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How Teacher Beliefs About Mathematics Affect Student Beliefs About Mathematics

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Introduction

In the field of psychology, it is now common knowledge that one's prejudices and stereotypes affect one's behavior. In psychology, prejudices are associated with how one feels about something; they are related to one's emotions. Stereotypes or beliefs are associated with one's conscious thoughts about something; they are related to cognition. Both how one feels about something and how one thinks about something will affect how one acts towards that something.

This concept has very important implications in the field of education – a field that is driven by results in terms of student achievement. As achievement is strongly linked to a student's actions regarding a particular subject, such as study habits, interest in the topic, and effort put into assignments, looking into student beliefs and feelings about that subject could be very enlightening. The subject of interest in this study is mathematics. The next logical question

would be how to change student feelings and beliefs about mathematics so that students take more positive actions in relation to mathematics and reach a higher level of achievement. One clear area to look is the influence of the teacher. Could a teacher's feelings and beliefs about the subject be transferred to their students?

It is well known that good teachers have an immense impact on student understanding, quality of learning, and student achievement. Researchers have shown that how students are taught has an impact on how well they understand the material. But not much research has been done on why teachers chose particular practices in their classroom. If some teaching practices produce higher levels of student achievement, others promote more positive student beliefs about mathematics, and others produce more positive dispositions regarding mathematics, then it is important to know what it is about different teachers that make them choose to enact different practices in the classroom. This research project is an attempt to show that the beliefs that teachers hold about the nature of mathematics and the nature of doing mathematics influence their teaching practices in a distinct and measurable way through teacher interviews, surveys, and observations of their classrooms.

Using this information regarding teachers' beliefs about mathematics and how they affect the teachers' classroom practices, one can address the question of whether these beliefs and practices affect student beliefs. If students' beliefs can be positively influenced by their teachers, then student actions can be positively influenced, which means that student achievement in mathematics will improve. This research project will explore how student beliefs about mathematics change over time after being influenced by a particular mathematics teacher in a quantitative and qualitative manner through self-reporting surveys about one's mathematical beliefs and beliefs about mathematics education.

Research Questions

1. What do secondary mathematics teachers believe it means to do mathematics?

2. How do secondary mathematics teachers believe that new mathematics is attained?

3. In what context do mathematics teachers believe that mathematics is useful or meaningful?

4. To what extent and how do the above beliefs that teachers hold impact their classroom practices?

5. What do secondary mathematics students believe it means to do mathematics?

6. How do secondary mathematics students believe that new mathematics is attained by mathematicians?

7. What qualities and skills do good math students have?

8. In what context do mathematics students believe that mathematics is useful or meaningful?

9. To what extent do the above beliefs that students hold about mathematics initially align with that of their current teacher's?

10. To what extent do the above beliefs that students hold about mathematics align with that of their current teacher's after a semester?

11. To what extent and how are the beliefs that students hold about mathematics changed over a semester by having a mathematics class with a particular teacher?

Beliefs are not easily measured by quantitative means, since they may not be fully formed in the participant's mind. Also, different aspects of beliefs may be difficult to distinguish from one another or may interact and affect one another. The research questions were created in an attempt to capture and distinguish the specific aspects of mathematical beliefs that may contribute to the experience in the classroom.

The first and fifth research questions aim to understand the definitions and conceptions of mathematics that students and teachers have that are the foundation of their further beliefs about how mathematics is useful and their beliefs about teaching and learning mathematics. This question may seem to have an obvious answer but there is a simple example that clearly shows how this question can have vastly different answers. New curriculum in elementary school mathematics is often met with pushback from current parents because how their children are doing this "new" math conflicts with their own beliefs of what it means to do math, which was developed from the way that they were taught math in school. Teachers are of a very different generation from students and possibly from each other and have had different experiences with mathematics education, so beliefs about what it means to do mathematics could differ drastically between each of the participants.

Research questions two and six address how teachers and students believe that new mathematics is acquired. There are different but important consequences of this belief for teachers and students. One of the major roles of a mathematics teacher is to prepare students for mathematics they may encounter in the future, wherever the future may take them. This preparation is especially important if a student's future is in the field of mathematics. Different beliefs about how new mathematics is attained my mathematicians may change a teacher's

preparation of students, either by cover different material or by providing a different perspective. A student's belief about how new mathematics is attained by mathematicians may affect that student's willingness to go into the fields of science and mathematics and may affect the student's confidence in their own mathematical abilities.

Research questions three and eight address how teachers and students believe that mathematics is useful or meaningful to the world. This question is the key question of this research project. Since teachers have more knowledge and more interest in mathematics than students, it is reasonable to suspect that teachers may find mathematics to be more meaningful and useful overall than students. There are differences in this belief that are easily seen in the general public. A writer is more likely to say that mathematics is only useful when paying their bills whereas a scientist is more likely to say that mathematics is useful in nearly every field of study. It is important to determine how students and teachers believe mathematics is useful to the world in order to determine how teachers' beliefs affect students' beliefs overall.

Research question four addresses how teacher beliefs affect their classroom practices. This question is important because it is the link of how teacher beliefs are transmitted to students. It is possible that some beliefs are not incorporated into classroom practices and others are very much so, and others yet are only somewhat incorporated. And it is logical to hypothesize that the beliefs that are most often incorporated into a teacher's classroom practices are the beliefs that would change the most drastically in their students due to that teacher's influence. The answer to this question also leads into ways teachers can incorporate their mathematical beliefs more explicitly in their classroom practices in an attempt to make more of an impact on their students' beliefs.

Lastly, questions nine, ten, and eleven address how closely student beliefs align with their teachers' beliefs before and after having that teacher for a mathematics class for a semester, and how student beliefs have changed over this time period. These questions are especially important to the study because the answers to these questions will determine whether or not teachers' beliefs affect students' beliefs about mathematics. Questions nine and ten will create two sets of data that can be compared for significant differences when answering question eleven. Finally, the answer to question eleven will lead to a conclusion about the strength of transference of mathematical beliefs from teachers to students.

Background Research

In A. G. Thompson's 1992 handbook chapter on teacher beliefs and conceptions, Thompson noted that most research regarding teacher beliefs and conceptions was interpreted using qualitative analysis and were detailed, small case studies. One of the major problems that Thompson found regarding this topic of research is that the term "belief" is a word commonly used in education so many researchers did not define it. However, there are important distinctions to be made when doing research that are not typically made when the terms are used in common speech, such as beliefs, affect, and conceptions. Thompson defined beliefs as the understandings that one has about the interaction of mathematics and the world that one believes to be true (Lester, 2007, p. 259). It is important to point out that beliefs are cognitive and are inherently difficult to change because the mind naturally adapts observations to confirm already held beliefs, instead of changing beliefs to align with new observations.

Below is a list of important terms regarding beliefs that Thompson (Lester, 2007, p. 259) defined which are related but distinctly different from one another. These definitions have been used in past research and also in current research.

Affect: a disposition or tendency or an emotion or feeling attached to an idea or object. Affect is composed of emotions, attitudes, and beliefs.

Emotions: feelings or states of consciousness, distinguished from cognition.

Attitudes: manners of acting, feeling, or thinking that show one's disposition or opinion.

Beliefs: psychologically held understandings, premises, or propositions about the world that are thought to be true… Beliefs might be thought of as lenses that affect one's view of some aspect of the world or as dispositions toward action. Beliefs, unlike knowledge, may be held with varying degrees of conviction.

Beliefs system: a metaphor for describing the manner in which one's beliefs are organized in a cluster, generally around a particular idea or object.

Conception: a general notion or mental structure encompassing beliefs, meanings, concepts, propositions, rules, mental images, and preferences.

Knowledge: beliefs held with certainty or justified true belief.

Value: the worth of something. A belief one holds deeply, even to the point of cherishing, and acts upon.

When thinking about the three components of affect (emotions, attitudes, and beliefs), an important distinction between them is that emotions are the most intensely felt and the beliefs are the least intensely felt. Also, beliefs are the most cognitive of the three and emotions are the least cognitive. When comparing beliefs and knowledge, knowledge is a belief that is held with such certainty that it is considered a fact to that particular person. A statement that is a belief to one person may be considered knowledge by another. When comparing beliefs and values, beliefs are often seen as either true or false, whereas values are often seen as either desirable or undesirable. Values are also used more globally than beliefs because they are less specific to a particular situation.

The historical approach for measuring beliefs is qualitatively through methods such as interviewing and observations. However, as demand for larger sample sizes grew, measurement of beliefs moved to surveys because they were faster and easier to evaluate than qualitative measures. The most commonly used survey was a Likert scale, where participants select their level of agreement or disagreement with a given statement. There is concern about whether this method of measuring beliefs is accurate because answers would change depending on how the statement was phrased and teachers may not be able or willing to report their own beliefs, especially if they are inconsistent with how they teach (Lester, 2007, p. 268). The challenge for

researchers is to get as accurate of data as in qualitative measures as quickly and easily as the data from surveys so that more research can be done with larger sample sizes.

Research conducted by Raymond in 1997 explored the question of why teachers may hold inconsistent beliefs within their system of beliefs. Raymond found that there are two major factors that may lead to inconsistencies in a teacher's beliefs: the first is that the teacher's classroom practices may be more aligned to the teacher's beliefs about mathematics than about the teacher's beliefs about teaching and how students learn best. The second factor is that there are educational issues such as time constraints, limited resources, stressors such as standardized tests, and negative student behavior that can lead a teacher to have inconsistent beliefs (Lester, 2007, p. 272). In this second case, a teacher's beliefs may change depending on the circumstances and the constraints during a particular class. Also, a teacher's beliefs may be overpowered by student needs such as building student confidence and managing classroom behavior. In 2003, Sztajn found that teachers with the same mathematical beliefs may differ in classroom practices due to differing beliefs about children, society, and education (Lester, 2007, p. 274).

As our beliefs change our perspective on what we see, teacher beliefs affect how teachers view instruction that they observe. Naturally, the question became whether teacher beliefs are able to be changed because that will affect instruction. Between 1971 and 1999, there were several research studies exploring how teacher beliefs may be changed. The key component that was found to impact a change in beliefs was whether teachers reflected upon their observations of instruction, giving them the opportunity to learn new ways of making sense of their observations (Lester, 2007, p. 277). Researchers also found that there are impediments to

changing beliefs. For example, teachers' concern for students' well-being restrains teachers' willingness to challenge students in the classroom.

Since Thompson's research in 1992, there has been research in four major areas regarding teacher beliefs: teacher beliefs related to student thinking, teacher beliefs related to the use of mathematics curricula, teacher beliefs related to technology, and teacher beliefs related to gender. There were several important discoveries found by research on teacher beliefs related to student thinking. Firstly, Fennema et al. found that changes in beliefs that involved instruction that reflected a focus on mathematical thinking were related to gains in student understanding and performance (Lester, 2007, p. 282). Staub and Stern found that there is a direct correlation between teachers' beliefs about students' mathematical thinking and student achievement. And lastly, Nathan and Koedinger found that verbal reasoning skills in students preceded that of symbolic reasoning skills, which was opposite what most high school math teachers in the study believed (Lester, 2007, p. 285). This is a key example of the expert blind spot hypothesis in relation to mathematics education.

Research on teachers' beliefs related to (or changed by) the use of mathematical curricula found that teachers' orientation toward a particular curriculum affects how that curriculum is used. For example, if the teacher's beliefs are inconsistent with the foundational beliefs of the curriculum, the teachers do not use that curriculum as intended. However, research has also found that less experienced teachers, such as prospective teachers, are more likely than experienced teachers to read and learn from supportive materials and curriculum given to teachers (Lester, 2007, p. 291).

Research on teachers' beliefs related to the use of technology has found that support for teachers is needed to use technology in the classroom effectively, and that teachers' beliefs about

technology are constrained by their beliefs about mathematics and the teaching and learning of

mathematics (Lester, 2007, p. 294). Research on teachers' beliefs related to gender in 2001 and

2003 has found that teachers still hold the stereotype that mathematics is a male domain and that

this stereotype affects students (Lester, 2007, p. 295).

Rationale

The reason this research is needed is that although there has been much research on mathematical beliefs in general, there has been very little done on the interaction between teacher beliefs and student beliefs. A lot of the research that has been done in this area has focused on affect: how students and teachers feel about certain aspects of mathematics and how those feelings impact performance in terms of teaching and learning. This research focuses specifically on beliefs, which is the more cognitive area of this topic of interest.

Additionally, much of the research in the past has involved either teachers or students and not both. For example, several studies worked solely with prospective teachers, current teachers, or current students and did not look into the interactions between these groups. This study is important because not only does it involve both teachers and students, but the goal is to examine how their mathematical beliefs interact with one another's, thus adding to the research on how mathematical beliefs are changed.

Also, much of the research in the past has focused on the relationship between affect regarding mathematics and student achievement in mathematics, or how beliefs about mathematics affect student achievement. Since the effect on student achievement is so important, this research project attempts to uncover some of the determining factors of a student's mathematical beliefs. From that information, it may be possible to determine how to change student beliefs in the most positive direction possible: to lead student to the mathematical beliefs that correlate with the highest mathematical achievement.

In terms of teachers, this research in important in determining to what extent a teacher's beliefs are displayed through their classroom practices and how well these beliefs are translated to students. This research will give the mathematics educational community more insight in how to better plan lessons that embody a teacher's mathematical beliefs in a reasonable and consistent manner that will not negatively affect the teaching of mathematical content. Thus teachers will be able to also teach mathematical beliefs to their students that will help them be more successful mathematics students now and in the future. However, without the research on how student beliefs are formed and influenced and changed, this goal of positively influencing student learning will not be possible.

Methodology

Participating teachers in the research were found through existing connections in the University of New Hampshire Mathematics Education Department and through the researchers. Principal agreement or SAU agreement was obtained from each school. The three participating schools are similar in terms of student demographics, size, and structure of curriculum. Teachers gave their consent to participate in the research by signing the informed consent form from Appendix A. Teachers gave consent for data from interviews, surveys, and observations to be compared to data from students in the consent form in Appendix B. The participating students are the students of the three participating teachers. In order to participate, both a parent and the student themselves would have to sign the informed consent form in Appendix C. Neither the students nor the students received any benefit from participating in the study, aside from gaining more insight into their own mathematical beliefs.

The research was partitioned into two separate sections: research on teacher beliefs about mathematics, and research on student beliefs about mathematics. Later, the data would be combined and analyzed to deduce a possible relationship between the two. Teachers were interviewed, observed in the classroom, and took a survey. Students took a survey on two separate occasions.

Each Participating teacher was interviewed before any observations of their classroom. They were asked questions such as what they believe it means to do mathematics, what it means for students to know and understand mathematics, how they believe new mathematics is attained, in what context they believe mathematics is useful or meaningful, and how they think their

beliefs about mathematics impact their classroom practices. The interview questions are included in Appendix D. The interviewer occasionally asked clarifying questions or questions to bring out more depth in a teachers answer. The interviews were audio recorded and later transcribed.

Participating teachers also took a survey before they were interviewed or their classroom practices were observed. For some questions on the survey the teacher was given a statement and was required to indicate how much they agree with the statement on a spectrum of "strongly disagree", "disagree", "no opinion/not sure", "agree", and "strongly agree". An example of the type of statement on the survey is "Most problems one faces in the real world typically do not have a `correct answer' per se". Other forms of questions were multiple choice or ranking questions where the teacher was required to choose one, many, or all of several different answers given. An example of this kind of question is "What skills do you think make a student good at mathematics? [Rank the three most important choices in order, 1 being the most important.]" and several choices were given. The survey questions for teachers are included in Appendix E.

Participating teachers were observed in the classroom to determine their classroom practices 2-4 times, observing two different classes on a typical day of teaching. Notes were taken by hand in a notebook and only reflected the teacher's actions, routines, and speech and not the work, speech, or actions of any students. The observations attempted to note how teacher beliefs that were found in the surveys and interviews were displayed or not displayed through the teacher's classroom practices.

Participating students took a survey at the beginning of the school year dealing with feelings and beliefs about mathematics, and took the same survey at the end of the semester. Participating students from Teacher C took the initial survey a month into the semester and took the final survey approximately a month later, so the time between the surveys was much shorter

than the other two teachers. The survey included fill in the blank questions, multiple choice

questions, choose all that apply questions, and questions where the students must rank in order of

importance or relevance. The survey was an adaptation of the teachers survey, with some of the

exact same questions, some questions added, some reworded, and some of the questions from the

teachers' survey were not included in the students' survey. The survey questions for students are

included in Appendix F.

Teacher Data

Based on teachers' responses to the interview questions, the survey questions, and on

information found through observing classroom practices, the following descriptions of the

different teachers could be made:

Teacher A

Experience: 18 years teaching high school math at the same school with the exception of

a single 7th grade class.

Degree: Bachelor's degree in Mathematics Education, Master's degree in Masters of

Science for Teaching

School Description: traditional mathematics curriculum including a couple of AP

courses. Students are tracked into three different levels, the lowest of which has an

integrated math program, which is a four-year sequence that covers Algebra I, Geometry,

and Algebra II or a three-year sequence that covers Algebra I and Geometry.

Mathematical Philosophy: Mathematics is a way of making sense of the world and trying

to explain natural phenomena with numbers. Math is useful for its real world applications

(for example, engineering) but also useful in everyday people's lives when applied as

basic life skills. Mathematics is a creative, a science, a language, quantitative and

analytic, and in which technology and computers are occasionally helpful. This teacher

does not have any strong ideas about what pure mathematics is and how it is useful in the

world and has only some knowledge of math history. However, Teacher A believes that

mathematics is useful outside of its applications to real world problems and that pure math is useful to the world. New mathematics is acquired by noticing a pattern and testing and proving conjectures that arise from that pattern. Teacher A believes that mathematics was created in order to make sense of the world, but in a way that fits the rules that already exist in the world.

Mathematical Teaching Philosophy: The thought process is the most important aspect of learning mathematics. The thought process one follows in creating a proof allows one to practice stringing together logical arguments and come up with strategies to solve problems. The most important quality of a good math student is tenacity: the ability to stick with a problem and not give up easily. The most important skill for a good math student is critical thinking because it is important to think deeply about problems in order to understand them thoroughly. Collaboration and discussion are also important in doing mathematics because people interpret and go about problems differently and pick up different ideas. Teacher A would rather have students figure out a formula or show them where a formula comes from than simply tell them what the formula is and how to use it. The most important goal of learning mathematics in the classroom is to develop the ability to use the material learned to solve unfamiliar problems. Students' grades should be based on content knowledge and not effort, however, the more effort a student puts into the class work, the more likely they are to know the content required for the course.

Origin of Beliefs: Many of Teacher A's beliefs about math and about mathematics teaching have remained the same Teacher A's whole life, but Teacher A's ideas about collaboration were developed in college.

Evidence in the Classroom: Teacher A often asked open ended questions to the class, where students would work in groups in an attempt to answer them. Also, the teacher often explained or proved formulas and how they were derived and used reasoning to explain to the class. Teacher A stressed coming up with a strategy before jumping into a problem. Students felt free to ask questions, but sometimes the teacher had students discuss the question among themselves and come up with a reasonable answer. Teacher A also spent the time to solve problems in multiple ways and show equivalent answers and also asked the class questions to clarify areas where they may have made mistakes. Students would work in groups to develop formulas, take notes, and discuss problems, however there were certain tasks where students worked individually. Teacher A also used analogies to help students make sense of the material (pizza and pizza crust to relate area and perimeter of a circle).

Teacher B

Experience: 18 years teaching high school math

Degree: Bachelor's degree in Applied Math, Bachelor's degree in Math Education

School Description: The curriculum is traditional with Algebra I, Geometry, and Algebra II but they have recently added a Pre-Algebra class. AP classes are offered as well as a couple classes through community colleges where students can earn college credit and several math electives. Students are tracked into different leveled classes.

Mathematical Philosophy: Mathematics is a science, a language, a tool, is analytical, and is creative. Much of mathematics is now computerized so technology is useful for the field. Mathematics is a far reaching science that has many applications and has much

more theory that is currently unknown, such as the millennium problems. Pure math and math beyond applications is a useful field of study. New mathematics is acquired by being curious, trying a technique or testing a conjecture, and exploring the consequences, just like every other science. Math is necessary in the world because it is everywhere, including the sciences. Everyone does math, although they may not realize it because it may not look like an algebra question, such as balancing a checkbook or shopping. Mathematics exists and is discovered because a statement is either true or it's not, and it needs to be figured out.

Mathematical Teaching Philosophy: Students should be taught math and how to use it as a tool, but should also be exposed to some of the theory because math can help students make sense of the world. Students doing math at a lower level looks much different from students doing math at a higher level. It is the difference between regurgitating the process and understanding concepts to apply them to new problems. The most important attribute of a good math student is a good attitude: prepared to work, willing to be wrong, and not giving up, because an unwillingness to work hard or be wrong will impede one's willingness to continue when faced with a problem. Working hard, learning from mistakes, and not giving up is what helps students gain more knowledge and know more of the course content overall. The most important skill to gain in a math class is the ability to use the learned material to solve new problems and get the correct answer. Students' grades should be based on content knowledge and not effort. Students are effectively doing math when they are discussing the problem with each other and trying to figure it out, especially when the problem is an open-ended question. It is important to

explore how concepts can be used in realistic situations because many students will not go into a mathematical field.

Origin of Beliefs: Teacher B's beliefs about math have remained the same throughout their life. This teacher believes that this is because mathematical beliefs remain constant and are based on an individual's personality and the way they think.

Evidence in the Classroom: Teacher B showed students the millennium problems in class so they could see what they looked like. The teacher gave explanations and formulas (told, not discovered) when teaching new material, but also showed steps for using calculators and sometimes asked clarifying questions and exploratory questions. The teacher also showed students multiple ways to solve the same problem on the board and connected material to older lessons and real world situations. Students regularly work at the board in pairs and are often allowed to work with neighbors during class. However, sometimes they are required to work on their own.

Teacher C

Experience: 20 years teaching high school math

Degree: Master's degree in Technology in Education

School Description: The curriculum at the school is traditional: Algebra I, Geometry, Algebra II, math electives are offered as well as a couple AP courses. Students are tracked into three different levels of courses.

Mathematical Philosophy: Mathematics is a beautiful, elegant system that is a creative, symbolic way to represent questions we want to answer. It is creative, qualitative,

quantitative, analytical, and is a science, a language, and an art. Mathematics is a game of symbolic manipulation that needs application to areas such as science to give it meaning and drive to find the truth. The field of mathematics is the gateway to higher order thinking, problem solving, and developing strategies involving logic and reasoning, which strengthens the brain, and is also the gateway to its applications, and the strong career choices related to those applications. These mental exercises make us better, healthier, and stronger people. Not all problems are solvable and there are multiple ways to solve a given problem. The symbolic system used in mathematics is created by humans to describe the world, but the mathematics uncovered can be seen in nature and the human body and the world. New math is acquired through practice, studying, and applying knowledge to try to find new theorems, postulates, and rules.

Mathematical Teaching Philosophy: Students are attempting to learn mathematics as a system and learn to apply and manipulate the rules within the system correctly. The most important quality of good math student is perseverance and not giving up until they finally understand. Thus, the most important skill a student can have is a good attitude when approaching a problem so they will push harder and not give up. Retention of facts and automaticity of these facts helps students become less frustrated with a long problem solving for a higher order thinking question. Students should ideally leave a math class having a deep conceptual understanding of the course material. Students are effectively doing math when they are discussing, debating and questioning each other about the problem, working to finish the problem, and rewriting the work in a presentable manner. However, too much collaboration can distract students so they need time by themselves to work on problems. Repetition, practice, awareness, and confidence are important for

students learning new mathematics. There are three stages of learning: the initial learning involving taking notes and listening, practicing and relearning the sections that one did not quite understand or made mistakes in, and applying this knowledge to an unfamiliar situation, which is a stage that not all students get to. Cross-curricular lessons are important, especially with the sciences. In the problem solving process, one must expect failure and learn from it to fix the problem. Students need to be shown counterexamples of their misconceptions to be successful.

Origin of Beliefs: Many of this teacher's beliefs developed from living a military lifestyle as a child and from the influence of teachers that Teacher C had in high school and experiences growing up.

Evidence in the Classroom: Teacher C uses explanations, prior mathematical knowledge, clarifying questions, and memory tricks in their lectures on new topics. Students in one class worked with peers throughout the class on several applied problems relating to bacteria and toxic substances. The teacher relates the problems to real life, such as referencing Hannaford's when discussing unit pricing. Teacher C also spent time asking students how they study and recommended studying in groups. The teacher has a demonstration of how radians work using a string and student volunteer.

Student Data

There were 59 students from Teacher A who participated in the study. All of these students were taking a geometry class. A summary of the data from the surveys is shown below in Figure 1.

Figure 1: Student Data from Teacher A

Survey Question	Initial Student Response (mean on 1-5 scale with 1 being strongly agree and 5 being strongly disagree or a percentage breakdown of student responses)	Final Survey Response (mean on 1-5 scale with 1 being strongly agree and 5 being strongly disagree or a percentage breakdown of student responses)
I like math.	Mean = 2.678 Slightly agree	Mean = 2.508 Slightly agree
I am good at math.	Mean = 2.356 Slightly agree	Mean = 2.356 Slightly agree
Mathematics is_____.	Exciting: 17% Boring: 34% Neither: 49%	Exciting: 15% Boring: 29% Neither: 53%
Mathematics is _____.	Difficult: 25% Easy: 22% Neither: 53%	Difficult: 20% Easy: 19% Neither: 59%
Mathematics is a science.	Mean = 2.356 Slightly agree	Mean = 2.345 Slightly agree
Mathematics is a language.	Mean = 2.085 Agree	Mean = 2.203 Agree
Mathematics is an art.	Mean = 3.203 Neutral	Mean = 3.085 Neutral
There is nothing creative about mathematics; it's just memorizing formulas and things.	Mean = 3.169 Neutral	Mean = 3.153 Neutral
Mathematics is a _____ subject.	Qualitative: 80% Quantitative: 68% Analytical: 58% Other: 3%	Qualitative: 56% Quantitative: 63% Analytical: 53% Other: 5%
The most important thing in determining a student's grade	Mean = 2.271 Slightly agree	Mean = 2.322 Slightly agree

in a math course should be the effort they put in, not necessarily whether or not they always obtained the correct answers.		
Most problems one faces in the real world typically do NOT have a `correct answer' like in textbooks.	Mean = 2.475 Slightly agree	Mean = 2.237 Agree
Mathematicians come about new math by _____.	Inspiration: 32% Collaborating: 56% New perspectives: 90% Technology: 47% Other: 0%	Inspiration: 32% Collaborating: 56% New perspectives: 80% Technology: 36% Other: 5%
Very little new math has been discovered in the past 50 years.	Mean = 3.186 Neutral	Mean = 3.102 Neutral
Most mathematics has already been discovered or created.	Mean = 2.864 Slightly agree	Mean = 2.831 Slightly agree
Math is useful outside of the mathematics classroom, finances, and the sciences.	Mean = 1.983 Agree	Mean = 2.153 Agree
Math is only useful because it can be applied to real world problems.	Mean = 2.746 Slightly agree	Mean = 2.695 Slightly agree
Mathematics is worth learning even if it cannot be directly applied to a real world situation.	Mean = 2.424 Slightly agree	Mean = 2.627 Slightly agree
It is important for students to learn mathematics because _____.	Useful tool: 81% Needed for science: 69% Make sense of world: 47% Required for testing: 61% Other: 0%	Useful tool: 80% Needed for science: 58% Make sense of world: 36% Required for testing: 56% Other: 0%
What skills do you think make a student good at mathematics?	Critical thinking: 95% Neat handwriting: 20% Communication skills: 42% Abstract thinking: 73% Previous studies: 37% Attitude: 41%	Critical thinking: 92% Neat handwriting: 14% Communication skills: 24% Abstract thinking: 69% Previous studies: 47% Attitude: 49%

There were 35 students from Teacher B who participated in the study. These students were taking either calculus or pre-calculus. A summary of the data from the surveys is shown below in Figure 2.

Figure 2: Student Data from Teacher B

Survey Question	Initial Student Response (mean on 1-5 scale with 1 being strongly agree and 5 being strongly disagree or a percentage breakdown of student responses)	Final Survey Response (mean on 1-5 scale with 1 being strongly agree and 5 being strongly disagree or a percentage breakdown of student responses)
I like math.	Mean = 2.257 Slightly agree	Mean = 2.200 Slightly agree
I am good at math.	Mean = 2.000 Slightly agree	Mean = 2.143 Slightly agree
Mathematics is_____.	Exciting: 26% Boring: 6% Neither: 69%	Exciting: 31% Boring: 9% Neither: 60%
Mathematics is _____.	Difficult: 31% Easy: 20% Neither: 49%	Difficult: 34% Easy: 14% Neither: 51%
Mathematics is a science.	Mean = 2.371 Slightly agree	Mean = 2.143 Agree
Mathematics is a language.	Mean = 1.943 Agree	Mean = 1.914 Agree
Mathematics is an art.	Mean = 3.029 Neutral	Mean = 2.829 Neutral
There is nothing creative about mathematics; it's just memorizing formulas and things.	Mean = 3.571 Slightly disagree	Mean = 3.429 Slightly disagree
Mathematics is a _____ subject.	Qualitative: 60% Quantitative: 80% Analytical: 89% Other: 0%	Qualitative: 60% Quantitative: 63% Analytical: 74% Other: 0%
The most important thing in determining a student's grade in a math course should be the effort they put in, not necessarily whether or not they always obtained the correct answers.	Mean = 2.729 Slightly agree	Mean = 2.657 Slightly agree
Most problems one faces in	Mean = 2.400	Mean = 2.457

the real world typically do NOT have a `correct answer' like in textbooks.	Slightly agree	Slightly agree
Mathematicians come about new math by _____.	Inspiration: 37% Collaborating: 57% New perspectives: 86% Technology: 34% Other: 6%	Inspiration: 34% Collaborating: 60% New perspectives: 97% Technology: 37% Other: 3%
Very little new math has been discovered in the past 50 years.	Mean = 3.000 Neutral	Mean = 2.800 Neutral
Most mathematics has already been discovered or created.	Mean = 2.834 Slightly agree	Mean = 2.714 Slightly agree
Math is useful outside of the mathematics classroom, finances, and the sciences.	Mean = 2.071 Agree	Mean = 1.886 Agree
Math is only useful because it can be applied to real world problems.	Mean = 2.886 Slightly agree	Mean = 2.771 Slightly agree
Mathematics is worth learning even if it cannot be directly applied to a real world situation.	Mean = 2.443 Slightly agree	Mean = 2.486 Slightly agree
It is important for students to learn mathematics because _____.	Useful tool: 74% Needed for science: 74% Make sense of world: 40% Required for testing: 57% Other: 6%	Useful tool: 86% Needed for science: 74% Make sense of world: 40% Required for testing: 63% Other: 3%
What skills do you think make a student good at mathematics?	Critical thinking: 91% Neat handwriting: 11% Communication skills: 37% Abstract thinking: 74% Previous studies: 43% Attitude: 43%	Critical thinking: 100% Neat handwriting: 9% Communication skills: 23% Abstract thinking: 69% Previous studies: 51% Attitude: 49%

There were 22 students from Teacher C who participated in the study. These students were taking either pre-calculus or trigonometry. A summary of the data from the surveys is shown below in Figure 3.

Figure 3: Student Data from Teacher C

Survey Question	Initial Student Response (mean on 1-5 scale with 1 being strongly agree and 5 being strongly disagree or a percentage breakdown of student responses)	Final Survey Response (mean on 1-5 scale with 1 being strongly agree and 5 being strongly disagree or a percentage breakdown of student responses)
I like math.	Mean = 2.182 Agree	Mean = 2.091 Agree
I am good at math.	Mean = 2.227 Agree	Mean = 2.045 Agree
Mathematics is_____.	Exciting: 9% Boring: 5% Neither: 86%	Exciting: 9% Boring: 5% Neither: 86%
Mathematics is _____.	Difficult: 36% Easy: 9% Neither: 55%	Difficult: 36% Easy: 23% Neither: 41%
Mathematics is a science.	Mean = 2.364 Slightly agree	Mean = 2.182 Slightly agree
Mathematics is a language.	Mean = 1.955 Agree	Mean = 2.091 Agree
Mathematics is an art.	Mean = 3.045 Neutral	Mean = 3.091 Neutral
There is nothing creative about mathematics; it's just memorizing formulas and things.	Mean = 3.455 Slightly disagree	Mean = 3.500 Slightly disagree
Mathematics is a _____ subject.	Qualitative: 77% Quantitative: 68% Analytical: 82% Other: 0%	Qualitative: 77% Quantitative: 68% Analytical: 82% Other: 0%
The most important thing in determining a student's grade in a math course should be the effort they put in, not necessarily whether or not they always obtained the correct answers.	Mean = 2.341 Slightly agree	Mean = 2.364 Slightly agree
Most problems one faces in the real world typically do NOT have a `correct answer' like in textbooks.	Mean = 2.364 Slightly agree	Mean = 2.455 Slightly agree
Mathematicians come about new math by _____.	Inspiration: 82% Collaborating: 41% New perspectives: 68% Technology: 82%	Inspiration: 36% Collaborating: 64% New perspectives: 68% Technology: 27%

	Other: 32%	Other: 0%
Very little new math has been discovered in the past 50 years.	Mean = 3.545 Slightly disagree	Mean = 3.318 Slightly disagree
Most mathematics has already been discovered or created.	Mean = 3.182 Neutral	Mean = 3.000 Neutral
Math is useful outside of the mathematics classroom, finances, and the sciences.	Mean = 2.000 Agree	Mean = 2.091 Agree
Math is only useful because it can be applied to real world problems.	Mean = 2.818 Neutral	Mean = 2.818 Slightly agree
Mathematics is worth learning even if it cannot be directly applied to a real world situation.	Mean = 2.386 Slightly agree	Mean = 2.591 Slightly agree
It is important for students to learn mathematics because _____.	Useful tool: 82% Needed for science: 50% Make sense of world: 36% Required for testing: 45% Other: 5%	Useful tool: 82% Needed for science: 68% Make sense of world: 18% Required for testing: 45% Other: 0%
What skills do you think make a student good at mathematics?	Critical thinking: 95% Neat handwriting: 5% Communication skills: 14% Abstract thinking: 82% Previous studies: 45% Attitude: 64%	Critical thinking: 100% Neat handwriting: 5% Communication skills: 14% Abstract thinking: 73% Previous studies: 55% Attitude: 50%

General Findings and Analysis

In order to compare one set of quantitative student data from the survey to both the other set of quantitative student data and the quantitative teacher data, both sets of student data were converted to differences between the student and teacher answers to survey questions. For each question on the survey with numerical data, the numerical value of the teacher's response was subtracted from the numerical value of each student's response in both the initial and final survey. Then, to compare the data from the student surveys to each other, a t-test was performed to determine whether there was a significant change in student responses from the initial to the final survey.

Ten of the questions on the survey were key questions that could be measured quantitatively (Questions 7, 8, 9, 10, 14, 15, 17, 18, 19, and 20 in Appendix G). For the students of Teacher A, only one of those questions was answered significantly different by students between the initial survey and the final survey. The question required students to rate on a scale of 1 to 5 how much they agreed or disagreed with the following statement: Most problems one faces in the real world typically do NOT have a 'correct answer' like in textbooks. In the initial survey, the mean of the student answers was 2.475, indicating that they somewhat agreed with the statement. In the final survey, the mean of the student answers was 2.237, indicating that they mostly agreed with the statement. However, Teacher A answered neutral on this question, so overall students answers were not more closely aligned with the teacher's after having Teacher A for a semester. Below is the distribution of data for that question, with Figure 4 showing the initial survey and Figure 5 showing the final survey.
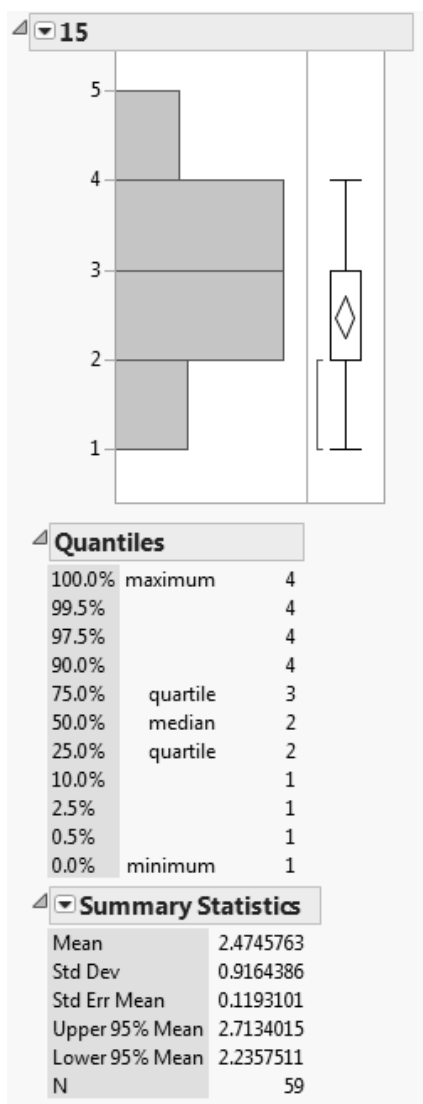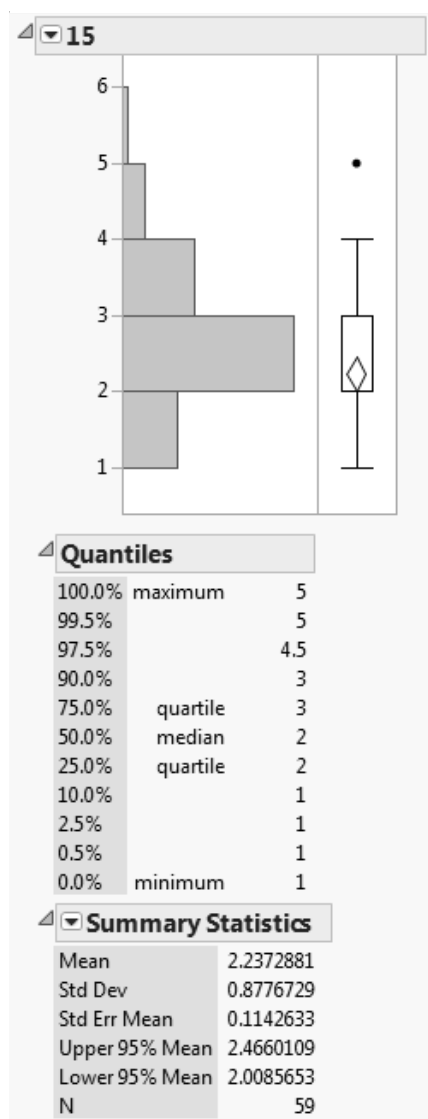
Figure 4: Teacher A Distribution Survey 1

Figure 5: Teacher A Distribution Survey 2

15

Quantiles		
100.0%	maximum	4
99.5%		4
97.5%		4
90.0%		4
75.0%	quartile	3
50.0%	median	2
25.0%	quartile	2
10.0%		1
2.5%		1
0.5%		1
0.0%	minimum	1

Summary Statistics	
Mean	2.4745763
Std Dev	0.9164386
Std Err Mean	0.1193101
Upper 95% Mean	2.7134015
Lower 95% Mean	2.2357511
N	59

15

Quantiles		
100.0%	maximum	5
99.5%		5
97.5%		4.5
90.0%		3
75.0%	quartile	3
50.0%	median	2
25.0%	quartile	2
10.0%		1
2.5%		1
0.5%		1
0.0%	minimum	1

Summary Statistics	
Mean	2.2372881
Std Dev	0.8776729
Std Err Mean	0.1142633
Upper 95% Mean	2.4660109
Lower 95% Mean	2.0085653
N	59

When looking at the data for the students of teacher B, there was only one question that was answered significantly different by students from the initial survey to the final survey. The question required students to rate on a scale of 1 to 5 how much they agreed or disagreed with the following statement: mathematics is a science. In the initial survey, the mean of the student answers was 2.371, indicating that students agreed somewhat with the statement. In the final

survey, the mean of the student answers was 2.143, indicating that students mostly agreed with the statement. On this question Teacher B strongly agreed with the statement, so this data indicates that the influence of being taught mathematics by Teacher B did affect student beliefs about whether mathematics is also a science. Below is the distribution of data for that question, with Figure 6 showing the initial survey and Figure 7 showing the final survey.

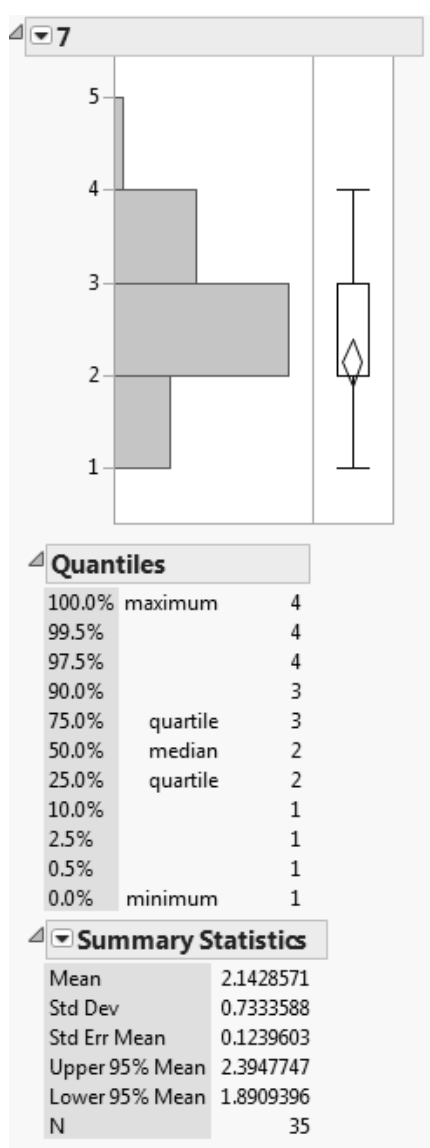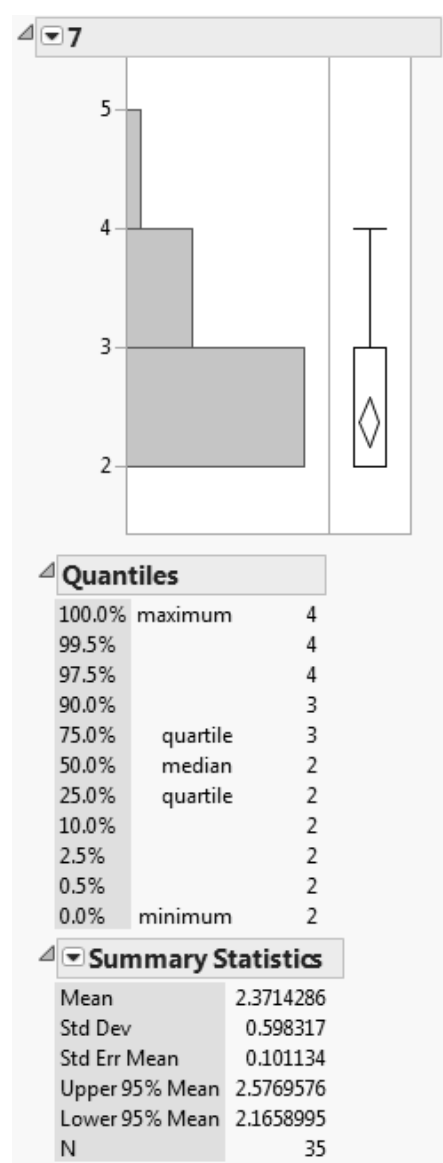Figure 6: Teacher B Distribution Survey 1

Quantiles		
100.0% maximum		4
99.5%		4
97.5%		4
90.0%		3
75.0%	quartile	3
50.0%	median	2
25.0%	quartile	2
10.0%		1
2.5%		1
0.5%		1
0.0%	minimum	1

Summary Statistics	
Mean	2.1428571
Std Dev	0.7333588
Std Err Mean	0.1239603
Upper 95% Mean	2.3947747
Lower 95% Mean	1.8909396
N	35

Figure 7: Teacher B Distribution Survey 2

Quantiles		
100.0% maximum		4
99.5%		4
97.5%		4
90.0%		3
75.0%	quartile	3
50.0%	median	2
25.0%	quartile	2
10.0%		2
2.5%		2
0.5%		2
0.0%	minimum	2

Summary Statistics	
Mean	2.3714286
Std Dev	0.598317
Std Err Mean	0.101134
Upper 95% Mean	2.5769576
Lower 95% Mean	2.1658995
N	35

For all ten key survey questions that were evaluated quantitatively, none of the student answers to the initial surveys were significantly different from the answers to the final surveys for the students of Teacher C. Thus being taught mathematics by Teacher C did not affect the mathematical beliefs of students in the areas covered by those ten key questions in the survey.

Below is a sample of the data from question 20 on the student survey listed in Appendix G. These charts are given in terms of differences: the student's answer on the survey minus the teachers answer on the survey. Note that the number of students who agree with the teacher, indicated by the bar labeled "0" is smaller in the final survey results than in the initial survey results. Teacher A answered with a 4 (disagree), Teacher B answered with a 4 (disagree), and Teacher C answered with a 4 (disagree).
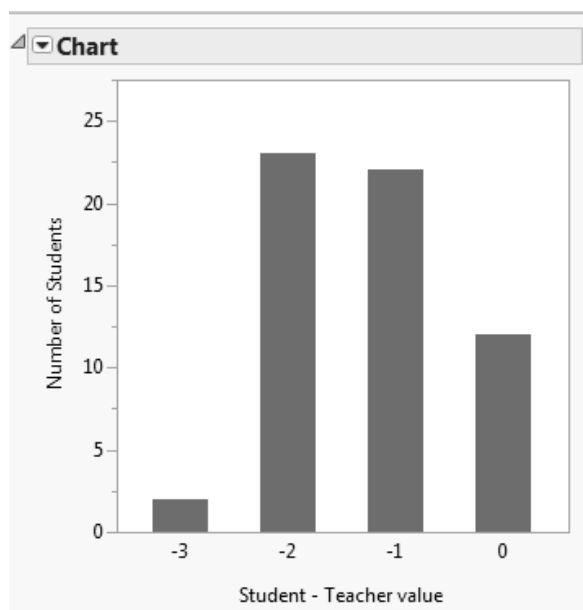
Figure 8: Teacher A Survey 1

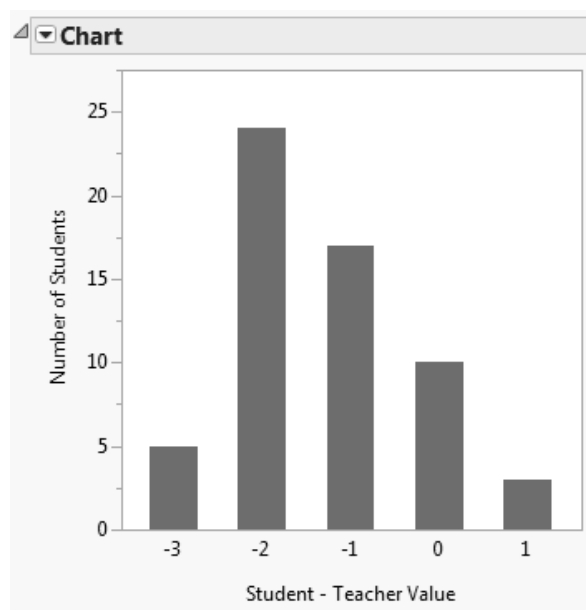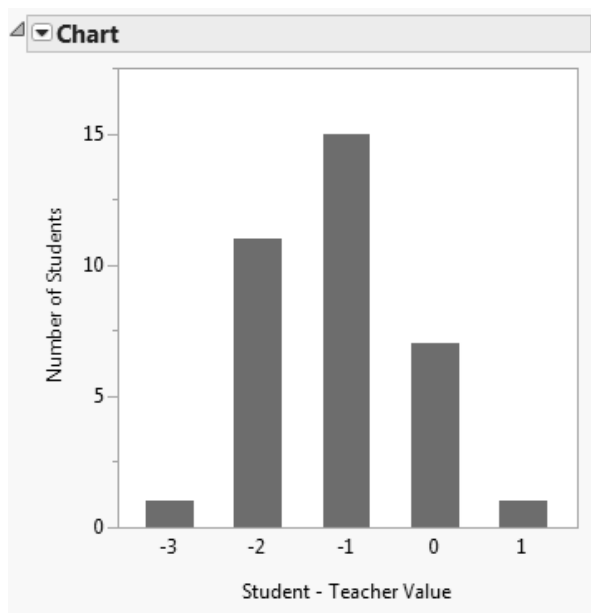Figure 9: Teacher A Survey 2

Figure 10: Teacher B Survey 1

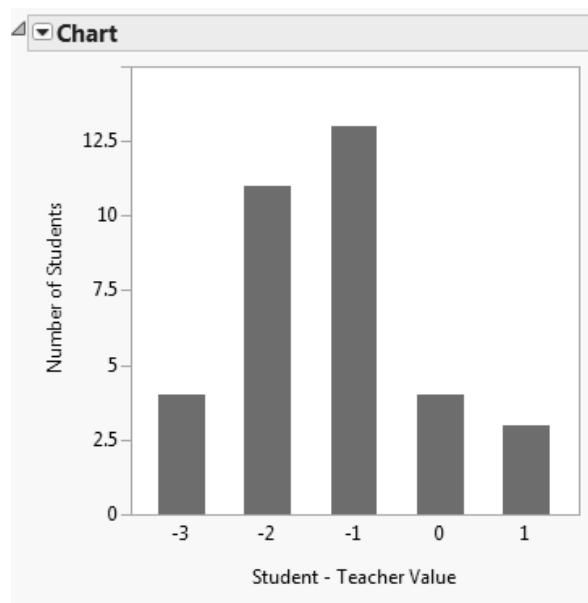Figure 11: Teacher B Survey 2
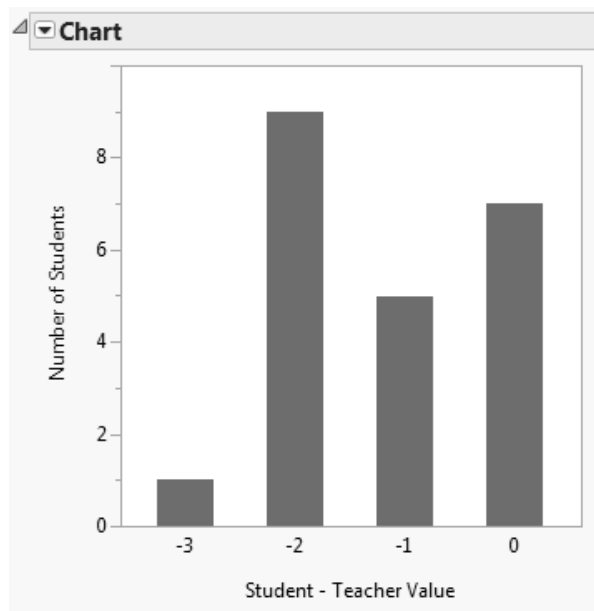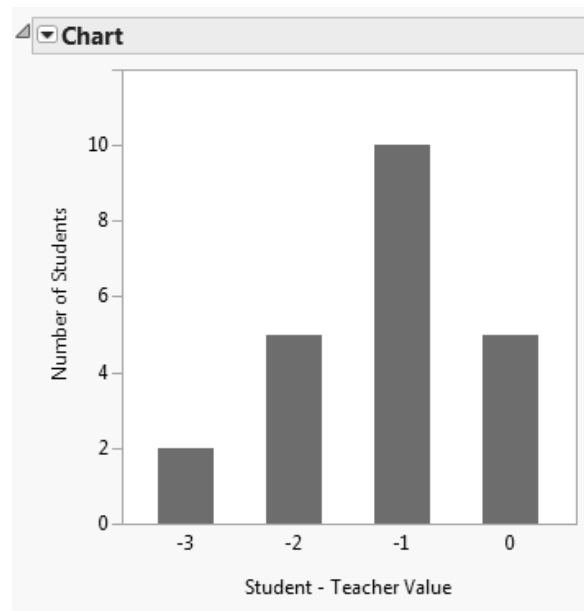

Figure 12: Teacher C Survey 1

Figure 13: Teacher C Survey 2

There are several important limitations to this study. The sample of both teachers and schools was very small. The teachers and schools that participated were also not chosen in a random manner. Thus the sample of teachers is not representative of all teachers and the sample of schools is not representative of all schools. Also, due to the fact that the students who were participating needed parental consent, the sample of students was also not a random sample. Therefore, the students are not representative of the general population of students. For these reasons, the findings of this study are not suitable to be generalized to the population of schools, teachers, or students.

Another limitation to the study is that the surveys may not have completely captured students' beliefs. Due to the fact that participation would have drastically diminished if student interviews were required because parental consent was needed, the research did not involve any conversations or follow ups with the students. Thus, it is unclear how accurate the surveys were in capturing students' mathematical beliefs. Also, it was clear from student comments that in some specific instances, students did not truly understand the question that was being posed.

Yet another possibility is that high school students may not be old enough to truly understand ideas as abstract as mathematical beliefs. In human development, the ability to think abstractly is one of the latest stages and occurs in the late teens to early adulthood. It may be that there is a significant effect on students' beliefs, but that the change occurs only after students' have reached and appropriate level of abstract thinking ability. Or it may be that since beliefs can be difficult to change, a longer time period of study than a semester is needed to capture the change. It could be that changes in mathematical beliefs are a slow change that occurs over several years.

Conclusions

Based on the data from this research project, there is no indication from this study that what teachers believe about mathematics affects what students believe about mathematics. Of the few pieces of data that support the hypothesis, there are many more that contradict the hypothesis that teacher beliefs affect student beliefs. However, it is important to note that since this study consisted of schools, teachers, and students that were not representative samples of their populations, and because there was such a small sample size of teachers and schools, the results of this study should not be generalized.

Possible reasons for the outcome of this study are that teachers generally do not actively think about their mathematical beliefs when creating lesson plans and when teaching, so if their beliefs emerge in their classroom practices, they do so in more subtle ways which students may or may not consciously notice. Thus, it would seem that students are not affected by teachers' mathematical beliefs. It is also important to point out that many teachers do not often think about their own mathematical beliefs, except when needed in the occasional educational scenario. This thinking about beliefs in only specific contexts means that teachers often do not have clearly defined beliefs about mathematics, which can sometimes lead to contradictions within their own beliefs. These contradictions would likely be displayed in their classroom practices, and if student are influenced by teacher beliefs, students would receive mixed messages which complicates the formation and change of mathematical beliefs in students. Thus, this scenario

may also give the impression that teachers' mathematical beliefs do not affect students' mathematical beliefs.

For further research on this topic, insight from this research project points to obtaining as random and as representative sample as possible. It would also be beneficial to obtain a larger sample size of schools and teachers. Interviews and observations were very effective in determining teacher beliefs, so it is advised that student are also interviewed about their mathematical beliefs. It is helpful to use surveys as preliminaries to determine more pointed questions to ask during the interview process but they should not be considered the most accurate indicator of one's mathematical beliefs. However, the surveys used in this study can also be improved upon. It was clear from some of the student comments on the surveys that they did not fully grasp what the question was asking. So some of the questions may need to be explained more fully or another way to determine an aspect of one's beliefs must be devised, such as using anecdotal situations and asking what should be done and examining a students' reasoning. Thus, it may also be useful to have short answer questions for students to explain their thinking more.

Due to the inconclusive nature of this study, it is recommended that more research be done in the area, and that this study be used to guide further research to more successful methods of capturing student and teacher beliefs. With improved data collection methods, it is likely possible that a relationship between teacher and student mathematical beliefs, or lack of, can be determined in a measurable and scientific manner.

References

Lester, Frank K.. *Second Handbook of Research on Mathematics Teaching and Learning: a project of the National Council of Teachers of Mathematics.* Charlotte, NC: Information Age Publishing, 2007. Print.

Appendix A: Informed Consent Form for Teachers

UNIVERSITY *of* NEW HAMPSHIRE

INFORMED CONSENT LETTER FOR ADULT PARTICIPANTS

Date: April 18, 2013

Dear Participant:

I am a student in the mathematics department at UNH and I am conducting a research project to find out how teacher beliefs about mathematics affect their teaching practices. I am writing to invite you to participate in this project. I plan to work with approximately 8 teachers in this study.

If you agree to participate in this study, you will be asked to fill out a survey and participate in an interview about your mathematical beliefs, and allow the researchers to observe several of your math classes. The expected time commitment is at most an hour and a half for the survey and the interview and three to six hours of classroom observation. Please note that the interviews will be audio recorded for efficiency which may later be transcribed and used in a qualitative analysis of data in the study. You will not receive any compensation to participate in this project.

There are no significant risks anticipated for participating in this study. Although you are not anticipated to receive any direct benefits from participating in this study, the benefits of the knowledge gained are expected to be insight into your own mathematical beliefs and how they affect the way you teach the class, which may lead to practices that they are more aligned with your own mathematical beliefs.

Participation in this study is strictly voluntary; your refusal to participate will involve no prejudice, penalty, or loss of benefits to which you would otherwise be entitled. If you agree to participate, you may refuse to answer any question and/or if you change your mind, you may withdraw at any time during the study without penalty.

I seek to maintain the confidentiality of all data and records associated with your participation in this research. There are, however, rare instances when I am required to share personally-identifiable information (e.g., according to policy, contract, regulation). For example, in response to a complaint about the research, officials at the University of New Hampshire, designees of the sponsor(s), and/or regulatory and oversight government agencies may access research data. Further, any communication via the Internet poses minimal risk of a breach of confidentiality. I will keep physical data in a locked file cabinet in my home office and I will keep audio data and transcriptions of audio data in a password-protected computer; only I and my faculty advisor, Dr. Fukawa-Connelly, will have access to the data. I will report the data using pseudonyms. The results will be used in reports and presentations.

If you have any questions about this research project or would like more information before, during, or after the study, you may contact Kelly Smith, (603) 489-7125, kna25@wildcats.unh.edu. If you have questions about your rights as a research subject, you

may contact Dr. Julie Simpson in UNH Research Integrity Services at 603-862-2003 or Julie.simpson@unh.edu to discuss them.

I have enclosed two copies of this letter. Please sign one indicating your choice and return in the enclosed envelope. The other copy is for your records. Thank you for your consideration.

Sincerely,

Kelly Smith
UNH Undergraduate Student

Yes, I, _____consent/agree to participate in this research project.

No, I, _____do not consent/agree to participate in this research project.

_____   _____
Signature   Date

Appendix B: Use of Data Consent Form for Teachers

UNIVERSITY *of* NEW HAMPSHIRE

INFORMED CONSENT LETTER FOR TEACHERS

Date: 7/3/13

Dear Teacher,

I am a student in the mathematics department at UNH and I am conducting a research project to find out how teachers' beliefs about mathematics affect student beliefs about mathematics. As you have participated in my last study about how teacher's beliefs about mathematics affect their classroom practices, I would like to ask you for consent to use the data from that study in the research project mentioned above.

Your data will be compared with that of your students who are participating in my current study. There are no significant risks anticipated for using your data in this study. Although you are not anticipated to receive any direct benefits from participating in this study, the mathematics education community will benefit from awareness regarding how teacher beliefs affect student beliefs about mathematics.

Participation in this study is strictly voluntary; your refusal to participate will involve no prejudice, penalty, or loss of benefits to which you would otherwise be entitled.

I seek to maintain the confidentiality of all data and records associated with your participation in this research. I will keep data in a locked file cabinet in my office; only I and my faculty advisor, Dr. Sharon McCrone, will have access to the data. I will report the data in aggregate and pseudonyms will be used to maintain confidentiality of the teachers. The results will be used in reports and presentations.

If you have any questions about this research project or would like more information before, during, or after the study, you may contact Kelly Smith, (603) 489-7125, kna25@wildcats.unh.edu. If you have questions about your rights as a research subject, you may contact Dr. Julie Simpson in UNH Research Integrity Services at 603-862-2003 or Julie.simpson@unh.edu to discuss them.

I have enclosed two copies of this letter. Please sign one indicating your choice and return in the enclosed envelope. The other copy is for your records. Thank you for your consideration.

Sincerely,

Kelly Smith
UNH Undergraduate Student

Yes, I, _____consent/agree to allow my data from "How Teacher's beliefs about Mathematics Affect their Classroom Practices" to be used in this research project.

No, I, _____do not consent/agree to allow my data from "How Teacher's beliefs about Mathematics Affect their Classroom Practices" to be used in this research project.

_____   _____
Signature   Date

Appendix C: Informed Consent Form for Students

UNIVERSITY *of* NEW HAMPSHIRE

INFORMED CONSENT LETTER FOR PARTICIPANTS

Date: 7/3/13

Dear Student,

I am a student in the mathematics department at UNH and I am conducting a research project to find out how teachers' beliefs about mathematics affect student beliefs about mathematics. I am writing to invite you to participate in this project. I plan to work with approximately 100 students in this study.

If you agree to participate in this study, you will be asked to take two surveys, one at the beginning of the school year and one at the end of the semester, before holiday break in December. Each of the surveys is expected to take approximately 20 minutes. Students who do not participate in the study will do work assigned by the teacher while their peers complete the survey. You will not receive any compensation to participate in this project.

There are no significant risks anticipated for participating in this study. Although you are not anticipated to receive any direct benefits from participating in this study, the benefits of the knowledge gained are expected to be insight into your own beliefs and awareness in the mathematics education community regarding how teacher beliefs affect student beliefs about mathematics.

Participation in this study is strictly voluntary; your refusal to participate will involve no prejudice, penalty, or loss of benefits to which you would otherwise be entitled. If you agree to participate, you may refuse to answer any question and/or if you change your mind, you may withdraw at any time during the study without penalty. Refusal to participate or withdrawal will not impact your grade in the class nor class standing.

I seek to maintain the confidentiality of all data and records associated with your participation in this research. I will keep data in a locked file cabinet in my office; only I and my faculty advisor, Dr. Sharon McCrone, will have access to the data. I will report the data in aggregate. The results will be used in reports and presentations.

If you have any questions about this research project or would like more information before, during, or after the study, you may contact Kelly Smith, (603) 489-7125, kna25@wildcats.unh.edu. If you have questions about your rights as a research subject, you may contact Dr. Julie Simpson in UNH Research Integrity Services at 603-862-2003 or Julie.simpson@unh.edu to discuss them.

I have enclosed two copies of this letter. Please sign one indicating your choice and return to your teacher. The other copy is for your records. Thank you for your consideration.

Sincerely,

Kelly Smith
UNH Undergraduate Student

Yes, I, _____consent/agree to participate in this research project.

No, I, _____do not consent/agree to participate in this research project.

_____   _____
Signature   Date

Appendix D: Informed Consent Form for Parents

UNIVERSITY *of* NEW HAMPSHIRE

INFORMED PARENTAL CONSENT LETTER

Date: 7/3/13

Dear Parent,

I am a student in the mathematics department at UNH and I am conducting a research project to find out how teachers' beliefs about mathematics affect student beliefs about mathematics. I am writing to invite your child to participate in this project. I plan to work with approximately 100 children in this study.

If you allow your child to participate in this study, your child will be asked to take two surveys, one at the beginning of the year and one at the end of the semester, before holiday break in December. Each of these surveys is expected to take approximately 20 minutes. Students who do not participate in the study will do work assigned by the teacher while their peers complete the survey. Neither you nor your child will receive any compensation to participate in this project.

There are no significant risks anticipated for your child by participating in this study. Although your child is not expected to receive any direct benefits from participating in this study, the benefits of the knowledge gained are expected to be insight into their own beliefs and awareness in the mathematics education community regarding how teacher beliefs affect student beliefs about mathematics.

Participation is strictly voluntary; your refusal to allow your child to participate will involve no prejudice, penalty, or loss of benefits to which you or your child would otherwise be entitled. Your child may refuse to answer any question. If you allow your child to participate in this project and your child wants to, and then either you change your mind or your child changes his/her mind, you may withdraw your child, or your child may withdraw, at any time during the study without penalty. Refusal to participate or withdrawal will not impact your child's grade in the class nor class standing.

I seek to maintain the confidentiality of all data and records associated with your child's participation in this research. I will keep data in a locked file cabinet in my office; only I and my faculty advisor, Dr. Sharon McCrone, will have access to the data. I will report the data in aggregate. The results will be used in reports and presentations.

If you have any questions about this research project or would like more information before, during, or after the study, you may contact Kelly Smith, (603) 489-7125, kna25@wildcats.unh.edu. If you have questions about your child's rights as a research subject, you may contact Dr. Julie Simpson in UNH Research Integrity Services at 603-862-2003 or Julie.simpson@unh.edu to discuss them.

I have enclosed two copies of this letter. Please sign one indicating your choice and return to your child's teacher. The other copy is for your records. Thank you for your consideration.

Sincerely,

Kelly Smith
UNH Undergraduate Student

Yes, I, _____consent/allow my child _____ to participate in this research project.

No, I, _____do not consent/allow my child _____ to participate in this research project.

_____   _____
Signature of Parent   Date

Appendix E: Teacher Interview Questions

Research Interview Questions

- How long have you been teaching high school mathematics? Have you taught mathematics at any other age level?

- What degree of higher education have you acquired and in what field?

- What is the mathematics curriculum at your school like?

- Did the mathematics curriculum at your school affect why you took a job there?

- What is your mathematical philosophy?

- What qualities does a good mathematics student have?

- What does it looks like when students are effectively doing mathematics?

- How would you describe the field of mathematics?

- What does it mean for a mathematician to do mathematics? How does that differ from a student?

- How is new mathematics acquired?

- Is mathematics a solitary or collaborative activity?

- How is mathematics useful to the world? To individuals?

- Is math meaningful to individuals? How can it be meaningful to individuals?

- Can math be useful or meaningful outside of the sciences?

- Is mathematics something that already exists and is discovered? Is mathematics created? Is it some combination of the two or neither?

- Do you think any of these beliefs about mathematics affect your classroom practices? How?

Appendix F: Mathematics Beliefs Survey for Teachers

Mathematics Attitude and Beliefs Survey

The purpose of this survey is to determine the participant's beliefs about mathematics. Please include any additional comments (where applicable) that you think would be of value.
• Please answer all questions.
• Please circle the answer(s) most appropriate for you.
• Some questions require you to numerically rank the options in the blank spaces provided.
• When prompted for written explanations, please write clearly and legibly.

1. Mathematics is a science. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

2. Mathematics is a language (e.g., a set of tools to express scientific ideas). [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

3. Mathematics is an art. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

4. There is nothing creative about mathematics; it's just memorizing formulas and things. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

5. Mathematics is _____. [Choose one]
(a) Discovered
(b) Created
(c) Other (explain)

6. A high school mathematics curriculum should cover a wide range of topics so to broadly expose one to different areas/approaches. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

7. A high school mathematics course should focus on a core set of principles so to really understand those ideas deeply. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

8. What skills do you think make a student good at mathematics? [Rank the three most important choices in order, 1 being the most important.]
____ Critical thinking
____ Being a neat writer
____ Effective communication skills (verbal and written)
____ Ability to think abstractly
____ Previous studies (e.g., having taken numerous courses)
____ Attitude
Please provide rationale for your top choice:

9. Calculators and computers are _____ for solving math problems. [Choose one]
(a) Essential
(b) Useful
(c) Occasionally helpful
(d) Useless
Please explain briefly:

10. Mathematics is a _____ subject. [Choose all that apply]
(a) Qualitative
(b) Quantitative
(c) Analytical
(d) Other (explain):

11. Rank the following in terms of their relative importance for establishing a grade a student should receive in a mathematics course: [1 to 4, 1 being the most important and 4 the least]

_____ Getting the correct answers on homework/exams
_____ Having a deep conceptual understanding of the course material
_____ Being able to use the material to solve problems not seen in class
_____ Amount of time spent on the course (e.g., studying)

Please provide rationale for your top choice:

12. The most important thing in determining a student's grade in a math course should be the effort they put in, not necessarily whether or not they always obtained the correct answers.
[Choose one]
 (a) Strongly agree
 (b) Agree
 (c) Neutral
 (d) Disagree
 (e) Strongly disagree

13. Most problems one faces in the real world typically do not have a `correct answer' per se.
[Choose one]
 (a) Strongly agree
 (b) Agree
 (c) Neutral
 (d) Disagree
 (e) Strongly disagree
Please explain briefly:

14. Mathematicians come about new mathematics by _____. [Choose all that apply]
(a) Having a moment of inspiration
(b) Collaborating with other mathematicians
(c) Approaching problems from a different perspective
(d) Using new technology
(e) Other (explain):

15. Successful mathematicians are _____. [Rank these in order of agreement with 1 being the statement you most agree with and 3 being the least]
___Geniuses
___Intelligent mathematicians who collaborate with others
___Young
Please provide rational for your top choice:

16. Very little new mathematics had been discovered in the past 50 years. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

17. Most mathematics has already been discovered or created. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

18. Math is useful outside of the mathematics classroom, finances, and the sciences. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree
Explain:

19. Math is only useful because it can be applied to real world problems. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

20. Pure mathematics is a useful discipline. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

21. It is important for students to learn mathematics because _____. [Choose all that apply.]
(a) It is a tool that everyone can use in their life
(b) It is necessary for technology, engineering, and the sciences
(c) It can help them make sense of the world
(d) It is a required topic on state and national tests and college entrance exams
(e) Other (explain):
Some Questions from or adapted from http://www.asmcue.org/documents/Bergevin.AttitudeQuestionnaire.pdf.

Appendix G: Mathematics Beliefs Survey for Students

Mathematics Attitude and Beliefs Survey   Name: _____

The purpose of this survey is to determine the participant's beliefs about mathematics. Please include any additional comments (where applicable) that you think would be of value.
• Please answer all questions.
• Please **circle** the answer(s) most appropriate for you.
• Some questions require you to numerically rank the options in the blank spaces provided.
• When prompted for written explanations, please write clearly and legibly.

1. What is your math teacher's name?

2. Have you had this teacher before for a math class? [Choose one]
(a) Yes
(b) No

3. I like math. [Choose one]
(a) Strongly agree
(b) Somewhat agree
(c) Neutral
(d) Somewhat disagree
(e) Strongly disagree

4. I am good at math. [Choose one]
(a) Strongly agree
(b) Somewhat agree
(c) Neutral
(d) Somewhat disagree
(e) Strongly disagree

5. Mathematics is _____. [Choose one]
(a) Exciting
(b) Boring
(c) Neither

6. Mathematics is _____. [Choose one]
(a) Difficult
(b) Easy
(c) Neither

7. Mathematics is a science. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

8. Mathematics is a language (a set of tools to express scientific ideas). [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

9. Mathematics is an art. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

10. There is nothing creative about mathematics; it's just memorizing formulas and things. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

11. It is better to know a little bit about a lot of different math topics than to know a few math topics really well. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

12. Calculators and computers are _____ for solving math problems. [Choose one]
(a) Essential
(b) Useful
(c) Occasionally helpful
(d) Useless

13. Mathematics is a _____ subject. [Choose ALL that apply]
(a) Qualitative: dealing with the characteristics, properties, or the nature of different concepts
(b) Quantitative: describing or measuring quantities
(c) Analytical: describing and investigating using logical reasoning
(d) Other (explain):

14. The most important thing in determining a student's grade in a math course should be the effort they put in, not necessarily whether or not they always obtained the correct answers. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

15. Most problems one faces in the real world typically do NOT have a `correct answer' like in textbooks. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

16. Mathematicians come about new math by _____. [Choose ALL that apply]
(a) Having a moment of inspiration
(b) Collaborating with other mathematicians
(c) Approaching problems from a different perspective
(d) Using new technology
(e) Other (explain):

17. Very little new math has been discovered in the past 50 years. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

18. Most mathematics has already been discovered or created. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

19. Math is useful outside of the mathematics classroom, finances, and the sciences. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

20. Math is only useful because it can be applied to real world problems. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

21. Mathematics is worth learning even if it cannot be directly applied to a real world situation. [Choose one]
(a) Strongly agree
(b) Agree
(c) Neutral
(d) Disagree
(e) Strongly disagree

22. It is important for students to learn mathematics because _____. [Choose ALL that apply.]
(a) It is a tool that everyone can use in their life
(b) It is necessary for technology, engineering, and the sciences
(c) It can help them make sense of the world
(d) It is a required topic on state and national tests and college entrance exams
(e) Other (explain):

23. What skills do you think make a student good at mathematics? [Rank the THREE most important choices in order, 1 being the most important.]

____ Critical thinking

____ Being a neat writer

____ Effective communication skills (verbal and written)

____ Ability to think abstractly

____ Previous studies (e.g., having taken numerous courses)

____ Attitude

Please provide rationale for your top choice:

24. Rank the following in terms of their relative importance for establishing a grade a student should receive in a mathematics course: [1 to 4, 1 being the most important and 4 the least]

____ Getting the correct answers on homework/exams

____ Having a deep conceptual understanding of the course material

____ Being able to use the material to solve problems not seen in class

____ Amount of time spent on the course (e.g., studying)

Please provide rationale for your top choice:

25. When confronted with a mathematical problem I do not know how to solve, the first thing I would likely do is: [Rank the THREE most relevant in order, 1 being the most relevant]

____ Verify I know what the question is asking for

____ Attempt to write down all the known and unknown quantities

____ Try to find information that can help lead to answer (e.g., Google, a textbook, notes)

____ Ask someone for help

____ Give up or skip it

____ Guess an answer that sounds reasonable

____ Try to think of similar problems that I already know the answer to

____ Draw a picture or diagram

Please provide rationale for your top choice:

Some Questions from or adapted from http://www.asmcue.org/documents/Bergevin.AttitudeQuestionnaire.pdf.