on our *own*." Katie (H) also reported that her teacher explains new concepts first,

*Katie (H): She teaches us first and then we all do it.*

*Interviewer: Okay, so she always teaches first?*

*Katie (H): Yeah.*

*Post-interviews and last focus group.* Three interview participants reported that the teacher should let students figure out how to solve problems. Chris (H) believed that his teacher should let him figure out how to solve problems. Chris (H) said, "They should let us figure it out because if they just tell us the answers we won't learn it." David (L) said that the teacher should "like let them figure out and then tell them what they did wrong." James (H) also said that teachers should let students figure problems out and then explain how to solve the problem after the students have been given a chance to solve it.

*Interviewer: Okay, so are there times where your teacher should let you figure things out?*

*James (H): Mmhuh (yes).*

*Interviewer: Okay, all right. Umm… can you give me an example?*

*James (H): Umm… at times our teachers help us out well… of when me and my friends are like stuck on a problem and we are working together on it and we can't figure it out we can go up to Ms. XXXXX and ask her…umm... if she can help us and she says yes and so then we figure it out.*

*Interviewer: So then does she just tell you how or does she make you try to figure it out all by yourselves?*

*James (H): Umm… she makes us try and if we can't get it then she helps us.*

All seven of the participants in the focus group said that there are times when the teacher should let students figure problems out before explaining them. Only two of these participants were able to provide an example of an activity where the teacher had students do an activity first and then explained it. Both students were in the same class and described the same activity that was not observed by the researcher.

*Interviewer: What were you guys thinking? Becka (M), Mike (N), what were you guys thinking? Does your teacher ever make you figure stuff out first and then tell you something new?*

*Becka (M): Sometimes.*

*Mike (N): Sometimes yeah.*

*Interviewer: Can you give an example?*

*Mike (N): The water. The pennies and the water and then she showed us a video on water tension.*

*Interviewer: Okay. So you did it first and then she talked to you about it?*

*Mike (N): We found out water tension is when a positive and a negative stick together and it feels hard. That's why when you do a belly flop it hurts.*

Three participants reported that the teacher explains content and then lets them figure it out for themselves on tests. Amy (M) reported “Both. Like doing a lesson they help us but if a test if we ask them a question they ask us like do you remember the lessons we did the week before.”

One participant said that there were times when the teacher should let you figure out how to do math by yourself but the example that she provided was of the teacher explaining first and then having students solve problems:

*Interviewer: is there a time when teachers let you just figure stuff out on your own or should they always give you the answer?*

*Ashley (L): Umm... what do you mean?*

*Interviewer: So you’re learning something new, is there a time where the teacher should let you try to figure things out. Like we kind of did in the after-school program... Is there ever a time where a math teacher should do that?*

*Ashley (L): Probably, yeah.*

*Interviewer: Can you think of an example?*

*Ashley (L): Cause well for example when the teacher is telling you to do this… you have to let them do it themselves cause they need to know for … for like to know if they really know it then not just give an answer away cause you are not going to really learn that way.*

*Interviewer: Okay, when you are learning math then usually the teacher will work a problem with you and then she'll give you a problem to do on your own for you to show you how much you know?*

*Ashley (L): Yeah.*

Ashley still believed that the teacher is the source of knowledge. Although Ashley said that there were times where the teacher should let students figure things out on their own, she provided an example where the teacher explained material first.

Two participants in the focus group also said that there are times where the teacher should let students figure out problems for themselves, but these students provided examples where the teacher first explained and then had students work problems. Chloe (H) said, "Like after the teacher teaches you and then she says, 'Work on it by yourself' but when you don't listen to the thing then you get in trouble." Jennifer (H) agreed with Chloe (H). Jennifer (H) said, "like she [pointing to Chloe (H)] said, the teacher first teaches us and then she gives us a worksheet and we have to work some problems that we learned around that lesson."

Five students stated that the teacher should explain new content. When Chris (H) was asked what the teacher should do when teaching a new concept he said that his teacher should explain it first:

*Interviewer: When you are learning something new for the first time should your teacher give you something and let you struggle with it for a little bit or should she like show you how to do it first?*

*Chris (H): Show you how to do it first.*

*Interviewer: Okay so she is going to show you how to do a problem…*

*Chris (H): And then she lets us try three or four of them to see if we do the right algorithm.*

Chris still believed that the teacher should always explain material to students.

Amy (M) also stated that if they were learning new concepts the teacher should explain things first.

*Interviewer: Okay, now what about if you have something brand new you are doing in class?*

*Amy (M): She helps us.*

*Interviewer: Is that always the way it goes? She shows you and then you guys do it together that way?*

*Amy (M): Yeah, like if we have any questions then we ask her and she helps us.*

*Interviewer: Now is there ever a time where she gives you something and lets you try to figure it out?*

*Amy (M): Not that much, she usually helps us with everything.*

Amy believed that her teacher should always explain mathematics. In the pre-interviews and focus group, one participant reported that the teacher should both explain content and let students figure problems out for themselves. Three participants, who were not referring to learning new content, said that the teacher should let them try problems first then explain what they were doing wrong. Three participants said that the teacher should always explain new material.

During the last focus group and post-interviews, three participants said that the teacher should let students solve problems before explaining how to do them--referring to practice problems and not new content.  Seven participants in the focus group said that the teacher should

let them figure out problems first; however, only two of these participants were able to provide a specific example where they were learning new material. Three participants responded that the teacher should always explain first and then let them practice. Three participants said that they should be allowed to figure problems out for themselves and then the teacher should explain the problems. However, these participants then provided examples of the opposite scenario. Five participants believed that the teacher should always explain new content.

**View of self and ability in mathematics.** Only the participants who participated in the semi-structured interviews were asked if they thought that they were good at mathematics. When Ashley (L) was asked if she thought she was good at mathematics in her first interview she replied, "I'm kind of good but I'm not sure if I'm fully" and when the researcher asked her to clarify what she meant she replied, "Well, I don't really know my division all the way or multiplication cause I like know my 10s and everything but I don't know my 12s and 11s." In the post-interview Ashley's (L) response was similar,

*Interviewer: Umm… do you think you are good at math?*

*Ashley (L): Probably not.*

*Interviewer: How come?*

*Ashley (L): I don't know umm… I don't know how to multiply by my 12s and 11s.*

*Interviewer: Yeah, those are hard. Is there any other reason why you think you are not good at math?*

*Ashley (L): No… I just don't know how to multiply by my 12s and 11s.*

Ashley's (L) belief about herself in mathematics was connected to her ability to do one specific skill: multiplying by 11s and 12s.

In the pre-interview, Piper (M) said that she was good at mathematics because she was able to do it quickly.

*Piper (M): I'm good at it because usually I can answer a question really good in math but sometimes if it's really hard I need a few seconds.*

*Interviewer: So by really good you mean fast?*

*Piper (M): Yeah, like medium.*

*Interviewer: Okay, and so is like if you're given multiplication … like if I say what's 2 times 3 you can go like that (I snap my fingers)?*

*Piper (M): Yeah pretty much.*

In the post- interview, Piper's (M) belief about what made her good at math changed. Piper (M) said, "*Well I get Bs in my math and if you give me a certain… if you give me a question I can probably do it but if it's really hard then there is a possibility that I may not be able to*." At the end of the after-school program her belief about her ability in math was related to her grade and her ability to do most problems that she was given.

When Amy (M) was asked in the pre-interview if she was good at mathematics, Amy (M) replied, "a little bit" because "some math is difficult for me…like long multiplication and division." So Amy (M) believes that she is not really good at mathematics because she struggles with specific skills. When Amy (M) was asked in the post-interview if she thought that she was good at mathematics she replied, "Sometimes if it's not too difficult I can finish it really easily. If it's difficult it takes me a little while to figure it out." Amy's (M) beliefs about her ability to do mathematics were connected to her ability to do math quickly.

In both the pre- and post- interviews Chris's (H) beliefs about his ability to do mathematics were connected to his grade in mathematics. In both the pre- interview when Chris

(H) was asked if he thought he was good at mathematics he replied "yes" and then when asked why he responded that he had an A in mathematics.

In the pre-interview David (L) said that he thought he was not good at mathematics because he needed help to solve some problems and that he was not very confident in his ability to do mathematics.

*Interviewer: Okay, do you think that you are good at math?*

*David (L): Umm… no, not really.*

*Interviewer: Why?*

*David (L): Cause like…umm... there are things that I don't know and there are things that I need a little help on.*

*Interviewer: Like what? Can you give me an example? Would you mind?*

*David (L): Like if it's a… umm… we had a problem on the test and you had to figure out how many cubes go in so I started counting the rows and the ones that go down and I got the wrong answer.*

*Interviewer: So how confident do you feel about doing math?*

*David (L): Umm... not.*

David's (L) belief about his ability to do mathematics was connected to his struggles to complete one certain task. When asked if he was good at mathematics in the post- interview he replied,

*David (L): Not really.*

*Interviewer: Not really, why?*

*David (L): Cause I'm like not that good in math I'm getting like a C or B on it.*

*Interviewer: So because you are getting a bad grade you don't think that you are good at math?*

*David (L): Mmhuh (yes)*

In the post-interview his belief that he was not good at mathematics was connected to the grade he was getting in his mathematics class.

*In the pre-interview, James (H) said that he was good at mathematics but when he was asked why he replied, "Umm… I don't actually know why. I'm just like good at it I don't really have a reason why I'm good at it." In the post-interview when James (H) was asked if he was good at math he replied,*

*Interviewer: Okay, so umm… do you think you are good at math?*

*James (H): Mmhuh (yes)*

*Interviewer: why?*

*James (H): Umm… it is mostly because of science.*

*Interviewer: Because of science?*

*James (H): Because I really, really like science and I use a lot of math in that.*

Now James's (H) belief that he was good in mathematics was connected to the fact that he used a lot of mathematics in another content area: science.

In the pre- interviews three participants' beliefs about self were connected to their ability with a certain skill or mathematical task; one participant thought that being able to do mathematics quickly equated to being good at mathematics; one participant thought a good grade in mathematics demonstrated that he was good at mathematics and one participant gave no reason why he was good at mathematics.

In the post-interviews, one participant connected their ability to do mathematics to their ability to do a certain skill, three participants thought that grades were an indicator of their mathematical abilities, one thought that being able to do mathematics quickly meant that she was good at mathematics and one participant thought that using mathematics in another subject made him good at mathematics.

**Student opinions of the activities and teamwork.** Another theme that was observed was the students' opinions about the different activities that were completed in the after-school program. Another theme that will be reported in the section is *teamwork* because some of the student opinions of each activity were influenced by teamwork. While the opinions that students had are not directly related to their beliefs about mathematics, the researcher considered these opinions as a possible factor in the change or lack of change in the students' mathematics related beliefs.

***Rationale for participating in the after-school program.*** An important theme that was observed in the first focus group was the students' rationale for participating in the after-school program. One said she participated because she liked math, another because she liked math and science, and three more said they participated because they liked science:

*Interviewer: What made you guys decide that you wanted to do the program? Go ahead.*

*Kelly (H): Because I really love math and science and my mom [inaudible 00:00:58] on it.*

*Interviewer: That's good.*

*Katie (H): I like math and I like building stuff and you said we would build a rocket.*

*Becka (M): Just because I like science and building stuff.*

*Interviewer: Okay, I'm sensing a theme here. Anyone else want to tell me … what did you like?*

*Wyatt (M): I like science.*

*Interviewer: You like science? Anyone else? What do you want to do?*

*Ashley (L): Ultimately I like science.*

*Interviewer: You like science?*

*Ashley (L): Plus I like to get outside and do stuff.*

Most of the students chose to participate in the after-school program because they liked science.

***Impressions after each activity.*** After each activity the participants in the semi-structured interviews and focus groups were asked what they liked and didn't like about each of the activities.

*Survivor MEA.* For the Survivor MEA, three participants liked that it was based on real life. Becka (M) said, " I like how it was based off the real thing. We got to build it off the real thing so that we could know what to do if we got on the show 'Survivor.'"

Five participants said they liked the activity because of the materials that they used. Three of these participants said they liked the activity because they got to use play Dough. James (H) said, "The materials we had and how we had to build it like with sand and water" and Piper (M) said, "we had to use materials that are sort of like the ones in the wilderness and it was fun, the Play Dough was supposed to be mud. That was the fun part of it 'cause we got to mess with it and try to get it the right texture."

One participant reported that he liked the activity because of its novelty. David (L) said, “I like the fact that you had to go …Like not all the time you can always have certain materials… Like that was the first time I got to do that.”

One student reported that he did not like the activity because his team had trouble building the actual structure. Chris (H) said, “ It wouldn’t stay up…. It kept leaning.” When asked if there was anything else he didn’t like he replied no.

Three participants said they liked working in teams. Katie (H) said, “I liked how we brainstormed.” Jennifer (H) said, “I liked this [MEA] better because we already got to know all of each other and on the marshmallow one we were like stop doing that or stop doing this, don't touch it. On this we we're like had no problems.” Jennifer (H) also thought that working in groups made the task easier, “Yeah because if it was just one of us it would be super hard. Who would grab this part and help me? In a group, you help each other you grab something and you put the thing on.” Katie (H) also thought that working in a group made the task easier, “Another thing that I liked was with two partners you guys are going to do this and do that to help us do this and that. So we were like in little groups but we're helping each other build.” Jennifer and Katie appreciated having a pre-existing rapport with their teammates.

Five participants reported that they did not like the teamwork component of the Survivor MEA. Amy (M) said, “It was kind of hard thinking about all the ideas and one of the teammates kept thinking about new ideas when we just made a good one.” Although Amy (M) reported teamwork as a component that was challenging for this MEA she also thought that working in a team made it easier as well. Amy (M) said, “It seemed like we all worked together as much as we can and if we like messed up we just kept like sticking together.” Katie (H) also reported that she didn’t like it when group members were off task, “One thing I didn't like was one girl was

like come on and help but she didn't want to do it, she was playing the Play Dough" Mia (M) reported that her group argued but were able to work through it, "It's the same thing she said but the thing that I liked was that once we were done arguing is when we started to be able to see what we could do with the house." However, David (L), a member of her group, did not report anything negative about working in a group. Piper (M) also reported that her group had trouble with arguing but that they were able to work through it:

*Interviewer: Okay, how was working in a team?*

*Piper (M): It was okay. It was just hard 'cause we kept on arguing where to put it and what jobs we needed to do and yeah.*

*Interviewer: So what did you like about working in a team?*

*Piper (M): Is that when we were done with it, it turned out amazing… well good and it didn't knock over and the water didn't really go under it. At the end it always turns good*."

James (H) also reported that he didn't like how his group worked together, "*I didn't really like how our team was working cause we all kind of like fighting yeah and that's what made it not work*." However, he did say that he liked some aspect of working together, " *Yeah like how we get to work together instead of just being on our own. Umm it adds more like I don't know what to really call it but it like gives more friendship to the project that we're working on*."

While the participants reported some positive experiences working as a team they also had some negative experiences. Participants reported negative experiences with teamwork when other group members were off task or when they were unable to agree with their group members about the implementation and design of their models.

*Rocket MEA.* There were six participants present for the focus group after the Rocket MEA. All six of these participants said that this was their favorite activity that they had completed so far. One participant liked the activity because of the teamwork that her group used to build their rocket. Jennifer (H) liked the activity because, "we could design it however we wanted to" and Zach (H) liked the activity because "we got to build stuff that we normally don't build in real life every day and we got to see how high it would go." Mike (N) also said he liked the activity because they got to see how high the rocket went. Mike (N) and Jennifer (H) also liked the activity because they got to go outside. Jennifer (H) said, "Because we actually got to go outside and actually make them go up."

When the participants in the focus group were asked what they liked about working as a team, one said that they got it done faster, one liked how his team cooperated, and another liked the creative ideas that her group was able to generate together.

*Interviewer: What did you guys like about working in a team?*

*Mike (N): It was fun [laughter] and we got it done faster*

*Interviewer: The what?*

*Joseph (H): The coop that was in it.*

*Interviewer: The cooperativeness. Yes.*

*Elizabeth (H): The creative ideas*

*Interviewer: The creative ideas, yes.*

Ashley (L) was asked what she liked and didn't like about the Rocket MEA and she responded,

*Interviewer: So what did you like about it?*

*Ashley (L): Umm... I liked that we built it together and this time we had no arguments and everything so it was kind of fun.*

*Interviewer: What did you not like about the activity?*

*Ashley (L): That the fin broke off cause we named him Sharky.*

When asked how it was to work in a team she responded, “Awesome!.” When asked if there was anything that she didn’t like about working in a team she responded no, there wasn’t.

When Piper (M) was asked what she liked and disliked about the activity she responded,

*Piper (M): I like that we had to use the materials to make it like launch. I think that was the best.*

*Interviewer: What did you not like about the activity?*

*Piper (M): That umm it didn’t go as high as we expected.*

When Piper (M) was asked what she did not like about working in a team she responded it was okay and then complained about another group member’s behavior. Piper (M) said, “*It was okay. Just Katie (H), she kept blowing in the thing when we were talking*.”

Amy (M) was also asked what she liked and disliked about the Rocket MEA and she replied,

*Amy (M): Umm. I liked how we had to measure on the computer and how like when we launched it.*

*Interviewer: Okay. Cool. Is there anything you didn’t like about it?*

*Amy (M): How we made the model, it was kind of difficult.*

*Interviewer: Okay, why?*

*Amy (M): It was umm like we kept on thinking of new ideas and we tried to put it all together.*

*Interviewer: So it was hard to focus?*

*Amy (M): Yeah.*

Previously Amy (M) had been working in a large group for the Marshmallow Challenge and a mixed gendered group for the Survivor MEA where she was the only female participant. When Amy (M) was asked about what she liked about working in a group for the Rocket MEA she replied,

*Interviewer: What did you like about working in a group this week?*

*Amy (M): It was all girls so we kind of like worked together better instead of all boys or mixed.*

*Interviewer: And that goes back to the weeks before. What did you not like about working when you were in the mixed group?*

*Amy (M): There was many people*

*Interviewer: Mmhuh [affirmative]. Oh yeah cause you had five.*

*Amy (M): And we … it was hard like working together and putting all of our ideas together.*

*Interviewer: Okay. What about the group where there were the three boys.*

*Amy (M): There was this one kid who kept on destroying everything.*

When Chris (H) was asked what he liked about the activity he replied, "that we actually made it fly." Chris (H) did not dislike anything about this activity. When Chris (H) was asked how it was to work together in a group he responded, "Couldn't be better." After further prompting from the researcher he replied the reason he liked working in a team was because "we got together… everybody had the same idea about how to build it."

James (H) also liked the fact they got to build the rocket and he said that he liked everything about the activity. When asked what he liked about working in a team he replied, “Mostly that we didn’t fight or yell at each other.”

*Mars Rover MEA.* There were four participants present for the focus group that met after the Mars Rover MEA. Three of these participants said they liked the activity. Becka (M) said she liked it because they were successful. Jennifer (H) liked it because they got to use eggs and Joseph (H) liked it because he did most of the work. Chloe (H) said, “I kind of liked it a little bit because well most of my team was pretty much arguing.”

When the participants of the focus group were asked what they liked about working in a team, two responded that they got to use all of their ideas; one responded that most people in his group helped and one responded that her group worked together.

*Interviewer: Okay. What did you like about working in a team?*

*Joseph (H): That most of us helped.*

*Interviewer: That most of you helped. A little bit of not…*

*Joseph (H): Mitchell didn’t help.*

*Interviewer: What about you?*

*Jennifer (H): If we were going to use an idea, each of us got an idea and we had to put in there. So all of our ideas got in there.*

*Interviewer: Okay, that's cool. You guys used a little bit of what everybody said.*

*Becka (M): It's kind of like mixing all of our ideas.*

*Interviewer: Okay.*

*Jennifer (H): And it made a big tape mass.*

*Interviewer: A big tape. That happens with Duck tape. What about you, Chloe (H)? Did you guys like working in a group?*

*Chloe (H): Mmm…Kind of.*

*Interviewer: Kind of?*

*Chloe (H): Yeah.*

*Interviewer: What do you like about it?*

*Chloe (H): I like how we work together. Like building things but then they kind of made fun of me because I didn't know how to blow a balloon.*

All of the participants in the focus group reported that working together in a group made this activity challenging. Joseph (H) reported that one of his group members did not help. Jennifer (H) reported that Mike (N) and Becka (M) were off task most of the time.

*Interviewer: … What did you not like about working in a team? You said you guys fought, right?*

*Chloe (H): Yeah.*

*Joseph (H): Once again, Mitchell didn't help.*

*Interviewer: You had someone who didn't help. What about you guys? What did you not like?*

*Jennifer (H): I would say Becka (M) and Mike (N) were kind of not helping us. When me and Elizabeth (H) say, "Help us please!" Mike's (N) like, "I'm trying to," but he was-*

*Becka (M): [interrupts Jennifer (H)] I got the tape for you.*

*Jennifer (H): He was under the table and like, "But Becka's (M) trying to catch me." Becka's (M) like, "I'm going to get you."*

All of the participants felt that if this activity was to be completed in their regular classroom individual participation needed to be included in their grades for the activity and said that they were willing to grade their other group members on their contributions to the activity.

*Interviewer: Okay. If you were going to do this in a classroom, somehow, for a grade do you think that you should get graded on teamwork?*

*Joseph (H): Yes.*

*Group: Yeah*

*Interviewer: Yes?*

*Joseph (H): For everyone.*

*Interviewer: Okay. Have you guys ever had your teachers use rubrics where they grade?*

*Becka (M): Mm-hmm (affirmative).*

*Interviewer: Okay. It's a way to score. They could score your teamwork but what about you guys scoring your teamwork? Would you be comfortable scoring your other team members if they are not going to see it? If you were in a class, would you be comfortable telling the teacher the same kind of things you're telling me?*

*Joseph (H): Yeah.*

*Group: (nod head affirmative)*

*Interviewer: Yeah? Okay. Because I know in older grades, sometimes they'll factor in the teamwork but then you'll get to grade the other three people in your team. The teacher will look at that and factor it into the grade for the activity. So grading teamwork would be vital?*

*Group: (nods affirmative)*

Ashley (L) reported that she liked the activity because "pretty much like how my whole entire group was here 'cause for the water rocket my whole entire group wasn't here. But at least we used teamwork and pretty much bonded together." Ashley (L) also stated that she did not dislike anything about the activity.

Piper (M) reported that she liked the fact that they had lots of materials to use and that they were given a budget.

> *I like that we had to use a lot of materials and we had a budget. So if we didn't have enough money… so if we didn't have enough money we couldn't get it. But we had enough money we had $200 left or $100 left so I think that was cool.*

When asked what she did not like about the activity Piper (M) replied, "kind of that when we took the tape off it would pop… the balloons would pop and that we had a $300 budget."

Piper (M) liked sharing ideas and thought her team worked well together. Piper (M) said, "that we all worked together. We all had … I went first with my little idea and Amy (M) went with her idea, Kelly (H) went with her idea… so I think that was the best part of it." When Piper (M) was asked what she didn't like about working in a team she said, "that we like when I was with Amy (M) she kind of got annoyed cause I was trying to show her what we could have done during when she was doing it."

When Amy (M) was asked what she liked about the activity she replied the balloons. Additionally, when was asked what was challenging about the activity, she replied, "It was kind of hard working with everybody cause we kept on getting new ideas and we had to put it together and take it apart again." Amy (M) said that she liked that her group didn't fight but reported that her group argued. Amy (M) said, "Yeah like one girl she kept umm she wasn't helping us at all. She kept on thinking of new ideas and wasn't doing what we were doing."

When Chris (H) was asked what he liked most about the activity he replied,

*Chris (H): Uh that we get to like drop it from the roof.*

*I: Okay.*

*C: Cause I have always wanted to do that at school 'cause I have seen it in movies and everything and I've always wanted to do this.*

Chris (H) reported that there was nothing he disliked about the activity. He said, "It was awesome!." When Chris (H) was asked what he liked about working in a team he replied, "It was good we didn't fight or yell at each other."

David (L) liked the activity because he had never done an activity like this one. David (L) said, "Umm that this was the first time I ever got to do this like to build something to protect the egg." David (L) also reported that there wasn't any part of the activity that he didn't like. David (L) said, "No, I liked every single part of it." When David (L) was asked what he liked about working in a team he replied, "That we trust each other and we always like umm like every once in a while everyone gets to choose like …like it would be one person's turn and then the next." There was nothing that he disliked about working in a team.

*Freighter MEA.* The purpose of this section is to describe the participants' opinions about the Freighter MEA. This activity was disliked by most of the participants. David (L) liked the Freighter MEA because it was simple but didn't like it because he was given a limited amount of materials to build the boat.

*David (L): I like how it was like really umm… like umm… simple but like you had to make sure it floats and everything.*

*Interviewer: Umm… What did you not like about it?*

*David (L): Umm… I thought we were going to get more materials and we just found out it used to be the tin foil.*

*Interviewer: The tin foil, so you said it was simple what did you mean by that?*

*David (L): Like is not like hard anything to build. It doesn't take that much time to think. It just has to float and you just make a boat.*

Another participant liked that the goal of the activity was to make the boat float but did not like the activity because his group was unable to successfully build a prototype. When Chris (H) was asked what he liked about the activity he replied, "That you could actually make it float." When Chris (H) was asked what he didn't like about the Freighter MEA he replied, "That it didn't float."

Ashley (L) liked the activity because her group's boat was able to hold 27 pennies. She did not like the activity because her group had trouble working with the aluminum foil.

*Interviewer: So what about the one with the foil and water?*

*Ashley (L): Umm… I didn't kind of like it because the foil had come with tiny holes in it and I couldn't find it no matter what.*

*Interviewer: That's frustrating.*

*Ashley (L): (nods yes) So I tried patching it but it still didn't work.*

*Interviewer: Okay, so is there anything you liked about it?*

*Ashley (L): Umm… I liked how it didn't take that long to sink and how it only took 27 pennies because I was guessing it would probably take only 27.*

Amy (M) said she liked the activity. When asked what she liked about the activity Amy (M) said, " Umm… I liked how it was limited amount of material and that gave us more to think

about instead of using all of our ideas we just did one thing." However, Amy (M) also believed that limited amount of supplies also made working together more challenging.

*Interviewer: Is there anything that you didn't like about it?*

*Amy (M): Teamwork was hard.*

*Interviewer: Yeah, you had teamwork issues. Now do you think that was more challenging because you had only one piece of foil?*

*Amy (M): Yeah.*

*Interviewer: So maybe if you were to do that would it be easier in a smaller group?*

*Amy (M): Yeah.*

Piper (M) also liked the Freighter MEA because of the limited materials that they were provided. When asked what she did not like about the activity Piper (M) said, "That we were using the foil and we put over… We were so close to 200 pennies it started to kind of burst a little."

None of the six participants in the last focus group reported that they liked the Freighter MEA,

*Group: Oh... Nothing!*

*Becka (M): Ours floated 4 seconds and then it dropped.*

*Joseph (H): Should I stick with 5 ... 50 pennies but then we decided we put 100.*

*Interviewer: What did you guys not like about it? Apparently there's a lot.*

*Zach (H): Everything.*

*Chloe (H): It stank. It sank.*

*Jennifer (H):  Little tiny tiny holes and we put it ... make it go in and it made the boat even go in and it made a huge mess of water because we took it out and it squirted all over the place.*

*Interviewer: I know. That part was bad.*

*Zach (H): I think everything.*

*Interviewer: You didn't like the activity at all?*

*Zach (H): No because all we had was aluminum foil.*

*Jennifer (H): We should have had tape.*

*Joseph (H): Yeah. Tape and some sticks and we should have [inaudible 00:03:15]. Sticks, tape, top part, a bottom part.*

*Interviewer: If I do it again, I might modify it because I was thinking the sticks might be good.*

*Becka (M): It kept sinking every time we put one penny in it.*

*Interviewer: It was really hard then.*

*Mike (N): The water just kept filling up when we thought we covered the holes with the aluminum foil.*

*Joseph (H): First of all, it sank. Second of all, it sank. Third of all, it sank. Fourth of all, it sank.*

*Interviewer: Okay. I'm guessing a pattern.*

*Becka (M): I'm guessing the fifth reason was it sank.*

Another participant liked using limited materials and the modeling process. When James (H) was asked what he liked about the Freighter MEA he said,

*Oh, that we were only given one piece of tinfoil to make a boat out of but the boat didn't work sometimes so we had to like take it out of the water and remake it and put it back in and see if it worked and if it didn't then we had to take it out again and rework it until it finally did but we didn't get to do it because it failed right at the last second and it all like just dumped over and fell.*

When James (H) was asked what he did not like about the Freighter MEA he responded, "Our teamwork wasn't very good."

During the last interviews and focus group the participants were asked if they would participate in something like the after-school program again and all six participants said that they would.

*Interviewer: If you had a chance to do something like the STEM Academy again, would you do it?*

*Mike (N): Yes…*

*Jennifer (H): For sure.*

*Zach (H): Yes.*

*Becka (M): Triple yes.*

*Katie (H): Yes, yes, yes, yes, yes.*

*Joseph (H): Yes.*

*Chloe (H): I might, but I'm going to a different school.*

*Interviewer: But what if they had one there? Would you do it?*

*Chloe (H): yes*

Individuals participated in the after-school program for three reasons. Three participants said they participated in the program because they liked science, one said it was because she

liked mathematics and science and another said she participated in the after-school program because she like mathematics.

Five participants liked the Survivor MEA because of the materials that they used; one like it because it was based on real life, and another liked the activity because it was new. Three participants said that they enjoyed working in groups, while five participants did not like the activity because of the groups.

Seven participants said that the Rocket MEA was their favorite. One said it was because of their teamwork, three said that it was because they got to choose their own designs, and six liked the activity because they got to go outside and launch the rockets. Only one participant disliked the activity and this was because of the teamwork.

Seven participants liked the Mars Rover because of their teamwork. Of these participants four liked that they used all of their ideas, two liked that all of their team members helped build the rocket and four believed that their team worked well as a group. One participant liked the activity because the capsule was dropped off of the roof and another said he liked the activity because he had never done it before.

Seven participants disliked the Freighter MEA--one because of teamwork and the others because of the materials that were used. While six participants reported liking the activity, four liked the activity because of the materials used, one because it was simple, one because of the goal to make the boat float, one because they were successful and one because of the modeling process. All six of the individuals who were interviewed and the six focus group participants indicated that they would participate in a program that was similar to the after-school program again.

**Overall Change in Beliefs Based on Ability**

The purpose of this section is to present a summary of the results for the six participants who were interviewed based on ability level (see Appendix N). The participants' answers to the pre- and post- questionnaires are presented. On the questionnaires a change in beliefs is considered to occur when the participants' answers changed categories. For example if a participant answered 4 on the pre-questionnaire and 2 on the post-questionnaire then it is considered as a change in beliefs.

**High-ability level students.** The two high-ability level students who were interviewed were Chris and James. Both of these students were in the fifth grade and from the same class.

***Changes for Chris.*** Chris somewhat disagreed with the statement "the role of the teacher is to provide answers to problems" on the pre- questionnaire; on the post- questionnaire he neither agreed nor disagreed with this statement. On the pre- questionnaire Chris neither agreed nor disagreed with the statement "all knowledge comes from the teacher." On the post-questionnaire he somewhat disagreed with this statement. In Chris's interviews there was no change in beliefs reported.

***Changes for James.*** On the pre- questionnaire James somewhat disagreed with the statement "math makes me confused" but on the post- questionnaire he somewhat agreed with this statement. On the pre- questionnaire James somewhat agreed math is not used in his other classes and on the post- questionnaire he strongly disagreed with the statement. There was no change in beliefs about mathematics reported in James's interviews.

***Shared changes.*** Both high-ability students' answers changed from the pre- to post-questionnaires for the statement "there are math problems that cannot be solved by following a predetermined sequence of steps." Chris somewhat agreed with this statement on the pre-

questionnaire and neither agreed nor disagreed with this statement on the post-questionnaire while James somewhat agreed with this statement on the pre- questionnaire and strongly disagreed with this statement on the post- questionnaire. For the statement “I use math in my science class” both participants indicated that they had no opinion on the pre-questionnaire. Chris somewhat agreed and James strongly agreed that math is used in science class on the post-questionnaire. Both participants somewhat agreed with the statement “the role of the teacher is to facilitate learning” on the pre-questionnaire. However Chris neither agreed nor disagreed and James somewhat disagreed with this statement on the post- questionnaire. Neither high-ability level student reported a change in beliefs about mathematics in their interviews.

Overall, participating in the MEAs had little impact on the mathematics-related beliefs of either high-ability level participant. These activities may have helped Chris and James see that mathematics and science were connected.

**Middle-ability level students.** The two middle-level students who were interviewed were Amy and Becka. Only Amy was present for both the pre- and post-questionnaires. There were only two answers to the questionnaire statements that changed from the pre- to post-questionnaire for both the middle-ability level students.

***Changes for Amy.*** On the pre- and post- questionnaires there was little change in Amy’s mathematics-related beliefs. On the pre- questionnaire Amy somewhat agreed with the statement “there are math problems that cannot be solved by following a predetermined sequence of steps” but on the post- questionnaire she indicated that she neither agreed nor disagreed on this statement. On the pre- questionnaire Amy indicated that she somewhat disagreed with the statement “I usually do well in math” but on the post-questionnaire she somewhat agreed with this statement.

In Amy's interviews there were some changes in her beliefs about mathematics. After the Survivor MEA when Amy was asked if her beliefs about mathematics changed she said "earlier I think that math is just like addition and multiplication but it's also measuring and doing and like using calculators and not just doing it with pencil and paper." After the Rocket MEA Amy said, "like we had to measure it was kind of … it was kind of weird measuring it on the computer." After the Mars Rover MEA, when Amy was asked if the activity changed her beliefs about mathematics, she said, "Umm...it made me think like instead of just writing it on your desk with a pencil and paper you also use like rulers, and you can like writing it on the board not just pencil and paper." After the Freighter MEA Amy reported no change in her beliefs about mathematics.

Overall, participating in the MEAs expanded Amy's beliefs about mathematics. She came to see that mathematics could involve more than just practice problems through the hands-on MEAs. This may have helped her to see how mathematics is used in her other classes through measurement and the use of computer programs. Participating in the MEAs may have given her more confidence in her mathematical abilities as well because she agreed on the post-questionnaire that she usually does well in mathematics.

***Changes for Becka.*** There was little change between the pre- and post- questionnaires for Becka. On the pre- questionnaire Becka somewhat agreed with the statement "I don't use math in my everyday life" and on the post-questionnaire she neither agreed nor disagreed with the statement. On the pre- questionnaire Becka somewhat disagreed with the statement, "math is not used in my other classes" and on the post- questionnaire she somewhat agreed with this statement. On the pre- questionnaire Becka neither disagreed nor agreed with the statement "math is about following rules" and on the post- questionnaire she somewhat agreed with this statement. On the pre- questionnaire Becka somewhat agreed with the statement "I never use

math outside of school" and changed to strongly disagreed with this statement on the post-questionnaire. On the pre- questionnaire Becka strongly agreed with the statement, "The role of the teacher is to facilitate learning" and on the post- questionnaire she somewhat agreed with this statement.

During the focus groups there was little change in Becka's beliefs. During the first focus group when Becka was asked to describe mathematics, she said, "I think it's a part of a science. Science and other stuff to get your mind building." When Becka was asked what she meant by it was part of science she replied, "Math and science have the same symbols and sometimes you have to use a calculator for math and science to figure out the problems that you're having trouble with." When asked how mathematics was used in her everyday life during the first focus group, Becka responded that she used mathematics when she cooked. When asked the same question during the last focus group, in addition to cooking Becka said that music was connected to mathematics. After the Mars Rover MEA when the focus group was asked if the activity changed their beliefs about mathematics Becka replied that this activity made her think "it can be fun doing mathematics."

In general, participating in the MEAs may have altered Becka's beliefs about mathematics. These activities may have facilitated Becka's ability to see how mathematics can be applied outside of school. This also may have enabled Becka to better connect mathematics and her everyday life. Most importantly, through participating in the MEAs Becka came to believe that mathematics could be fun.

***Shared changes.*** Becka and Amy's beliefs changed for two of the items on the questionnaire. For the statement "the teacher lets students figure things out for themselves" Becka somewhat agreed on the pre- questionnaire and somewhat disagreed with this statement

on the post- questionnaire. Conversely, Amy's beliefs changed in the opposite directions because on the pre- questionnaire Amy somewhat disagreed with the statement, "the teacher lets students figure things out for themselves" and on the post-questionnaire she indicated that she had neither agreed nor disagreed with this statement. On the pre- questionnaire Amy strongly disagreed and Becka somewhat disagreed with the statement "math is not used in my other classes" and on the post- questionnaire both Amy and Becka somewhat agreed with this statement.

While participating in the MEAs, both of the middle-ability level participants reported some change in their mathematics-related beliefs. These activities changed how Becka and Amy viewed mathematics. Amy was able to see how mathematics was connected to her other classes and Becka was able to see how mathematics was used in her everyday life.

**Low-ability level students.** The two low-ability level students reported the most change in answers from the pre- to post- questionnaires. Only three of the statements changed for both of the participants.

***Changes for David.*** For the statement "math is about exploring new ideas" David strongly disagreed with this statement on the pre- questionnaire but he had neither agreed nor disagreed with this statement on the post- questionnaire. For the statement "math is used to create the technology I use everyday" David somewhat disagreed with this statement on the pre-questionnaire and neither disagreed or agreed with this statement on the post- questionnaire. On the pre- questionnaire David somewhat disagreed with the statement "math is not used in my other classes" and on the post-questionnaire he neither agreed nor disagreed with this statement. On the pre- questionnaire David strongly disagreed with the statement "math is memorizing" and on the post- questionnaire he somewhat agreed with this statement. For the statement "word problems can be solved without remembering formulas" David strongly agreed with this

statement on the pre- questionnaire and neither agreed nor disagreed with this statement on the post- questionnaire. For the statement "there are math problems that cannot be solved by following a predetermined sequence of steps" David neither agreed nor disagreed with this statement on the pre- questionnaire and strongly disagreed with this statement on the post-questionnaire. On the pre- questionnaire David strongly disagreed with the statement that the role of the teacher is to facilitate learning but on the post- questionnaire he neither agreed nor disagreed with this statement.

After the Survivor MEA when David was asked if his beliefs about mathematics had changed he answered, "Not all the time… like everything is the same thing repeated and repeated now it's just like different." David was absent for the Rocket MEA but after the Mars Rover MEA he said that his beliefs about mathematics had changed.

*Interviewer: So did this activity change your opinion about mathematics?*

*David: A little*

*Interviewer: How?*

*David: Like there's always like you like don't always have to think about it this way there is always another way*

*Interviewer: And so what do you mean by like math that way?*

*David: Umm… like if you have like a math problem and you don't get it like try and like to like say something like remember this and try and compare it to that and if it is the same thing just remember that.*

*Interviewer: Okay.*

*David: Remember the fun things you did so you won't get bored.*

There was no change in beliefs reported after the Freighter MEA for David.

Overall, participating in the MEAs significantly altered the way that David viewed mathematics but had little impact on Ashley's beliefs. In general David came to see that there are different ways to problem solve in mathematics. David also no longer thought of mathematics as repetitive and boring. As a result of participating in the after-school program David believed that MEAs could be used to motivate him in the classroom.

***Changes for Ashley.*** On the pre- questionnaire Ashley neither agreed nor disagreed with the statement that math is more than doing operations like adding, subtracting, multiplying and dividing but on the post- questionnaire she strongly agreed with this statement. On the pre-questionnaire Ashley strongly disagreed with the statement "math makes me confused" but on the post- questionnaire she somewhat agreed with this statement. On the pre-questionnaire Ashley strongly disagreed with the statement that the teacher lets students figure things out for themselves; however, on the post-questionnaire, she somewhat agreed with this statement. On the pre- questionnaire Ashley somewhat disagreed with the statement that all knowledge comes from the teacher but on the post-questionnaire she neither agreed nor disagreed with this statement. Ashley strongly disagreed with the statement "I never use math outside of the school" on the pre- questionnaire and on the post- questionnaire she somewhat agreed with this statement. On the pre- questionnaire Amy strongly agreed with the statement "math is about following rules" and on the post- questionnaire she neither agreed nor disagreed with the statement. Ashley did not report any changes in beliefs about mathematics during her interviews.

Participating in the MEAs changed how Ashley viewed mathematics. These activities may have made Ashley realize that she is capable of learning mathematics without first having the teacher explain a new concept.

***Shared changes.*** Both participants' answers to the statement "the role of the teacher is to answer problems" changed. However, David's answers changed to somewhat agreeing with this statement to having neither agreed nor disagreed and Ashley's answers changed in the reverse direction from strongly disagreeing with this statement to neither agreed nor disagreed. For the statement "I don't use math in my everyday life" Ashley's answers changed from strongly disagree to neither agree nor disagree and David's answers changed from neither agree or disagree to somewhat agree. On the pre-questionnaire for the statement "Mathematics is hard" David indicated that he had neither agreed nor disagreed and Ashley indicated that she somewhat disagreed but on the post-questionnaire both participants indicated that they somewhat agreed with the statement that mathematics was hard.

For the participants there was no consistent change observable across the ability levels. The high-ability level students had no change in their beliefs after each activity. There was also only one statement, "I use math in my science class," where both participants' beliefs changed in the same directions from no opinion to agree or strongly agree.

Only one middle-ability level student's beliefs about mathematics changed after each activity. After participating in the program, both middle-ability level students views about mathematics changed. One was able to see how mathematics was connected to other subjects and the other was able to see how mathematics was used in their everyday life.

For the low-ability level students only one reported changes in the beliefs about mathematics after each activity. There was only one statement on the questionnaires where the low-ability level students' answers changed in the same direction. For the statement "mathematics is hard" both low-ability level participants' answers changed from no opinion and somewhat disagree to somewhat agreeing with the statement that mathematics is hard.

In general, there was more change observed in the medium- and low-ability level students who participated in the MEAs. The MEAs did not seem to affect how the high-ability students viewed the nature of mathematics or mathematics learning.

# Chapter 5: Discussion of Findings and Implications

In chapter four, the findings for this study that examined the mathematics-related beliefs of fourth and fifth grade students who participated in an after-school STEM program were presented. The research questions were “What is the nature of the change in mathematics-related beliefs of students who participate in an after-school MEA program? In particular, what is the difference, if any, of the nature of the change in beliefs across varying ability levels?” The rationale for this study was explained in chapter 1 and supported by the literature review in chapter 2. In chapter 3 the methodology of the study was explained. In this chapter the findings, implications and recommendations for future education and research will be discussed.

## Discussion of Findings and Implications Related to the Research Question

### Beliefs about the Nature of Mathematics

**Perceptions of problems in mathematics, mathematical modeling and word problems.** On the pre- and post-questionnaires- approximately 80% of the participants strongly agreed that mathematics was more than doing operations like addition, subtraction, multiplication and division. Yet in the pre-interviews and focus group all of the participants described word problems as simple one-step addition problems. On the pre- questionnaire 87% of the participants strongly agreed that math problems could be solved using the right set of steps but on the post-questionnaire only 65% of the participants strongly agreed with this statement. There is evidence to suggest that the participants’ perceptions of math problems changed. During the post-interviews and focus groups the participants described word problems in a more general manner that included any sentence with numbers and letters.

Approximately 70% of the participants on the pre- questionnaire and 65% on the post-questionnaire agreed or strongly agreed that math was about exploring new ideas. However,

approximately 78% of the participants on the pre-questionnaire and 96% on the post-questionnaire agreed or strongly agreed with the statement “mathematics is memorizing.” These results are significantly higher than those reported by the National Center for Education Statistics (NCES) for the 2003 administration of the NAEP where it was reported that 45% of test takers agreed that mathematics is memorizing (2003). Fifty-six percent of the participants on the pre-questionnaire and 60% on the post-questionnaire disagreed or strongly disagreed with the statement “word problems can be solved without memorizing formulas.” These two statements contradict the statement that mathematics is about exploring new ideas. Brown and colleagues (1988) found this also to be true for seventh and eleventh grade students who participated in the fourth NAEP assessment. These students understood that mathematics was a process but yet also continued to believe that mathematics consisted of memorizing and following rules. It is not surprising that participants hold conflicting views about mathematics. The three classes that were observed by the researcher were based strictly on memorizing and following rules. During one of the observations, the entire lesson consisted of timed tests on multiplication and division facts. Classroom environments continue to support the idea that mathematics is based on rules and memorizing while mathematics was conveyed to students as exploring and creating from the MEAs the students completed in the afterschool program. It will be difficult for students at the fourth and fifth grade levels to understand this abstract idea of mathematics as a process if their classroom experiences support the belief that mathematics is rules and memorizing. If the mathematics classroom supports the belief that mathematics is procedural and based on memorization then students will continue to hold this belief (Underhill, 1988).

McLeod (1989, 1992) suggested that teachers’ beliefs about mathematics influence students’ beliefs and Underhill (1988) suggested that the teacher establishes the group norms of

the classroom. If we want students to view mathematics as a process, and not just memorizing rules, we need to focus first on changing the beliefs of teachers because their beliefs will influence students' beliefs.

On the first day of the program participants completed the Marshmallow Challenge. This was followed by a presentation that connected the problem solving strategies used to complete this challenge to engineering and the engineering design process. Due to the age of the participants there was little instruction on mathematical modeling. When asked to describe mathematical modeling only one participant described the process of mathematical modeling. The majority of participants described mathematical modeling as graphs and pictures that they used to solve multiplication problems. Participants did not connect mathematical modeling with the problem-solving process that they used to complete the activities in the after-school program. This is consistent with Greer, Verschaffel and De Corte's (2002) belief that mathematical modeling is ignored in school mathematics, although it can be used as a tool to connect school mathematics to the real world. This study demonstrated that elementary-aged students can participate in mathematical modeling but it is much more difficult for them to describe what mathematical modeling means. English (2010) also found that elementary-aged students were able to create models that represented complex systems but in her research she only studied how students model and not if they understood the term mathematical modeling. In order for students to be able to better describe the process of mathematical modeling it needs to be explicitly connected to each activity after the students have completed them.

**Mathematics is useful.** Presmeg (2002) found students' beliefs about the nature of mathematics influenced the ability to connect school mathematics to the mathematics that was used in everyday life. Approximately 80% of the participants reported that mathematics was

useful outside of school, and disagreed with the statement “studying math was a waste of time” on the pre- and post- questionnaires. However less than 65% of the participants disagreed with the statement that “they didn’t use mathematics in their everyday life.” These results are slightly lower than those reported by the NCES (2003), who reported that approximately 69% of the 2003 NAEP test takers and 68% of students who tested in 2000 reported that they believed mathematics was useful for every day problems. When the participants were interviewed they stated that mathematics was useful for daily tasks like cooking, shopping, measuring and counting money. Presmeg (2002) found this to also be true for high school students. In order for students to see a strong connection between their school mathematics and their daily lives teachers need to build mathematical knowledge on students’ lived experiences. Despite being able to see a connection with mathematics and their daily lives, participants struggled to find ways that mathematics was connected to their future careers. This is consistent with Kloosterman (1996) because he found that children’s’ beliefs about the usefulness of mathematics varied by topic so children could see some mathematics as useful for simple day-to-day tasks but not see how it might be connected with the workplace. Kouba et al. (1988) also found that third grade students who took the fourth NAEP struggled to connect mathematics with careers. Brown et al. (1988) found this trend continued for seventh and eleventh grade students as well. These researchers found that in general students believed that mathematics was important to society but not important to students at an individual level.

It appears that the participants’ beliefs about the nature of mathematics in general and that school mathematics are disconnected. From the questionnaire and the statements given in the interviews the participants think that school mathematics is different than the mathematics in the world around them. On the pre- and post- questionnaire, 82% and approximately 74%

respectively, strongly disagreed or disagreed with the statement “I never use math outside of school” but when asked in the interviews and focus groups participants struggled to provide examples of mathematics that were not related to school.

**Mathematics is connected with other subjects.** Results were inconsistent for this belief. In the pre- and post- interviews approximately 78% and 96% respectively agreed or strongly agreed that mathematics was not used in their other classes. This could be due to the fact that mathematics was taught in isolation of other subjects. However, on the pre and post-questionnaires approximately 77% of the participants agreed or strongly agreed that mathematics is used in science. This could be because the idea that mathematics is used in science has become common rhetoric, similar to Kloosterman’s (1996) belief that students thought mathematics was useful because they were told mathematics was useful by parents and teachers.

### Beliefs about Mathematics Learning

**Social context in which mathematics is learned.** Before the after-school program participants were asked how they learned mathematic--as activities that were done in isolation or teacher led. Three participants said that they learned math by practicing math problems, two said that flashcards helped them learn mathematics and five said that their teacher helped them learn mathematics. None of the participants said that hands-on activities helped them learn mathematics. During the post- interviews, two participants said that the teacher helped them learn mathematics, one said practicing mathematics, two said worksheets, one said flashcards and three reported that games helped them learn mathematics. Five of the participants said that hands-on activities helped them learn mathematics and two specifically said they could learn mathematics as engineers. This suggests that their beliefs about how mathematics is learned changed.

**Mathematics used in the activities.** Data were collected through interviews and focus groups that occurred after each activity. In the Survivor MEA 60% of the participants who participated in the interviews or the group reported that they used mathematics to build their shelter. For the Rocket MEA only 36% of the participants reported that they used mathematics. None of the participants described the mathematics that was used to design the rocket such as the geometry used to design the fins. For the Mars Rover MEA 67% of the participants reported that they used mathematics but only one participant reported mathematics besides what was used to determine the budget. After discussing this activity in the focus group one participant realized that he often used mathematics and was completely unaware of it. Sixty-seven percent of the participants reported that they used mathematics while completing the Freighter MEA (see Table 16).

*Table 16.* Summary of Participant Identified Mathematics

| MEA | Mathematics Identified in MEA |
|---|---|
| Survivor | • Measurement<br>• Area and perimeter<br>• Estimation |
| Rocket | • Measurement<br>• Estimation |
| Mars Rover | • Addition, subtraction and multiplication for budget<br>• Measurement |
| Freighter | • Counting<br>• Modeling<br>• Estimation |

**Role of the teacher.** Based on the questionnaire there was some change in the participants' beliefs about the role of the teacher. According to the t-test there was a marginally significant difference between the pre- and post- questionnaires for the statement that the teacher was the source of knowledge; on the pre- questionnaire participants were unsure if the teacher was the source of knowledge but on the post- questionnaire participants disagreed with this

statement. From the interviews and the focus groups participants initially believed that the teacher should always explain new material first but that the teacher should let students figure out practice problems and then only help the students after they got stuck on the problems.

Kloosterman (1996) found that students believed that the teacher was the source of knowledge. On the pre- questionnaire this was also found to be true with approximately 48% of the participants agreeing with the statement that all knowledge comes from the teacher while 18% of the participants stated that they had no opinion. However, on the post-questionnaire only 30% of the participants agreed with this statement and 26% said they had no opinion. Kloosterman also found that participants thought that the role of the teacher was to provide answers. This was not true for this study, as 48% of my participants disagreed with this statement on the pre- questionnaire. This was also true for the post- questionnaire because approximately 44% of the participants disagreed with the statement "the role of the teacher is to provide answers to problems." In the post- interviews and focus group the majority of participants believed that the teacher should let students figure out problems for themselves before explaining the problems.

This is promising for the implementation of integrated STEM education because according to Hmelo-Silver (2004) the teachers' role is more as a facilitator and not the source of all knowledge in the classroom. Lerman (1989) stated that learning begins with the student and not the teacher and Underhill (1988) suggested that student' beliefs influence what is considered acceptable classroom behavior. Also, according to McLeod (1989), student beliefs about the role of the teacher profoundly affect their ability to solve non-routine problems like MEAs. So when students believe that they construct their own knowledge this becomes the acceptable behavior and students learn the critical thinking skills necessary to succeed in society.

**View of self and ability in mathematics.** Kouba et al. (1988) found that the majority of third grade students who completed the fourth NAEP assessment had positive views of themselves in mathematics and Brown et al. (1988) found that this positive self image continued for the seven and eleventh grade students who were tested in their study. Similarly, most of the participants in this study had positive self-images about mathematics that remained unchanged. In both the pre- and post- questionnaires approximately 91% of the participants agreed or strongly agreed with the statement, "I usually do well in math." On the pre- questionnaire 87% of the participants agreed or strongly agreed that mathematics makes sense to them, and on the post- questionnaire 82% either agreed or strongly agreed with this statement.

More participants indicated that they believed mathematics was hard and that it confused them though; for both of these categories approximately 30% of the participants agreed a little with this statement on the post- questionnaire. It should be noted that on the post- questionnaire approximately 56% of students still disagreed or strongly disagreed that mathematics was hard or made the students confused. It appears that student perceptions of self and ability in mathematics have only slightly changed since the fourth NAEP assessment. The positive view that students have about their ability in mathematics is consistent with the findings of Kouba et al. (1988) and similar to the data reported by the NCES for the 2003 administration of the NAEP. However, the students' belief about the difficulty of mathematics does not directly conflict with their positive self-image in mathematics.

**Overall change in beliefs about mathematics.** When considering both the interviews and the questionnaires the medium and low-ability students had more changes in their beliefs. In the questionnaires there was some change in beliefs that was observed for the different ability levels. There were three items that changed for both of the high-level students: there are math

problems that cannot be solved by following a predetermined sequence of steps, I use math in my science class and the role of the teacher is to facilitate learning. Only for the statement “I use math in my science class” did both participants’ beliefs change from no opinion to agree or strongly agree. The other beliefs changed but not in a consistent direction. For the middle-ability students there were two items on the questionnaire that changed: the teacher lets students figure things out for themselves and math is not used in my other classes. For the low-ability level students there were also three items that changed for both participants: the role of the teacher is to answer problems, I don’t use math in my everyday life and mathematics is hard. Only for the statement “mathematics is hard” did the participants’ beliefs change in the same way. Both participants thought that mathematics was hard on the post-questionnaire.

Of the participants who were interviewed after each activity, two participants, one middle-ability student and one low-ability student, reported a change in their beliefs about mathematics after every activity except the Freighter MEA. For the middle-level student her beliefs changed from one where mathematics is pencil and paper work to mathematics as measuring, building models and connected to technology. Prior to this after-school program this participant thought that mathematics was only the pencil and paper type problems that she had seen in her mathematics classroom. During the after-school program she realized that mathematics was connected to technology because she could use the computer to assist her in creating calculations and measurements that were used to aid in the construction of her model. For the low-level student these activities made him realize mathematics can be different from what he does in the classroom and is not the same thing repeated over and over again. These activities also made him realize that there is more than one way to do mathematics. Also for this student the MEAs motivated him to do the “boring stuff” in his mathematics classroom. No other

interview participant reported a change in his or her beliefs about mathematics in any of their interviews.

The MEAs made two of high-ability participants from the focus groups believe that they could learn mathematics as engineers but they also said that they didn't get to do these types of activities in their mathematics classroom. After the Mars Rover MEA two high-ability focus group participants said that MEAs made them believe that doing mathematics was fun. A third high-ability focus group participant said that she used to think mathematics was boring but the STEM program made her realize that you can do different things with mathematics.

## Main Implications for Education

Although there was little significant change in the mathematics-related beliefs of the participants, this study showed the impact that mathematics-related beliefs can have in connection to integrated STEM MEAs. While the MEAs did not seem to affect the high-ability participants as much as the other students, these students are generally given more opportunities to participate in problems like MEAs. This study has shown the benefit of having all ability levels participate in MEAs. This study also demonstrated how integrated STEM MEAs could be used to motivate students to learn mathematics. It can be inferred from this study that in order for the mathematics-related beliefs of students to change, students need to be consistently taught in an environment that supports the use of mathematical modeling and integrated STEM education. Finally, this study highlights the necessity for real change to occur in the mathematics classroom so that integrated STEM MEAs can be incorporated into the mathematics curriculum.

## Limitations

Beliefs are highly stable and it takes time to change them so one limitation of this study was the time duration and limited contact with the participants. Also, in order to increase the

internal consistency of the questionnaire different questions need to be developed because students at this level do have conflicting beliefs such as believing that mathematics is hard but not thinking that mathematics is confusing. In addition, there is no inter-rater reliability because only the researcher coded the data. Also, a larger sample size would increase the statistical power to get a statistically significant result on the questionnaire.

## Recommendations for Future Research

There are numerous studies based upon this dissertation that can be conducted in the future. For future research I would like to use a more focused problem solving experience to examine how integrated STEM MEAs might affect students' mathematics-related beliefs and student performance in mathematics. This could be a longitudinal study that occurs in the classroom where students are taught using integrated STEM. It could also be an enrichment program that meets either after-school for a longer period of time or as summer enrichment program where students meet everyday for a certain period of time.

A future study could examine the implicit and explicit mathematics in integrated STEM activities. This is important because mathematics can be implicitly incorporated into integrated STEM activities so it is not clear to students what mathematics that they are using to solve these problems. If students are unaware that they are doing mathematics then how can these activities be used to motivate students in mathematics? By making mathematics explicit through model-exploration activities students can become more aware of the mathematics that they used and see other situations in which they use and apply this mathematics.

This study only examined students' mathematics-related beliefs; however, the beliefs teachers bring to the classroom can influence how they incorporate mathematical modeling in

their teaching. A future study could examine student and teacher mathematics-related beliefs--specifically how they develop or impede each other's beliefs.

Studying mathematical modeling and integrated STEM will continue to be important for many years to come because mathematical modeling and integrated STEM are based on best teaching practices and help students learn content knowledge as well as valuable life skills. In order to implement authentic real-life mathematics problems in the curriculum it will continue be important to study mathematics-related beliefs because these beliefs affect not only how students solve, but also how teachers implement mathematical modeling problems in their classrooms.

## Appendix A: . Definitions for Individual STEM Subjects

| Subject | Definition |
|---|---|
| Mathematics | The study of patterns and relationships among quantities, numbers, and space. Claims in mathematics are warranted through logical arguments based on foundational assumptions. The logical arguments themselves are part of mathematics along with the claims. As in science, knowledge in mathematics continues to grow, but unlike science, knowledge in mathematics is not overturned unless the foundational assumptions are transformed. Specific conceptual categories of K–12 mathematics include numbers and arithmetic, algebra, functions, geometry, and statistics and probability. Mathematics is used in science, engineering, and technology. |
| Science | The study of the natural world, including the laws of nature associated with physics, chemistry, and biology and the treatment or application of facts, principles, concepts, or conventions associated with these disciplines. Science is both a body of knowledge that has been accumulated over time and a process—scientific inquiry—that generates new knowledge. Knowledge from science informs the engineering design process. |
| Technology | Not a discipline in the strictest sense. It comprises the entire system of people and organizations, knowledge, processes, and devices that go into creating and operating technological artifacts, as well as the artifacts themselves. Throughout history, humans have created technology to satisfy their wants and needs. Much of modern technology is a product of science and engineering, and technological tools are used in both fields. |
| Engineering | Both a body of knowledge—about the design and creation of human made products—and a process for solving problems. This process is design under constraint. One constraint in engineering design is the laws of nature, or science. Other constraints include time, money, available materials, ergonomics, environmental regulations, manufacturability, and reparability. Engineering utilizes concepts in science and mathematics as well as technological tools. |

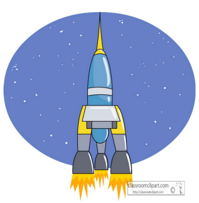
NRC (as citied in National Academy of Sciences, 2014)

## Appendix B: Recruitment Flyer

# STEM Academy

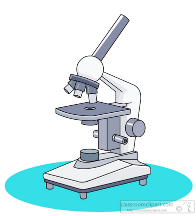
UNLV
UNIVERSITY OF NEVADA LAS VEGAS

## Want to be a rocket scientist? Astronaut? Survive in the wild? Design your own ship? Then come to the After School STEM Academy.



**What it is:** An after school program where students will do fun and exciting hands-on math and science activities.

**Who can participate:** Any 4th or 5th grade student enrolled at [redacted]

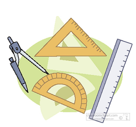


**When: April 7, April 21, April 28, May 5 & May 12**

**Time:** 2:20pm to 4:50pm

- snacks will be served at 2:15

**Space is limited so register early Registration is due by March 18.**



There will be a research study conducted during the After SchoolSTEM Academy. Your child does not have to participate in the research study in order to enroll in the program, but they will complete the same activities regardless; just their work will not be used in the research. By signing the consent form you are agreeing to have your child participate in the research study. Please read the consent form below, sign it, return it. There are no foreseeable risks to this research study. No identifiable information will be used in writing the results of this study. This study can better help us understand how to help students enjoy mathematics and learn it deeply. If you have any questions please email Cathrine Maiorca (maiorcac@unlv.nevada.edu) (702) 374-3973 or Micah Stohlmann (micah.stohlmann@unlv.edu) or call (702) 895-0836.

**REGISTRATION FORM FOR AFTER SCHOOL STEM ACADEMY**

**Please print clearly.**

**STUDENT INFORMATION:**

Student's name:______________________________________________

Age: ________________

**PARENT INFORMATION:**

Parent/Guardian
name(s):_____________________________________________________
Address:

______________________________________________________________
Phone:

Home:__________________________

Work/Cell:_______________________

Email: ____________________________________________

**EMERGENCY CONTACT:**

Emergency contact name (if Parent/Guardian cannot be reached):

NAME: _______________________

Phone:_____________________________

Does your child have any allergies? **YES NO**

1 of 2

______________________________________________________________________

If yes, to what?

______________________________________________________________________

Is your child eligible for free and reduced lunch at school? **YES/ NO**
**Parent/Guardian signature:**

______________________________________________________________________

Date:____________________

STEM Academy is limited to 24 students. To ensure you have a place please register early. Registration is due 3/18/2015.

Registration forms can be returned by e-mailing the scanned registration form to maiorcac@unlv.nevada.edu or by returned to the main office at [redacted]

If you have any questions or concerns please contact Cathrine Maiorca at maiorcac@unlv.nevada.edu or Micah Stohlmann at micah.stohlmann@unlv.edu

UNLV
UNIVERSITY OF NEVADA LAS VEGAS

## PARENT PERMISSION FORM

**Department of Teaching and Learning**

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**TITLE OF STUDY: A Multiple Case Study: Students' Mathematics-Related Beliefs from Integrated STEM Model-Eliciting Activities**

**INVESTIGATOR(S): Cathrine Maiorca and Dr. Micah Stohlmann (Advisor)**

**CONTACT PHONE NUMBER: Cathrine Maiorca at 702.374.3973 or Micah Stohlmann at (702)-895-0836**

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**Purpose of the Study**
Your child is invited to participate in a research study. The purpose of this study is to describe the mathematics-related beliefs for fourth and fifth grade students.

**Participants**
Your child is being asked to participate in the study because he or she is signed up for the after school STEM Academy.

**Procedures**
If you allow your child to participate in this study, your child will be asked to do the following: have their work collected from pre and post questionnaires that examine their mathematics-related beliefs. If your child does not participate in the study they will still complete the pre and post questionnaires but their work will not be included in the research. All participants in this study will take part in the STEM academy which will meet for 2.5 hours once a week for six weeks. Your child will be interviewed for 30 minutes before and after school when the STEM academy begins and once after it has ended. Your child will also be interviewed after each meeting of the STEM academy. This time is included in the after school program. Your child may be asked to participate in focus groups. These will be once a week for 10- 30 minutes before or after school. Both these activities will be videotaped. However if you do not want your child to be videotaped an audio recording may be used instead. Your child's CRT, DE scores and demographic information will be given to me by Dr. Mayorga.

**Benefits of Participation**
There *may not* be direct benefits to your child as a participant in this study. However, we hope to learn how participating in a hands-on mathematics and science activities influences their mathematics-related beliefs.

**Risks of Participation**
There are no foreseeable risks to subjects or others associated with this study.

***Deemed exempt by the UNLV IRB. Protocol 1409-4922***
***Exempt Date: 11-14-14***

**Cost /Compensation**
There *will not* be financial cost for participation in this study. The after school program will meet weekly for six weeks and your child may be interviewed before and after the six week program. Your child will also be invited to participate in a weekly focus group. Your child *will not* be compensated for their time.

**Contact Information**
If you or your child has any questions or concerns about the study, you may contact Cathrine Maiorca at **702.374.3973 or Maiorca@unlv.nevada.edu.** For questions regarding the rights of research subjects, any complaints or comments regarding the manner in which the study is being conducted you may contact **the UNLV Office of Research Integrity – Human Subjects at 702-895-2794, toll free at 877-895-2794, or via email at IRB@unlv.edu.**

**Voluntary Participation**
Your child's participation in this study is voluntary. Your child may refuse to participate in this study or in any part of this study. Your child may withdraw at any time without prejudice to your relations with the university. Not participating in this study will no way affect your child's participation in the after school program.

You or your child is encouraged to ask questions about this study at the beginning or any time during the research study.

**Confidentiality**
All information gathered in this study will be kept completely confidential. No reference will be made in written or oral materials that could link your child to this study. All records will be stored in a locked facility at UNLV for 3 years after completion of the study. After the storage time the information gathered will be physically destroyed.

**Participant Consent:**
I have read the above information and agree to allow my child to participate in this study. I am at least 18 years of age. A copy of this form has been given to me.

Signature of Parent | Child's Name (Please print)

Parent Name (Please Print) | Date

TITLE OF STUDY: **A Multiple Case Study: Students' Mathematics-Related Beliefs from Integrated STEM Model-Eliciting Activities**

Video Taping:

I agree to allow my child to be video taped for the purpose of this research study.

Signature of Parent Date

Parent Name (Please Print)

Audio Taping:
I agree to allow my child to be audio taped for the purpose of this research study.

Signature of Parent Date

Parent Name (Please Print)

***Participant Note: Please do not sign this document if the Approval Stamp is missing or is expired.***

## ASSENT TO PARTICIPATE IN RESEARCH

A Multiple Case Study: Students' Mathematics-Related Beliefs from Integrated STEM Model-Eliciting Activities

1. My name is Cathrine Maiorca.

2. I am asking you to take part in a research study because I am trying to learn more about your beliefs about mathematics and how hands-on math and science activities might change them.

3. If you agree to be in this study you will answers some questions before and after we have completed all of the activities. You might also be asked to answer questions, individually or in a group about your beliefs about math. All participants in this study will meet once a week for six weeks for 2.5 hours for the after school STEM academy. You will be interviewed for 30 minutes before the after school program begins and once after it has ended. This will take place before or after school. You may be asked to answer questions once a week in a group for 10- 30 minutes, before or after school. Both of these activities will be videotaped. However if you do not want it to be videotaped an audio recording could be used instead.

4. Your CRT, DE scores and information about yourself will be given to me by Dr. [redacted]

5. There are no likely risks to you or others associated with this study.

***Deemed exempt by the UNLV IRB. Protocol 1409-4922***
***Exempt Date: 11-14-14***

6. There *may not* be direct benefits to you. However, we hope to learn how participating in a hands-on mathematics and science activities change your beliefs about math.

7. Please talk this over with your parents before you decide whether or not to participate. We will also ask your parents to give their permission for you to take part in this study. But even if your parents say "yes" you can still decide not to do this.

8. If you don't want to be in this study, you don't have to participate. Remember, being in this study is up to you and no one will be upset if you don't want to participate or even if you change your mind later and want to stop. Not participating in this study will no way affect your participation in the STEM academy.

9. You can ask any questions that you have about the study. If you have a question later that you didn't think of now, you can call me at 702.374.3973 or ask me next time. You may also contact Micah Stohlmann (micah.stohlmann@unlv.edu) or call (702)-895-0836. You may call me at any time to ask questions. If I have not answered your questions or you do not feel comfortable talking to me about your question, you or your parent can call the UNLV Office of Research Integrity – Human Subjects at 702-895-2794 or toll free at 877-895-2794.

10. Signing your name at the bottom means that you agree to be in this study. You and your parents will be given a copy of this form after you have signed it.

***Deemed exempt by the UNLV IRB. Protocol 1409-4922***
***Exempt Date: 11-14-14***

________________________ ______________

Print your name Date

________________________

Sign your name

Video Taping:

I agree to be video taped for the purpose of this research study.

__________________________________ ______________

Your Signature Date

__________________________________

Name (Please Print)

Audio Taping:
I agree to be audio taped for the purpose of this research study.

__________________________________ ______________

Your Signature Date

__________________________________

Your Name (Please Print)

***Deemed exempt by the UNLV IRB. Protocol 1409-4922***
***Exempt Date: 11-14-14***

## Appendix C: Original Questionnaire Linked to Beliefs

**Part A (5 point Likert-scale items)**

**Belief 1:** Perceptions of problems in mathematics (Kloosterman & Stage, 1996)

+ Math is more than doing operations like adding, subtracting, multiplying and dividing

+Math is about exploring new ideas

- Math is memorizing

-Math is about following rules

**Belief 2:** Beliefs about the usefulness of mathematics (Fennema- Sherman usefulness scale)

+ Math is useful outside of school

+ Math is an important subject to know.

- I never use math outside of the school

- Studying math is a waste of time

**Belief 3:** Beliefs about how mathematics is connected to other subjects.

+I use math in my science class

+Math is used to create the technology I use everyday

-Math is not used in my other classes

-I don't use math in my everyday life

**Belief 4:**Beliefs about mathematics word problems (mathematical modeling) (Kloosterman & Stage, 1996)

+ There are math problems that cannot be solved by following an already determined sequence of steps.

+ Word problems can be solved without remembering formulas.

- Any problem can be solved if you remember the right steps to follow

- Most word problems can be solved using the correct step-by-step procedures

**Belief 5:** Beliefs about the social context in which mathematics is learned

+Math is best learned in groups

+Math can be learned from other students

-Math is learned alone at your desk

-I can only learn math from my teacher

**Belief 6:** Beliefs about the role of the teacher

+The role of the teacher is to guide learning

+The teacher lets students figure things out for themselves

- The role of the teacher is to provide answers to problems

- All knowledge comes from the teacher

**Belief 7:** Beliefs about the self and ability in mathematics

+ I usually do well in math

+Mathematics makes sense to me

- Mathematics is hard

- Math makes me confused

**Part B (open-ended items)**

1. How do you use math outside of your math classroom?

2. What do you want to do when you grow up?

3. How will you use math doing this job?

## Appendix D: Questionnaire

**Questionnaire** **Name:___________________________**

**How much do you agree with each statement? Circle your answer.**

1. Math is more than doing operations like adding, subtracting, multiplying and dividing

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

2. Math is a worthwhile and necessary subject to know.

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

3. I don’t use math in my everyday life

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

4. Math makes me confused

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

5. The role of the teacher is to provide answers to problems

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

6. Any problem can be solved if you remember the right steps to follow

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

7. Math is about exploring new ideas

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

8. Math is used to create the technology I use everyday

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

9. Most word problems can be solved using the correct step-by-step procedures

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

10. The teacher lets students figure things out for themselves

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

11. Mathematics is hard

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

12. Math is not used in my other classes

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

13. Math is memorizing

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

14. Word problems can be solved without remembering formulas.

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

15. All knowledge comes from the teacher

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

16. Math is about following rules

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

17. I never use math outside of the school

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

18. There are math problems that cannot be solved by following a predetermined sequence of steps.

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

19. Mathematics makes sense to me

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

20. I use math in my science class

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

21. Studying math is a waste of time

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

22. The role of the teacher is to facilitate learning

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

23. I usually do well in math

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

24. Math is useful outside of school

| Disagree a lot | Disagree a little | No opinion | Agree a little | Agree a lot |
|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 |

**Part B (open-ended items)**

1. How do you use math outside of your math classroom?

2. What do you want to do when you grow up?

3. How will you use math doing this job?

## Appendix E: Semi-Structured Interview

**Beliefs about the nature of mathematics**

***Belief 1: Perceptions of problems in mathematics***

What do you think doing math looks like outside of school?

***Belief 2: Beliefs about the usefulness of mathematics***

Is math useful? Why or why not? How?

***Belief 3: Beliefs about how mathematics is connected to other subjects***

Do you use math when you study other subjects? How?

**Beliefs about learning mathematics**

***Belief 4: Beliefs about mathematics word problems (mathematical modeling)***

Describe what you think word problems look like in a math class?

***Belief 5: Beliefs about the social context in which mathematics is learned***

What activities help you learn math? Why?

***Belief 6: Beliefs about the role of the teacher***

Are there times where teachers should let students figure things out or should they explain everything?

***Belief 7: Beliefs about self and ability in mathematics***

Do you think that you are good at math? Why do you think that way?

Is there anything that you would like to add to this interview?

## Appendix F: After Activity Interview Protocol

1. What did you like about the activity?

2. What did you not like about the activity?

3. Which activity have you enjoyed most so far (after first day)?

4.What math did you use to solve this problem?

5. Did this activity change how you think about mathematics? How?

## Appendix G: Focus Group (Before the After-School Program)

1. Define mathematics.

2. How is mathematics used in your everyday life?

3. How is math connected to other subjects?

4. Describe math mathematical modeling.

5. How is mathematics learned?

6. Describe what the role of a math teacher is.

## Appendix H: Marshmallow Challenge

The task is simple: in eighteen minutes, teams must build the tallest free-standing structure out of 20 sticks of spaghetti, one yard of tape, one yard of string, and one marshmallow. The marshmallow needs to be on top.

. ✦**Build the Tallest *Freestanding* Structure:** The winning team is the one that has the tallest structure measured from the tabletop surface to the top of the marshmallow. That means the structure cannot be suspended from a higher structure, like a chair, ceiling or chandelier.

. ✦**The *Entire* Marshmallow Must be on Top:** The entire marshmallow needs to be on the top of the structure. Cutting or eating part of the marshmallow disqualifies the team.

. ✦**Use as Much or as Little of the Kit:** Your team can use as many or as few of the 20 spaghetti sticks, as much or as little of the string or tape. Your team cannot use the paper bag as part of their structure.

. ✦**Break up the Spaghetti, String or Tape:** Teams are free to break the spaghetti, cut up the tape and string to create new structures.

✦**The Challenge Lasts 20 minutes:** Teams cannot hold on to the structure when the time runs out. Those touching or supporting the structure at the end of the exercise will be disqualified.

At the end of the 20 minutes measure the height of your structure in inches (to the nearest ¼ inch)

After students have had the opportunity to share out their strategies they will be given 18 minutes to build another structure.

## Appendix I: Survivor MEA

**TOPIC**

Estimation and Mathematical Reasoning, and Problem Solving

**KEY QUESTION**

How would you build a shelter using a scale model?

**LEARNING GOALS**

Students will:

- Work in dissimilar measurement scales, convert between scales
- Make decisions about whether or not a solution meets the needs of a client
- Communicate the solution clearly to the client

**RECOMMENDED SUPPLIES FOR ALL MODEL-ELICITING ACTIVITIES**

It is recommended to have all of these supplies in a central location in the room. It is recommended to let the students know that they are available, but not to encourage them to use anything in particular.

- Overhead transparencies and transparency markers/pens, whiteboards and markers, poster boards, or other presentation tools such as a document camera.
- Calculators
- Rulers
- Markers, colored pencils, pencils
- Graph paper, lined paper
- Paper towels or tissues (for cleaning transparencies)
- Manila folders or paper clips for collecting the students' work
- Optional: Computers with programs such as Microsoft Word and Excel

**THE SURVIVOR MEA CONSISTS OF FOUR COMPONENTS**:

**1) Video Clip:**

2) **Readiness questions:** Students individually answer these reading comprehension questions about the newspaper article to become even more familiar with the context and beginning thinking about the problem..

3) **Problem statement:** In teams of three or four, students work on the problem statement for 45 – 90 minutes. This time range depends on the amount of self-reflection and revision you want the

students to do. It can be shorter if you are looking for students' first thoughts, and can be longer if you expect a polished solution and well-written letter.

4) **Process of sharing solutions:** Each team writes their solution in a letter or memo to the client. Then, each team presents their solution to the class. Whole class discussion is intermingled with these presentations to discuss the different solutions, the mathematics involved, and the effectiveness of the different solutions in meeting the needs of the client.

In totality, each MEA takes approximately 2-3 class periods to implement, but can be shortened by having students do the individual work during out-of-class time.

**RECOMMENDED PROGRESSION OF THE SURVIVOR MEA**

While other implementation options are possible for MEAs, it is recommended that the MEA be implemented in a cooperative learning format. Numerous research studies have proven cooperative learning to be effective at improving student achievement, understanding, and problem solving skills. In this method students will complete work individually (Newspaper article and readiness questions; as well as initial thoughts on the problem statement) and then work together as a group. This is important because brainstorming works best when students have individual time to think before working as a group. Students can be graded on both their individual and group contributions. Social skills' discussions at the beginning of the MEA and reflection questions at the end of the MEA are also essential aspects of cooperative learning.

**Video Clip and Readiness Questions:**

The purpose of the newspaper article and the readiness questions is to introduce the students to the context of the problem.

(10 minutes): Give the article and the questions to the students the day before for homework. Then, in the next class, discuss as a class the answers to the readiness questions before beginning to discuss the problem statement.

**Problem Statement:**

You may want to read the problem statement to the students and then identify as a class: a) **the client that the students are working for** and b) **the product that the students are being asked to produce**. Once you have addressed the points above, allow the students to work on the problem statement. Let the students know that they will be sharing their solution to the rest of the class. Tell students you that you will randomly pick a group member to present for each group.

Tell the students that they need to make sure that everyone understands their group's solution so they need to be sure to work together well. Assigning each group member a number can pick the group member who will present.

***Working on the Problem Statement*** (35-50 minutes)**:** Place the students in teams of three or four. Students should begin to work by sharing their initial ideas for solving the problem. If you already use teams in your classroom, it is best if you continue with these same teams since results for MEAs are better when the students have already developed a working relationship with their team members. If you do not use teams in your classroom and classroom management is an issue, the teacher may form the teams. If classroom management is not an issue, the students may form their own teams. You may want to have the students choose a name for their team to promote unity.

***Teachers' role:*** As they work, your role should be one of a facilitator and observer. Avoid questions or comments that steer the students toward a particular solution. Try to answer their questions with questions so that the student teams figure out their own issues. Also during this time, try to get a sense of how the students are solving the problem so that you can ask them questions about their solutions during their presentations.

***Presentations of Solutions*** (15-30 minutes)**:** The teams present their solutions to the class. There are several options of how you do this. Doing this electronically or assigning students to give feedback as out-of-class work can lessen the time spent on presentations. If you choose to do this in class, which offers the chance for the richest discussions, the following are recommendations for implementation. Each presentation typically takes 3 – 5 minutes. You may want to limit the number of presentations to five or six or limit the number of presentations to the number of original (or significantly different) solutions to the MEA.

Before beginning the presentations, encourage the other students to not only listen to the other teams' presentations but also to a) ***try to understand the other teams' solutions*** and b) ***consider how well these other solutions meet the needs of the client.*** You may want to offer points to students that ask 'good' questions of the other teams, or you may want students to complete a reflection page (explanation – page 4, form – page 14) in which they explain how they would revise their solution after hearing about the other solutions. As students offer their presentations and ask questions, whole class discussions should be intermixed with the presentations in order to address conflicts or differences in solutions. When the presentations are over, collect the

student teams' memos/letters, presentation overheads, and any other work you would like to look over or assess.

**OBSERVING STUDENTS AS THEY WORK ON THE SURVIVOR MEA**

You may find the Observation Form (page 10) useful for making notes about one or more of your teams of students as they work on the MEA. We have found that the form could be filled out "real-time" as you observe the students working or sometime shortly after you observe the students. The form can be used to record observations about what concepts the students are using, how they are interacting as a team, how they are organizing the data, what tools they use, what revisions to their solutions they may make, and any other miscellaneous comments.

**COMMON CORE STATE STANDARDS**

- 5.MD 1 Convert like measurement units within a given measurement system.
- 5.MD2 Represent and interpret data.
- 5.MD Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition.

3. Recognize volume as an attribute of solid figures and understand concepts of volume measurement.

a. A cube with side length 1 unit, called a "unit cube," is said to have "one cubic unit" of volume, and can be used to measure volume.

b. A solid figure which can be packed without gaps or overlaps using n unit cubes is said to have a volume of n cubic units.

4. Measure volumes by counting unit cubes, using cubic cm, cubic in, cubic ft, and improvised units.

5. Relate volume to the operations of multiplication and addition and solve real world and mathematical problems involving volume.

a. Find the volume of a right rectangular prism with whole-number side lengths by packing it with unit cubes, and show that the volume is the same as would be found by multiplying the edge lengths, equivalently by multiplying the height by the area of the base. Represent threefold whole-number products as volumes,

e.g., to represent the associative property of multiplication.

b. Apply the formulas $V = l \times w \times h$ and $V = b \times h$ for rectangular prisms to find volumes of right rectangular prisms with whole number edge lengths in the context of solving real world

and mathematical problems.

c. Recognize volume as additive. Find volumes of solid figures composed of two non-overlapping right rectangular prisms by adding the volumes of the non-

- 6.RP Understand ratio concepts and use ratio reasoning to solve problems
- 6.G Solve real-world and mathematical problems involving area, surface area, and volume.

1. Find the area of right triangles, other triangles, special quadrilaterals, and polygons by composing into rectangles or decomposing into triangles and other shapes; apply these techniques in the context of solving real-world and mathematical problems.
2. Find the volume of a right rectangular prism with fractional edge lengths by packing it with unit cubes of the appropriate unit fraction edge lengths, and show that the volume is the same as would be found by multiplying the edge lengths of the prism. Apply the formulas V = l w h and V = b h to find volumes of right rectangular prisms with fractional edge lengths in the context of solving real-world and mathematical problems.
3. Draw polygons in the coordinate plane given coordinates for the vertices; use coordinates to find the length of a side joining points with the same first coordinate or the same second coordinate. Apply these techniques in the context of solving real-world and mathematical problems.
4. Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures. Apply these techniques in the context of solving real-world and mathematical problems.

- 7.G Draw, construct, and describe geometrical figures and describe the relationships between them.

1. Solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale. 1Computations with rational numbers extend the rules for manipulating fractions to complex fractions.
2. Draw (freehand, with ruler and protractor, and with technology) geometric shapes with given conditions. Focus on constructing triangles from three measures of angles or sides, noticing when the conditions determine a unique triangle, more than one triangle, or no triangle.

3. Describe the two-dimensional figures that result from slicing three-dimensional figures, as in plane sections of right rectangular prisms and right rectangular pyramids.

- 7.G Solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

  4. Know the formulas for the area and circumference of a circle and use them to solve problems; give an informal derivation of the relationship between the circumference and area of a circle.
  5. Use facts about supplementary, complementary, vertical, and adjacent angles in a multi-step problem to write and solve simple equations for an unknown angle in a figure.
  6. Solve real world and mathematical problems involving area, volume and surface area of two- and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms.

- G-CO G-MG Apply geometric concepts in modeling situations

  1. Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).
  2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).
  3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios)

Background video can be watched at https://www.youtube.com/watch?v=V7J5_Ds5Xf

## Readiness Questions

1. What things would you have to consider when building a shelter?

2. How would you describe the rain in Costa Rica?

3. If you have ever seen Survivor would you consider going on the show?

4. What is the benefit of building a scale model?

## Problem Statement

Survivor returns to Costa Rica and Mark Burnett, the producer of Survivor, has decided to give survivors the materials to build a shelter as a reward for a challenge. He wants to provide materials to make the shelter as realistic as possible to one that the survivors of a plane crash might build. He will be providing a strip of metal supposedly from a plane, tarp from the rescue raft, rope that has washed ashore and of course mud from the island. To determine who will be the contestants on the show he wants to see who can design the best scale model of a shelter. The shelter must fit three people and withstand both wind and rain. Design a quality shelter and your team could be on the next show of survivor.

Your shelter must:

- Not move, tip or be damaged when given three gusts of wind
- Remain dry when given three squirts of water to simulate rain
- Have enough room to fit three people with at least 1 cubic meter of space

Before building your scale model decide on a scale that you will use to determine how much of each material that you will use. For example, if your scale was 1 meter: 2cm, then you would have 20 craft sticks that are 6 cm long.

| **Actual materials that will be provided on the island** | **Materials that you will be given** |
|---|---|
| Logs ( 20 logs, 3 meters long each) | Craft sticks: 20 sticks x ___cm: |
| ( Total of 60 meters) | Total of ______cm |
| Plane siding (2.5 meters x 4 meters) | Aluminum foil: ___ cm x ___ cm |
| Tarp (1 piece 3 meters x 5 meters) | Wax paper: ___cm x ___ cm |
| Rope (6 meters) | String: ___ cm |
| Mud ( 1 bucket with 1 cubic meter ($m^3$)(1m x 1m x 1m) | Play Dough: __ cm x___cm x___cm |

After designing and testing the shelter write Mark Burnett a letter describing why your shelter is the best. Include in the letter the design for the shelter, the materials that you used, and general guidelines for how to make scale models for any purpose. A few example shelters are provided below for your team to begin to develop ideas.

**STUDENT REFLECTION FORM –** SURVIVOR MEA

Name ________________________________ Date_________________________________

1. What mathematical or scientific concepts and skills (e.g. ratios, proportions, forces, etc.) did you use to solve this problem?

2. How well did you understand the concepts you used?

| | | | | |
|---|---|---|---|---|
| Not at all | A little bit | Some | Most of it | All of it |

Explain your choice:

3. How well did your team work together? How could you improve your teamwork?

4. Did this activity change how you think about mathematics?

# Appendix J: Rocket MEA

**TOPICS**

Mathematical Reasoning and Problem Solving

**KEY QUESTION**

How would you design a rocket?

**LEARNING GOALS**

Students will:

- Learn about aerospace engineering
- Learn about engineering design and redesign
- Learn about the space station
- Make decisions about whether or not a solution meets the needs of a client
- Communicate the solution clearly to the client

**STANDARDS ADRESSED**

**Next Generation Science Standards Grades 3-5 (Ages 8-11) Motion and Stability: Forces and Interactions** Students who demonstrate understanding can:

> 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

**Energy**

Students who demonstrate understanding can:

> 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

**Next Generation Science Standards Grades 3-5 (Ages 8-11) Engineering Design**

Students who demonstrate understanding can:

> 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
>
> 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

**Engineering Design**

Students who demonstrate understanding can:

3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

**Next Generation Science Standards - Grades 6-8 (Ages 11-14) Motion and Stability: Forces and Interactions**

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

**Engineering Design**

Students who demonstrate understanding can:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

. MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

. **Standards for Technological Literacy - All Ages The Nature of Technology**

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

. **Technology and Society**

Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

Standard 7: Students will develop an understanding of the influence of technology on history.

**Design**

Standard 8: Students will develop an understanding of the attributes of design.

Standard 9: Students will develop an understanding of engineering design.

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

**Abilities for a Technological World**

Standard 11: Students will develop abilities to apply the design process.

**Common Core State Standards for Mathematical Practice**

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.

## News Paper Article

### SpaceShipTwo: The World's First Commercial Spaceship


In 2011, in the skies above Mojave Air and Spaceport CA, SpaceShipTwo, the world's first commercial spaceship, demonstrated its unique reentry 'feather' configuration for the first time. In 2012, Virgin Galactic announced that its vehicle developer, Scaled Composites (Scaled), has been granted an experimental launch permit from the Federal Aviation Administration (FAA) for its suborbital spacecraft, SpaceshipTwo, and the carrier aircraft, WhiteKnightTwo

Already, SpaceShipTwo and WhiteKnightTwo have made significant progress in their flight test program. With 80 test flights completed, WhiteKnightTwo is substantially through its test plan, while the more recently constructed SpaceShipTwo has safely completed sixteen free flights, including three that tested the vehicle's unique "feathering" re-entry system. Additionally, ten test firings of the full scale SpaceShipTwo rocket motor, including full duration burns, have been safely and successfully completed.
With this permit now in hand, Scaled is now authorized to press onward towards rocket-powered test flights. In preparation for those powered flights, SpaceShipTwo will soon return to flight, testing the aerodynamic performance of the spacecraft with the full weight of the rocket motor system on board. Integration of key rocket motor components, already begun during a now-concluding period of downtime for routine maintenance, will continue into the autumn. Scaled expects to begin rocket powered, supersonic flights under the just-issued experimental permit toward the end of the year.
"The Spaceship program is making steady progress, and we are all looking forward to lighting the vehicle's rocket engine in flight for the first time," said Doug Shane, president of Scaled.

Although a handful of experimental launch permits have been granted to other rockets, SpaceShipTwo is the first rocket-powered vehicle that carries humans on board to receive such a permit.

Virgin also announced in 2012 that they will construct a rack system to allow research payloads to fly to space aboard Virgin Galactic's SpaceShipTwo (SS2). With these new racks, SS2 will allow researchers to conduct experiments during several minutes of microgravity using a mounting system also employed on the International Space Station (ISS). Standard racks will support up to 108 cubic feet of usable payload volume. Additionally, experiments can be positioned within the rack system for a view through Virgin Galactic's large, 17-inch-diameter-windows should acquisition of spectral data or imaging be desired

(Source: Virgin Galactic.  More details and updates on this effort at www.virgingalactic.com)

**Readiness Questions**

1. What makes Spaceship 2 unique?

2. How will the rack system help with research?

3. If you could would you go into outer space on one of Virgin Galactic's spaceship?

4. What would you need to keep in mind if you were to design a rocket**?**

## Problem Statement

Virgin Galactic wants to redesign a rocket that will be used to provide supplies to the international space station.  Virgin Galactic has asked for your help to build the model. Because the materials are expensive Virgin Galactic has asked you to build your model rocket using a plastic bottle for the body and other everyday materials for the rest of the rocket. Your goal is to shoot the rocket the highest and straightest.

After designing and testing the model write a letter to the CEO of Virgin Galactic describing why your model is the best. Include in the letter the design for the model, the materials that you used, and general guidelines for how to make your model.

My model is the best because

The materials that we used to build to rocket were

If you want to build our rocket you should do

When will build another rocket we would change or not change

**STUDENT REFLECTION FORM** Name: _____________________________

1. How did you use math and science to build and launch your rocket?

2. How well did your team work together?

3. How could you improve your teamwork?

4. How did this activity change how you think about mathematics?

5. Of the three activities we have done (Marshmallow Challenge, Survivor, Rocket)

a) What was your favorite activity?

b) What was your least favorite activity? What changes could be made to make the activity better?

## Appendix K: Mars Rover MEA

**TOPIC**

Mathematical Reasoning and Problem Solving

**KEY QUESTION**

How can you design a capsule that will land without damaging its payload?

**LEARNING GOALS**

Students will:

- Demonstrate an understanding of the challenges of soft landing a spacecraft on Mars
- Make decisions about whether or not a solution meets the needs of a client
- Communicate the solution clearly to the client

**STANDARDS ADRESSED**

**Next Generation Science Standards Grades 3-5 (Ages 8-11) Motion and Stability: Forces and Interactions** Students who demonstrate understanding can:

3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

**Energy**

Students who demonstrate understanding can:

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

**Next Generation Science Standards Grades 3-5 (Ages 8-11) Engineering Design**

Students who demonstrate understanding can:

3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

**Engineering Design**

Students who demonstrate understanding can:

3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

**Next Generation Science Standards - Grades 6-8 (Ages 11-14) Motion and Stability: Forces**

**and Interactions**

MS-PS2-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

**Engineering Design**

Students who demonstrate understanding can:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

. MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

. **Standards for Technological Literacy - All Ages The Nature of Technology**

Standard 1: Students will develop an understanding of the characteristics and scope of technology.

. **Technology and Society**

Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

Standard 7: Students will develop an understanding of the influence of technology on history.

**Design**

Standard 8: Students will develop an understanding of the attributes of design.

Standard 9: Students will develop an understanding of engineering design.

Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

**Abilities for a Technological World**

Standard 11: Students will develop abilities to apply the design process.

**Common Core State Standards for Mathematical Practice**

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively
3. Construct viable arguments and critique the reasoning of others.

4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.

**Readiness Questions**

1. What can a spacecraft see from orbit around Mars?

2. Where has life on earth been found?

3. What evidence is there that there was water on Mars?

4. Why is it important to study Mars?

5. What are some of the challenges encountered while studying Mars?

## Problem Statement

Because sending people into space is difficult, NASA uses rovers for many missions. To land safely on other worlds, the rovers must be protected. Three Mars missions used balloon-landing systems: *Mars Pathfinder* and the two Mars Exploration Rovers (*Spirit* and *Opportunity*) but landing these missions has been extremely challenging.

NASA wants to send another rover to Mars and has asked for your help to redesign the landing capsule. Using the materials provided and a budget of no more than $300, you need to design a capsule that will protect the payload when it lands on the surface of Mars.

Your payload (the egg) must not break when it is dropped from a ladder. You may not spend more than $300.

After designing and testing the capsule write a letter to the engineers at NASA describing why your capsule is the best. Include in the letter the design for the capsule, the materials that you used, and general guidelines for how to design a Mars rover to protect a payload when landing.

—You have $300 to purchase materials to build your model.

| Items | Sale price | Number you purchased | Cost spent you on this item |
|---|---|---|---|
| Clear plastic container | $ 40.00 | | $ |
| Cardboard container | $40.00 | | $ |
| Straws | $5.00 each | | $ |
| Balloons | $10.00 each | | $ |
| Cotton balls | $5.00 each | | $ |
| Paper clips | $5.00 each | | $ |
| Foam | $5 per sheet | | $ |

| | | |
|---|---|---|
| White paper | $5 per sheet | $ |
| Bubble wrap | $20.00 per sheet | $ |
| Cardboard tubes | $10.00 per tube | $ |
| Hardboiled egg | $30.00 per egg (max 2) | $ |
| | **Total amount spent** | **$** |

Dear NASA Engineers,

Our model cost $ _________ to build (please attach your budget). Our Mars Rover is the best because

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

If you were to build our model you would need to do

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

If we were to build our model again we would change (or not change) ________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

_______________________________________________________________________________

**MARS ROVER STUDENT REFLECTION FORM**

Name: ____________________________

1. How did you use math to build your Mars Rover?

2. Rank the activities from your favorite to least favorite. (1 is your favorite and 3 is your least favorite)

________ Survivor

________ Rocket

________ Mars Rover

a) Why was this your favorite activity?

b) What was tour least favorite activity? What changes could be made to your least favorite activity to make it better?

3. How did this activity change your opinion of mathematics?

4. How well did your team work together?

5. How could you improve your teamwork?

## Appendix L: Freighter MEA

**TOPIC**

Estimation and Mathematical Reasoning, and Problem Solving

**KEY QUESTION**

How can you design a boat that can hold the most freight with the least expense to the boat-building company?

**LEARNING GOALS**

Students will:

- Work in dissimilar measurement scales, convert between scales
- Make decisions about whether or not a solution meets the needs of a client
- Communicate the solution clearly to the client

**COMMON CORE STATE STANDARDS**

- 5.MD 1 Convert like measurement units within a given measurement system.
- 6. SP5 Summarize numerical data sets in relation to their context, such as by:
    - a. Reporting the number of observations.
    - b. Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
    - c. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.
    - d. Relating the choice of measures of center and variability to the shape of the data

distribution and the context in which the data were gathered. GRADE6.RP Understand ratio concepts and use ratio reasoning to solve problems

- G-CO G-MG Apply geometric concepts in modeling situations
  - 1. Use geometric shapes, their measures, and their properties to describe objects (e.g., modeling a tree trunk or a human torso as a cylinder).
  - 2. Apply concepts of density based on area and volume in modeling situations (e.g., persons per square mile, BTUs per cubic foot).
  - 3. Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios

**Readiness Questions**

1. What things would you have to consider when building a freighter?

2. Why would companies want to use bigger freighters?

3. How do you navigate a freighter ship?

4. Why is it important for the captain to eat with the crew?

**Problem Statement**

In order to make more profits Atlantic International Shipping Company wants to design a new model for a freighter and they have asked for your help. Design and build the best boat using the materials that are provided to you. Pennies will be used to represent the cargo containers.

Prepare a letter to the client that explains how you determined what was the best model for the freighter.

Dear Atlantic International Shipping Company,

Our team decided that the best design for your new freighter is ____________________

This is the best design because ______________________________________________

Best regards,

**FREIGHTER MEA STUDENT REFLECTION FORM** Name: ____________________________

1. How did you use math to build your Freighter?

2. Rank the activities from your favorite to least favorite. (1 is your favorite and 4 is your least favorite)

________ Survivor

________ Rocket

________ Mars Rover

________ Freighter

a) Why was this your favorite activity?

b) What changes could be made to your least favorite activity to make it better?

3. How did this activity change your opinion of mathematics?

4. How well did your team work together?

5. How could you improve your teamwork?

## Appendix M: Open Coding

| Code | Sources | Frequency |
|---|---|---|
| Area & Perimeter in Survivor | 1 | 1 |
| Changes in model | 1 | 1 |
| Estimation - Rocket | 1 | 1 |
| Fractions | 1 | 1 |
| Fractions- Survivor | 2 | 2 |
| Freighter MEA change in beliefs | 1 | 1 |
| Geometry | 1 | 1 |
| Liked about Survivor | 3 | 3 |
| Likes math | 3 | 3 |
| MC- addition | 2 | 2 |
| MC- changed beliefs about math | 1 | 1 |
| MC- counting | 1 | 1 |
| MC- measurement | 1 | 1 |
| MR- used addition in budget | 1 | 1 |

| | | |
|---|---|---|
| Mars Rover- Liked about the activity | 2 | 2 |
| Marshmallow Challenge | 0 | 0 |
| Materials were similar to real life items | 1 | 1 |
| Math used in Survivor MEA | 6 | 6 |
| Math used in the Mars Rover MEA | 9 | 11 |
| Mathematical word problems | 5 | 6 |
| Mathematics used in activity | 3 | 4 |
| Multiplication | 2 | 2 |
| Multiplication- Survivor | 1 | 1 |
| New activity | 1 | 1 |
| Rationale for being good at math | 2 | 2 |
| Reason why students participated in program | 1 | 1 |
| Repetition helps student to learn | 1 | 1 |
| Rocket MEA taught math | 1 | 1 |
| Rocket- change belief about math | 1 | 1 |
| SMP 3 | 4 | 6 |

| | | |
|---|---|---|
| SMP 4 | 1 | 1 |
| STEM helps students learn math | 1 | 1 |
| Survivor MEA- challenges | 3 | 4 |
| Survivor- measurement | 3 | 4 |
| Teachers should explain mathematics before students do i | 11 | 18 |
| Teamwork | 5 | 7 |
| Teamwork was faster | 1 | 1 |
| Volume - survivor | 1 | 1 |
| Activities that help learning mathematics | 9 | 9 |
| Activities - multiplication (repeated addition) | 1 | 1 |
| Activity is new | 1 | 1 |
| Activity that normally not done | 1 | 1 |
| Activity was fun | 1 | 1 |
| Addition & subtraction MR | 1 | 1 |
| Addition and subtraction | 1 | 1 |
| Bad grades = not good at math | 1 | 1 |

| | | |
|---|---|---|
| Baking- everyday life | 1 | 1 |
| Based off real life | 1 | 1 |
| Belief about self in mathematics | 10 | 11 |
| Belief about math connected to ability to do specific skill | 2 | 2 |
| Belief math is fun | 3 | 3 |
| Belief math is hands-on | 2 | 2 |
| Belief math is not boring | 1 | 1 |
| Beliefs about math after Mars Rover MEA | 5 | 5 |
| Beliefs about math after Survivor MEA | 2 | 2 |
| Beliefs about math related to grade | 1 | 1 |
| Beliefs after MR | 1 | 1 |
| Beliefs after Rocket MEA | 1 | 1 |
| Can learn math as engineer | 1 | 1 |
| Change beliefs about mathematics | 5 | 5 |
| Change in model - Group 5 | 1 | 1 |
| Change in model Survivor | 1 | 1 |

| | | |
|---|---|---|
| Change in model group 6- Rocket | 1 | 1 |
| Change in model was teamwork | 1 | 1 |
| Changes in model- Survivor MEA | 2 | 2 |
| Changes to model - MR | 2 | 2 |
| Changes to model in Rocket MEA | 2 | 2 |
| Changes to the Mars Rover model | 4 | 4 |
| Confidence in math ability | 1 | 1 |
| Connect math to future employment | 2 | 2 |
| Connected -counting | 1 | 2 |
| Connected other subjects- music | 1 | 2 |
| Connected to art | 1 | 1 |
| Connected to history | 1 | 2 |
| Connected to science measuring | 3 | 3 |
| Connection to other subjects | 11 | 13 |
| Connection to other subjects- counting | 3 | 3 |
| Connection to other subjects- measurement | 2 | 2 |

| | | |
|---|---|---|
| Connection to science | 6 | 7 |
| Connection to science - finding the mean | 1 | 1 |
| Cooking- everyday life | 1 | 1 |
| Current beliefs about mathematics | 2 | 2 |
| d=r*t lesson we did helped student learn mathematics | 1 | 1 |
| Definition of math | 1 | 1 |
| Did activity then watched video | 1 | 1 |
| Didn’t like about Freighter MEA | 2 | 2 |
| Didn’t like about activity | 4 | 4 |
| Didn’t like activity because they were not successful | 1 | 1 |
| Didn’t like activity because few supplies | 1 | 1 |
| Difficulty agreeing on idea | 1 | 1 |
| Difficulty seeing math in probability lesson | 1 | 1 |
| Difficulty working as a team | 3 | 3 |
| Distance= rate x time | 1 | 2 |
| Doing math and don't even know it | 1 | 1 |

| | | |
|---|---|---|
| Don't like math | 1 | 1 |
| Employment- everyday life | 1 | 1 |
| Estimation | 3 | 4 |
| Estimation Freighter | 1 | 1 |
| Estimation MR | 1 | 1 |
| Favorite activity so far | 1 | 1 |
| Feeling towards math | 1 | 1 |
| Feels good to answer hard questions | 1 | 1 |
| Flash cards help you learn math | 2 | 2 |
| Freedom to design the way we want | 1 | 1 |
| Games help to learn mathematics | 2 | 2 |
| Geometry- Rocket | 1 | 1 |
| Good because problems can be solved quickly | 1 | 1 |
| Good grades = good at math | 3 | 3 |
| Grades = math ability | 1 | 1 |
| Hands on activities can teach math | 1 | 1 |

| | | |
|---|---|---|
| Hands on activity from class | 1 | 1 |
| Hands-on activities in class help learn math | 1 | 1 |
| Helping each other build | 0 | 0 |
| History measurement of time | 1 | 1 |
| How math is learned | 1 | 1 |
| Implicit math in classroom activity | 1 | 1 |
| Is difficult | 2 | 3 |
| Is easy | 2 | 2 |
| Is fun | 3 | 3 |
| Learn by doing worksheets in class | 1 | 1 |
| Learn math in group | 1 | 1 |
| Learn math- after Rocket | 1 | 1 |
| Learned by doing problems | 1 | 2 |
| Learning in group different that classroom | 1 | 1 |
| Learns math alone | 2 | 2 |
| Library | 1 | 1 |

| | | |
|---|---|---|
| Liked about Freighter MEA | 1 | 1 |
| Liked about Rocket MEA | 1 | 2 |
| Liked about teamwork - survivor | 3 | 3 |
| Liked about teamwork MR | 1 | 2 |
| Liked about working together | 2 | 2 |
| Liked building things | 1 | 1 |
| Liked cooperating with others- Rocket | 1 | 1 |
| Liked working together Rocket | 2 | 3 |
| Looks like school mathematics | 1 | 1 |
| Looks like science | 2 | 2 |
| Major learning activity in Survivor | 1 | 1 |
| Math is a tool | 1 | 1 |
| Math is a tool to use in science | 1 | 1 |
| Math is algorithmic | 1 | 1 |
| Math is building | 1 | 1 |
| Math is built in activities | 1 | 1 |

| | | |
|---|---|---|
| Math is connected to other subjects | 1 | 1 |
| Math is measurement | 2 | 3 |
| Math is measuring | 1 | 1 |
| Math is multiplication, division, addition and subtraction | 2 | 2 |
| Math is part of science | 1 | 3 |
| Math is problem solving | 1 | 1 |
| Math is procedures | 2 | 2 |
| Math is trigonometry | 1 | 1 |
| Math is used for homework | 1 | 1 |
| Math is used in history to measure time | 1 | 1 |
| Math is used in your everyday life | 2 | 3 |
| Math learned in STEM Academy | 2 | 2 |
| Math outside of school | 7 | 8 |
| Math outside of school connected to jobs | 1 | 3 |
| Math outside of school is measuring | 2 | 2 |
| Math outside of school looks like word problems | 1 | 1 |

| | | |
|---|---|---|
| Math problems are quick | 2 | 3 |
| Math used Mar Rover | 1 | 1 |
| Math used in Rocket MEA | 4 | 7 |
| Math used in the Freighter MEA | 4 | 5 |
| Math was boring, now we get to use it | 1 | 1 |
| Mathematical modeling | 1 | 2 |
| Mathematical modeling is graphs | 1 | 1 |
| Mathematical modeling is pictures | 1 | 1 |
| Mathematical word problems and modeling are different | 1 | 1 |
| Mathematics in future employment | 4 | 4 |
| Mathematics outside of school | 4 | 6 |
| Measurement | 8 | 10 |
| Measurement Freighter | 1 | 1 |
| Measurement MR | 1 | 1 |
| Measurement connected to other subjects | 1 | 1 |
| Measurement- Rocket | 1 | 1 |

| | | |
|---|---|---|
| Measuring & cutting important to Survivor MEA | 0 | 0 |
| Modeling is pictures | 1 | 2 |
| Models- represent mathematical operations | 1 | 1 |
| Money | 10 | 14 |
| Money everyday life | 1 | 1 |
| More than one way to do a math problem | 1 | 1 |
| More than one way to solve a problem | 1 | 1 |
| Music counting | 1 | 1 |
| Multiplication MR | 1 | 1 |
| Need to work together | 1 | 1 |
| Negative belief about ability in math | 2 | 2 |
| Never did this type of activity before | 3 | 3 |
| New application of math change beliefs | 1 | 1 |
| No STEM in the classroom | 1 | 1 |
| No activities help learn to learn math | 1 | 1 |
| No change in beliefs | 1 | 1 |

| | | |
|---|---|---|
| No change in beliefs about math- Freighter | 1 | 1 |
| No change in model- Survivor | 1 | 1 |
| No change to model- Survivor | 0 | 0 |
| No connections to the real world | 2 | 2 |
| No reason for being good at math | 1 | 1 |
| No specific connection just needed in other subjects | 1 | 1 |
| No specific example of learning activity | 1 | 1 |
| Not connected to future jobs | 3 | 3 |
| Not everyone was working | 1 | 1 |
| Not just pencil and paper | 2 | 2 |
| Not just problems on a page | 1 | 1 |
| Not really used in science | 1 | 1 |
| Not repetitive | 1 | 1 |
| Not working well together | 0 | 0 |
| Other students have knowledge | 1 | 1 |
| Outside of school - math is stuff on paper | 1 | 1 |

| | | |
|---|---|---|
| Paying bills | 2 | 3 |
| Playing games | 1 | 3 |
| Reason why tools help to learn mathematics | 2 | 2 |
| Remember fun activities when you get bored | 1 | 1 |
| Reviewing for test the night before | 1 | 1 |
| Rocket- used no math | 2 | 3 |
| Role of teacher | 14 | 28 |
| Science- fractions | 1 | 1 |
| Sees no connection to other subjects | 1 | 1 |
| Shows way can do our way | 1 | 1 |
| Speed = good at math | 1 | 1 |
| Starts concrete and then becomes abstract | 1 | 1 |
| Students need to measure own materials | 1 | 1 |
| Superficial connection to the real world | 1 | 1 |
| Superficial examples of how math is useful | 2 | 2 |
| Taking turns sharing ideas | 1 | 1 |

| | | |
|---|---|---|
| Teacher is the source of knowledge | 11 | 19 |
| Teacher lets us figure it out | 2 | 2 |
| Teacher makes math pencil & paper | 1 | 1 |
| Teacher should explain first | 4 | 6 |
| Teacher should explain new content | 1 | 1 |
| Teacher tries to make learning math fun | 1 | 1 |
| Teaches new knowledge first | 1 | 1 |
| Team work was a challenge | 1 | 1 |
| Teamwork was a challenge- Survivor | 2 | 2 |
| Teamwork was fun- Rocket | 1 | 1 |
| Testing the model | 2 | 3 |
| Thinks STEM would help him learn math | 1 | 1 |
| Thinks not good at math because missed problem on test | 1 | 1 |
| Time will wait to ask teacher for help | 1 | 2 |
| Tools that are helpful to learn math | 3 | 3 |
| Trig connected to other subjects | 1 | 1 |

| | | |
|---|---|---|
| Use calculator | 1 | 1 |
| Use math in science | 1 | 2 |
| Used counting- Freighter MEA | 1 | 1 |
| Used everyone’s ideas | 1 | 1 |
| Used in other subjects | 1 | 1 |
| Used in reading | 1 | 1 |
| Used in science measurement | 2 | 2 |
| Used math in activity | 2 | 2 |
| Useful | 7 | 7 |
| Useful - multiplication | 1 | 1 |
| Useful for counting | 2 | 3 |
| Useful for dividing time | 1 | 1 |
| Useful for measuring | 3 | 3 |
| Useful for school | 3 | 3 |
| Useful taxes | 1 | 1 |
| Useful- money | 1 | 1 |

| | | |
|---|---|---|
| Want individuals to be accountable | 1 | 1 |
| Way to learn math is the same | 1 | 1 |
| What happens if you struggle with problem | 1 | 1 |
| Why activities help you learn math | 2 | 2 |
| Word problems & mathematical modeling | 6 | 6 |
| Word problems - multiplication | 1 | 1 |
| Word problems are addition | 1 | 1 |
| Word problems are doing operations | 1 | 1 |
| Word problems are easy | 1 | 1 |
| Word problems are sentences | 4 | 4 |
| Word problems are straightforward | 1 | 2 |
| Word problems can be frustrating | 1 | 1 |
| Word problems difficulty | 4 | 4 |
| Word problems have key words | 2 | 2 |
| Word problems have one answer | 3 | 3 |
| Worksheet help you learn math | 1 | 1 |

## Appendix N: Axial Coding

| Codes<br>**Axial Coding**<br>Open Codes | **Sources** | **Frequency** |
|---|---|---|
| Ability in Math | 13 | 20 |
| Likes math | 3 | 3 |
| Rationale for being good at math | 2 | 2 |
| Reason why students participated in program | 1 | 1 |
| Bad grades = not good at math | 1 | 1 |
| Beliefs about math related to grade | 1 | 1 |
| Confidence in math ability | 1 | 1 |
| Feeling towards math | 1 | 1 |
| Good because problems can be solved quickly | 1 | 1 |
| Good grades = good at math | 3 | 3 |
| Grades = math ability | 1 | 1 |
| Negative belief about ability in math | 2 | 2 |
| No reason for being good at math1 | 1 | |

| | | |
|---|---|---|
| Speed = good at math | 1 | 1 |
| Thinks not good at math because missed problem on test | 1 | 1 |
| Belief about math connected to grade | 4 | 4 |
| Belief about math based on grades | 1 | 1 |
| Is fun | 3 | 3 |
| Beliefs Survivor | 4 | 5 |
| Beliefs about math after Survivor MEA | 2 | 2 |
| Not just pencil and paper | 2 | 2 |
| Not repetitive | 1 | 1 |
| Beliefs after Freighter | 2 | 2 |
| Freighter MEA change in beliefs | 1 | 1 |
| No change in beliefs about math- Freighter | 1 | 1 |
| Beliefs after MC | 2 | 2 |
| MC- changed beliefs about math | 1 | 1 |
| Belief math is not boring | 1 | 1 |
| Beliefs after Mars Rover | 8 | 13 |

| | | |
|---|---|---|
| Belief math is fun | 3 | 3 |
| Beliefs about math after Mars Rover MEA | 5 | 5 |
| Beliefs after MR | 1 | 1 |
| Math was boring, now we get to use it | 1 | 1 |
| More than one way to do a math problem | 1 | 1 |
| Not just problems on a page | 1 | 1 |
| Remember fun activities when you get bored | 1 | 1 |
| Beliefs after Rocket MEA | 3 | 4 |
| Rocket- change belief about math | 1 | 1 |
| Beliefs after Rocket MEA | 1 | 1 |
| Learn math- after Rocket | 1 | 1 |
| New application of math change beliefs | 1 | 1 |
| Connected to other subjects | 13 | 56 |
| Belief about math connected to ability to do specific skill | 2 | 2 |
| Connected -counting | 1 | 2 |
| Connected other subjects- music | 1 | 2 |

| | | |
|---|---|---|
| Connected to art | 1 | 1 |
| Connected to history | 1 | 2 |
| Connected to other subjects | 0 | 0 |
| Connected to science measuring | 3 | 3 |
| Connection to other subjects | 11 | 13 |
| Connection to other subjects- counting | 3 | 3 |
| Connection to other subjects- measurement | 2 | 2 |
| Connection to science | 6 | 7 |
| Connection to science - finding the mean | 1 | 1 |
| History measurement of time | 1 | 1 |
| Library | 1 | 1 |
| Looks like science | 2 | 2 |
| Math is a tool to use in science | 1 | 1 |
| Math is connected to other subjects | 1 | 1 |
| Math is used in history to measure time | 1 | 1 |
| Measurement connected to other subjects | 1 | 1 |

| | | |
|---|---|---|
| Music counting | 1 | 1 |
| No specific connection just needed in other subjects | 1 | 1 |
| Not really used in science | 1 | 1 |
| Science- fractions | 1 | 1 |
| Sees no connection to other subjects | 1 | 1 |
| Trig connected to other subjects | 1 | 1 |
| Use math in science | 1 | 2 |
| Used in other subjects | 1 | 1 |
| Used in reading | 1 | 1 |
| How math is learned | 6 | 12 |
| Repetition helps student to learn | 1 | 1 |
| How math is learned | 1 | 1 |
| Learn math in group | 1 | 1 |
| Learned by doing problems | 1 | 2 |
| Learning in group different that classroom | 1 | 1 |
| Learns math alone | 2 | 2 |

| | | |
|---|---|---|
| Reviewing for test the night before | 1 | 1 |
| Thinks STEM would help him learn math | 1 | 1 |
| Way to learn math is the same | 1 | 1 |
| Worksheet help you learn math | 1 | 1 |
| Liked about Freighter MEA | 1 | 1 |
| Liked about Freighter MEA | 1 | 1 |
| Liked about Mars Rover | 3 | 5 |
| Mars Rover- Liked about the activity | 2 | 2 |
| Liked about teamwork MR | 1 | 2 |
| Liked building things | 1 | 1 |
| Liked about Survivor | 3 | 7 |
| Materials were similar to real life items | 1 | 1 |
| Liked about teamwork - survivor | 3 | 3 |
| Math in Marshmallow Challenge | 5 | 6 |
| MC- addition | 2 | 2 |
| MC- counting | 1 | 1 |

| | | |
|---|---|---|
| MC- measurement | 1 | 1 |
| Used math in activity | 2 | 2 |
| Math in Rocket MEA | 8 | 20 |
| Estimation - Rocket | 1 | 1 |
| Distance= rate x time | 1 | 2 |
| Estimation | 3 | 4 |
| Geometry- Rocket | 1 | 1 |
| Learn by doing worksheets in class | 1 | 1 |
| Math used in Rocket MEA | 4 | 7 |
| Measurement- Rocket | 1 | 1 |
| Rocket- used no math | 2 | 3 |
| Math used in activities | 15 | 19 |
| Fractions | 1 | 1 |
| Geometry | 1 | 1 |
| Mathematics used in activity | 3 | 4 |
| Math is built in activities | 1 | 1 |

| | | |
|---|---|---|
| Math learned in STEM Academy | 2 | 2 |
| Measurement | 8 | 10 |
| Mathematical modeling behaviors | 16 | 27 |
| Changes in model | 1 | 1 |
| SMP 3 | 4 | 6 |
| SMP 4 | 1 | 1 |
| Change in model - Group 5 | 1 | 1 |
| Change in model Survivor | 1 | 1 |
| Change in model group 6- Rocket | 1 | 1 |
| Change in model was teamwork | 1 | 1 |
| Changes in model- Survivor MEA | 2 | 2 |
| Changes to model - MR | 2 | 2 |
| Changes to model in Rocket MEA | 2 | 2 |
| Changes to the Mars Rover model | 4 | 4 |
| No change in model- Survivor | 1 | 1 |
| Starts concrete and then becomes abstract | 1 | 1 |

| | | |
|---|---|---|
| Testing the model | 2 | 3 |
| Role of teacher | 15 | 81 |
| Teachers should explain mathematics before students do it | 11 | 18 |
| Math is procedures | 2 | 2 |
| No STEM in the classroom | 1 | 1 |
| Role of teacher | 14 | 28 |
| Shows way can do our way | 1 | 1 |
| Teacher is the source of knowledge | 11 | 19 |
| Teacher lets us figure it out | 2 | 2 |
| Teacher makes math pencil & paper | 1 | 1 |
| Teacher should explain first | 4 | 6 |
| Teacher should explain new content | 1 | 1 |
| Teacher tries to make learning math fun | 1 | 1 |
| Teaches new knowledge first | 1 | 1 |
| Uniqueness of activities | 4 | 6 |
| New activity | 1 | 1 |

| | | |
|---|---|---|
| Activity is new | 1 | 1 |
| Activity that normally not done | 1 | 1 |
| Never did this tie of activity before | 3 | 3 |
| Activities help you learn math | 12 | 30 |
| Mars Rover MEA taught math | 1 | 1 |
| STEM helps students learn math | 1 | 1 |
| | 9 | 9 |
| Activities - multiplication (repeated addition) | 1 | 1 |
| Can learn math as engineer | 1 | 1 |
| D=rt lesson we did helped student learn mathematics | 1 | 1 |
| Flash cards help you learn math | 2 | 2 |
| Games help to learn mathematics | 2 | 2 |
| Hands on activities can teach math | 1 | 1 |
| Hands on activity from class | 1 | 1 |
| Hands-on activities in class help learn math | 1 | 1 |
| No activities help learn to learn math | 1 | 1 |

| | | |
|---|---|---|
| No specific example of learning activity | 1 | 1 |
| Reason why tools help to learn mathematics | 2 | 2 |
| Tools that are helpful to learn math | 3 | 3 |
| Belief about self in mathematics | 10 | 15 |
| Don’t like math | 1 | 1 |
| Is difficult | 2 | 3 |
| Beliefs about math | 9 | 10 |
| Belief math is hands-on | 2 | 2 |
| Change beliefs about mathematics | 5 | 5 |
| Current beliefs about mathematics | 2 | 2 |
| Doing math and don't even know it | 1 | 1 |
| Classroom activity | 2 | 3 |
| Did activity then watched video | 1 | 1 |
| Difficulty seeing math in probability lesson | 1 | 1 |
| Implicit math in classroom activity | 1 | 1 |
| Definition of math | 4 | 12 |

| | | |
|---|---|---|
| Definition of math | 1 | 1 |
| Math is a tool | 1 | 1 |
| Math is algorithmic | 1 | 1 |
| Math is building | 1 | 1 |
| Math is measurement | 2 | 3 |
| Math is part of science | 1 | 3 |
| Math is problem solving | 1 | 1 |
| Math is trigonometry | 1 | 1 |
| Didn’t like about Freighter MEA | 2 | 3 |
| Didn’t like activity because few supplies | 1 | 1 |
| Didn’t like about activities | 6 | 9 |
| Survivor MEA- challenges | 3 | 4 |
| Didn’t like about activity | 4 | 4 |
| Didn’t like activity because they were not successful | 1 | 1 |
| Liked about Rocket | 4 | 10 |
| Activity was fun | 1 | 1 |

| | | |
|---|---|---|
| Based off of real life | 1 | 1 |
| Favorite activity so far | 1 | 1 |
| Free to design the way we want | 1 | 1 |
| Liked about Rocket MEA | 1 | 2 |
| Liked cooperating with others- Rocket | 1 | 1 |
| Liked working together Rocket | 2 | 3 |
| Math in Freighter MEA | 5 | 8 |
| Estimation Freighter | 1 | 1 |
| Math used in the Freighter MEA | 4 | 5 |
| Measurement Freighter | 1 | 1 |
| Used counting- Freighter MEA | 1 | 1 |
| Math in Mars Rover MEA | 11 | 20 |
| MR- used addition in budget | 1 | 1 |
| Math used in the Mars Rover MEA | 9 | 11 |
| Multiplication | 2 | 2 |
| Addition & subtraction MR | 1 | 1 |

| | | |
|---|---|---|
| Addition and subtraction | 1 | 1 |
| Estimation MR | 1 | 1 |
| Math used Mar Rover | 1 | 1 |
| Measurement MR | 1 | 1 |
| Multiplication MR | 1 | 1 |
| Math in Survivor MEA | 8 | 20 |
| Area & Perimeter in Survivor | 1 | 1 |
| Fractions- Survivor | 2 | 2 |
| Math used in Survivor MEA | 6 | 6 |
| Multiplication- Survivor | 1 | 1 |
| Survivor- measurement | 3 | 4 |
| Volume - survivor | 1 | 1 |
| Major learning activity in Survivor | 1 | 1 |
| Math is measuring | 1 | 1 |
| Math is multiplication, division, addition and subtraction | 2 | 2 |
| Students need to measure own materials | 1 | 1 |

| | | |
|---|---|---|
| Math is challenging | 1 | 2 |
| Feels good to answer hard questions | 1 | 1 |
| More than one way to solve a problem | 1 | 1 |
| Math outside of school | 18 | 58 |
| Math is what you need to work | 1 | 1 |
| Baking- everyday life1 | 1 | |
| Connect math to future employment | 2 | 2 |
| Cooking- everyday life | 1 | 1 |
| Employment- everyday life | 1 | 1 |
| Is easy | 2 | 2 |
| Looks like school mathematics | 1 | 1 |
| Math outside of school | 7 | 8 |
| Math outside of school connected to jobs | 1 | 3 |
| Math outside of school is measuring | 2 | 2 |
| Math outside of school looks like word problems | 1 | 1 |
| Math outside of school time | 1 | 1 |

| | | |
|---|---|---|
| Mathematics in future employment | 4 | 4 |
| Mathematics outside of school | 4 | 6 |
| Money | 10 | 14 |
| Money everyday life | 1 | 1 |
| No connections to the real world | 2 | 2 |
| Not connected to future jobs | 3 | 3 |
| Outside of school - math is stuff on paper | 1 | 1 |
| Superficial connection to the real world | 1 | 1 |
| Superficial examples of how math is useful | 2 | 2 |
| Mathematical modeling | 3 | 7 |
| Mathematical modeling | 1 | 2 |
| Mathematical modeling is graphs | 1 | 1 |
| Mathematical modeling is pictures | 1 | 1 |
| Modeling is pictures | 1 | 2 |
| Models- represent mathematical operations | 1 | 1 |
| Teamwork | 10 | 23 |

| | | |
|---|---|---|
| Teamwork | 5 | 7 |
| Teamwork was faster | 1 | 1 |
| Difficulty agreeing on idea | 1 | 1 |
| Difficulty working as a team | 3 | 3 |
| Liked about working together | 2 | 2 |
| Need to work together | 1 | 1 |
| Not everyone was working | 1 | 1 |
| Taking turns sharing ideas | 1 | 1 |
| Team work was a challenge | 1 | 1 |
| Teamwork was a challenge- Survivor2 | 2 | |
| Teamwork was fun- Rocket | 1 | 1 |
| Used everyone's ideas1 | 1 | |
| Want individuals to be accountable | 1 | 1 |
| Usefulness of math | 10 | 32 |
| Math is used for homework | 1 | 1 |
| Math is used in your everyday life | 2 | 3 |

| | | |
|---|---|---|
| Paying bills | 2 | 3 |
| Playing games | 1 | 3 |
| Used in science measurement | 2 | 2 |
| Useful | 7 | 7 |
| Useful - multiplication | 1 | 1 |
| Useful for counting | 2 | 3 |
| Useful for dividing time | 1 | 1 |
| Useful for measuring | 3 | 3 |
| Useful for school | 3 | 3 |
| Useful taxes | 1 | 1 |
| Useful- money | 1 | 1 |
| Word problems | 10 | 41 |
| Mathematical word problems | 5 | 6 |
| Math problems are quick | 2 | 3 |
| Other students have knowledge | 1 | 1 |
| Time will wait to ask teacher for help | 1 | 2 |

| | | |
|---|---|---|
| Use calculator | 1 | 1 |
| What happens if you struggle with problem | 1 | 1 |
| Word problems & mathematical modeling | 6 | 6 |
| Word problems - multiplication | 1 | 1 |
| Word problems are addition | 1 | 1 |
| Word problems are doing operations | 1 | 1 |
| Word problems are easy | 1 | 1 |
| Word problems are sentences | 4 | 4 |
| Word problems are straightforward | 2 | |
| Word problems can be frustrating | 1 | 1 |
| Word problems difficulty | 4 | 4 |
| Word problems have key words | 2 | 2 |
| Word problems have one answer | 3 | 3 |
| Mathematical word problems and modeling are different | 1 | 1 |

## Appendix O: Answers to Pre and Post-questionnaires of Interview Participants

| Questions | | Participants by Ability Level | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Low** | | **Middle** | | **High** | |
| | | **Ashley (L)** | **David (L)** | **Amy (M)** | **Becka (M)** | **Chris (H)** | **James (H)** |
| 1.Math is more than doing operations like adding, subtracting, multiplying and dividing | | | | | | | |
| | Pre | 3 | 5 | 5 | 5 | 5 | 5 |
| | Post | 5 | 5 | 5 | 5 | 5 | 5 |
| 2. Math is a worthwhile and necessary subject to know | | | | | | | |
| | Pre | 5 | 5 | 5 | 4 | 5 | 5 |
| | Post | 5 | 5 | 5 | 4 | 5 | 5 |
| 3. I don't use math in my everyday life | | | | | | | |
| | Pre | 1 | 3 | 1 | 4 | 1 | 1 |
| | Post | 3 | 4 | 1 | 3 | 2 | 1 |
| 4. Math makes me confused | | | | | | | |
| | Pre | 1 | 5 | 4 | 1 | 1 | 2 |
| | Post | 4 | 4 | 4 | 1 | 1 | 4 |
| 5. The role of the teacher is to provide answers to problems | | | | | | | |
| | Pre | 1 | 4 | 5 | 2 | 2 | 1 |
| | Post | 3 | 3 | 4 | 2 | 3 | 1 |
| 6. Any problem can be solved if you remember the right steps to follow | | | | | | | |
| | Pre | 5 | 5 | 5 | 5 | 5 | 5 |
| | Post | 5 | 5 | 4 | 4 | 5 | 5 |
| 7. Math is about exploring new ideas | | | | | | | |
| | Pre | 4 | 1 | 5 | 4 | 4 | 4 |
| | Post | 4 | 3 | 5 | 4 | 4 | 4 |
| 8. Math is used to create the technology I use everyday | | | | | | | |
| | Pre | 4 | 2 | 4 | 4 | 4 | 5 |
| | Post | 2 | 3 | 4 | 4 | 4 | 5 |
| 9. Most word problems can be solved using the correct step-by-step procedures | | | | | | | |
| | Pre | 5 | 5 | 4 | 5 | 5 | 5 |
| | Post | 5 | 5 | 4 | 5 | 5 | 5 |
| 10. The teacher lets students figure things out for themselves | | | | | | | |
| | Pre | 1 | 5 | 2 | 4 | 4 | 5 |
| | Post | 4 | 4 | 3 | 2 | 4 | 5 |
| 11. Mathematics is hard | | | | | | | |
| | Pre | 2 | 3 | 4 | 1 | 1 | 2 |
| | Post | 4 | 4 | 4 | 1 | 1 | 2 |
| 12. Math is not used in my other classes | | | | | | | |
| | Pre | 1 | 2 | 1 | 2 | 1 | 4 |
| | Post | 1 | 3 | 4 | 4 | 1 | 1 |
| 13. Math is memorizing | | | | | | | |
| | Pre | 5 | 1 | 4 | 4 | 4 | 5 |
| | Post | 5 | 4 | 5 | 4 | 5 | 5 |
| 14.Word problems can be solved without remembering formulas | | | | | | | |
| | Pre | 1 | 5 | 5 | 1 | 2 | 3 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Post | 1 | 3 | 4 | 1 | 2 | 4 |
| 15.All knowledge comes from the teacher | | | | | | |
| Pre | 2 | 5 | 2 | 2 | 3 | 2 |
| Post | 3 | 4 | 2 | 2 | 2 | 2 |
| 16. Math is about following rules | | | | | | |
| Pre | 5 | 1 | 2 | 3 | 4 | 5 |
| Post | 3 | 2 | 2 | 4 | 4 | 4 |
| 17. I never use math outside of the school | | | | | | |
| Pre | 1 | 3 | 1 | 4 | 1 | 1 |
| Post | 4 | 3 | 1 | 1 | 1 | 1 |
| 18. There are math problems that cannot be solved by following a predetermined sequence of steps | | | | | | |
| Pre | 3 | 3 | 4 | 1 | 4 | 4 |
| Post | 3 | 1 | 3 | 1 | 3 | 1 |
| 19. Mathematics makes sense to me | | | | | | |
| Pre | 5 | 2 | 2 | 4 | 5 | 5 |
| Post | 4 | 1 | 2 | 4 | 5 | 5 |
| 20. I use math in my science class | | | | | | |
| Pre | 5 | 5 | 4 | 4 | 3 | 3 |
| Post | 5 | 5 | 5 | 4 | 4 | 5 |
| 21. Studying math is a waste of time | | | | | | |
| Pre | 1 | 1 | 1 | 1 | 1 | 1 |
| Post | 1 | 2 | 1 | 1 | 1 | 1 |
| 22. The role of the teacher is to facilitate learning | | | | | | |
| Pre | 5 | 3 | 4 | 5 | 4 | 4 |
| Post | 5 | 3 | 4 | 4 | 3 | 2 |
| 23. I usually do well in math | | | | | | |
| Pre | 4 | 1 | 2 | 4 | 5 | 4 |
| Post | 4 | 3 | 4 | 4 | 5 | 5 |
| 24. Math is useful outside of school | | | | | | |
| Pre | 5 | 4 | 5 | 5 | 5 | 5 |
| Post | 5 | 5 | 5 | 5 | 5 | 5 |

Note: 1= disagree a lot, 2= disagree a little, 3= no opinion, 4= agree a little and 5 = agree a lot

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Yoon, C., Dreyfus, T., & Thomas, M. O. J. (2010). How high is the tramping track? Mathematising and applying in a calculus model-eliciting activity. *Mathematics Education Research Journal*, *22*(2), 141–157. doi:10.1007/BF03217571

## Curriculum Vitae

## Cathrine Maiorca

## EDUCATION AND WORK EXPERIENCE

Education

| | |
|---|---|
| **Spring 2016** (Anticipated Completion Date) | **University of Nevada, Las Vegas, NV**<br>Ph.D. Curriculum and Instruction (emphasis Mathematics Education, content centration in Applied Quantitative Statistical Methods)<br>*A Case Study: Students' Mathematics-Related Beliefs from Integrated STEM Model-Eliciting Activities*<br>Committee: Dr. Micah Stohlmann and Jeff Shih (co-chairs), Dr. Travis Olson, Dr. Alice Corkill and Dr. Jori Beck |
| **2011** | **Sierra Nevada College, Incline Village, NV**<br>M.A.T., Secondary Education |
| **1997** | **Austin College, Sherman, TX**<br>B.A. Mathematics and Music |
| **2000- 2003** | **Portland State University, Portland, OR**<br>Graduate Studies Mathematical Statistics |

**Professional Experience**

| | |
|---|---|
| **June 2016** | Field Supervisor, University of Nevada, Las Vegas, Rebel Academy, Las Vegas, NV |
| **2012 to 2016** | Graduate Teaching Assistant, University of Nevada, Las Vegas, Department of Teaching and Learning, Las Vegas, NV |
| **2013- 2014** | Model-Eliciting Activity Reviewer, Florida State University, Tallahassee, FL |
| **2008 - 2012** | High School Mathematics Teacher, Clark County School District, Las Vegas, NV |
| **2005- 2007** | High School Mathematics Teacher, Allen Independent School District, Allen, TX |
| **2004- 2005** | High School Mathematics Teacher, Desoto Independent School District, Desoto, TX |
| **2003 - 2004** | Part Time Mathematics Instructor, Tacoma Community College, Tacoma, WA |
| **2003- 2004** | Part Time Mathematics Instructor, Peirce Community College, Puyallup, WA |
| **2000- 2003** | Graduate Teaching Assistant, Portland State University, Portland, OR |
| **2000- 2003** | Mathematics Lecturer, Portland State University, Portland, OR |

**1999- 2000** High School Mathematics Teacher, San Francisco Independent School District, San Francisco, CA

## SCHOLARSHIP

### Peer Review Journals

Stohlmann, M., Maiorca, C., & Olson, T. (2015). Preservice secondary teachers conceptions from a mathematical modeling activity and connections to the Common Core State Standards. *The Mathematics Educator Journal.*

Stohlmann, M., Cramer, K., Moore, T., & Maiorca, C. (2014). Changing preservice elementary teachers' beliefs about mathematical knowledge. Mathematics Teacher Education and Development

Stohlmann, M., Maiorca, C., & Allen, C. (In review). A Case Study of Teachers' Development of Well-Structured Mathematical Modeling Activities. Journal of Mathematical Modeling and Application.

Stohlmann, M., Maiorca, C., & Allen, C. (In review). A Case Study of Teachers' Development of Well-Structured Mathematical Modeling Activities. Journal of Mathematical Modeling and Application.

Stohlmann, M. Maiorca, C. & DeVaul, L. (submitted). Elementary teachers' engineering design activities from a state without engineering standards. Pre-College Engineering Education Research.

### Book Chapters

Maiorca, C & Stohlmann, M. (2016). Inspiring students in integrated STEM education through modeling activities. Annual Perspectives in Mathematics Education 2016: Mathematical Modeling and Modeling Mathematics. Reston, VA: NCTM.

### Conference Proceedings (*Refereed)

*Stohlmann, M., Maiorca, C., & Allen, C. (2015). A case study of teachers' development of well-structured mathematical modeling activities. Proceedings of the 13th annual Hawaii International Conference on Education. Honolulu, HI: HICE.

### Conference Presentations

Maiorca, C. & Stohlmann, M. (2016). Integrated STEM and Model-Eliciting Activities: Making math more engaging. Annual Meeting of the National Council of Teachers of Mathematics. San Francisco, CA

Maiorca, C. (2016). The Elephant in the Room: Students' Mathematics-Related Beliefs. Annul Meeting of the Research Council on Mathematics Learning. Orlando, FL.

Maiorca, C. & Olson, T. (2015). Making mathematics more relevant through integrated STEM. Annual Meeting of the National Council of Teachers of Mathematics. Boston, MA.

Stohlmann, M. & Maiorca, C. (2015). Mathematical modeling: A model approach to keep students engaged. Annual Meeting of the National Council of Teachers of Mathematics. Boston, MA.

Maiorca, C. & Olson, T. (2015). Investigations into teachers' perspectives on mathematical modeling. Annual Meeting of the Research Council on Mathematics Learning. Las Vegas, NV.

Stohlmann, M., Allen, C. & Maiorca, C. (2015). *A case study of teachers' development of well-structured mathematical modeling activities*. Hawaii International Conference on Education. Honolulu, Hawaii.

Stohlmann, M., Maiorca, C., & Olson, T. (2014). *The mathematics of hotel/casino management*. Annual Meeting of the National Council of Teachers of Mathematics. New Orleans, LA.

Maiorca, C. & Stohlmann, M. (2014). *The how and why of integrated STEM model- eliciting activities*. Annual Meeting of the National Council of Teachers of Mathematics. New Orleans, LA.

Stohlmann, M., Cramer, K., Moore, T., & Maiorca, C. (2013). *Changing preservice elementary teachers' beliefs through models of students' thinking about fraction division*. Poster presented at the National Council of Teachers of Mathematics Research Pre-session. Denver, CO.
Stohlmann, M. & Maiorca, C. (2013). *It's not STEM without the M.* Southern Nevada Math and Science Annual Conference. Las Vegas, NV.

### Conference Posters

Maiorca, C. (2015). Students' mathematics-related beliefs and STEM model-eliciting activities. Annual Meeting of the Research Council on Mathematics Learning. Las Vegas, NV.

## Workshops

Maiorca, C. (2015). After School STEM Academy. Sister Robert Joseph Bailey Elementary School. Las Vegas, NV.

Stohlmann, M. & Maiorca, C. (2013 & 2014). Saturday STEM. University of Nevada, Las Vegas.

Olson, T & Maiorca, C. (2013). Rebel STEM Academy. University of Nevada, Las Vegas.

# TEACHING

## Courses Taught

Math Methods Courses at UNLV

1. Teaching Middle School Mathematics (Spring 2016)
2. Teaching Elementary School Mathematics (Fall 2015, Spring 2016)

University Level Mathematics Courses taught at Previous Institutes

1. Intro to Elementary Algebra (2003)
2. Intermediate Algebra (2003- 2004)
3. Pre-Algebra (2003)
4. Intro to Probability and Statistics I (2001- 2004)
5. Intro to Probability and Statistics II (2001-2004)

## Graduate Teaching Assistant

Math Education Courses at UNLV

1. CIE 625 Instructional Intermediate Elementary Mathematics Education
2. EDMS 453/ CIS 533M Teaching Middle School Mathematics
3. CIE 629 Curriculum Development in Mathematics Education

Math Courses at Portland State University

1. Intermediate Algebra (2000)
2. Intro to Probability and Statistics (2001)

## SERVICE

### Professional Service

2015 Research Council of Mathematics Learning Annual Conference, Las Vegas, NV. local arrangement support

2016 Research Council of Mathematics Learning Annual Conference, Orlando, FL. proposal reviewer

### Professional Organizations

National Council of Teachers of Mathematics
Research Council on Mathematics Learning
School Science and Mathematics Association

### Honors and Awards

Golden Key International Honors Society

### Grants

UNLV Graduate and Professional Student Association Travel Grant, 2015
UNLV Graduate and Professional Student Association Travel Grant, 2016