An Investigation into the Effect of Educational Background and Math Anxiety on Teacher Candidates' Pedagogical Beliefs

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Abstract

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Theodore Simantirakis

This paper examines the potential effects of educational background and math anxiety on Teacher Candidates' (TCs') pedagogical beliefs. To investigate this relationship, I conducted a mixed-methods study. Twenty-five TCs were given a quantitative survey consisting of Likert scales to measure their math anxiety levels and their pedagogical beliefs concerning constructivism and traditionalism and an additional question inquiring about their educational experience with mathematics. Six TCs were then selected for follow-up semi-structured interviews. The data were analysed using Values Coding and Focused Coding. The findings suggest that TCs draw upon personal experience when justifying beliefs, adopt flexible approaches to pedagogy, value the highly disputed Theory of Learning styles, and demonstrate that math anxiety is a motivator for constructivist beliefs. This research helps fill a gap in the literature about how educational background and math anxiety affect TCs' pedagogical beliefs and provides further insight into how TCs' beliefs are formed.

Keywords: math anxiety, beliefs, teacher candidates, pre-service teachers, educational background, mathematics, constructivism, teacher preparation programs, mathematics education

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Introduction

In this thesis, I examine the relationships between educational background, math anxiety, and Teacher Candidates' (TCs') pedagogical beliefs about how mathematics should be taught. My thesis focuses on how TCs' pedagogical beliefs are affected by their math anxiety and educational background (e.g., if the TC has a minor or major in mathematics, a graduate degree, etc.). In particular, I hope to answer the following research questions:

1) How do Teacher Candidates' educational experiences impact their pedagogical beliefs about teaching mathematics?
2) How does Teacher Candidates' math anxiety impact their pedagogical beliefs about teaching mathematics?

This research is significant for educational reform, teachers' beliefs, and for teacher preparation programs.

I have chosen these research questions because I am interested in the topic of mathematics reform and because there is a gap in the literature around the impact of educational background and math anxiety on pedagogical beliefs. Being a mathematics teacher, I have witnessed the ways in which the traditional approach to teaching mathematics has failed students and left them with severe anxiety about mathematics and a lack of conceptual understanding. Education should leave students feeling empowered and knowledgeable, not confused and helpless. As such, I am a firm believer in the importance of reforming how mathematics is taught in our education system.

Teacher preparation programs are a major influence in teachers' pedagogy and findings that demonstrate differences between TCs' pedagogical beliefs based on their educational background would better enable these programs to meet TCs' needs. Such findings could help universities to adapt to the unique educational experience of TCs in order to properly foster constructivist beliefs. This research also attempts to help fill a gap in the current body of research as there are few studies examining how educational background affect Teacher Candidates' pedagogical beliefs and what role math anxiety plays. As such, this research offers further insight into how teachers' beliefs are formed and opens further potential avenues of research.

In 1989, the National Council of Teachers of Mathematics (NCTM) released the *Curriculum and Evaluation Standards for School Mathematics* (commonly referred to as the *Standards*). The release of the *Standards* marked the beginning of what has since been called "reform mathematics" and sparked a decades long debate between proponents of reform and traditional mathematics instruction (Schoenfeld, 2004). Reform mathematics is an educational movement which aims to disrupt the traditional way that mathematics is taught by placing more "emphasis on the need for engaging students of all ages in meaningful problem-solving activities" and urging "that problems which are suitable for collective investigation also be included" in mathematics education (Klein, 1992, p. 337). As such, reform mathematics is focused on "promoting deep conceptual understanding via *problem-solving*" and argues that mathematics knowledge "is centered in the community of learners, not in the authority of the text or teachers" (Gill & Boote, 2012, pp. 2-3). Conceptual understanding in this case refers to the attainment of an expertlike fluency with the conceptual structure of a domain. This level of understanding allows learners to think generatively within that content area, enabling them to select appropriate procedures for each step when solving new problems, make predictions about the structure of solutions, and construct new understandings and problem-solving strategies (Richland et al., 2012, p. 190).

Conceptual understanding often stands in contrast to procedural understanding, which is students' understanding of how to perform procedures correctly. As such, procedural understanding (which is often the focus of traditionalist practices of math) is often viewed as a shallower understanding of mathematics. Richland et al. (2012) continue on to say that "By asking students to remember procedures but not to understand when or why to use them or link them to core mathematical concepts, we may be leading our students away from the ability to use mathematics in future careers" (p. 190). Fostering students' conceptual understanding is therefore seen as an important part of reform mathematics.

This reform mathematics movement was strongly influenced by constructivist philosophy which "recognizes that knowing is active, that it is individual and personal, and that it is based on previously constructed knowledge" (Ernest, 2006, p. 1). Constructivism is an umbrella term which encompasses a number of different philosophies which each have their own focus. In its broadest sense, however, constructivism is an educational theory which argues that "individuals construct their knowledge by engaging in new activities and fitting them into prior knowledge and experiences" (Holm & Kajander, 2019, p. 31). A key principle of constructivist philosophies is that “knowledge is not passively received but actively built up by the cognizing subject” (Ernest, 2006, p. 1). As a result of this principle, constructivist-based mathematics lessons are centered around “student thinking and active learning, are problem-centered and intensely interactive, and highlight communication, reasoning, and conceptual understanding” (Alsup, 2004, p. 3). Constructivism thus represents a departure from the traditional view of learning as it seeks to make learners more active participants in their education through the use of dialogue and problem-solving while the traditional view sees learning as a passive activity in which a central authority (e.g., the teacher in the classroom) transmits facts and procedures for the learner to memorize and repeat for assessment (Ernest, 2006). Traditional mathematics education is thus more procedurally and individually oriented than constructivist mathematics education, which is more conceptually and socially oriented.

The *Standards* was the result of major breakthroughs in research in the 1970s and 1980s that produced new understandings of learning. While the traditional view is that mathematical competence is the result of what someone knows (i.e., the facts and procedures), studies of expert mathematicians showed that “there are other, equally critical aspects of mathematical competence,” which are not captured under this traditional view of learning (Schoenfeld, 2004, p. 262). This research highlighted a number of factors which are essential for mathematical competence. These factors are “having a strong knowledge base; having access to productive problem-solving strategies; making effective use of the knowledge one has (this is known as meta-cognition); and having a set of productive beliefs about oneself and the mathematical enterprise…” (Shoenfeld, 2004, P. 263). While traditional instruction provides students with a knowledge base, research shows that it often deprives students of problem-solving knowledge and fosters unproductive beliefs (seen commonly in what is referred to as “math anxiety”) (Boaler, 2019; Higgins, 1997; Schoenfeld, 2016).

The *Standards* was therefore an attempt to implement this new research and to foster more mathematically competent students by creating a new set of guidelines for teachers to follow. Since the release of the *Standards*, the NCTM has released numerous documents further elaborating and expanding upon reform mathematics, such as *Principles and Standards for School Mathematics* (2000) and *Curriculum Focal Points for Prekindergarten through Grade 8 Mathematics: A Quest for Coherence* (2006). One of its more recent documents, *Principles to Action* (2014), highlights eight teaching practices which the NCTM considers to be in-line with reform mathematics. In order to promote students’ conceptual understanding, the NCTM recommends that math teachers should establish mathematics goals to focus learning, implement tasks that promote reasoning and problem solving, use and connect mathematical representations, facilitate meaningful mathematical discourse, pose purposeful questions, build procedural fluency from conceptual understanding, support productive struggle in learning mathematics, and elicit and use evidence of student thinking (NCTM, 2014).

The release of the *Standards* and attempts at math reform resulted in significant pushback from various stakeholders (such as parents, mathematicians, politicians, and education researchers) who favoured the more traditionalist approach to teaching mathematics. The traditionalists raised a number of concerns about the new direction that math instruction was taking. Many of these concerns were influenced by social, economic, and political values and are outside the scope of this paper. As such, I will focus more on the research-based objections that the traditionalists raised. First, traditionalists pointed out that, at the time that the *Standards* was released, there were no large-scale studies or data demonstrating that the new curriculum or practices would be effective. As such, there was a worry that the new curriculum would be even less effective than the traditionalist one. As Schoenfeld (2004) says

> No large-scale data were gathered on the effectiveness of these curricula. Many of the NSF-supported reform curricula were in either alpha or beta testing at that point; it was not until the mid-1990s that they became widely available, and testing data on those curricula tended to use "home-grown" measures. It was not until the late 1990s that full cohorts of students had worked their way through the entire reform curricula. Only at the turn of the 21st century did large-scale data evaluating the impact of those curricula begin to become available. (pp. 269-270)

As such, there was a real cause for concern that the new *Standards*, while being theoretically supported, was not supported by empirical evidence. Schoenfeld (2004) does go on to point out that the large-scale data which emerged in the 21st century supported the reform but argues that "such data turn out to be largely irrelevant to the story of the math wars. When things turn political, data really do not matter" (p. 270).

Second, traditionalists argue that there are some basic facts and procedures that students should be expected to memorize and learn prior to attempting more complicated problem-solving. Stokke (2015), for instance, argues that constructivist-informed methods

> ignore the limitations of working memory by eschewing conventional techniques such as times table memorization and by encouraging multiple, convoluted strategies instead of efficient, standard methods. Teaching through problem solving without providing the foundational skills necessary to solve problems overburdens working memory, and might not alter long-term memory, thereby inhibiting learning of mathematical concepts. (p. 6)

However, I would argue that if we just want students to efficiently solve multiplication problems, the most efficient method would be to teach them how to use a calculator. In my view, efficiency is a poor measure of student learning. Problem-solving strategies may be convoluted, inefficient, and varied but, if it is more meaningful to the student and gets them to actually think deeply about and understand the problem rather than simply mimicking what their teacher does with no understanding of the content, then I think that inefficiency is a price worth paying. As Liljedhal (2021) says, problem-solving "is not the smooth execution of a formula. Problem solving is a messy, non-linear, and idiosyncratic process. Students will get stuck. They will think. And they will get unstuck. And when they do, they will learn" (p.20). Such a process allows students to develop a deeper, conceptual understanding of the fundamentals of math as opposed to a shallower, procedural understanding of them.

The third concern often raised by traditionalists is that constructivist-inspired classrooms are too chaotic, lack sufficient teacher oversight, and need more structure in order to ensure student learning. Stokke (2015) goes on to say that constructivist-based

> learning environments often result in students becoming confused and frustrated and it is an inefficient style of instruction characterized by frequent false starts. Numerous studies have found that, in contrast, direct instruction techniques such as worked examples, scaffolding, explicit explanations and consistent feedback are extremely beneficial for learning. (p. 6)

However, in my view, this description is a frequent mischaracterization of constructivist-based instruction. Opponents of constructivist-teaching often characterize it as being an unguided or minimally guided approach in which teachers assume a passive role while students are fully and solely in charge of their own learning. I instead view constructivist-inspired teachers as taking a different role in the classroom, but one that is nonetheless very active. Schoenfeld (2004) describes the role teachers should take according to the *Standards* as involving

> both knowledge and flexibility on the part of the teacher, who must provide support for students as they engage in mathematical sense making. This means knowing the mathematics well, having a sense of when to let students explore and when to tell them what they need to know, and knowing how to nudge them in productive directions. (p. 272)

Thus, I believe that a constructivist teacher should be actively working to ensure that student do not become too confused and do not experience such high levels of frustration that they give up on their task. A constructivist teacher ought to be selecting tasks which are appropriate for their students and providing them with guidance *as necessary* to ensure that students are having a productive struggle with the problems that are selected.

This distinction between a passive and active constructivist teacher is also noted by Alfieri et al. (2011) who performed a meta-analysis examining the efficacy of unassisted discovery (i.e., constructivist) learning versus direct instruction and another one examining the efficacy of enhanced and/or assisted discovery education versus the other forms of instruction. The researchers found that, while direct instruction was generally superior to unassisted discovery learning, both methods were inferior compared to enhanced discovery learning. As such, they conclude that

> teaching practices should employ scaffolded tasks that have support in place as learners attempt to reach some objective, and/or activities that require learners to explain their own ideas. The benefits of feedback, worked examples, scaffolding, and elicited explanation can be understood to be part of a more general need for learners to be redirected, to some extent, when they are mis-constructing. (p. 12)

I do not think that any of their recommendations are contrary to constructivist beliefs and that they can still be accomplished in a student-led and constructivist way (e.g., consolidating lessons by having students explain their solutions to the problem). Alfieri et al. (2011) also note that their findings are perhaps unsurprising as “it does not seem that many researchers on either side of the argument would disagree with such a claim [i.e., that unassisted discovery learning is inferior to explicit instruction” (p. 12). As such, I believe that the traditionalist concern that constructivist classrooms are too unstructured is largely a mischaracterization.

Despite the NCTM's effort to push reform mathematics, there is "little evidence that practice has significantly changed" and most mathematics teaching still relies on the traditional approach (Gill & Boote, 2012, p. 4). The traditional approach has also continued despite research demonstrating that it is associated "with numerous negative outcomes for students, from a lack of conceptual understanding, to the inability to solve real-world problems, to compliance and overreliance on the teacher as authority figure" (Gill & Boote, 2012, p. 4). As such, mathematics education is stuck in a difficult position as there is widespread recognition that the current system is insufficient, and perhaps even actively harmful, while at the same time still having failed at achieving widespread systematic change. Therefore, I believe that if mathematics reform is to become a reality, more research is needed in order to help guide future attempts at reform.

One avenue through which mathematics can be reformed is by changing teachers' beliefs to better align with constructivist principles as opposed to traditionalist ones. Research has shown that teacher beliefs play an important role in implementing reform and that teachers' beliefs and values about teaching and learning affect their teaching practices (Donnell et Gettinger, 2015; Liou et al., 2019; Stipek et al., 2000). As such, it is crucial to ensure that teachers' beliefs align with constructivist principles if a constructivist reform of the current mathematics educational system is to be successful. However, constructivist beliefs can be particularly problematic for mathematics teachers. A survey of teachers across various disciplines showed that "teachers from language, social science and practical disciplines had a significant preference for an incremental theory of intelligence [i.e., the theory that intelligence is malleable] compared to an entity theory of intelligence [i.e., the theory that intelligence is fixed] whilst the teachers in mathematics did not". This study is significant as it demonstrates that teachers with a mathematics background are more likely to ascribe to a fixed mindset of intelligence, which is antithetical to constructivist principles. As such, they may be more reluctant to embrace constructivist teaching than teachers from other educational backgrounds. This research also suggests that philosophical beliefs about the nature of teaching and learning are influenced by academic discipline. Since teacher education programs occur after teachers have trained in their respective fields, they represent a powerful potential stage in which interventions could occur to further develop future teachers' constructivist beliefs. As such, this research focuses on TCs' beliefs.

While there has been a lot of research examining TCs' beliefs, much of this work has been focused on elementary and middle school teachers and often does not analyze data along the lines of educational background/discipline (e.g., Alsup, 2004; Gresham & Burleigh, 2019; McGinnis et al., 2002; Mizell & Cates, 2004; Smith et al., 2012; Twohill et al., 2020). The issue with this approach is that elementary and middle school teachers often do not have a mathematics background. One study, for instance, found that, over the course of two years, only 3% of elementary TCs had a mathematics background (Holm & Kajander, 2020). Due to this focus on elementary TCs, researchers may have missed a potential link between teachers' academic backgrounds and their pedagogical beliefs. In my own experience as a high school mathematics teacher and former TC, I have found that some TCs were more predisposed to constructivism and, as such, I wonder how much of an impact educational background has on this predisposition. For myself, I only met the credit requirement for teaching mathematics and do not have a major or minor in the subject. As such, I wonder if my more interdisciplinary background might result in me being more predisposed to constructivism than some of my fellow classmates, who were strict mathematics majors. If educational background does impact the propensity of TCs' beliefs, then it may serve as a novel avenue for intervention addressing these beliefs, as teacher education programs may need to directly address TCs' educational background.

There is a second way in which TCs' educational backgrounds may affect their propensity for constructivism. If someone has a higher level of mathematics competency, then they may see less need for systemic reform than someone who does not. Meanwhile if someone has a low level of mathematics competency and feels anxious about mathematics, these negative feelings may be more of a motivator for mathematics reform. Said another way, due to being more experienced in mathematics, TCs with a mathematics background are likely to be more comfortable and less anxious about mathematics than TCs who do not have this educational background. As such, TCs with more mathematics experience may not feel that there is the same need for reform as someone who has higher levels of math anxiety as a result of their educational experience. Thus, I think that there may be links between educational background, math anxiety, and the propensity for TCs' constructivist beliefs which have not been fully elucidated by the research. Further research into these links could help to devise instructional strategies that better address TCs' educational backgrounds and experiences in order to ensure the success of future mathematics reform.

Literature Review

As was previously mentioned, there is a gap in the literature about how educational background and math anxiety affect TCs' pedagogical beliefs. There are however a number of studies that look at these phenomena individually and that are relevant to my research questions (see Celik, 2021; Holm & Kajander, 2020) or that look at the individual effect of one variable on the other (see Gresham & Burleigh, 2019; Mizell & Cates, 2004).

Math Anxiety

"Math anxiety" is the term that is used to refer to "feelings of apprehension and tension concerning manipulation of numbers and completion of mathematical problems in various context" (Hopko et al., 2002). Math anxiety can result "in negative thoughts (e.g., 'I can't do maths') and poor cognitive performance" and can also involve "physiological symptoms (e.g., nausea, sweaty palms, rapid heartbeat), and avoidance and disengagement behaviours (e.g., excuses to miss mathematics class)" (Wilson, 2018, p. 172). As a result, it leads to a decrease in mathematical competency, as well as leading to higher error rates on mathematical tasks (Hopko et al., 2002). With regards to TCs, it has been found that "Impoverished school mathematics experiences have left many pre-service teachers [i.e., TCs] with strong negative affective responses about mathematics [i.e., math anxiety]" (Namukasa et al., 2009, pp. 46-47).

Unfortunately, math anxiety in TCs has been associated with a number of negative outcomes. One study of TCs found that there was a statistically significant relationship between TCs' math anxiety scores and their teaching efficacy scores (Celik, 2021). In other words, as math anxiety scores decreased, TCs' mathematics teaching efficacy scores increased. This finding is also “in parallel with other research findings” which “focused on maths anxiety related to maths teaching competency in their study and has found negative correlations between the two” (p. 164). A similar study also found that math anxiety was negatively correlated with beliefs about mathematics teaching efficacy (Swars et al., 2006). Thus, it is clear that math anxiety plays a role in teaching competency and influences teachers’ beliefs. As such, it may also be significant in teachers’ pedagogical beliefs, although there is a gap in the literature about this possible relationship.

Another negative effect of math anxiety is that it has been found to affect the performance of female students. A study by Beilock et al. (2010) found that female elementary school students who had female teachers with high levels of math anxiety performed worse on math assessments than their female peers who had teachers with low levels of math anxiety and they performed worse than boys regardless of the teachers’ math anxiety. These students were also more likely to endorse traditional gender beliefs about mathematics (e.g., that boys are naturally good at math while girls are not). The authors argue that

> If it is simply the case that highly math-anxious teachers are worse math teachers, one would expect to see a relation between teacher anxiety and the math achievement of both boys and girls. Instead, teachers with high math anxiety seem to be specifically affecting girls’ math achievement—and doing so by influencing girls’ gender-related beliefs about who is good at math (p. 1862).

This finding is alarming as female teachers make up the majority of schoolteachers in Ontario (Ontario College of Teachers, 2022). As such, addressing math anxiety in teachers and TCs is an important element in achieving equitable outcomes for mathematical competency among students. Another study of elementary teachers found that math anxiety was positively associated with anxiety about teaching mathematics, which was in turn negatively associated with student achievement of all genders (Hadley & Dorward, 2011).

Given math anxiety's predominance and its negative impact on both students and teachers, researchers have recognized the importance of addressing math anxiety in order to better foster mathematical competence. Boaler (2019) argues that we need to move away from traditional conceptions of mathematics in favour of constructivist-inspired ones that will foster mathematical mindsets by engaging students in problem-solving and mathematical discussions and thinking. She states that mathematical mindsets are ones in which students view math as "a subject of growth and that their role is to learn and think about new ideas" rather than seeing math as "a fixed set of methods that either they get or they don't" (p. 29). She argues that such a mindset shift, and creating instructional strategies necessary to foster it, will help to deal with math anxiety and help improve students' confidence and competency.

Several studies have highlighted how constructivist-inspired courses can reduce math anxiety and foster a mathematical mindset. A case study by Gresham & Burleigh (2019) found that a constructivist-based mathematics education course was effective in helping to reduce TCs' math anxiety and improved their beliefs about their mathematics and teaching self-efficacy. This finding is also significant to my research as it may provide an explanation for why TCs with higher levels of math anxiety could be more supportive of a constructivist approach to mathematics. This finding was also supported by Namukasa et al. (2009) who found that constructivist-inspired teaching gave TCs “the opportunity to (re)-experience and to feel positively about learning mathematics” and argued that “it is central that pre-service teachers be offered starting points for positive, warm affective responses and intimate relations with mathematics” (p. 60).

However, this finding was somewhat contradicted by a study by Alsup (2004), which had more mixed results. Alsup found that “Control-group students [i.e., those not part of a constructivist-based class] actually realized the steepest decline in math anxiety of all three classes, so the overall decrease in math anxiety was not due to the majority of participants being included in the experimental courses but was probably due to the instructor’s personality and teaching style” (p. 13). Alsup goes on to explain that, while all groups experienced decreases in math anxiety, one of the experimental groups saw little improvement, which the researcher attributed to it not being “the right interaction of students, curriculum, and instruction” as the curriculum was less familiar to the TCs compared to the curriculum of the first experimental course, which had much greater success (p. 15). Nonetheless, these studies demonstrate that constructivist-informed mathematics education courses can help to decrease math anxiety in TCs. As such, it may be that TCs who have seen a decrease in their math anxiety or who have mathematical mindsets would be more willing to employ constructivist teaching methods than those who have not experienced the same benefit from constructivist-based mathematics education courses or who feel that they have benefitted from a traditional approach to mathematics.

Educational Background

A study of TCs with a background in mathematics found that there was "no evidence that strong undergraduate mathematics preparation supported conceptual understanding of elementary mathematics…" (Holm & Kajander, 2020, p. 36). It should be noted that these are only preliminary findings and, as such, further research into this area would be necessary to draw more definitive conclusions. However, these findings are also consistent with literature that "indicates that teachers need a specialised understanding of mathematics to teach" (Holm & Kajander, 2020, p. 38). This specialized knowledge of a subject is known as pedagogical content knowledge, a term coined by Shulman, and whose importance has become increasingly recognized over the past few decades (Silverman & Thompson, 2008). As such, this research demonstrates that mathematics degrees are insufficient for developing pedagogical content knowledge and that teachers need specific courses aimed at providing them with specialized knowledge, regardless of their educational background. The researchers also found that the participants all held strong beliefs about mathematics being a set of procedures which students must learn (Holm & Kajander, 2020). That is, they all had a strong traditionalist understanding of mathematics as opposed to a constructivist one and lacked conceptual knowledge.

The findings of this study are particularly troublesome when viewed in conjunction with another study which found that beliefs about mathematics teaching efficacy is positively associated with the level of mathematics attainment that a TC has (Twohill et al., 2022). As such, these two studies suggest that TCs with a mathematics background may have a high sense of teaching efficacy and strong beliefs in traditionalist teaching while lacking the conceptual knowledge and beliefs necessary to implement a constructivist mathematics education.

However, more research is needed to examine this relationship. Another study also found that "there is a weak correlation relationship between mathematical beliefs and mathematical experience" and that this association is statistically significant (Adnan, 2012, p. 1718).

As was previously mentioned, a study found that entity theories of intelligence (i.e., that intelligence is fixed and unchangeable) are more pronounced among teachers in mathematics than among teachers in other disciplines (Jonsson et al., 2012). This finding is consistent with the idea that mathematics teachers tend to subscribe to traditional ideas of education as the idea that intelligence is fixed is antithetical to constructivism, which argues that knowledge is being continually built upon and modified. The authors also note that these findings are in line with notions that different disciplines have their own epistemological beliefs and that these beliefs could influence teachers' pedagogy (Jonsson et al., 2012). The authors also note that research has shown that

> pupils who viewed intelligence as incremental [i.e., those who viewed intelligence as malleable and changeable] adopted more progressive learning goals, viewed effort as more likely to have significant positive effects on performances, less frequently explained failure with low ability and more frequently reported mastery-oriented responses of increased effort and persistence to be of value compared to those holding an entity theory. (p. 389)

As such, this study also demonstrates the need to foster a mathematical mindset in students, although mathematics teachers may be predisposed against such conceptions of intelligence. It should be noted that the research outlined in this section is preliminary, but it does indicate that there may be a relationship between TCs' educational background and their constructivist beliefs as well as highlighting the need for further research in this area.

Teacher Candidates' Pedagogical Beliefs

The effect of additional mathematics courses on TCs' beliefs has also been measured. One study by Mizell and Cates (2004) "examined the impact that completing additional mathematics courses had on TCs' beliefs regarding mathematics content and pedagogy" by having an experimental group which underwent additional mathematics courses compared to a control group. The researchers administered a survey upon the completion of all the courses in order to measure TCs' pedagogical and content beliefs. The researchers found that "Although Group One [i.e., the experimental group] gained confidence in their own mathematical abilities from taking the additional courses, they also grew more traditionalist in their pedagogical beliefs. They more strongly believed a lot of workbook practice was good for students and that teachers should know all the answers" (p. 6). The researchers attributed this change to the possibility that "The participants may have experienced traditional teacher-directed instruction in their content courses both contributing to and reinforcing their own traditionalist beliefs about mathematics instruction" (p. 7). As such, this study indicates that taking additional courses may negatively affect TCs' constructivist beliefs, especially when those courses are taught in a traditionalist way. This finding may be significant in that it indicates that TCs who have taken more math course (i.e., those with math majors) may be more traditionalist than TCs who do not have the same background.

A longitudinal study by Smith et al. (2012) examined the effect of mathematical content courses and mathematical methods courses on TCs' beliefs in an elementary teacher preparation program. The first group of TCs completed their teacher preparation program with three mathematics content courses and two mathematics methods courses, while the second group completed their program with four mathematics content courses and a single mathematics methods course. The researchers found that there were no notable differences in the mathematical knowledge for teaching between the two groups of TCs, which suggests that more mathematics content courses for elementary teachers do not necessarily result in greater knowledge for teaching mathematics than content-specific pedagogy courses (Smith et al., 2012). However, the researchers found that completing the second mathematics methods course "significantly influenced the prospective teachers' beliefs in their capabilities to teach mathematics effectively and affect student learning, as well as their beliefs that children can construct mathematical knowledge" (p. 345). This study's findings thus suggest that, in order to promote constructivist-oriented beliefs, the focus of teacher preparation programs should be more on mathematics pedagogy as opposed to just on mathematics content.

A pseudo-longitudinal study by Safrudiannur et al. (2021) examined how a cohort of mathematics TCs' beliefs about the nature of mathematics changed over the course of their teacher education. First, the researchers found that the traditionalist view of mathematics (called the instrumentalist view by the researchers) started high in TCs and remained high at the program's end. The researchers hypothesized that the high traditionalist rating in TCs is a result of how university mathematics is usually presented (Safrudiannur et al., 2021). A similar finding was reached by Geisler and Rolka (2021) who examined students' beliefs in their transition from high school to university and found that static beliefs (i.e., traditionalist beliefs) of mathematics were high in incoming university students and remained high during their first semester. However, Safrudiannur et al. (2021) found that a problem-solving view (i.e., a more constructivist view) of mathematics started low in TCs but increased as they went through their course work. This finding is contradicted by Geisler and Rolka (2021) who found that dynamic beliefs (i.e., constructivist views) about mathematics decreased in their sample group.

The increase in constructivist beliefs among Safrudiannur et al.'s (2021) cohort may be a result of the fact that the cohort was receiving mathematical pedagogical courses, which developed their pedagogical content knowledge, as well as teaching in practica and were not just taking mathematical content courses like in Geisler and Rolka's (2021) cohort who, as a result, may have lacked the necessary pedagogical knowledge. As such, this research demonstrates how university mathematics preserves traditional understandings of mathematics, although mathematical pedagogical courses may act to promote more constructivist views of mathematics. This finding is also in line with the concept of pedagogical concept knowledge that was outlined above and highlights the importance of developing teachers' specialized knowledge about teaching mathematics rather than just relying on their mathematical knowledge. More research is still needed in this area, but I believe that the findings demonstrate a potential link between educational background and beliefs which have not been fully elucidated by the research.

Safrudiannur et al.'s (2021) assertion that traditionalist beliefs remained high while constructivist beliefs also increased over time in TCs may seem odd seeing as constructivism and traditional pedagogy are often conceptualized as being at opposite ends of the spectrum. One might expect that, as constructivist beliefs increased, traditionalist beliefs would decrease in turn. However, Safrudiannur et al.'s assertion is also supported by a cluster analysis of TCs performed by Hanin & Holm. Hanin & Holm (2023) found that three distinct profiles of beliefs emerged from their analysis: socioconstructivist, anti-socioconstructivist, and flexible, which was a more intermediate profile. The authors found that, at the end of their training, "less than 40% of the sample defends a traditional conception of the nature of mathematics, its teaching and learning. More than 40% defend a socioconstructivist approach and approximately one fifth of the sample adopt a flexible perspective" (p. 16). Their research also highlights how TC beliefs are more complex than the traditional binary model that is usually used because "Not only is there the presence of an intermediate profile, but the anti-socioconstructivist/pro-traditional and anti-traditional/pro-socioconstructivist profiles are not as clear-cut as that" (p.17). Viewed in this light, Safrudiannur et al.'s results further highlight the inadequacy of the binary model of beliefs for accurately reflecting TCs' beliefs. Rather than viewing TCs as being on the constructivist side of the spectrum or on the traditionalist side (i.e., one dimensionally), it may be more accurate to view constructivism and traditionalism as two axes and teachers' beliefs as consisting of elements from both of these axes (i.e., to view their beliefs two-dimensionally).

Learning Styles

A common theme which emerged during the course of this research was the idea of learning styles. The theory of learning styles has been called "the most accepted 'neuromyth' in education…" with around 76% of educators endorsing the theory despite there being no research studies supporting it (Westby, 2019, p. 4). The central idea behind learning styles is that each learner has a specific learning style and that they learn best when information is presented in that manner. For example, auditory learners learn best when they are given information to listen to as opposed to having the same information taught to them via visuals or movements.

The idea of learning styles has had widespread pop cultural appeal, even though it is widely criticized by education researchers. A prominent voice of this criticism is Howard Gardner, whose idea of multiple intelligences (MI) is often used as the foundation for learning styles. Gardner distances his idea of MI from the theory of learning styles in a Washington Post op-ed in which he says that the idea of learning styles is “incoherent” and that “there is not persuasive evidence that the learning style analysis produces more effective outcomes than a ‘one size fits all approach’” (Strauss & Gardner, 2013, p.1). Westby (2019) also criticizes the idea as being at odds with our understanding of neuroscience, saying that “Memory is usually stored in terms of meaning, independent of any modality—not in terms of whether you saw, heard, or physically interacted with the information” (p. 6). Rather than focusing on providing different modalities of information, Westby argues that teachers ought to “focus on the content’s best modality—not the student’s learning style or preferences. Modality does have an impact on learning, but this impact is the same for all students. Each modality is effective in carrying certain types of information” (p. 6).

As such, rather than having teachers focusing on the specific modality that they use to deliver their information, their focus should instead be on developing students’ mathematical understanding. The Pirie-Kieren model is a “well-established and recognized theoretical perspective on the nature of mathematical understanding" and "offers a means, through its layered model, for observing and describing the process through which knowledge is organized and reorganized, and for how learners think about their understandings and build on these in appropriate ways" (Martin, 2008, p. 64). As such, it provides a more useful framework through which to conceptualize students' learning as opposed to the theory of learning styles and is more in-line with neuroscience. The model "contains eight potential layers-of-action for describing the growth of understanding of a specific person and for a specified topic or concept" (Martin, 2008, p. 65). Of particular relevance to this paper is the Image-Making stage which is when "the learner is engaging in activities aimed at helping him or her to developing particular representations for the topic and mathematical idea; to get an idea of what the concept is about" (p. 65). As is discussed in the "Discussion" section below, many of the TCs made explicit or implicit references to this stage of mathematical understanding.

Conceptual Perspective

This paper focuses on the beliefs of TCs in order to examine how their beliefs developed in response to their educational experiences. Beliefs are a powerful way through which reform can be enacted and I think that top-down, large scale reforms are unlikely to be successful if teachers' beliefs do not align with these initiatives' principles. Liou et al. (2019), for example, argue that the success of the implementation of Common Core State Standards (CCSS) in the US

> hinges largely on teachers' beliefs about the CCSS, as individual teachers' beliefs about CCSS may influence how they interpret and go about implementing the new standards. We argue that in order to sustain successful largescale reform change, it is imperative to examine teachers' beliefs about the reform at the early

> implementation stage, as the results may inform school districts to make strategic planning. (p. 61)

Therefore, I have chosen research questions that focuses on beliefs and hope that this research will help to provide further insight into how TCs' beliefs are formed.

Research has highlighted the importance of teachers' pedagogical beliefs in accepting and implementing educational reform (Donnell et Gettinger, 2015; Liou et al., 2019; Stipek et al., 2000). As such, teachers' beliefs must be researched further in order to better guide future attempts at reform. While there is not a firmly and widely accepted definition of teachers' beliefs, there are multiple co-existing definitions (Bourrie, 2024). For the sake of this paper, I will be using Saldana's (2013) definition of beliefs. I chose Saldana's definition because he defined it as part of his description of Values Coding and, since I utilized Values Coding in my qualitative analysis, it seemed like a fitting choice. Saldana says that beliefs are "part of a system that includes our values and attitudes, plus our personal knowledge, experiences, opinions, prejudices, morals, and other interpretive perceptions of the social world" (p. 111). This definition is the one that I relied upon while coding for beliefs and, as such, is the one that I use throughout this paper.

Methods

Data Collection

In order to examine my research questions, I used a mixed methods approach to gather data. Participants for the study were recruited through Trent's consecutive Bachelor of Education program and consisted of TCs from both the Primary/Junior (PJ) and

Intermediate/Senior (IS) streams. For the Intermediate/Senior stream, I recruited participants with mathematics as one of their teachables as they were likely to have a background in mathematics and since, as was previously mentioned, only a very small percentage of TCs from the P/J stream are likely to have a mathematics background. I recruited TCs directly through their mathematics pedagogy courses, which is required for I/S TCs who have mathematics as one of their teachables and for all P/J TCs. There were 81 PJ TCs and 16 IS TCs enrolled in the courses that I recruited from. I had hoped that recruiting in this way would provide me with a diverse sample of TCs with a variety of educational backgrounds but most of the TCs whom I recruited for the interviews had similar backgrounds (see the "Limitations" Section for more information).

The first stage of the study was the quantitative approach. I administered two surveys which were designed to measure math anxiety and beliefs. The first survey (seen in Appendix A) is called the Teacher Beliefs Survey and it is adapted from Woolley and Woolley (1999). It is intended to measure teachers' pedagogical beliefs using Likert scales as it has teachers express their level of agreement or disagreement with multiple statement on a 5-point rating scale (1 being strongly disagree and 5 being strongly agree). The survey is intended to measure teachers' agreement with constructivist and traditionalist (called "Behaviorist" by Woolley and Woolley) principles. Pedagogical beliefs in the Teacher Beliefs Survey are measured via four different dimensions. The first is teachers' beliefs about Constructivist Teaching (CT), followed by their beliefs about Behaviourist Management (BM) score, then their beliefs about Behaviourist Teaching (BT), and finally their beliefs about Constructivist Parents (CP).

I have implemented the survey as was described by the authors, although I made two modifications. The first modification is that I removed the CP section of the survey which measured constructivist attitudes towards the students' parents. I removed this section for two reasons. First, while the rest of the survey had a sufficiently high Cronbach's alpha value, the parenting section only had a value of 0.57, which is considered too low for a survey to demonstrate internal consistency (Demirci, 2015). Second, I did not think that the section was very relevant to my research questions, and I believed that TCs would not have much experience interacting with parents. In addition to removing this section, I also removed Question 25 of the survey, which asked about using a teacher's guide to lead discussions about a story or text, as it did not seem very applicable to a mathematics class. I have also added an additional section at the beginning of the survey inquiring into TCs' educational experiences with math in order to better answer my research questions.

The second survey (Appendix A) is the Abbreviated Math Anxiety Scale (AMAS), which has been adapted from Hopko et al. (2003). This survey has been independently and externally validated and, as such, should be an effective way to measure TCs' math anxiety (Caviola et al., 2017; Hopko et al., 2003). I have also added a prompt for participants to add their email address and name so that they can express their interest in participating in the interviews. There is also a brief description of what the next stage of the study would entail.

This research project used human participants and, as such, it required approval from Trent's Research Ethics Board (ROMEO file #28784). Prior to the data collection stage, participants provided their consent by signing a consent form (Appendix D) which outlined the purpose and methods of the research, what their role in the research will be (including the estimated duration of the time involved), how their data will be used and for how long it will be stored before being properly disposed of. To ensure the confidentiality of the participants, all data that were collected were anonymized before being analyzed. The quantitative aspect of the study was completed anonymously via printed off surveys (except for participants who volunteered for the interviews) and the interviews were transcribed from audio recordings before being anonymized to ensure the confidentiality of participants' data.

Seeing as participants were being surveyed and interviewed about their pre-existing beliefs and experiences, the research was non-experimental (i.e., there is no manipulation of variables/subjects), and all the participants were above the age of the consent; the risk for participants was minimal. One additional ethical consideration was that one of my supervisors, Heather Bourrie, was also the instructor for the mathematics pedagogy courses that I recruited participants from. As such, Bourrie was removed from the data collection process to ensure that participants could freely express themselves without fear of academic repercussions and to prevent any undue influence from her presence on the data. Any data that Bourrie saw was anonymized beforehand to ensure participant confidentiality and to minimize their risks. I also informed participants of such precautions ahead of time in order to assure them of the confidentiality of their data.

In order to recruit participants, I attended their math pedagogy courses during the first few weeks of January 2024 and, at the end of their lesson, I gave a quick recruitment speech outlining the research project, its goals, and what they would be required to do (Appendix C). I then offered the quantitative consent forms for TCs to pick up in order to read more about the project and to sign if they were interested in participating (Appendix D). I also offered to answer any questions that they may have had. In total, there were three PJ math pedagogy courses and one IS math pedagogy course. After I had photocopied their consent forms and given each volunteer a copy, I booked classrooms for specific hours on Trent's Peterborough campus. TCs were then invited to come to whichever session they could attend, provided that they were still interested in participating. Twenty-five TCs completed surveys (16 PJ TCs and nine IS TCs) and all of the surveys were administered and completed by hand. This first part of the study was intended to give me a quantified baseline from which I could analyze the participants' beliefs before I more deeply investigated them via the qualitative stage. As such, participants were also given the opportunity to provide their email addresses and names on their surveys if they were interested in being interviewed.

The second part of the study was qualitative and involved me recruiting a subset of the quantitative sample size for interviews in order to further investigate TCs' pedagogical beliefs and how their educational background and anxiety play a role in the formation of their beliefs. These interviews (Appendix B) were semi-structured in order to allow TCs to express their beliefs more freely and to allow for follow-up questions on any connections that may have arisen whilst still keeping the interviews focused on the primary area of research.

Of the 25 TCs who completed a survey, 12 of them expressed being interested in the follow-up interviews. Three of those who expressed interest were IS TCs while nine of them were PJ TCs. I then selected six participants for the interviews, three PJ TCs and three IS TCs. For the PJ TCs, I attempted to select a mix of TCs; however, I was unable to recruit one who had only completed high school level mathematics and my participants ended up having similar profiles (See the "Participant Profiles and Their Teachable Class" section below for more information). For the IS TCs, due to the low number of volunteers, I selected all of the volunteers for the interview stage. Participants were emailed a consent form and asked to sign and return it as well as figuring out the arrangements for their $25 honorarium and what date and time worked best for them for their interview. All of the interviews were conducted and recorded over Zoom. The interviews ranged in length from approximately 30 to 80 minutes. All of the interviews were recorded and transcribed using Zoom. After editing and confirming the accuracy of the Zoom transcript, each participant was emailed a copy and given an opportunity to modify or expand upon their interviews prior to the data analysis stage. In total, the data collection stage lasted approximately three months and took place over the course of January to March 2024.

Data Analysis

Since this research's objective is to discover if pedagogical beliefs are influenced by math anxiety and/or educational background, I had originally planned to conduct a regression analysis on the quantitative data that was collected from the surveys. However, I ended up having a fairly small sample size and I do not think that a quantitative analysis would have led to meaningful results. For instance, only three participants had a major in mathematics and only one had a minor. As such, it would be difficult to draw out any definitive conclusions from the sample. The sample size is also biased in that all of the participants were drawn from the same program. Therefore, due to the small sample size and biased selection process, I realised that the results would lack generalizability and so I decided to focus more on the qualitative analysis instead. I had also planned to use the quantitative results to inform my study, but I had so few volunteers for the interviews that the quantitative results had little impact on my selection process.

The qualitative data was analyzed via thematic analysis. Thematic analysis is "the process of identifying themes in the data which capture meaning that is relevant to the research question, and perhaps also to making links between such themes" (Willig, 2014, p. 147). Since I am attempting to make links between pedagogical beliefs, math anxiety, and educational background and trying to see how these TCs' experiences interact to form their pedagogical beliefs, thematic analysis is an appropriate way to answer my research questions. Coding was done using a word processor to highlight and comment codes on relevant sections of the participants' transcripts.

For the first cycle of coding, I used Values Coding. Values Coding is the labelling of codes that "reflect a participant's values, attitudes, and beliefs, representing his or her perspectives or worldview. Though each construct has a different meaning, Values Coding, as a term, subsumes all three" (Saldana, 2013, p. 110). Values Coding is particularly useful for qualitative analyses "that explore cultural values, identity, intrapersonal and interpersonal participant experiences and actions in case studies, appreciative inquiry, oral history, and critical ethnography" (p. 111). Given that the research focused on participants' intrapersonal experiences with math (i.e., their math anxiety) and interpersonal experiences (i.e., their experience teaching and being taught math) as well as on their pedagogical beliefs, Values Coding seemed like an appropriate method for the first coding cycle.

For the second coding cycle, I used Focused Coding which consists of searching through the transcripts to find the most frequent or significant codes in order to develop the most notable categories (Saldana, 2013). This method helped me to further refine my codes and to develop categories. Following the coding, the codes were then written out on to cue cards and physically arranged to draw out relationships between the codes and to identify the major themes that emerged from the data. This method was recommended by Saldana (2013) in order to "better discover and understand such organizational concepts as hierarchy, process, interrelationship, themeing, and structure" (p. 205). The results of this categorization then formed the basis for the Code Tree which can be found in Appendix E.

Participant Profiles and Their Mathematics Pedagogy Class

As was previously mentioned, participants were recruited through two math pedagogy courses. The first course is entitled "Mathematics PJ" and it is a mandatory course for all PJ TCs in Trent's Bachelor of Education Program. The course is designed to help TCs develop their math practice and reflect critically on it by relating it to their own education experience, examining current theories of teaching and learning mathematics, and examining different ways of knowing/doing math. The second course is entitled "Mathematics Curriculum Methods (IS)" and it is a mandatory course for all IS TCs who have selected math as one of their teachables. This course is similar in intent to the PJ course, but it is more extensive as it was a full credit course (72 hours of instruction), while the PJ course was a half-credit one (36 hours of instruction). Both the PJ and the IS mathematics pedagogy class run the full duration of the Bachelor of Education academic year (September-March). While the PJ course is offered in the first year of the program, the IS course may be offered in either Year 1 or Year 2 depending on when the TC enrolls; in the case of the participants of this study, all registered in the IS mathematics pedagogy course in their second year. Both of these courses were taught by one of my supervisors, Dr. Heather Bourrie.

As part of the "Mathematics Curriculum Methods (IS) course," TCs became familiar with Liljedahl's concept of the "Thinking Classroom." The "Thinking Classroom" is a problem-based learning approach to mathematics which is research-based and heavily influenced by constructivist ideas (Liljedahl, 2021). As such, it is designed to help move students towards thinking about and reflecting upon the math that they are learning, as opposed to merely mimicking it (Liljedahl, 2021). When I interviewed the IS TCs, they all referred to the "Thinking Classroom" when discussing their pedagogical beliefs. As such, I decided to label the method used in their math pedagogy course (and the PJ math pedagogy course) as the "Thinking Classroom" when coding for it.

It is important to note, however, that the course also drew upon other influences as well and was not a "pure" "Thinking Classroom" method. In particular, a heavy influence was the article *Orchestrating Discussion* by Smith et al. (2009), which is intended to help teachers to foster mathematically rich discussions among their students in order to promote thinking, reasoning, and problem-solving skills. It was also heavily informed by *Growing Success* which was published by the Government of Ontario (2011) in order to "ensure that [assessment] policy is clear, consistent and well aligned across panels and across school boards and schools, and that every student in the system benefits from the same high-quality process for assessing, evaluating, and reporting achievement" (p. 2). However, when TCs referred to the method taught in their math pedagogy course, they often referred to it as the “Thinking Classroom” method and, as such, I have decided to use that name as a shorthand for what they were taught in their math pedagogy course.

After recruiting participants for the interviews, they were all randomly assigned a two-digit number to their transcripts in order to ensure their anonymity. Participant 13 was a first-year PJ TC who, at the time of their interview, had completed one practicum and taught math during it. They completed a Bachelor of Arts degree in Child and Youth Studies prior to entering the BEd program at Trent. Participant 24 was a second-year IS TC who had completed three practica at the time of their interview, including having one placement in math. Prior to their enrollment in the BEd program, they had completed both a Bachelor and a Master of Engineering degree in Engineering Physics. Their primary teachable is physics while math is their secondary teachable. Participant 33 was also a second-year IS TC who had completed three practica at the time of their interview and had one placement in math. Prior to their enrollment in the BEd program, they had completed a Bachelor of Science in Conservation Biology. As such, math was also their secondary teachable. Participant 61 was a first-year PJ TC who had completed one practicum and taught math during it. They had also completed a Bachelor of Arts degree in Child and Youth Studies. Participant 82 was likewise a first-year PJ TC who had completed a Bachelor of Arts degree in Child and Youth Studies. They had also completed one practicum at the time of their interview although they had not yet taught math. Participant 93 was a second-year IS TC who had completed three practica and had one placement in math. They had completed a Bachelor of Arts degree in English Literature and, as such, also had math as their second teachable. The participant profiles are summarized in Table 1 below.

Table 1

A Summary of Interview Participants' Educational Background

Participant ID Number	Stream and Teachables	Educational Background	Year in Program
13	PJ	BA in Child and Youth Studies	First
24	IS (Physics and Mathematics)	BEng and MEng in Engineering Physics	Second
33	IS (Biology and Mathematics)	BSc in Conservation Biology	Second
61	PJ	BA in Child and Youth Studies	First
82	PJ	BA in Child and Youth Studies	First
93	IS (English and Mathematics)	BA in English Literature	Second

Findings

Quantitative Findings

Overall, there were 25 surveys administered and collected which represents a response rate of approximately 25.8%. Nine IS TCs completed the survey while 16 PJ TCs completed it, which means that the IS TCs had a response rate of 56.3% while the PJ TCs had a response rate of 19.8%. TCs demonstrated a moderate level of math anxiety with an average score of 2.68 on the AMAS section of the survey. IS TCs appeared to have lower levels of math anxiety than their PJ counterparts as the IS TCs had an average score of 2.04 while the PJ TCs had an average score of 3.04.

In terms of pedagogical beliefs, TCs scored the highest on the Constructivist Teaching measure with an average score of 4.12. The second highest score was the Behaviorist Management measure, which had an average score of 3.21. The lowest score was on the Behaviorist Teaching measure, which had an average score of 2.51. The PJ and IS TCs scored similarly although there was a bit of a discrepancy for the BT measure. For the CT measure, the

IS TCs had an average score of 4.18 while the PJ TCs had an average score of 4.09. For the BM measure, the IS TCs had an average score of 3.24 while the PJ TCs had an average score of 3.19. For the BT measure, the IS TCs had an average score of 2.81 while the PJ TCs had one of 2.34. A summary of these findings is shown in Figure 1 below.

Figure 1

PJ and IS TCs' Average Level of Math Anxiety and Their Pedagogical Beliefs

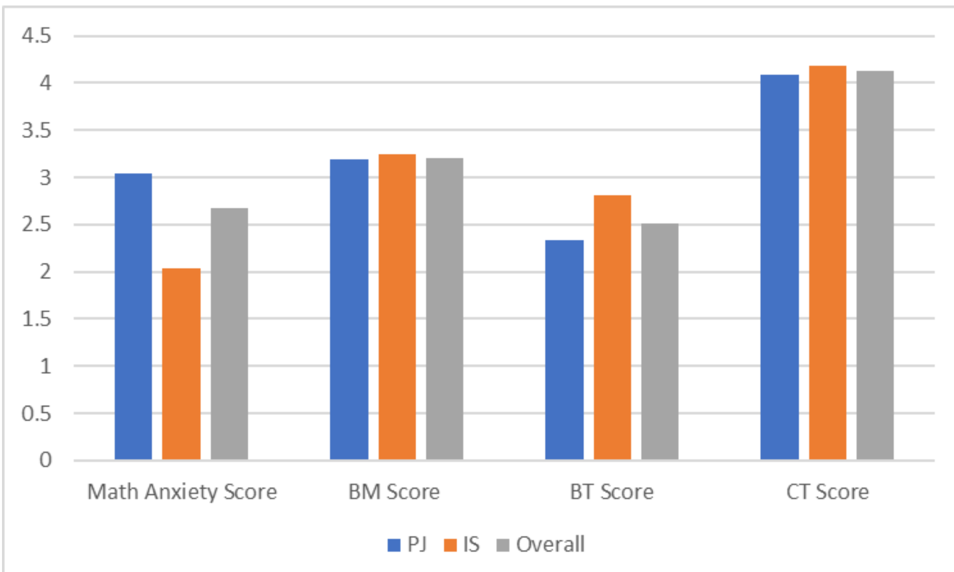
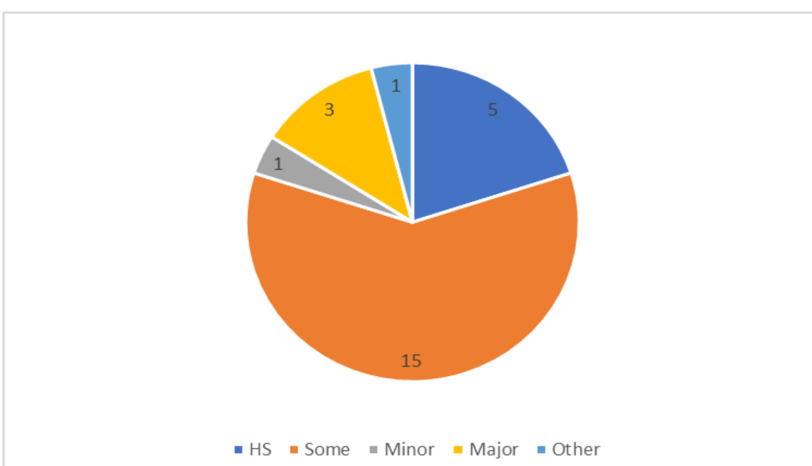


Figure 2 below shows a breakdown of TCs' educational experiences with mathematics. Most TCs identified as having completed some university level mathematics courses with approximately 44.4% of IS TCs and 68.8% of PJ TCs identifying with this option. None of the PJ TCs that were surveyed had completed a minor or major in mathematics and none of the participants had completed a graduate or postgraduate degree in mathematics. One IS participant selected "Other," due to having a Master of Engineering degree, but all of the other participants selected the pre-made categories. One important caveat is that it seems that several PJ TCs selected that they had completed some university-level mathematics courses and were referring to mathematics courses designed for teachers (i.e., mathematics pedagogy courses). When I had designed the survey, I had intended to survey participants about their completion of math content courses (i.e., math courses in which participants were learning about new mathematical concepts as opposed to learning about how to teach mathematical concepts that they had already learned through their education). However, since I did not specify this distinction, this confusion resulted in some PJ TCs selecting that they had completed "Some Post-Secondary Mathematics Courses" when I would have classified them as having completed "High School Mathematics." As such, the PJ TCs' percentage of those who completed high school mathematics as their highest level of mathematics is likely much higher than what was recorded while the percentage of those who selected "Some Post-Secondary Mathematics Courses" is likely much lower. This caveat is discussed in more detail in the "Limitations" Section below.

Figure 2

A Breakdown of TCs' Educational Experience with Mathematics



Qualitative Findings

Relationship to Math

A major category which emerged from the data was the participants' *Relationship to Math.* The two predominant attitudes towards math were an *Appreciation* of math and an *Aversion* to it. For *Appreciation,* the TCs expressed that they appreciated math because they **Enjoy Doing Math** and/or were **Confident About Math**.[1] For TCs who enjoyed doing math, they often pointed to how they **Like the Problem-Solving and Puzzle Elements of Math**. Participant 82 explained how this attitude towards math helped them to enjoy it more, as they recounted a classmate who said "'It[math]'s like you're solving a puzzle' and ever since somebody said that to me, I was like 'Oh it's like literally solving a puzzle!' So ever since then, I've really had like a pretty positive relationship with it." Another reason that TCs enjoyed math was that they **Enjoy Understanding How the World Works**. Participant 24 remarked how they began to really enjoy math once they saw how it was applied, saying that

> I remember I always felt good with math, then we got into science in high school and -- especially like Grade 11 physics -- And I just had this like moment of like 'Oh like this is how the world sort of interconnects and like all of these things.' And I was like, 'That's such a cool thing!' that I would have never, ever thought

[1] Saldana (2013) recommends that "key assertions and theories should be italicized or bolded for emphasis in a final report. The same advice holds for the first time significant codes, themes, and concepts are addressed" (p. 253). With this in mind, I have decided to italicize themes and categories and to bold codes the first time that they are mentioned in order to improve the readability and flow of the text and to make it clearer how my analysis is structured.

about had I not like had this you know, this mathematical concept or like this physics idea behind it …

For TCs who are averse to math, they often pointed to feeling **Anxious About Math** due to a lack of understanding. Participant 61 said that "I just remember never getting it [math] and being in kindergarten and not knowing how to do like basic addition or subtraction, just being confused by that ... I didn't like math. It was -- it was a scary thing for me." Another reason for the aversion towards math for several TCs was that they **Dislike Tests**. Participant 82, for instance, described having a positive relationship with math, but scored quite high on the AMAS. When we discussed this, they replied that "I feel like when it's like tests and quizzes, that's what I get really big anxiety …"

All of the participants described having a mix of appreciative and aversive feelings towards math with none of them being fully on either end of the spectrum. Participant 61 seemed to be the most averse to math saying, "So overall honestly, I've just -- I've never liked math." However, they would go on further to say that their relationship to math is "negative in the sense that my experiences have been bad. But it's also something that I have excelled at in the past so I think it's also very rewarding. But I would say the negativity trumps the positivity ..." Among the IS TCs, a recurring motif was that they all had very positive experiences with math up until university where their relationship with math was complicated by the increased difficulty and abstraction of the subject. As such, there was a belief that **More Abstract Math Equals Less Understanding**. For example, Participant 33 said that

> I really enjoyed in first year -- I took linear algebra and that really made sense to me. But then when I went to take the second half, I ended up dropping out of it because it was – it was too much, but I like the earlier stuff. I did enjoy calculus in high school as well. I don't know, I think I really liked the earlier math that wasn't crazy hard. And then when it got … I guess more theoretical. That's when I just didn't click with it anymore.

This was a recurring sentiment throughout all of the IS interviews. Participant 93 likewise said that "I loved mathematics when I was in high school and elementary school ... And I dreaded it and hated it in university so much ... when it was something that was so out of reach for me." There seemed to be a point in university at which all of the IS TCs became lost in the abstraction of math and, as a result, developed a more complicated relationship with math. Participant 24 drew parallels between their experience of math anxiety in university and the experiences of their more math anxious peers in high school. They said that "And like it was incredibly disheartening when it [experiencing math anxiety] happened to me…" before going on to say that "And I obviously didn't think about it in the moment, but like, yeah, I had lots of friends and stuff in high school who had that happen to them at that time whereas it happened to me just many years later."

This experience of math anxiety later in their education often led to **Feelings of Inadequacy** as TCs' identities as a "math person" seemed to conflict with the new reality of their university experience. Participant 93 remarked that "the fact I wasn't doing well in it [math] and I wasn't able to get like a higher grade for sure was affecting me, making me feel like, ‘Oh I wasn't good at it anymore.’” When TCs encountered difficulty in their math courses (both in university and in high school), they tended to adopt either one of two approaches in dealing with the difficulty. The first was a **Pragmatic Approach to Math Classes** in which they aimed to just get through the course with a decent grade. When TCs adopted this approach, it seemed to have a preserving effect on their positive relationship with math. For instance, when I asked Participant 33 about whether their negative experiences in university math had resulted in math anxiety, they replied

> I guess at that point I kind of was doing what I had to to get a decent mark and to pass the course. So, we would have, we got to get a cheat sheet on our exams. So, I was focusing on -- on that to kind of carry me through the exam. And I didn't necessarily -- it didn't necessarily make me dislike math. I just knew that I needed to get through that course and then I could maybe take a few easier math courses after that so I could get … enough for my teachable.

In contrast, other TCs had a more **Idealistic Approach to Math Courses** in which they were taking math courses not just for the practical benefit of a credit or mark, but for more intangible benefits like their enjoyment or it being part of their identity. The most striking example of this approach was Participant 61 who, despite disliking math and not needing higher level math courses for their profession, took math all through high school in order to prove that they could do it. Participant 61 described how, in Grade 9, their academic math teacher encouraged them to drop down to applied level math. The following exchange shows the impact that this had on their relationship with math

Participant 61: It [their teacher recommending that they drop out of his course] just reaffirmed what I already believed. (Pauses) So that was really hard, but then it also pushed me to, you know, wanna do well. So I stayed in his class, I ended up getting a decent mark and then (exhales) I put so much effort into math through high school. Which honestly just made the experience more negative because I had like put so much pressure on myself to do well. So overall honestly, I've just -- I've never liked math.

Theodore: Okay. And … did you continue like with academic and university [level math courses] throughout high school?

61: I did, yeah. And math actually ended up being my highest mark every year. But not because I liked it. Because I was proving a point basically.

As such, it seems to me that TCs who adopted a more idealistic approach to their math courses ended up experiencing more of an aversion to math than those who adopted a more pragmatic approach. Participant 93 also seemed to adopt a more idealistic approach, which seemed to result in the feelings of inadequacy and increased math anxiety that were shown in their previous quote.

Another key factor that impacted TCs' relationship with math was their math teachers. Overall, math teachers were discussed in a negative light and as having negatively impacted TCs' relationship with math. Several TCs had experiences of math teachers who pushed them away from math. For instance, Participant 61's story about their Grade 9 math teacher which was discussed above. Participant 13 also described being pushed out of math saying

> And my teacher, like we were talking, and she kind of encouraged me to drop out of the class just because she's like 'This is a very demanding course and if you don't like -- you're already in another math course so, if you don't need it, then why would you take it? Like have a -- have a spare, give yourself a nice break.' So then -- I don't want to blame her for me dropping out because like, obviously, it was my decision at the end of the day, but I think it was just an influence. And I'm normally one who, like, is always pushing myself, like testing my boundaries and that was the first time where I like set myself a boundary and said, 'You know what? Like you're right. I don't need it.'

Despite both having teachers who attempted to push them out of their respective math courses, Participant 61 adopted a more idealistic approach to the course and remained in it while Participant 13 took a more pragmatic approach and dropped it. While both described the experience as a negative experience with math, it seems to have negatively impacted Participant 61 more as they have a strong dislike for math while Participant 13 has a significantly more positive relationship with it.

Aside from teachers explicitly pushing TCs away from math, TCs also identified math teachers' pedagogy as being a source of their negative relationship with math. Several TCs believed that, when it came to their teachers' pedagogies, that there was a **Mismatch Between Pedagogy and Learning Style** (see the "Learning Style" subsection below for more information). For instance, Participant 93 discusses how one of the reasons they struggled more in university than in high school was because

> I think it was a different style of teaching it [math], like learning it from some professor standing at the front of the room telling me what to do versus like that more interactive, smaller classroom from elementary and high school, that definitely made it feel so out of reach and different because it was just completely different from how I had done it before.

Participant 61 also identified this mismatch between their teacher's pedagogy and their learning style as being a source of their math anxiety, saying "Personally, I am a very visual learner. So, I (pauses) I always like used my fingers to count, which I always got in trouble for. I guess that's another reason why it was a negative experience in elementary school…" They go on to say that "I just remember every time I counted on my fingers I would get in trouble, and I would have to like do it under my desk. And I couldn't -- I couldn't figure out problems unless I could draw it out or like see it somehow ... It was always so frowned upon, which I don't really understand, but I think that made my experience a lot harder."

Most of the TCs' stories about their math teachers were negative but not all of them. Participant 82 for instance discussed how a Grade 12 math teacher incorporated collaborative practices into their class. They say that

> [Until Grade 11, it] was like, 'Here's a worksheet. Here's the algorithm. Here's a worksheet,' … but then Grade 12 is like 'Let's do it together, let's do this together, let's do the worksheets together, let's do the questions together,' and that was something that was like a game changer because I was like 'This is -- makes so much more sense to me, I can talk to my peers and like have that interaction.'

As such, while both positive and negative experiences with math teachers affected TCs' relationship with math, the negative seem to have had a bigger impact given how much more they were discussed.

Attitudes Towards Teaching Math

Like with their *Relationship to Math*, TCs had a wide-ranging set of *Attitudes Towards Teaching Math*. Most TCs expressed an *Affinity* for teaching math and were **Excited to Teach Math** or had previously taught it and said that they **Enjoy Teaching Math**. Perhaps unsurprisingly, all of the IS TCs expressed excitement, enjoyment, and confidence when it came to teaching math. The PJ TCs' reaction to teaching math was more mixed. Participant 13 had taught math during their first practicum and said that they were **Confident in Teaching Math** and found it to be a rewarding experience. Participant 82 was **Neutral About Teaching Math,** saying that "I had a little bit of experience in my practicum of teaching math and (pauses) I think I'm like almost like neutral about it. I'm not necessarily excited about it and I'm not necessarily like nervous about it."

Participant 61 described being very **Anxious About Teaching Math Due to Their Ability**, especially for the Junior grades. They said that

> In my most recent practicum, I had a [Grades] 5/6 and when I was discussing with my AT what I would be teaching I specifically said like 'Please don't give me math because Grade 6 math is scary. I don't -- I don't know how to do it.' I haven't … looked at the curriculum. I think it would take me a while to like learn.

TCs who expressed being anxious about teaching math usually identified one of two causes for their anxiety. The first source of *Anxiety* was about their own ability to do math and how this would affect their teaching ability as was described by Participant 61 above.

Among the IS TCs, Participants 24 and 33 also expressed that they were slightly **Anxious About Teaching Math Due to the Stigma** that they perceived students have about learning math. For instance, Participant 24 said that “I'm nervous in the fact that there is, you know, this stigma of -- that a lot of kids will have going into it.” In particular, they were worried about demonstrating the applicability of math. They said that, when asked by students about when they were going to use a specific mathematical concept, that they “can't answer that question for you, but I can show … a bunch of different applications where it's useful or even just like highlight the fact that the most useful thing to learn in math is the problem-solving side of everything.” Participant 33 also expressed that they found it difficult to motivate such students saying that “I also taught Grade 11 workplace math, which was a challenge … yeah, because the students weren't really … motivated to learn (laughs). That was tricky.”

Regardless of their feelings towards teaching math, many TCs expressed a desire to **Teach Like They Wish They Had Been Taught**. For instance, despite being very anxious about teaching math, Participant 61 was quite explicit about this desire, saying

> In my last year of my undergrad with teaching, there was like a quote we looked at and it was like ‘You teach what you know.’ And I think that, for me, I want to not do that. I want to teach in the way that I wish I was taught. And I think the things that I've told you, like more informal assessment, is an example of that. I

don't like sitting down for tests and so I probably will not be doing that a lot with my own students.

This attitude was also reflected in other TCs' interviews. Participant 82 said that "I think, for myself, I've obviously grown up in a very like 'Here's the equation. Let's do the worksheet. Here's your homework.' [sort of environment]." They then went on to say that "And I -- I don't want to do that for my students, I want them to be able to excel … in any way that makes sense to them." As such, participants' personal experiences with math seem to have impacted their attitude about how they want to teach math. For some TCs, this wish arose because they were introduced to the constructivist methods of their pedagogy course and preferred it over their own personal experience with traditionalist methods. For other TCs, this wish arose because of their personal education experience in the education system, as they consciously reflected on the differences between different courses and teachers that they experienced (see the *Experiences* section below for more information).

Another predominant attitude which emerged was *Concern*. Most TCs expressed **Concern About the Teaching Method** used in their math pedagogy course, even if they were overall positive towards it. Participant 33 expressed concern about ensuring that students were meeting their learning goals, saying "how do you get from your problem to 'This is the learning goals'? Like how do you make sure that the learning goals are fulfilled by the end of the lesson? That was probably the trickiest part." Participant 24 expressed similar concerns about ensuring that everyone was learning as well as concerns about its carryover to institutionalized testing (i.e., EQAO). They also said that

> I mean like there's obviously the unseen things [challenges] of like maybe the buy in from the students aren't as overwhelming as the text may imply. Or, you know, maybe student behavior isn't -- the -- the class dynamics don't work with it. I also think that there's certain parts of it that might be limiting to people with different disabilities and different like IEPs for example.

Participant 61 expressed concerns about doing it with younger students. They said that "I would like to try it with a young age group. And I think that's my only hesitation because it's easy as university students because we behave. We're not running around." They also worried about ensuring that the work was being done by the whole group and not dominated by one individual saying that "And also, the -- the problem with that is one person in the group could be doing all the work. And then everyone else is just there and they don't really understand how you got there." However, they still concluded positively by saying that they think that "any instructional method in math is going to have its cons. So I think that the one that we've been using has been just a really cool approach and one that I've never seen before. So. Yeah, I would definitely try it out." Participants 82 and 13 also expressed these concerns. Participant 13 also expressed concern about the amount of time the "Thinking Classroom" method took, saying that "I feel like it's going to take a lot of time and a lot of patience and courage to get a class to that point. And, in my opinion, to even facilitate and get a hang of it…"

Some TCs also expressed **Concern About Their Teaching Ability**. Participant 33, for example, expressed concern about ensuring that the learning goals were met. They said that "there is a possibility that they might just completely miss what you're trying to put out there and the learning goals for the day will not be fulfilled…" They also said that another concern of theirs was that they were unsure about "creating a task that will meet the learning goals. I don't know. I'm still trying to figure that part out." Participant 13 also expressed concerns about their ability to connect student work to the learning goals, saying "how do we identify 'Oh, you know what? This person did doubling and halving.' … like there are so many concepts where I like I couldn't pinpoint it. But once it was pinpointed, I understood it."

The final attitude which emerged was one of *Uncertainty*. Two participants remarked about being unsure how to answer my questions, saying that they would need to wait until they have their own classroom before they could properly develop an answer. Participant 33 seemed the most unsure, responding to several of my questions with uncertainty. For instance, when I asked about what role textbooks or worksheets would have in their classroom, they said that

> I don't know, right now I'm still kind of building an opinion on that [how to use textbooks and worksheets] with what I'm learning and I think seeing it in practice will be what … really helps me create that more solid opinion on textbooks and worksheets.

When participants were unsure, they often voiced a need to wait until they developed more classroom experience in order to decide what was most effective. For instance, when I asked Participant 82 about how students learn best, they replied that "I think it really depends on who -- who you're teaching and what you're teaching. (Pauses) Yeah, I would say -- I don't know. Especially with -- just like -- I've only had such limited experience with it." As such, participants seemed to put more value on their professional education experiences (e.g., their experience teaching in the classroom) than on their academic education (e.g., learning the research and theory behind education). This focus on professional education is explored more in the *Experience* section below.

As a result of this uncertainty, some TCs expressed being **Open to Other Pedagogies**. For instance, Participant 82 said that in their practicum class, it was

> a very busy class so we always had to be doing group work, moving, or doing something so I knew for them it was the best thing to do is like partner work or group work, have the question they can work through it. But if -- I don't know, I haven't had the experience of the classroom that's very, like, structured. So I don't know what it would look like out there so that could be changing my perspective…

As such, it became evident throughout the interviews that TCs' pedagogical beliefs were still malleable and changing and had not become firmly fixed as TCs expressed uncertainty about their pedagogy as well as a willingness and openness to changing it.

Experience

When justifying their pedagogical beliefs, TCs would draw upon three main types of experiences: their **Academic Education Experience,** their **Professional Education** Experience, and their **Personal Education Experience**. All of the participants drew from a mix of these three experiences when justifying their pedagogical beliefs. For their academic education experience (i.e., what they learned in school about teaching), they would often draw from their math pedagogy course. For example, Participant 61 said that they would structure their classroom around the “Thinking Classroom” model because of their pedagogy course saying that

> I think she's [their math pedagogy professor] onto something there. I really like how it's not just you sit down, and you get taught and then you go out for recess. Like I like how it's structured. I like that there's any sort of structure at all. It's like a minds-on, it's the action piece where you work together, and then it's the consolidation where you -- you go around and you see what other people have done and you try to understand why they've done and you have a little bit more freedom in -- in solving those problems and it's not like you have to use this equation to get there.

Often, when TCs drew from their academic experiences, it was because what they learned in class reflected own personal education experiences. Participant 33, for instance, justified the methods shown in their pedagogy course via their own personal experience, saying

> Yeah, I think (pauses) the biggest thing for me that made me kind of see that students can learn differently was the math teachable course because I've only really been exposed to the ‘I write you write’ kind of way that math is structured. And I think it is – it’s really important to get students to think about math on their own and not to be told what to do because that's what I did and I feel like I would be a lot better at math, if I was actually trained to think about it (laughs) and not to just copy and, you know, use the formula. I think that's where and why I wasn't doing so well in university is because I wasn't able to actually think

> about the problem and how to solve it. I was used to copying things down and mimicking.

As such, reflecting on their personal education experiences played a crucial role in the formation of their pedagogical beliefs.

Nearly every TC spoke about how **Reflection Impacted Their Pedagogical Beliefs**. For some TCs, this reflection only occurred once they started their Bachelor of Education. Participant 24 said that "Yeah, it wasn't really until like a bunch of the reflections in teacher's college where like I started to think about back in high school and how I felt and how like friends of mine in the same classes were struggling." This reflection made them more open to their pedagogy math course which they said taught them that "there are ways to teach math so that more people can find success" and so that students "will also now have a better conceptual understanding of the topic ahead of time which is, you know, it will be an even richer understanding and that's great." These TCs believed that the **Math Pedagogy Course Showed Them Other Ways of Teaching Math.**

In contrast, for some TCs, this reflection occurred while they were going through the school system and, as a result, they felt that the **Math Pedagogy Course Has Been Validating** for the beliefs that they developed prior to the course via their own reflection. For instance, Participant 93 said that, when they encountered difficulty in university, it provoked this kind of reflection. They said that

> I think it's [reflection] something that definitely happened during my first degree. Because I was experiencing at the moment – and, you know, when I was in high

> school I could still recognize when I thought a teacher was -- I -- like a teacher was more effective with their teaching in different classes but it was when I had finally like experienced some struggle myself that I could really reflect on my own abilities and think ‘Okay. Why am I struggling so much with this? Why is this way of learning like not effective to me specifically?’ And I think maybe because I wanted to become a teacher, I was able to have those types of reflections where I'm challenging like my thinking versus like how it's being taught here versus there. And I was -- I wanted to know because I really did want to improve on like my own practices as well.

Another key impact of their academic education experience was that it introduced them to other ways of teaching math. Some TCs said that the math pedagogy course taught them that math did not have to be taught in the traditional way that they were used to. Participant 61, for example, said that “I guess as a kid, I -- I just accepted like mad minute and tests and things as normal so I just over time -- like I just thought that that was how it is supposed to be.” As such, when they started taking university courses about pedagogy, their ideas changed “Because I've learned that there's a lot more freedom in how you teach, you don't you don't have to do all these things that you grew up doing…” As such, they concluded that their ideas about pedagogy have “changed and university and learning about pedagogy has influenced that.”

Another major source of experience from which TCs drew from was their professional education experience. This code included their experiences in practica as well as any teaching experience they had outside of the school system (e.g., tutoring, coaching, etc.). As an example, Participant 93 drew quite heavily on their tutoring experience when explaining the importance of fostering student engagement by learning about their interests (see also the "Student Engagement" section below). They said, "One of the ways, with a tutoring student of mine, that I like to foster engagement is kind of knowing what sort of things they're into." They then provided an example of a student that they tutored who was into video games and that they "taught her how to do like unit pricing by discussing the cost of like gems and things that you can like – in-game purchases. So, we discussed like what's the best in-game purchase you could do if you had to…" This lesson seemed to have an important impact on Participant 92's pedagogy as they went on to say that their student

> loved that because it was something she cared about, and she had like an 'Aha!' moment learning about it. And I think applying that sort of idea with all your students, like finding different things that they engage with -- of course you can't do it in every lesson -- every, you know, you're gonna have different lessons here and there. But trying to find different things that they like and applying it to the things that they're working on at that moment are really helpful.

All of the TCs also drew upon experiences from their practica when talking about their beliefs. They would either reference practices that their Associate Teacher (AT) did or point to the success of their own lessons as the basis for their beliefs. As an example, Participants 13 and 61 both justified aspects of their pedagogy with reference to their practica. Participant 13 justified their belief in outdoor education by pointing to the success of their lesson on their practicum, saying that

> Like I took math outside one day -- actually twice we took it outside. We did snow angels in the snow and talked about symmetry … so, I feel like I would like my math classroom to expand beyond the actual four walls of my classroom just because I feel like it gives students a-whole-nother level of connectedness with math.

Participant 61 discussed the usefulness of non-traditional assessments like observation by referencing their AT's practice. They said that their AT

> had like a checklist, and she would like do codes so she would highlight someone's name when they participated and … she would have letters that meant different things. And I think that that was a really good way to just track like where every student was …

The final experience from which TCs would draw from was their own personal education experiences. TCs would often justify their pedagogical beliefs by referencing their own experiences in the education system. For instance, Participant 93 discussed how they would not want to use tests to assess their students because they had test anxiety when they were in school, saying that "I'm not a big fan of tests because like I myself have test anxiety so it's just not -- to me it's not the most effective way [of assessing students]." Likewise, Participant 82 believed that students should be more often working collaboratively than independently by saying

> I wouldn't say necessarily [having students work] independently because I know -- like someone -- for myself if I get really frustrated, I shut down and I won't want

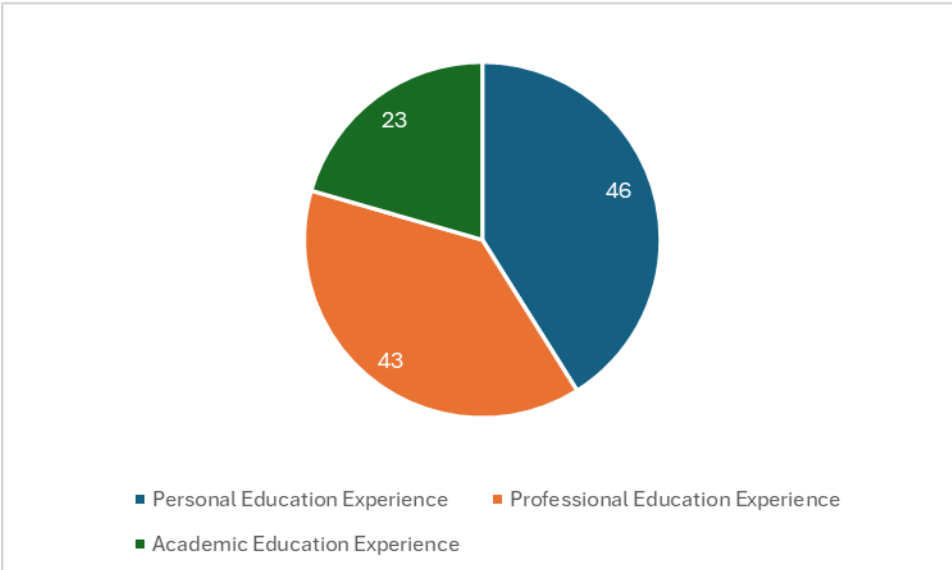
to do it. So I would say maybe [working] independently would be something that I wouldn't want my future students to experience.

An interesting code which also arose during discussion of their personal education experience was that many TCs felt that their **Educational Experience Hinders Their Teaching Ability** when it came to implementing the type of pedagogy that they thought was best. Participant 24 said that “the biggest obstacle currently is all of my educational experiences in this sort of classical way, the park and bark. Here's a theory, just do a bunch of examples. That's what I was used to in class.” Participant 82 also echoed this sentiment saying that “I've been taught the standard algorithm [of] ‘Here's the equation. We're putting this into this equation.’ So I think, for myself, to break down … doing just the standard algorithm is going to be the hardest part for me.” This lack of conceptual understanding and how they believe it will hinder their future teaching was a frequent belief among TCs (for more information about conceptual understanding, see the “Conceptual Understanding” section below). As such, it demonstrates that TCs’ experience, while being a strong source of inspiration for their pedagogy, can also be a large barrier to their implementation.

TCs’ experiences across these three areas formed the bedrock of their pedagogical beliefs. Almost all of their beliefs were justified with direct or indirect reference to experiences in these three areas. What is also interesting to note is the frequency to which TCs referenced their experiences. Figure 3 below illustrates the breakdown of references to experience and shows how TCs most heavily drew upon their personal education experience, followed by their professional education experience, and lastly upon their academic education experience.

Figure 3

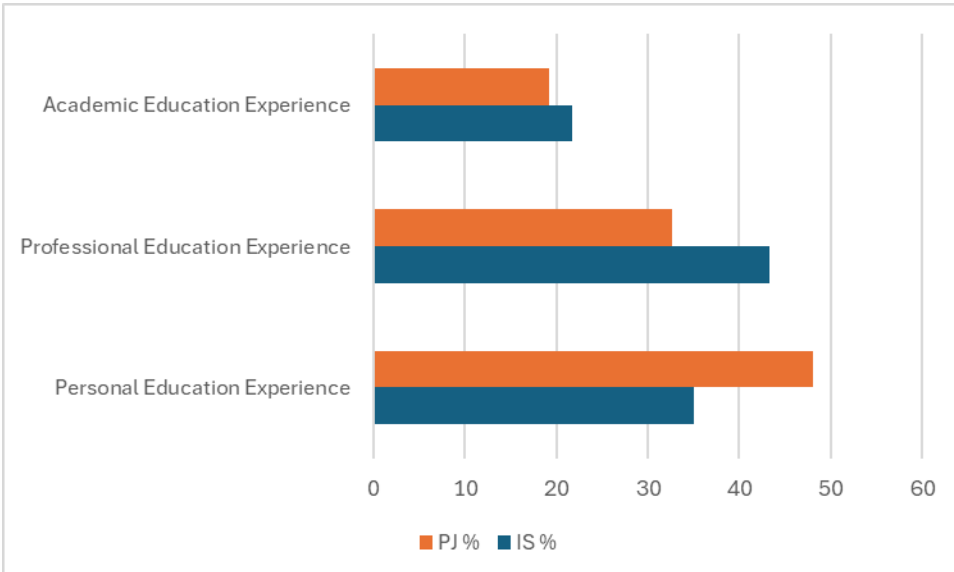
The Frequency of "Experience" Codes in Teacher Candidates' Interviews



It is also worth noting that, as mentioned above, many of the academic education experience references also incorporated personal education experiences due to the role that reflection played in developing their pedagogical beliefs. I coded these instances as academic education experience when they occurred within the context of their Bachelor of Education, but they nonetheless reflect the importance of TCs' personal education experience. Given the importance of reflection and the frequency of the personal education experience code, it seems that personal education experience played the largest role in influencing TCs' beliefs. What is also interesting to note is that there was virtually no discernable impact on TCs' beliefs from theoretical sources. That is to say that TCs almost never made explicit reference to pedagogical theories of learning, to child development, or to education research.

Figure 4

Percentage Breakdown of "Experience" Code Frequency by PJ and IS TCs



Another important note is that there was a difference between the IS and PJ TCs' uses of experiences. As shown in Figure 4 above, IS TCs tended to rely more on professional education experience while PJ TCs tended to rely more on personal education experience. A possible explanation of this phenomenon is that the IS TCs' were all second-year Bachelor of Education students and, as such, had had 3 practica at the time of their interviews while the PJ TCs were all first-year students and had only had one. This observation suggests that TCs (and by extension teachers) may start to rely on professional education experience more than personal education experience as they progress into their career.

Role of Teacher

The *Role of the Teacher* was a fairly small theme which emerged from the interviews. The most frequent code related to this theme was that **Teaching and Doing are Different**

Things, which was mentioned by two TCs. Participant 13 remarked that, when they were deciding whether to do PJ or IS, they deliberately chose not to have the credits necessary to do IS math in part because

> I've heard people say like 'If like you're really good at math, then sometimes it's hard to explain it to people, like to teach it.' If like you just kind of get everything and then it's like -- so I was like 'Well, maybe I could avoid that by not taking that and then kind of have like a good foundation of everything.' But then, have room where like we could like maybe I don't know an answer of like why this happened so like you know what like now I'm on like the same level as the rest of my kids and we're finding it out and figuring it out together.

As such, Participant 13 believed that being good at doing math did not necessarily entail that they would be good at teaching math. They wanted to focus more on being a good math teacher, something that they felt would be negatively impacted by them taking additional math courses. While Participant 13 found this belief to be encouraging, Participant 61 seemed to find it to be a cause of anxiety saying that "But I've also never taught math, so I don't know … if I'll be good at explaining it. Like it's one thing to do a question. It's another thing to teach it (exhales), so that's nerve-wracking a little bit."

Another code which emerged was **Teacher as Guide.** Participant 93 was most explicit about this, saying that "I like to see myself as (pauses) a guide to my students' learning. They're – they're – they're in charge of their own learning, but I would be there to support them whenever they need." Participant 33 also demonstrated this belief in their attitude towards making mistakes. In order to cultivate an environment where students felt safe making mistakes, they said that “it also comes from how I teach. So, if like, students see that ‘Oh sometimes I make mistakes,’ they can be like ‘Oh like that's not a big deal. You know I can make mistakes too.’” Thus, both TCs seemed to want to create a culture in which they were not viewed as an all-knowing authority.

This teacher as guide attitude conflicted with the conception of **Teacher as Expert**, which some TCs also demonstrated. Participant 61, while not feeling confident teaching math, felt that becoming a teacher would force them to become good at it because “the more I teach it the more I become an expert in it. And I'm excited for that because I'll be forced to learn it … I don't really have an option.” As such, they seemed to believe that a teacher had to be an expert in the area that they were teaching and sought to be an authority on it. Participant 93, while advocating for their role to be a guide in the classroom, also seemed to feel pressure to be an expert. When it came to trying new pedagogies or strategies, they felt that it was difficult to do so because

> you have to be able to be willing to make a mistake and try something new and have it go wrong to -- in order to have them go right afterwards. And I feel like teachers have this sort of pressure on them to be perfect all the time. And it's really hard to have that opportunity to explore different methods to see what's gonna work and what won't. And that's kind of -- yeah, that's definitely a struggle as well.

Therefore, both of the participants seemed to feel pressure to be an expert in their role, even though they did not feel comfortable adopting that role.

Participant 13 also criticized the "Thinking Classroom" method in that they felt it lacked a definitive enough conclusion since there was no final say or input from the teacher at the end of the lesson. They said that

> like then it ends. People get selected for sequencing. And then we talk about it. And then it's kinda … that's it. Like we never said like, 'Okay, like what was our learning goal?' or like -- Or like, it would be maybe multiplication, but no one once did multiplication. Or like -- it was just (pauses) the connections between our purpose and the options selected or even like what I was doing, like through anything like -- Yeah, there was almost like … the connection wasn't there.

As such, Participant 13 seemed to want the teacher to provide more explicit instruction on the lesson and to make the connections and learning evident to the students, instead of letting them make those connections for themselves. This lack of explicit guidance was thus a source of frustration for Participant 13.

Student Response to Pedagogy

Most of the TCs expressed valuing how their students reacted to their pedagogy and indicated that they would make adaptions to their pedagogy if they felt that it was not working for their students. The two main responses that they gauged were *Student Wellbeing* and *Student Engagement* (as are described in the next two sections). Participant 13 described how their students responded to worksheets and how they altered the lesson according to their response, saying that

> sometimes they were very silly with the worksheets and like would purposefully put all the 3D shapes on the 2D side and all the 3D shapes on the 3D side and be laughing about it. So then, I would go to them and I'd say, ‘Look at like -- how would you feel if I marked this?’ or ‘How would you feel if I showed it to your mom and dad?’ And then they're like, ‘Oh!’ So, then they go back and they fix it. But it's like you know that -- like I know that they know it, so like that kind of made me think like, ‘Okay, maybe are these worksheets boring for them or are they too easy?’ So then, we kind of went back and that's when we started doing more of like the hands-on and the smartboard things, started going outside and doing things like that. So I think they're beneficial, just to kind of maintain like that independent work but then, like, kind of reading the room and seeing how everything's going, it's also telling for what they need as well.

TCs also used student responses to their pedagogy from their professional education experience to justify their pedagogy (as is also described under the “Experience” section above). Participant 82 justified their use of collaboration, in part, by saying that “When I was teaching, I was doing a lot more like partner work and group work. And my students loved it so -- and I was like ‘Okay well this is obviously a great start to … start with, when I am teaching math.’” As such, TCs valued their students’ response to their pedagogy and it seemed to play a crucial role in their consideration of what effective pedagogy consisted of.

Student Wellbeing

A frequent theme in the transcripts was an emphasis on *Student Wellbeing*. Every TC remarked on the importance of fostering student wellbeing when teaching math in order to teach effectively. This focus on improving student wellbeing was primarily achieved via two approaches. The first approach was to minimize math anxiety. Some TCs pointed out that **Math Anxiety Turns People Away from Math** and, as such, they sought to minimize it. Participant 24 remarked that

> It is a little disheartening, like I have a lot of friends and stuff within the program who have a high amount of math anxiety and I have like younger siblings who did not enjoy math even in the slightest. And like I think that with like a deeper understanding, it can be such a beautiful thing of … like just being confident in this thing that has so many different like areas of reach.

Participant 93 also believed that **Experiencing Math Anxiety Makes Them More Receptive to Students**. They were excited to teach math, in part, due to their desire to minimize math anxiety through effective pedagogy. They sought this as a goal "because I know there's so much math anxiety around it and like I've experienced that as well so that I feel like it's exciting to be able to be part of like the change in it." Thus, Participant 93's own experience with math anxiety served as an important raison d'être for them as a math teacher.

TCs embraced two main strategies in order to combat math anxiety. The most common was to use different forms of assessment. As was described in the *Relationship to Math* section, several TCs have an aversion to tests as a result of their personal education experiences with math and, as such, they believed that **Tests Foster Anxiety**. Participant 61, for instance, said that "I think that the – like the test is very anxiety-provoking and it just -- like for me anyway, it turned me away from math and I never want to do that to my students." Some TCs who did not personally experience test anxiety, like Participant 13, nonetheless recognized that tests fostered anxiety in their peers. As such, they said that "I definitely stood away from doing a standard test, just because like, although like I never was bothered by a test, I know for other people, tests do have a lot of anxiety and there's a lot of pressure…" The recognition that tests negatively affect student wellbeing resulted in many TCs shifting away from using tests for their primary means of assessment.

In shifting away from tests, many TCs embraced non-traditional means of assessment (e.g., observations, conferences, or projects). Participant 82, for example, said that "I hated testing, I – I, especially with math for some reason, it's just -- it gives you so much anxiety for no reason." As such, they sought to use non-traditional means of assessment, saying that

> I think even just having a conversation or having maybe like a little group you like -- maybe you have like centers or something and one of the centers is like the teacher station where you give them a question and then you're asking them questions about how they did that or why they did that and that way you could have like almost a conversation assessment rather than just a testing. (Pauses) But yeah, I think that's how I would do it, it's more of like a conversation rather than 'Here's a test, good luck.'

Participant 93 echoed similar sentiments as well as embracing projects for Assessment of Learning over tests, saying that “I do like projects, where students can demonstrate all of the knowledge that they've learned over like a course … time and then they can apply it to themselves as well.” One exception to this general shift away from more traditional assessments like tests and quizzes was Participant 33 who expressed more uncertainty about assessment. This uncertainty is discussed more in the section below entitled “Assessment”.

The other way in which some TCs sought to minimize math anxiety was by creating a **Safe Environment** in which students could show **Vulnerability** by not feeling compelled to be right all of the time and having the opportunity of **Learning from Mistakes.** Participant 33 seemed to express this sentiment most, explicitly saying that “And one of the things that -- like I guess one of the facets of my teacher philosophy is that I want students to be in an environment where they are not afraid to make any mistakes ...” The importance of creating a **Safe Environment** for students was universal among IS TCs, although it was not mentioned by PJ TCs. The code of **Learning from Mistakes,** however, included a mix of two IS TCs and one PJ TC.

One interesting code which emerged from Participant 13’s interview was the idea that **Struggling with Math Would Foster a Negative Relationship with It.** In particular, when Participant 13 was discussing their issues with the “Thinking Classroom” method with younger students, they said that

> They [Grade 1 students] -- I don't want to say they're very sensitive, but if they don't get something right away, they will break down and cry and, giving them a

> problem like that, I think you would have 23 6-year-olds crying and I think it would foster a very negative relationship with math.

However, this belief was in tension with their own reason for enjoying math. They said that they enjoyed math because “like school was something that came very easily to me. So when it came to math, I was like, ‘Okay, like I'm ready to like … actually like turn on my thinking cap and get into it.’” It is not clear to me why Participant 13 felt that their Grade 1 students would not have a productive struggle with math, but more of their criticisms of the “Thinking Classroom” method are discussed in the section entitled “Effective Pedagogy.”

Another theme which often emerged when it came to ensuring students’ wellbeing was *Preparation*. TCs often spoke of the need to prepare students for events outside of their classroom. Participant 93 discussed differentiating their lessons so as to meet the needs of older students, saying that

> For me, I think … grade level is super important because you have Grade 12s and, at that point, like Grade 11s, Grade 12s, some of them are adults, they're becoming adults, they have that -- they have that increased maturity level to them and they might be applying for post-secondary, they might be applying to jobs, there's so much -- There's different things going on there. I would be doing different problems with an older group of students that would be more relevant to what they’re going -- what they're doing themselves.

Participant 24 also said that, while the “Thinking Classroom” was an effective method, they were nonetheless worried “Because there are certain things institutionally that like don't exactly gel with that [method]. I'm thinking like EQAO. And like am I … setting my students up for failure if they don't feel comfortable taking tests like that?” However, they did go on to recognize that these tests were not necessarily effective measures of student learning, saying that “then there's a whole conversation of like institutionalized … tests like that or IQ tests like they're probably not the best benchmark. But who knows? I – I really do like the ‘Thinking Class.’” Nonetheless, these quotes highlight the worth that Participant 24 put into preparing their students.

In two instances, this focus on preparation meant giving students more traditional math lessons such as using textbooks. Participant 13 spoke of the need to prepare their students for high school while Participant 33 mentioned the need to prepare their students for post-secondary education. Participant 13 said that

> if I were to use a textbook in, like, intermediate Grade 7 and 8, just because like, in high school, my experience -- like I had 4 textbooks in high school, whereas in elementary school, I rarely ever touched a textbook. So I would maybe like just start … you -- like using textbooks in Grade 7 and 8.

Participant 33 echoed similar sentiments about Grade 12 students saying “even in an older classroom, like Grade 12, it might be more appropriate to do worksheets and textbook work because that's what they're gonna see in university.”

This focus on preparing students via the methods they were most likely to see is closely related to the belief that **Students Need to Be Taught How to Learn.** This belief came up in an interesting way in that it often seemed to justify traditional approaches to pedagogy. That is, rather than acknowledging that textbooks might not be as effective as other teaching tools, these TCs seemed to believe that students simply needed to learn how to use them properly. Participants 13 and 33 also identified this belief as being an obstacle to implementing more constructivist lessons. Participant 33 said that they struggle with "conceptualizing the ideas of a thinking classroom that we've talked about in the math teachable class. I think it's -- the students aren't used to it yet, so it might take a little while for them to warm up to the idea…" Participant 13 echoed a similar sentiment saying that

> like, there's already not enough time in a school day so then it's like facilitating a math -- like you have to start off with it right away. And I feel like it would take awhile because like, even like the classroom norms, like, kids don't like -- even like the routines, like kids don't get comfortable with routines, like it kind of takes 3 months to break a habit. But I also think it takes 3 months to … like facilitate a habit. So to get a habit started, I feel like, yeah -- Like for almost (pauses) a third of the school year, are we gonna be trying to focus on how to get this transition, this process going? Or are we going to start off by chunks?

As such, the idea that it would take a lot of time for students to adapt to new pedagogical approaches or that they needed to be properly prepared for more traditional pedagogical approaches seemed to act as a barrier against implementing more constructivist practices.

As part of preparing students, TCs often talked about the **Soft Skills** that students would learn via math. By soft skills, I mean those skills which are not directly taught or required in the math curriculum (e.g., social skills, critical thinking, etc.) while hard skills would refer to skills that are explicitly part of the curriculum and are assessed (e.g., a student's ability to use Pythagorean Theorem to solve for a hypotenuse's length). This code was more predominant among the IS TCs who all mentioned it. When they did talk about soft skills, they often focused on developing social skills, critical thinking, and problem-solving skills. Participant 93 for instance said that

> And I'm trying to foster them to learn different things that might be useful to them in their own lives and like as a teacher you're also like -- you're a mentor but you're also another human being trying to help students -in -- later in their lives learning different social skills and learning how to engage with other students and collaborate. Like there's so many different things to go into it. You're helping them learn critical thinking.

For the PJ TCs, only Participant 13 mentioned soft skills and they said that "they need to learn their independent work, their collaboration and working on like their fine motor skills with cutting, so it was -- I think that they're necessary and they're beneficial for practicing … the skills that they're learning."

The focus on soft skills by IS TCs seemed to be, in part, a response to the idea that the hard skills that students were learning would not necessarily be useful in every student's future. As Participant 24 put it, "there's a classic, like, 'When am I going to use Pythagorean theorem in my real life?' And I realize I -- I can't answer that. I can't answer that question for you." However, Participant 24 believed that, even if students did not use the specific hard skills that they learned in mathematics, that "the most useful thing to learn in math is the problem-solving side of everything." As such, Participant 24 highlighted the importance of developing students' soft skills in addition to the hard ones. Meanwhile Participant 93's focus on soft skills seemed to be because they had a more holistic approach to learners and wanted to foster students' humanity rather than just their math skills, as was evidenced in their quote in the previous paragraph. As such, the IS TCs' focus on soft skills seems to be due to the belief that the hard skills that students learn in math classes were insufficient for the needs of their students.

Student Engagement

A major theme which emerged from the interviews was the importance of fostering *Student Engagement*. TCs identified three main ways to make lessons more engaging to students. The first was a focus on *Applied Math.* By applied math, I mean applying math to real-world examples as opposed to using it in isolation as would be done in pure math. Virtually all of the TCs valued applied math as a way to improve student engagement with some TCs explicitly stating their belief that **Applied Math Makes Learning More Relevant and Engaging.** Participant 24 said that they started their graphing unit by having students look at real-world examples of graphs. The TC believed that

> putting real world context and having them [the students] conceptualize the importance of what we're doing, suddenly they were way more engaged [with the lesson] than had I just started off being like 'This is a scatter plot. This is your x-axis. This is your y-axis(laughs).' Yeah, like … making it accessible and conceptual in a way that like is at the level where they are.

Participant 13 also discussed the importance of applied math in making content more engaging, saying that “it opens up more conversations because they know what they're learning in math and how it applies to the real world. And I think that that would foster their learning even more…”

This belief seemed to be largely based on their own experiences with math. As was discussed in the “Relationship to Math” section, many TCs felt anxious when encountering what they considered to be more abstract math, although the degree of abstraction which was tolerated without provoking anxiety varied by individual. Participant 61 for example preferred applied math because it was more tangible. They said that

> Yeah, like I will draw it out if there's like something that I can visualize, I will draw it out … versus like … the -- like if it's algebra and it's just like A and then the equation and you have to solve, like I was never good at that because it's not tangible. I can't draw it.

Participant 93 also argued that applied math was more relevant to students, which made it more engaging. They said that “one of the big things for me is it needs to be relevant because a lot of people wonder like, ‘Where is this useful? When are we gonna use this?' or ‘When is it going to be important?’” As such, they believed that connecting math to real-world examples, especially ones that students were interested in, was an effective way to foster student engagement.

The second way in which TCs believed they could foster student engagement was by incorporating collaborative activities. All of the TCs valued *Collaboration* as an important part of their pedagogy. Collaboration was seen as making lessons more engaging and as being effective for improving student learning. Participant 33, for example, said that “I think that students probably learn best kind of in a collaborative environment.” Participant 82 said that collaborative activities helped to engage students. They said that “definitely junior I know they love working with groups, that's something that they love doing. So, I definitely think for like most of my -- I would try to teach it in groups.” Thus, collaboration was a strong value across all of the interviews.

As part of fostering a collaborative environment, most TCs said that they would have their classroom arranged by **Grouped Desks** (i.e., having several desks grouped together) as opposed to the traditional arrangement of desks in rows or in isolated islands. For example, when Participant 61 was asked about how they think students learn best in a math classroom, they said that

> But yeah, I would say the biggest one is just like -- like having desks that are together so that students can work together rather than like individual desks where everything has to be done independently because that way -- you like -- you can learn from your mistakes, maybe, but you're not learning from each other you're not like bouncing ideas off of each other seeing where your friends or what your friends are thinking so I think group work is like very essential in – in math classes.

The importance of grouped desks for fostering a collaborative environment in which students could learn from one another was a prominent code throughout the interviews.

Many TCs also planned on incorporating white boards into their pedagogy in order to foster an environment in which students could work together and learn from one another. Participant 93 for instance said that

> For me, I think the physical classroom would be somewhere where you have either grouped desks together like in group work because I think it's a very collaborative thing. And that takes a lot of the pressure off of math. As well, I love having whiteboards or any sort of like vertical non-permanent board that you can write on and work in groups -- I really like those! Even when I was in high school, I had one class that had those, it makes all the difference. So, being able to have groupings where they can take away that stress, having the vertical whiteboards or any space like that where students who need that more kinesthetic learning can get up and move around and have movement in it is great.

This focus on grouped desks and whiteboards was echoed by most of the other TCs who sought to create classroom environments that fostered collaboration.

The third way TCs believed that they could foster student engagement was via *Differentiation*. TCs identified several ways in which they could modify their pedagogy in order to make their lessons more accessible or relatable to their students. Several TCs spoke about the importance of learning about **Student Interests** in order to make their math lessons more engaging. As an example, Participant 24 saw using students' interests as a way to get to know their learners as well as demonstrating the usefulness of math. They said that, during their practicum, they gave students a task in which they were allowed to choose their favourite sport and used it as an example of applied geometry (e.g., the dimensions of a fencing piste). Participant 24 believed that the task

> was just a really great way like, as an educator, to get to know them but then also for them to have an idea that like 'Yeah like this stuff that we're going over is important and has real world context.'

Participant 82 also discussed incorporating students' interests by making their math lessons more cross-curricular. When they were teaching math in their practicum, their class was learning about habits in science and so they decided to incorporate the idea of habits into their math lesson by having students find the dimensions of various habitats. They said that their students "were so engaged with [their lesson] -- if it was tailored to what they're interested at that moment, which can be super, super helpful." As such, TCs found that learning about their students' interests and incorporating them into their lessons was a way to meaningfully improve student engagement. This belief also further demonstrates the importance that TCs put on applied math as applied math gives them the ability to make math more relevant and interesting to their learners.

Another way that several TCs differentiated their lessons was by allowing for **Student Expression**. Participant 24's task that was described in the previous paragraph is one example of how TCs tried to allow students to express themselves better in math classes by giving them more options. Participant 82 also discussed wanting to give students the option of either individual or group work, saying that "I think I would give them options, if they want to do it in group work, that's totally fine. But if there's someone that's really excelling in that area and they want to do independent work then I would also offer that as well." Participant 93, in addition to wanting to give students options when completing projects, wanted the classroom to reflect their students' work and to allow them to express themselves in the decorating of their environment. They said that

> if you have that in a room -- like a Bristol board, you leave it open and have the students kind of engage with … how -- decorating however they want to, putting up anything there. To me, it's like I'd wanna have my students work put up in the classroom too so that they can see their own work. And then, of course, like if you have students, and you're finding out the different things they enjoy, you want to add that to the classroom as well.

The third way in which TCs differentiated their lessons was by considering students' learning styles. Participant 82's quote in the last paragraph is also an example of how TCs would differentiate their lessons to accompany different learning styles. TCs believed that **Students Have Different Learning Styles** and, as such, sought to incorporate different modalities into their pedagogy such as **Visuals** and **Manipulatives**. The focus on visuals and manipulatives was seen primarily among the PJ TCs, all of whom identified their importance. Participant 13 expressed the importance of both by saying that "I definitely like the application of real-life scenarios because then it almost gives you like a visual -- cause I am a visual learner and hands on, so I do like using manipulatives and things like that." This sentiment was also reflected in the interviews of the other TCs.

Another way in which TCs sought to differentiate their lessons was by ensuring **Accessibility** and adapting lessons to learners with learning exceptionalities. This code of **Accessibility** was seen in nearly all of the interviews. It was also part of the *Concern* about the "Thinking Classroom" method that some of the TCs raised, as was briefly mentioned in the "Attitude Towards Teaching" section above. For instance, Participant 24 said that "I also think that there's certain parts of it [the "Thinking Classroom"] that might be limiting to people with different disabilities and different like IEPs for example." Participant 24 went on to highlight how whiteboards may not be accessible to all students (e.g., ones with mobility concerns) and that some students may have problems with group work. As such, they felt that "there might be situations where like modifications to that have to happen without making those people feel like ousted from what's happening within the class." Participant 13 also emphasized the importance of additional supports in order to ensure that group work is functioning well, saying that "there can be like accommodations or modifications to the work. However, I think that like the group engagement is something that can still be managed with … the proper resources and supports." Participant 93 mentioned the importance of having a low-floor, high-ceiling approach to the problems used in their lessons in order to ensure that the lessons were accessible to all of their learners. They said that, in order to meet the needs of diverse learners, it was important to "have extensions for students that are just completely understanding it and you have questions that are still at that material that you want students to learn but have a bit more support so that they're able to understand that too." As such, accessibility was an important value for TCs, and they expressed a variety of ways of ensuring that their lessons were accessible.

Learning Styles

The theme of *Learning Styles* emerged several times throughout the interviews. As was discussed in the “Relationship to Math” section, many TCs felt that there was a mismatch between the pedagogy that their math teacher used and their learning style, which negatively impacted their relationship to math. *Learning Styles* were also considered an important way to differentiate lessons in order to make them more engaging to their students, as was discussed in the previous section. An interesting note is that four TCs identified as having a specific learning style. However, all four of the TCs who identified as having a learning style, identified as being a **Visual Learner**. Seeing as how all of the TCs who identified with a learning style identified with the same one, this seems to imply that the learning style framework may not be a useful one.

It may also be that TCs are interpreting conceptual understanding as visualization and visual learning. Participant 24, who did not identify as a visual learner or speak about learning styles, used visualize and conceptualize interchangeably, saying that “I think if they [students] can (pauses) visualize or conceptualize what is being talked about, then they learn the best; it doesn't necessarily mean that they do the best.” They also said that “I do think that I've always excelled when I've been able to like -- be able to conceptualize it and think it through.” This description of conceptualization seems to be very similar to how the visual learners described it when they were learning best. For example, Participant 82 said that they were a visual learner and that “There's no way I would be able to do -- answer the question if it wasn't drawn out. So I would draw -- if there's like 36 apples, you know, I was drawing 36 apples on that page. So I was, I need -- I need visuals, I need like … pictures, videos.” However, when I followed up by asking if they struggled with equations and more abstract math because they did not have a frame of reference to visualize what the numbers represented, they said that “Yeah, yeah, I feel like if I … If I had the opportunity to understand where each of those components were coming from, I feel like it would have been a lot easier for me to understand.”

As such, it seems that both Participant 24 and Participant 82 are visualizing math when doing it, it is just that Participant 82 feels they need a physical representation of that visualization in order to conceptualize it. Given the similar description of visualization and conceptualization and the fact that all of the TCs who identified as having a learning style said they were visual learners, I think that it may be better to focus on fostering conceptual understanding through the use of manipulatives and visuals, which can benefit and apply to all learners, as opposed to relying on the framework of learning styles, which may lead to a differentiation of pedagogy which is not as effective. This idea is also discussed more in the “Discussion” section below.

Assessment

Assessment was another major theme throughout the interviews. This theme was underpinned by TCs’ belief that they **Need to Monitor Individual Progress to Ensure Understanding**. As was discussed in the “Attitude Towards Teaching Math” section, one of the concerns which TCs expressed was ensuring that all students were learning. This code was observed in all of the PJ TCs who seemed to rely on assessment in order to ensure that their students were learning. As an example, Participant 61 said that “So I think it's really important to give everyone an opportunity to show what they're thinking, especially in a class that's like so full of IEPs and accommodations because otherwise you don't really know the ones that are falling behind.” This sentiment was shared by their PJ colleagues as well.

In terms of assessment, TCs embraced a wide variety of strategies towards different modalities. With regards to tests, most participants believed that **Tests Are Not a Good Way to Measure Student Learning.** This belief was primarily based on two underlying beliefs. The first was the belief that **Tests Foster Anxiety,** which was primarily discussed under the section “Student Wellbeing”. As such, TCs tended to want to avoid using tests as assessment tools as they felt that it would negatively affect student wellbeing. The second underlying belief was that tests do not accurately reflect students’ overall learning and understanding. For instance, Participant 24 said that

> there's always the people who say that they just wanna work through all the problems and then they'll do well on the test. And that's all that they care about. But like I would argue that, you know, that doesn't mean that they're learning the things as well.

Participant 13 also expressed similar concerns saying that “I know that like when you're doing a test, you're mainly testing how well somebody can memorize information, not how well they can necessarily apply it. So, that's like -- I just -- I'm not a big fan of tests.”

As a result of these two beliefs, many TCs shifted away from doing tests. Participant 33 was the only one who really considered still having tests. When asked about assessment in their class, they said that “I guess I haven't really figured that out yet. (laughs) I haven't really … seen many other assessments than like quizzes and tests and maybe an assignment in math. So I feel like that's probably where I would start and then go from there and see what happens." Given that Participant 33 was in the same courses as the other IS TCs, I think that their statement that they had not seen other forms of assessment implies that they had not seen them in their practica (as opposed to other forms of assessment not having been discussed in their classes). Thus, this statement is another example of how much weight TCs put on their professional education experience over their academic experience. Participant 61 also seemed a bit more conflicted in that, when asked about assessments, they said that "That's a hard one [question] because I never really like tests. But I also think that they're really good way to like show … like where someone is in their progress."

In place of tests, TCs advocated for using projects and classroom observations. Participant 61, while recognizing that tests were good measures of students' progress said that they think that

> the test is very anxiety-provoking and it just -- like for me anyway, it turned me away from math and I never want to do that to my students. I hope that they enjoy learning and they enjoy things like math. So I think a less formal ways is how I would approach it.

As such, they discussed the value of classroom observations. Participant 24 also argued that projects allowed for students to demonstrate and understand their learning in a much deeper way. When discussing a geometry culminating assignment that they used in their practicum, they said that the process was "significantly richer learning than what happened through most of the rest of the -- the unit."

When it came to the use of textbooks, TCs had a more mixed response. Several TCs believed that **Textbooks Are Often Misused** and that teachers over-relied on them, to the detriment of student learning. Participant 93, for instance, said that “I'm not really a big fan of textbooks just because I feel like … they're used in a way that's just -- they give it to the students and the students are supposed to do it themselves following the textbook.” As such, some of the TCs valued **Textbooks as an Additional Support for Students**. Participant 93 went on to say that “I think if the textbook was like an additional support, in the sense of like, if students need more assistance … or another way to have it explained, it could be a good tool...”

Despite opposition to the use of textbooks, **Textbooks for Practice** was still a common value among TCs. Participant 33 said that “Personally, I would say like textbooks are good for … practicing,” which was a sentiment shared by Participant 24 as well, who said that

> it's just like if you want to, here's some examples from the text[book] that like you could – he [Peter Liljedahl] doesn't like the word practice but like -- you could take some time and go through and make sure that you know the stuff that we went over.

I originally coded these segments as **Textbooks for Assessment as Learning**; however, I decided that it did not meet the criteria for Assessment as Learning. I decided it was not a form of Assessment as Learning because *Growing Success* defines Assessment as Learning as a formative assessment which “occurs frequently and in an ongoing manner during instruction, with support, modelling, and guidance from the teacher” (2010, p. 31). Since this textbook work would seemingly be unstructured and without much guidance from the teacher, I did not think it met the criteria to be considered Assessment as Learning. One possible exception to this is Participant 82, who said that "I think math worksheets or textbooks should definitely be used as like a self-assessment. But I think -- or like a good reflection tool, but I think that would have to be like … almost like taught." However, since they did not go into more detail about how it would be used as a reflection, I decided to keep it coded as **Textbooks for Practice**.

Most TCs also believed that textbooks could be useful as teacher supports. For instance, Participant 61 said that

> I think textbooks do a good job of explaining, you know, why you're learning what you're learning. I just feel like that is the responsibility of the teacher rather than the students to have to teach themselves about what it is that they're learning like the next unit, which was my experience personally.

As such, they seemed to believe that, while textbooks had valuable information, they should be used to help the teacher to formulate their own lessons rather than just having students learn from the textbooks themselves. Using the textbooks to help structure their own lessons was a common sentiment among TCs. Participant 24 also valued textbooks for helping to structure their lessons and making sure that the proper scaffolding was in place, saying that "I think the textbooks for the most part are well-written and like well-segmented to like scaffold."

Most of the TCs believed that **Worksheets Can Be Effective Tools When Used Properly** and seemed to have a more positive opinion about worksheets, although there was a mix of beliefs about how worksheets should be used**.** Worksheets were used in three different ways. The first way that some TCs valued worksheets was **Worksheets for Practice.** Participant 61 said that "I do think that worksheets have some value, 'cause I think it's practice and I think a lot of my learning came from doing worksheets because it-- it sets you up for success on like a test, right?" The second way that TCs thought worksheets could be effective was **Worksheets as Notetaking**. Participant 33 said that "And worksheets are definitely good to have students refer back to like their notes or whatever."

The final way that worksheets were used were as a part of an activity and to have students document their learning on. I coded this as **Worksheets for Assessment of Learning**. Participant 93, for example, said that

> I think worksheets can be used in an effective way … if they're paired with other methods like doing group work or having some sort of (pauses) engaging element to them, where students are actually actively participating in it -- as opposed to like, 'Here's a worksheet, fill it out. Sit at your desk do it silently.'

These codes were spread fairly evenly among the participants with only Participant 24 not explicitly embracing the use of worksheets and simply saying that "I worry that there's often too much of a reliance on worksheets."

Effective Pedagogy

All of the above themes coalesced or were a part of what TCs considered to be effective pedagogy. With *Experience* as their base, TCs formed different styles of pedagogies, which saw their expression in the *Assessments* that TCs preferred, the *Student Responses* that TCs looked for, their approach to *Learning Styles*, and what they believed their role should be. There were three general pedagogical approaches to which TCs subscribed. It is important to note that these approaches were not named in vivo during the interview process but are my labels for them. The first was *Constructivism*, which seemed to be the most prominent approach and consisted of five different beliefs. The first, and most common belief, is that the **"Thinking Classroom" Method is Effective**. Most TCs believed that the "Thinking Classroom" is effective and wanted to incorporate it, to some extent, into their pedagogy. Participant 24 expressed this strongly, saying that

> I really love the idea of the 'Thinking Classroom' about having these groups get together and work on rich problems. And going through a process of having them share information across different groups and going around doing a gallery walk to have them see people's different ways of approaching the same task. There's lots of rich value in conversation that can come from that.

Another common belief was that **Problem-Based Learning (PBL) is Effective**. Most TCs highlighted PBL's effectiveness, either on its own or in addition to the "Thinking Classroom" method. PBL was seen as a way of encouraging thinking as opposed to simply mimicking. Participant 33, for instance, said "that is something that I will try to do as a math teacher is to incorporate those thinking tasks so students move away from the mimicking and more to thinking." Some of the TCs referred to this method as inquiry-based learning. For example, Participant 82 said that

> in high school, we had a lot of like whiteboards that surrounded like our border of our classroom. So, like we would have a question and then we would do it like

> as a group or you would have like a small group try to figure out the question and then we would take it up as a group and then we would constantly do that until [you] have an understanding of what we're supposed to be doing and then we could do it on our own. So I feel like that is how I learned best … is just having that inquiry-based learning of like being able to do it on my own or like with each other and like figure it out kind of thing.

However, from this description, I believe that what they were describing was more akin to problem-based learning (PBL) than to inquiry-based learning (IBL). Gavric and Radivojevic (2022) defined IBL as “the art of questioning. The method is usually used during the realization of scientific content and consists of five steps: engagement, research, explanation, elaboration and evaluation” (p. 106). Participant 82’s description misses the research and elaboration steps of the IBL process. Meanwhile, Gavric and Radivojevic say that the characteristics of PBL are “providing students with the opportunity to learn by solving problems, cooperating with each other, creating their own learning models through practice and reflection. The student is encouraged to be an active participant during the presentation and acquisition of new knowledge” (p. 101). This description seems like a more apt reflection of what Participant 82 described. Therefore, even though some of the TCs said that IBL was effective, I believe that what they were describing was more akin to PBL and coded it as such.

Another code that fell under this category was the belief that students **Learn Better Through Mistakes**. This code is similar to the one described under “Student Wellbeing” as **Learning from Mistakes**. Participant 33 seemed to express the idea that creating an environment in which students could make mistakes was not only important for student wellbeing, but also allowed students to understand the material better. As such, I gave this segment a separate code. They said that

> you kind of learn better through your mistakes. And, as a student, I didn't like being wrong or making mistakes or anything. And I don't think I learned as much as I could have because I never liked being wrong. So, I want students to be able to make mistakes and to put themselves out there. And I think that -- that's kind of the first step to -- for students to learn best in a mathematics class -- is to, you know, be able to think and to attempt a problem without the fear of being wrong or making a mistake.

One code, which was only used in one interview, was the belief that **The Gradual Release of Responsibility Model (GRRM) is an Effective Method**. This code was used to code the method that Participant 13 described as working best for them. They said that

> So we would start off and then together we would fill it in and go through -- so the first one would be modeling, where like the teacher kind of did it all while explaining it. And then the second day would be guided and then … we would kind of just work through different problems and apply whatever we were learning to these problems. And then eventually it would almost get to like, ‘Okay, like’ -- then like almost giving the class the pencil and like, ‘Okay, what would you guys do here? What would you do there?’ Or like using … like we would have projects where it was like, ‘Okay, like, now you're going to look at …

> stats.’ Like I really like, like, the projects or like hands on. And just having like interactions within math rather than like, ‘Here's a work booklet, sit down and do it independently,’ I like … being able to talk about it.

Lin and Cheng (2010) state that the GRRM is one that “suggests that the task being taught should shift progressively and purposefully from explicit modeling, to joint responsibility, to independent practice and application by the learner” (p. 1869). Participant 13’s description seems to align quite well with this model, which is why I coded it as being an example of the GRRM (even though they did not use that phrase).

The final code which was used in this category was the belief that **Mimicry is Not Very Effective for Teaching Students**. This code was in tension with some TCs’ belief that **Mimicking Helps Them Learn**, which is part of the second pedagogical approach, *Traditionalism*. TCs who believed that mimicking was helpful for their own learning also recognized that it was not very helpful for their students. Participant 61 said that

> when they [their teachers] would -- and I know this, a lot of people would probably disagree with me, but when they would stand in front of the class and like draw it on the board with like direct instruction on how to solve it. That was also really helpful for me.

However, when discussing their time as a tutor who taught high school students, they said that “I don't know that I was teaching them. I was like, ‘Watch me do the question and then you do it’ kind of thing. And I don't think that that was the most effective strategy…” When asked why they felt it was not an effective pedagogy, they said that “I knew how to answer select questions that I had been working on, but I didn't know like the principles behind them. And I also just feel like I could improve in my explaining skills." Participant 33 believed that mimicking was the best way for them to learn because "I feel like that is how I learned best just because that's what I did throughout my entire school career. But I'm sure that I could learn … in a different way." As such, while several TCs believed that mimicking was helpful for their own learning, none of the TCs endorsed using it with their own students. Some TCs, like Participant 61 above, explicitly said that mimicking was not an effective form of pedagogy. Most were less explicit and simply did not endorse it when describing how they would teach math.

There were only two other beliefs associated with *Traditionalism*, both of which were critiques of the "Thinking Classroom" method. It is important to note that even though TCs were critical of the method, that does not mean that they were overall traditionalists in their pedagogical approach as TCs expressed beliefs across a spectrum of pedagogies. The first belief was that the **"Thinking Classroom" Is Not an Effective Method**. This belief was coded when TCs criticized the "Thinking Classroom" along traditionalist lines. As was discussed in the "Attitudes Towards Teaching Math" section, many TCs expressed concerns about the method, but this code was reserved for participants who were more critical of the "Thinking Classroom." Participant 13 was the only participant who was coded for this belief as they felt that it was an inappropriate method for younger students. In particular, they said that "And I never … could do Heather's … like the way that she wants the math classroom to be … facilitated. I don't think that that is a realistic expectation to do in a Grade 1 classroom …" They did, however, feel that it would be more appropriate to use with junior students and they tended to subscribe to the

GRRM model. As such, despite being critical of the "Thinking Classroom" method, Participant 13 still had strong constructivist tendencies.

Participant 13 criticized the method along two main lines (in addition to the lack of a definitive conclusion which was discussed in the section "Role of the Teacher"). The first was that younger students would lack the vocabulary and basic math skills to explain or understand their peers' work. They said that, for students in Grade 1 and 2, "having those words and those vocabulary and that like foundation of skills and understanding -- like understanding in math might not be there right away." As such, they felt that students needed more explicit instruction in order "to develop those like the vocabulary, the skills so that they're able to identify it [the learning in the lesson]." Their second critique was that younger students lacked the maturity for the conversations that formed the consolidation phase of the "Thinking Classroom." They said that

> Like if I ask, 'Oh what do you like about this problem? What do you think they did?' I think they would talk about the colors that they used or their choice of whiteboard marker or they're going to say 'I don't know' or even then … it's like that socio-emotional part of the children are still very -- like they're still kind of getting that under control so that it's like, 'Well, you didn't pick mine!' and then they get upset or 'No, that's not what I did!' and then they start arguing. So I feel like, specifically for Grade 1 and 2, that it's … very difficult to navigate something like that.

As such, they felt the “Thinking Classroom” method was not appropriate for younger students and subscribed to more of a GRRM approach to teaching.

The second critique was the belief that the “**Thinking Classroom” Takes More Effort than Traditional Pedagogy.** This critique was not always viewed as a negative by the several TCs who expressed it. Participant 24 still preferred the “Thinking Classroom” method while also acknowledging that the traditional approach was the path of least resistance. They said that it “takes a significant amount of effort, you know, to try to adapt more of the ‘Thinking Classroom’ and like make it a more engaging thing for students so that it isn't this, you know, doldrum class.” This attitude was also reflected in their belief about textbooks, as they said that

> I think that, often, textbooks are used -- maybe this is too stereotypical but like in a way of like the teacher being like ‘Here's a textbook, all the questions are in there, you go do your stuff. I'm just gonna sit up at the front.’ And -- and I'm hesitant because like I don't want to -- I feel like it's a pretty slippery and easy path to fall down. Like, ‘Well, that was easy. I liked that. I didn't have to put in this much effort. Oh, love it!’

As such, Participant 24 viewed the traditional approach to teaching as being the easier approach, even if it was less effective (or even harmful) to their students. They nonetheless liked the “Thinking Classroom” method as it better aligned with their values and was, in their opinion, more effective. They therefore sought to incorporate it into their pedagogy, even if it was more effort.

Participant 13 meanwhile saw this as a negative of the method. They felt that the trade-off in time was not worth any supposed benefit that would come from the method. They said that

> we [the class] start off in September and say maybe getting the hang of it might take (pauses) 2 I like -- I even want to say like 3 months -- like around 3 months to kind of get that process under smoothly. But then it's like, ‘Okay, but then what about all the content we were covering over the 3 months? Is like that going to be hampered because we've been so focused on like implementing this practice?’

As such, they viewed the time it would take to implement the practice as not being worth the trade-off.

The third pedagogical approach was *Eclecticism.* As was mentioned previously, TCs expressed a range of pedagogical attitudes and approaches and so often adopted a more eclectic approach. Participant 24 said that “my AT isn't doing a ‘Thinking Classroom’ but is taking elements from it that work for her. So, it wasn't randomized groups, but every unit she would randomize the seating arrangements so that people were always working with different people.” They went on to say that “it was nice to see like that there are steps you can take to get there without it being like a full implementation all at once. But that's definitely sort of where I see -- envision myself going with it for sure.” All of the TCs seemed to take an eclectic approach to their pedagogical style, focusing more so on what was effective than worrying about implementing consistent theoretical ideas.

Most of the TCs also believed that **Environment Affects Pedagogy**, whether that be the social or physical environment. As such, TCs felt that they had to adapt their ideal pedagogy to the material and social conditions of the classroom that they found themselves in. Participant 93 described how social conditions negatively impacted their pedagogy, saying that

> one thing I've noticed is there's a lot of pushback for changing how things are run in schools. And I would say like I had a really great experience in the schools that I've been in so far, in some of them, and others like I've noticed there is -- it's hard to do, to change things. I'm a big like Outdoor Ed person and I would love to bring that into like the math classroom as well, but there are so many risks involved, and it's gotten more complicated over the years to take trips due to safety and other factors so I find that that's gonna be an issue.

When asked about where they felt the pushback was coming from, they said that it came from "Other teachers, definitely. When it comes to like safety and things, administration. And I think too, parents … Honestly from everywhere." As such, the social environment acted as a barrier to implementing the pedagogy that Participant 93 believed would be effective.

Participant 33 meanwhile saw the potential for a positive change to their pedagogy depending on the environment that they were in. When they discussed implementing a more constructivist pedagogy, they said that they felt their own educational background would be a barrier to implementation as they were so used to traditional pedagogy and felt more confident in it. However, they continued on to say that

> I think that trying to break through that barrier and think about or create thinking tasks is going to come from collaboration – Definitely … like talking to other teachers and also from research and stuff. So that's definitely something I'm gonna have to put some energy and time into is developing these thinking problems and tasks … to kind of break out of that … structured note approach.

The obvious issue though is that the TC may find themselves in a social environment which is not conducive to collaboration or constructivist pedagogy and, as such, will default to the traditional approach. Further discussion of the impact of the environment on teachers' pedagogy, however, would involving assessing larger systems like the school environment, the education system, et cetera, which are outside the scope of this thesis.

The other way in which the environment affected TCs' pedagogy was the physical environment of their classes. For instance, several TCs pointed out a lack of space or materials necessary to do the "Thinking Classroom" method, thus negatively impacting their pedagogy. Participant 24 said that, during their practicum, "It was heartbreaking in my class that we had whiteboards up along the room. But there were so many desks in the class for all of the students that we just couldn't really access any of them." Participant 61 said about their own education experience that "We didn't use a lot of manipulatives like that wasn't really -- maybe it was the fact that I was you know, in a rural school and we didn't have resources …" As such, TCs recognized that, despite what their ideals might want, the environment in which they taught would have a large impact on their pedagogy and how they taught.

Some TCs also explicitly believed that a **Diversity of Pedagogies is Effective.** This belief was seen as being a way to differentiate their lessons and address all of the learning styles of their students (see the sections entitled “Learning Styles” and “Student Engagement” above for more information). For example, Participant 82 said that “If (pauses) my students are very independent and like … they -- they want to do worksheets on their own, that's totally fine. But I think I would always also offer that inquiry -- like that group work. And if -- and if that's not something that they like, that's totally fine.” Participant 13, when asked about how they thought that students learn best, said that “I think (pause) a combination of almost, like, anything.” Thus, some TCs viewed incorporating different pedagogical approaches as ways to differentiate their lessons for their students.

Conceptual Understanding

Effective Pedagogy was seen as a way of fostering *Conceptual Understanding* in their students, even if it was not explicitly called that. Many of the TCs recognized that **Traditional Math Teaching Did Not Encourage Conceptual Understanding** by reflecting on their own experiences with traditional math teaching and so sought practices that would better foster it. Participant 61, for instance, said that they “learned a lot of math in elementary school where I didn't really know why I was doing it or what it was solving. It was just an equation that I knew I had to memorize, and I've forgotten [that] now …” This sentiment was echoed by other TCs such as Participant 33 who said that

> it’s really important to get students to think about math on their own and not to be told what to do because that's what I did and I feel like I would be a lot better

> at math, if I was actually trained to think about it (laughs) and not to just copy and, you know, use the formula. I think that's where and why I wasn't doing so well in university is because I wasn't able to actually think about the problem and how to solve it. I was used to copying things down and mimicking.

As such, there was a widespread recognition that traditional math pedagogy was not effective for developing students' conceptual understanding.

Many TCs valued **Thinking** as a way of developing *Conceptual Understanding*. This value of **Thinking** was synergistic with the beliefs that **Problem-Based Learning is Effective** and that **Mimicry is Not Very Effective for Teaching Students** (see the previous section for more information about these beliefs). That is, the TCs who valued **Thinking** sought to incorporate more PBL into their pedagogy and saw it as a superior way to encourage thinking as opposed to traditional math approaches. For instance, Participant 33 went on to say that their math teachable course showed them the value of thinking in the math classroom and, as such, one thing they would "try to do as a math teacher is to incorporate those thinking tasks so students move away from the mimicking and more to thinking." This belief was echoed by other TCs as well who believed that tasks that developed thinking skills were better than traditional pedagogy.

Most TCs also recognized the importance of conceptual understanding and believed that **Conceptual Understanding Is Helpful for Learning**. Participant 82 believed that understanding where the algorithms they were using were coming from, as opposed to simply following the steps prescribed by the algorithm, made it easier for them to use it. They said that

> 2 weeks ago we had a question and I was like ‘I don't know why I'm doing this,’ and like … Heather, like, broke down everything to me and like to understand why I was doing what I was doing and that was super helpful so I feel like if my student -- if I … They have taught them in a way of the standard algorithm or if I …. might have done that, I would … want to walk them through why we're doing the steps we're doing to get to the answer that we're -- that we need.

Participant 24 also argued that developing conceptual understanding was important for student wellbeing and their learning, saying that “thinking back to the really advanced mathematics that I didn't love as much, I'm sure there are people that can conceptualize what's happening and feel good about it.” As such, Participant 24 believed that it was important to ensure that “whatever you're teaching to people, they -- you can frame it in a way that is conceptual for them. And then they'll have no problem with it or will at least have less of a problem with it.”

Participant 24 also emphasized the importance of conceptual understanding for ensuring that learning was more permanent and meaningful as opposed to just teaching for the test. Drawing from their experience with math during their master’s degree, they believed that it would take them a while to re-learn some of that math

> partially because I'm just a few years removed now from that world, but also just like the way that I learned it was in such a ‘I know it in this moment for this test or quiz coming up. And then it's gone from the ether.’ Yeah, and I know that that's what happens with a lot of people too at other levels. It's -- without that deeper understanding of what's going on, it -- it doesn't really stick.

As such, fostering students' *Conceptual Understanding* via *Effective Pedagogy* that promoted **Thinking** was a common theme throughout the interviews.

Doing Well in School

Perhaps unsurprisingly for six future teachers who were on at least their second post-secondary degree, **Doing Well in School** was a common value across all of the interviews. All of the TCs talked about wanting to do well in school, both as teachers and as learners. Many of the TCs mentioned doing well in school when they were students, with some specifically mentioning that they graduated with honours. This drive to do well also applied to their teaching. Participant 93, for instance, said that "I think that I always have a high standard for myself and I wanna make sure that I'm giving like the best possible education that I can to my students." TCs also wanted their students to do well and used their experiences to inform what they believed would be the most effective pedagogy for the students in order to set them up for success. One thing that I thought was interesting to note was that none of the TCs discussed maintaining their own wellbeing when teaching students while *Student Wellbeing* was a prominent theme throughout all of the interviews. The focus was always on ensuring student success and providing them with the best teaching possible.

Discussion

For my first research question, I sought to answer the question of how TCs' educational experiences impact their pedagogical beliefs about teaching mathematics. Unfortunately, I cannot fully answer this question as I lacked participants who had a math degree. Ideally, I would have interviewed someone with a math degree and who had had overall positive experiences with math in university in order to discern how these experiences affected their pedagogical beliefs. However, even with this limitation, I believe that the qualitative results illustrate that TCs' educational experiences had a large impact on their pedagogical beliefs. As was discussed above, TCs often justified their pedagogical beliefs via their experiences as learners and how they preferred to learn. Additionally, reflecting on these experiences seemed to also play a pivotal role in further developing their beliefs. As such, having TCs reflect on their experiences seems to be a powerful tool for promoting constructivist beliefs, especially for students who have had negative experiences with math. What remains unclear though is how effective reflection would be for TCs who did not have these same negative experiences with math pedagogy. Given the emphasis on personal education experience, it seems reasonable that TCs who did not have negative experiences with math pedagogy would be less susceptible to constructivist beliefs and wanting to reform mathematics; however, more research with a more diverse sample would be necessary to confirm this conjecture.

For my second research question, I sought to answer the question of how math anxiety affected TCs' pedagogical beliefs. I believe that these findings were more conclusive than the findings for the first research question. Most TCs explicitly referenced their anxiety as a learner for being a reason why they adopted one or more constructivist principles. For example, Participant 82 referenced how much they disliked tests and, as such, sought to use less traditional and anxiety-provoking means of assessment. Participant 24 also recognized the anxiety that was provoked by a lack of conceptual understanding and, as such, wanted to ensure that students had a solid conceptual understanding on which to build their math skills. Participant 93 explicitly said that "because I know there's so much math anxiety around it and like I've experienced that as well so that I feel like it's exciting to be able to be part of like the change in it."

However, while having experienced anxiety seemed to be a good motivator for implementing pedagogical reform, too much anxiety could also be detrimental and impede beliefs of self-efficacy. Participant 61 was the primary example of this as they had asked not to teach math during their practicum and stated that they were very nervous about teaching it. During their tutoring job, they also seemed to default to a mimicry-based approach because they did not fully understand the principles behind what they were teaching. They said that "I knew how to answer select questions that I had been working on, but I didn't know like the principles behind them." They also felt obliged to take on the role of the Teacher as Expert, saying that "So then I have to put all my effort into that. And I think if my AT asked me to do math, I would have spent a lot of time like making sure I was good at it. Or at least understood it." As such, it appears that having high levels of anxiety and/or low levels of beliefs about self-efficacy may result in TCs taking a more traditionalist approach as they lack the confidence to implement pedagogical reform.

Many of my findings are also in-line with the research that I highlighted in my literature review. As was in-line with Namukasa et al.'s (2009) statement, many of the TCs that were a part of my study indicated that they had math anxiety, both in the surveys and the interviews. Math anxiety affected both PJ and IS TCs although, looking at the quantitative results, PJ TCs seemed to have higher levels of math anxiety. Swars et al. (2006) also found that math anxiety was negatively associated with beliefs about teaching efficacy and this also seemed to be reflected in my interviews. As was discussed above, Participant 61 expressed disliking math due to their anxiety about the subject and not feeling confident in their math teaching ability. It is interesting to note that Participant 61 felt this way even though they said that math was consistently their highest mark in high school. I think that this contrast really highlights the impact that math anxiety can have on perceived efficacy as is discussed by Celik (2021). Even though Participant 61 had demonstrated high levels of math competency, their anxiety still resulted in them perceiving themselves as having a low efficacy. In contrast, Participant 24 had low levels of math anxiety, only really experiencing during their master's degree, enjoyed mathematics, and had a high sense of math teaching efficacy. As such, I believe that this really highlights the need to address TCs' math anxiety in order to facilitate productive beliefs about their math teaching efficacy.

As was argued by Boaler (2019), Gresham & Burleigh (2019), and Namukasa et al. (2009), the constructivist inspired pedagogy course that TCs took seemed to have positively impacted their relationship with math. As was discussed in the previous section, some TCs described how the course was validating for their pedagogical beliefs and many seemed to view their negative experiences with math as being the result of poor pedagogy on their teachers' part rather than a personal failing. As such, it seemed that their pedagogy course positively affected the interviewees' relationship to math.

Alsup (2004) found more mixed results with regards to constructivists' teachings. The researcher concluded that one of the constructivist-inspired experimental classes may not have been the right interaction of curriculum, students, and instructor, resulting in little improvement in math anxiety. This conclusion was, in part, due to the fact that the curriculum used in one of their experimental courses was unfamiliar to students. However, in regard to my own study, since the curriculum used in the math pedagogy course should be familiar to most of the TCs (as they went through the education system and presumably learned a similar curriculum), that might explain why the math pedagogy course had a more positive impact than what Alsup (2004) observed.

In terms of educational background, the study by Holm & Kajander (2020) found that undergraduate mathematics preparation was ineffective for developing students' elementary conceptual understanding. I found similar findings with regards to TCs' educational experiences with math. Many of the TCs believed that traditional math pedagogy did not encourage conceptual understanding and, in fact, many also felt that it hindered their teaching ability. Participant 82, for instance, stated that unpacking the standard algorithm for solving problems and understanding where that algorithm came from and why it worked so that they could better teach their students and develop their conceptual understanding would be their biggest hurdle. Likewise, Participant 33, while having successfully done math at the university level, felt that they struggled more in university because they lacked the conceptual understanding and thinking skills to fully grasp what was being taught. However, it is important to note that Holm & Kajander examined TCs with undergraduate math degrees while none of my interviewees had a math degree. Nonetheless, there seemed to be somewhat of a consensus among many TCs that there was a lack of the conceptual understanding necessary to enact more constructivist practices, especially for the PJ participants.

In contrast to Jonsson et al. (2012), I did not find evidence that TCs held beliefs that intelligence is fixed. Given their research, I would have expected the IS TCs to hold stronger beliefs about the entity theory of intelligence; however, both Participant 33 and 93 seemed to explicitly reject this theory and attributed their difficulties in university math courses to be due to a mismatch between pedagogy and their learning style as opposed to some personal limitation. This belief that intelligence is not fixed may have been encouraged or reinforced by their mathematics pedagogy course, which does place a strong emphasis on encouraging a growth mindset. Alternatively, it may be because of the limitation in my sample size and that I did not have the opportunity to interview a math major that may explain the discrepancy between Jonsson et al.'s results and my own. They also surveyed math teachers and not TCs, so it may be that there has been a general shift in attitudes among the education profession since the teachers in their study were surveyed over a decade ago and were not Canadian.

The quantitative results of my study are also similar to the ones found by Safrudiannur et al. (2021). Those researchers found that, at the end of their instruction, TCs had high levels of traditionalist pedagogical beliefs and constructivist ones. As was reported in my quantitative findings, the average score for CT beliefs was 4.12 while the average score for BM was 3.21. As such, TCs in my study tended to have a high constructivist score with a moderate traditionalist one. I believe that my findings are also in-line with Hanin & Holm (2023) as they argued that the binary model was inadequate and developed three distinct belief profiles. I saw evidence of two of these profiles throughout the interviews: the flexible and the socioconstructivist ones. As Hanin & Holm (2023) also discussed, these profiles are not as distinct as might be suggested by a binary model. The TCs that I interviewed, while overall leaning constructivist, tended to have a more flexible (or as I called it in my findings, eclectic) approach to pedagogy. TCs' seemed to embrace a variety of pedagogies depending on what they saw to be effective based on their students' response and depending on the circumstances which they found themselves in.

Safrudiannur et al. (2021) also found that, for some TCs' beliefs, there was

> no evidence to support the hypothesis that courses related to mathematics education contribute to the development. It seems that experiences in real teaching where PSTs can apply what is promoted in the courses related to mathematics education contribute to the development of the problem-solving view on PSTs' beliefs about teaching and learning. (p. 1116)

This finding seems to be reflected in my own qualitative findings. TCs used very little research, knowledge from their courses, or theory to justify their pedagogical beliefs. Instead, most of their justification came from their own educational experience as learners or from their professional experience. As such, it seems that their mathematical pedagogy course was only effective insofar as TCs could apply what they learned to the practical problems of teaching or insofar as what they learned reflected their own learning experiences or beliefs.

This finding presents a problem in that many TCs also acknowledged that there were environmental influences on their pedagogy. Thus, if the environment is not conducive to constructivist teaching, TCs may find it more difficult to apply constructivist principles, thereby concluding that they are ineffective. Participant 33, for instance, identified the importance of having a supportive and collaborative environment in order to develop a constructivist pedagogy. This finding highlights the importance of cultivating school environments which help to foster constructivist beliefs. Relatedly, Participant 93 identified that some of the schools/teachers they had been placed with were not open to changing pedagogies. As such, I believe that it is important to ensure that TCs are having practica which help to reinforce the constructivist values of their program rather than opposing them.

Additionally, there were two findings that I found quite surprising. The first finding was the value that TCs put on applied math. Virtually all of the TCs valued applied math while none of them seemed to really appreciate pure or theoretical math. Some TCs even viewed more abstract math as necessarily resulting in less understanding. While applied math is absolutely important for students to learn, I think that it is also important to offer students a glimpse of pure mathematics as that is a significant part of modern mathematics. I have several possible explanations for the focus on applied math. First, it may be because of the small sample size and lack of math majors. As such, the participants may have been less inclined towards an attitude of math for the sake of math compared to someone with a math degree. For instance, Participant 24, who had the most math experience of all of the participants, has a Master of Engineering degree and also said that they enjoyed math, in part, because it was a way of understanding how the world worked. This interest in engineering and physics may explain why they value applied math over pure math.

Second, several TCs mentioned the common perception among students and the public that the math taught in schools is useless. As such, the focus on applied math may be a way to address this common perception. Interestingly, it did not always seem to work as evidenced by Participant 33's experience on their practicum. They said that, for their practicum class,

> a lot of the course content is kind of geared towards math for real life. So, the unit I did with them was transportation. And it's interesting because, from my perspective, it's all the useful information that people are like 'Oh, why didn't we learn that in school?' But they -- I don't think they realize how important that stuff is in real life. Like the transportation with how to buy a car. What are your options to buy a car like leasing, buying a used car, buying a new car, whatever, which is actually useful (laughs), but they still didn't care (laughs).

The third possible explanation may be tied to how most TCs identified as being visual learners. Given how much emphasis is put on their own experience as learners, it may be that applied mathematics is viewed as being a better fit for their learning style compared to pure mathematics, which may seem more disconnected or difficult to visualize. The final possible explanation is that applied mathematics was seen as a better fit with PBL. Given that most of the TCs seemed to value PBL, it may be that the real-world scenarios, and the problems that result from them, are viewed as a better fit for PBL than the problems of pure mathematics, which are often more abstract and are disconnected from real-world scenarios. Further research would be needed to elucidate this finding, however, and to identify if TCs have a preference for applied math and why that may be.

The second surprising finding to me was the prevalence of the theory of learning styles among TCs. As was mentioned in the literature review, the theory of learning styles is extremely prevalent among education professionals and, as such, it is perhaps not surprising that so many of the TCs that were interviewed identified with it. It remains significant though in that it was one of the few theoretical concepts that TCs used to support their pedagogical beliefs and it is also one that is widely rejected by researchers.

Several TCs emphasized visuals as being an important modality for math. As I discussed in the previous section, all of the TCs who identified with a learning style also identified as a visual learner. I argue that what they consider to be a result of learning styles would better be conceptualized as part of the Pirie–Kieren model for the dynamical growth of mathematical understanding. As was discussed in the literature review, the Pirie-Kieren model contains eight potential layers-of-action. However, the one of particular relevance to this study is the Image-Making stage which is when learners engage in activities that help them develop a particular representation of the mathematical idea. Participant 24 seemed to describe this stage when they said "I think if they [students] can (pauses) visualize or conceptualize what is being talked about, then they learn the best…" I believe that the TCs who identified as visual learners are actually mistaking the Image-Making stage as being a distinct and individual learning style when, in reality, it represents an important stage in mathematical understanding that everyone needs, not just "visual learners." I think that Participant 24 (who did not identify or mention learning styles) probably is more mathematically inclined and was able to visualize mathematical concepts without the explicit aid of visuals for most of their educational career. Meanwhile, other participants like Participant 82 (who did identify as a visual learner) needed more explicit visuals to help develop their internal visualization.

This distinction between visuals being a part of some learners' needs versus it being an integral part of mathematical understanding is an important one because it means that all students benefit from visuals. The issue with the theory of learning styles is that TCs may feel obligated to incorporate other modalities in order to meet a variety of different learning styles when in reality there is no good evidential basis for learning styles and it would be more effective and simpler to simply focus on cultivating all students' conceptual understanding. As Westby (2019) says "experiences in different modalities simply for the sake of including different modalities should not be the goal. Material should be presented auditorily or visually because the information that the educator wants students to understand is best conveyed in that modality" (p. 7). While students should be given options in their work in order to foster student engagement, the options should be theoretically sound, especially when there is research showing that "there was no relationship between students' perception of their learning preferences, how they studied, and their test outcomes" (p. 5). TCs' mistaken focus on learning styles also highlights the need to ensure that TCs have a firmer theoretical underpinning to base their pedagogical beliefs on rather than relying mainly on their experience.

Implications

This research has several potential implications for future areas of research as well as practice. The first implication is that this research showed that reflection can be effective for developing TCs' pedagogical beliefs. Nearly every TC believed that reflecting on their own negative educational experiences had resulted in them developing a more constructivist outlook. For some, this reflection occurred prior to their math pedagogy course while for others it occurred during. For those who reflected on it prior, they tended to describe the math pedagogy course as being validating. Additionally, it may be beneficial for these reflections to be shared with their classmates when possible. Participant 13, for instance, stated that while they did not experience test anxiety, they would refrain from using tests because “I know for other people, tests do have a lot of anxiety and there's a lot of pressure…” As such, having TCs share their negative experiences and emotions around math and their reflections on their educational experiences may be helpful for developing sensitivity in those who did not have the same negative experiences.

The second implication is that I believe that PJ TCs should have a math content course prior to their math pedagogy course, which would act like a review of the content that they will have to teach. It should also be taught in a constructivist way and also make direct connections to the curriculum that PJs will be teaching and how the curriculum evolves as students progress through it. There are a number of reasons why I believe that this would be effective. First, as was discussed in the literature review, Mizell & Cates (2004) found that taking an additional math content course helped TCs with their math confidence. This finding, in conjunction with Boaler (2019), Gresham & Burleigh (2019), and Namukasa et al. (2009) about the benefits of constructivist courses for helping with math anxiety, suggests that, by having TCs take a constructivist-inspired math content course, PJ TCs would have lower levels of math anxiety and higher levels of beliefs about their efficacy. This is particularly important for the PJ TCs as the quantitative results showed that, on average, TCs had a moderate level of math anxiety, even towards the end of their math pedagogy course and, as was discussed above, this math anxiety needs to be addressed in order to mold more effective math teachers. Having the course be constructivist-inspired would also hopefully counteract the increase in traditionalist beliefs that Mizell & Cates (2004) observed.

The second reason why I believe that this would be effective is that it would ensure that all of the TCs had experienced constructivist-based learning. This factor is significant because, as has been discussed, TCs drew heavily from their personal education experiences. As such, giving them positive personal experiences with a constructivist math course and then having them make reflections about the differences between that course and the more traditionalist ones that they encountered in their own schooling in their follow-up math pedagogy course would help to ensure a powerful personal connection that TCs could draw from. The follow-up math pedagogy course could also draw explicit connections between the practices they all would have experienced in first year and the theoretical and evidential basis for these practices, thus helping to develop their theoretical knowledge and understanding while also creating a strong emotional motivation. Since TCs drew so heavily from personal education experience, I think that this format would provide a strong basis for TCs pedagogical beliefs and help to promote explicitly constructivist ones. The effectiveness of contrasting traditionalist and constructivist pedagogies was also seen in the interviews. Both Participant 93 and Participant 82 experienced constructivist and traditionalist inspired pedagogies and it was this contrast between the emotions experienced in both pedagogies that helped to cement strong constructivist beliefs in each TC. Participant 82 said that, up until Grade 12,

> it was like, ‘Here's a worksheet. Here's the algorithm. Here's a worksheet,’ but then ... Grade 12 is like ‘Let's do it together, let's do this together, let's do the worksheets together, let's do the questions together,’ and that was something that was like a game changer because I was like ‘This is makes so much more sense to me, I can talk to my peers and like have that interaction’ because

> normally when you're doing worksheets it's like quiet, like you can't talk. It's like -- it almost feels like a test, almost. So, like having that different perspective I was like 'This is -- this makes so much sense to me.' This is like, 'I can talk to my peers and interact with them that way. And be able to like know where I need to go to.'

If teacher education programs could replicate the experience and emotions that Participant 82 described above, I believe that it would serve as a powerful motivator for TCs and help to further foster their constructivist beliefs.

The third reason why I believe having TCs take a constructivist-inspired math content course would be helpful is that it would help to develop their conceptual understanding of math. Most of the TCs felt that the traditional pedagogy they experienced hindered their ability to teach math, either because they lacked the conceptual understanding necessary to properly implement constructivist lessons or because they were very used to the traditionalist pedagogy. While Trent does have TCs completed a math proficiency test upon entering its Bachelor of Education program, this test only assesses TCs procedural understanding of math. The issue is that even TCs who are confident in their math abilities may struggle to make the connections necessary to foster students' conceptual understanding. For instance, Participant 13 said that

> like it's [their math pedagogy course] showing us how to teach math, but if we don't understand what we're teaching, how are we supposed to be teaching it? Or like how do we identify 'Oh, you know what? This person did doubling and halving.' Like there is just -- like there are so many concepts where I like I couldn't pinpoint it [what concept they were learning]. But once it was pinpointed, I

> understood it. Because like, it was almost like, getting me to go back 16 years. And that's like -- that's a long time ago so it was like I feel like it should be more like a refresher of like "Okay you know what, this is what we focus on in Grade 1. Or like, these are the units that we do Grade 1 to 3. This is how they vary and build off of one another. Here are some things that you can do.

As such, I believe that having a constructivist-inspired math content course in first year would help PJ TCs to develop their conceptual understanding, thus making them more effective math teachers.

In terms of the IS TCs, I do not think having them take a math content course would be feasible due to their overall low levels of math anxiety and their high confidence in teaching the curriculum. As such, I think there would be very little buy-in from the TCs in having them re-learn the curriculum, even though it may still be beneficial for the same reasons that it is beneficial for the PJ TCs. Due to the limited and somewhat homogenous sample, I think that more research is necessary to fully examine the effects of educational background on IS TCs' beliefs and what can be done to help foster more constructivist beliefs in that cohort. As such, this area could be another avenue for further research to examine.

This research opens up several other further areas of research as well. First, the qualitative findings indicated that, as TCs gain more experience, they tend to draw more from professional education experience. A longitudinal study examining how/if this shift from personal education experience to professional education experience occurs and what impact this has on TCs' pedagogical beliefs could be beneficial for seeing the influence that teaching experience has on pedagogical beliefs. Second, a quantitative study that takes place across several universities and with a larger sample size measuring the same variables that this study attempted to examine would be beneficial for ensuring the generalizability of the results and more fully elucidating the relationships between educational experience, math anxiety, and pedagogical beliefs. Finally, while TCs' constructivist beliefs were high, many of them also acknowledged that the environment would affect how these beliefs played out and what their pedagogy would be like. As such, further research into the long-term beliefs of TCs, as well as what environmental factors affect these beliefs, could be vital in cultivating environments which help to support math reform.

Limitations

The present research suffers from a number of limitations. The first limitation was the limited sample size. While the sample represented a significant percentage of the TCs at Trent, it is nonetheless inadequate for broader generalizations. This limited sample size was particularly problematic in assessing how educational background affected TCs' beliefs as only a few of the TCs surveyed had a strictly math background and none of them volunteered to be interviewed. As such, it is difficult to draw out more definitive conclusions about the influence of educational background on pedagogical beliefs. The sample was also biased in that all of the participants were recruited through the same math pedagogy course. There is a chance that, had the participants been recruited from other programs or courses, they would have had different beliefs, depending on the priorities and structure of the program that they were enrolled in. The sample was also additionally biased in that it may have only attracted people who were interested in discussions of pedagogy and math reform and may therefore have been more critical of traditional pedagogies. As such, further research across multiple universities would be necessary in order to ensure generalizability.

A further limitation of the interviews is that my participants had a more homogenous educational background than I had initially planned for. For instance, all of the PJ TCs had completed a BA in Child and Youth Studies at Trent University. For the IS TCs, all of them had mathematics as their second teachable. Ideally, I would have liked to have one or two IS TCs with more of a math background and more of a variety of academic disciplines for the PJ TCs. The more homogenous educational background further complicates drawing out definitive conclusions about the impact of educational background on pedagogical beliefs. However, I believe that the study still helped to highlight some of the ways in which anxiety and educational experience help to shape TCs' pedagogical beliefs.

A third limitation came from the quantitative instruments that were used in this study. These limitations only appeared to me once I started interviewing participants as they helped me to dig deeper into the results. The first problem was that all three of the PJ TCs whom I interviewed interpreted the educational background question differently than what I had intended. All of them had signaled that they had completed "Some Post-Secondary Math Courses." During the course of the interviews, it became clear that these TCs had only completed math pedagogy courses in university (i.e., courses designed for teachers with the intent of teaching in the K-12 school system). However, with that question, I had meant to measure whether a TC had completed math content courses which were more advanced than high school math (e.g., calculus, linear algebra, etc.). As such, I would have expected those TCs to have selected "High School Mathematics" for their highest level of mathematics. Given the seemingly widespread confusion over the question, it is difficult to know what the educational background of the surveyed PJ TCs actually is. The question should have been clarified further in order to ensure consistent responses from the TCs.

Another issue was the use of the AMAS. As I indicated in the "Findings" section, Participant 82 scored 4.33 on the AMAS indicating a high level of math anxiety. However, they described their relationship with math as being fairly positive. When questioned about the discrepancy between their statement and their survey result, they attributed the high score as being due to test anxiety rather than math anxiety. Seeing as several of the AMAS questions ask about anxiety around assessments, it may be that the survey does not sufficiently distinguish between math and test anxiety and that test anxiety could be acting as a confounding variable for math anxiety scores. Additionally, the survey did not seem to capture past experiences with math anxiety. For instance, Participant 24 scored 1.33 on the AMAS indicating a very low level of math anxiety. However, they also described encountering math anxiety during the master's degree, saying that "as soon as it comes to like actively trying to solve problems in it … it's completely – I -- I absolutely freeze. It's awful." As such, despite scoring very low on the AMAS, Participant 24 seemed to nonetheless have experienced some intense math anxiety. This discrepancy may be because the AMAS does not specify the level of math being done and, given the context of their course, Participant 24 may have assumed it was referring to high school level math. This discrepancy may have been avoided by specifying a more specific situation (e.g., telling participants to imagine themselves as students in their last math class).

The final major limitation with the study is that it relied on participants to self-report their beliefs, which means that participants could only express conscious beliefs that they were aware of and that there may have been underlying, subconscious beliefs that also influenced their pedagogy but were not captured by the study. In order to address this, Hanin & Holm (2023) recommended cross-referencing data collection with discourse analysis and real classroom observations in order to infer beliefs from what participants say, intend, and do. Relatedly, given their course's focus on constructivism, the topic of the research, and that my supervisor was their course instructor, TCs may have also felt obliged to censor their true pedagogical beliefs in order to make them more palatable and thus more constructivist. Cross-referencing the data collection like Hanin & Holm recommended would have also addressed this problem and helped to establish how/if TCs beliefs played out in the classroom. This approach was outside of the scope of this thesis but should be examined with follow-up research.

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Appendix A: Survey on Teacher Candidates' Pedagogical Beliefs, Math Anxiety, and Mathematics Educational Background

What is the highest level of mathematics that you have completed? Please circle one.

High School Mathematics	Some Post-Secondary Mathematics Courses
Minor in Mathematics	Major in Mathematics
Graduate Degree in Mathematics	Post-Graduate Degree in Mathematics

Other (Please Specify): ____

For the statements below, indicate your agreement or disagreement by circling the number that best expresses what you think about the statement. Your reply to each statement can range from strongly agree (1) to strongly disagree (5).

1	2	3	4	5
Strongly Disagree	Disagree	Unsure	Agree	Strongly Agree

1. It is important that I establish classroom control before I become too friendly with students. 1 2 3 4 5

2. I believe that expanding on students' ideas is an effective way to build my curriculum. 1 2 3 4 5

3. I prefer to cluster children's desks or use tables so that children can work together. 1 2 3 4 5

4. I invite students to create many of my bulletin boards. 1 2 3 4 5

5. I feel a responsibility to make curriculum choices for children because they can't know what they need to learn. 1 2 3 4 5

6. I base student grades primarily on homework, quizzes, and tests. 1 2 3 4 5

7. To be sure that I teach students all necessary skills, I follow a textbook or workbook. 1 2 3 4 5

8. I teach subjects separately, although I am aware of the overlap. 1 2 3 4 5

9. I involve students in evaluating their own work and setting their own goals. 1 2 3 4 5

10. When there is a dispute between students in my classroom, I try to intervene immediately to resolve the problem.	1	2	3	4	5
11. I believe students learn best when there is a fixed schedule.	1	2	3	4	5
12. I make it a priority in my classroom to give students time to work together when I am not directing them.	1	2	3	4	5
13. I direct classroom events to prevent chaos.	1	2	3	4	5
14. My students spend the majority of their seatwork time working individually.	1	2	3	4	5
15. For assessment purposes, I am interested in what students can do independently.	1	2	3	4	5
16. I prefer to assess students informally through observation and conferences.	1	2	3	4	5
17. I find that textbooks and other published materials are the best sources for creating my curriculum.	1	2	3	4	5
18. I decorate my classroom primarily with posters and pictures, teaching charts, and/or seasonal decorations.	1	2	3	4	5
19. In my classroom, I take care of learning materials and set them out for students when they need them.	1	2	3	4	5
20. It is more important for learners to learn to obey class rules than to make their own decisions.	1	2	3	4	5
21. I am a firm believer in paper and pencil tests.	1	2	3	4	5
22. I often create thematic units based on the students' interests and ideas.	1	2	3	4	5

Imagine yourself in the situations described below. Evaluate each situation in terms of how much fear or nervousness you feel during the specified activities, circling the number that corresponds to your level of fear: please rate your feelings on a scale from one (no bad or negative feelings) to five (the worst feelings: the most fear, worry, or nervousness).

1	2	3	4	5
No bad feeling	Somewhat bad	Moderately fearful, tense, or nervous	Bad feeling	Very bad feeling

1.	Having to use the tables in the back of a math book.	1 2 3 4 5
2.	Thinking about an upcoming math test 1 day before.	1 2 3 4 5
3.	Watching a teacher work an algebraic equation on the blackboard.	1 2 3 4 5
4.	Taking an examination in a math course.	1 2 3 4 5
5.	Being given a homework assignment of many difficult problems that is due the next class meeting.	1 2 3 4 5
6.	Listening to a lecture in math class.	1 2 3 4 5
7.	Listening to another student explain a math formula.	1 2 3 4 5
8.	Being given a “pop” quiz in math class.	1 2 3 4 5
9.	Starting a new chapter in a math book.	1 2 3 4 5

If you would be interested in participating in a follow-up online interview which goes more in-depth about your math anxiety, educational background, and pedagogical beliefs, please write your name and email address below. The online interview is expected to take approximately 1 hour to complete with a total time commitment of approximately 2.5 hours. There is a $25 honorarium for participants who are selected for the interviews, although only 5 interviews will be conducted. Participants who are selected for the interview will be emailed a consent form to sign while participants who are not selected will be notified via email.

Name (optional): ____

Email address (optional): ____

Appendix B: Semi-Structured Interview Questions

1. What is your educational background?
    a. (For IS TCs): What is your other teachable?
2. What experience do you have with mathematics?
3. How do you feel that you learn mathematics best?
4. How would you describe your relationship with mathematics? How do you view mathematics?
5. How do you feel about teaching mathematics? Are you confident, nervous, excited, et cetera?
6. How do you think that textbooks and/or worksheets should be used in a mathematics class?
7. How do you think that students learn best in a mathematics classroom?
8. What does an ideal mathematics class look like to you?
    a. Are there any other considerations you would give for your ideal math class (e.g., age, grade, ability, etc.)?
    b. What issues do you think might prevent your ideal classroom?
9. Have your ideas about how students learn mathematics changed over time? If so, what do you think influenced them?

Appendix C: Recruitment Script

Hello everyone, my name is Theodore Simantirakis and I am a master's student in the School of Education here at Trent. I am currently completing my thesis with Heather Bourrie and Dr. Blair Niblett. I am studying how Teacher Candidates' educational backgrounds and math anxiety affect their beliefs about how mathematics should be taught, and I am looking for some participants to take part in my study. This research will lead to a better understanding of how teachers' beliefs form and provide more insight into how beliefs can be fostered to better lead to math reform.

If you volunteer as a participant in this study, you will be asked to complete a survey which will ask you about your educational background and have a number of questions designed to measure your pedagogical beliefs and your level of math anxiety. The survey is estimated to take about twenty minutes to complete. I am also doing follow-up interviews to dig deeper into the results of the survey, so you will also have the option to provide your name and email should you be interested in being interviewed.

This study has been reviewed and received ethics clearance through Trent University's Research Ethics Board. However, the final decision about participation is yours. If you are interested in participating, please come and see me and I will give you a consent form with more information about the study and answer any questions that you may have. You can also contact me if you have any further questions by emailing me at theodoresimantirakis@trentu.ca, which I'll write on the board for you. Thank you for your time!

Appendix D: Consent Forms

An Investigation into the Effect of Educational Background and Math Anxiety on Teacher Candidates' Pedagogical Beliefs: Surveys
Consent Agreement

You are invited to participate in a research study. Before you agree to participate, please read this form carefully and ask any questions you may have to be sure that you understand what your participation will involve.

An Investigation into the Effect of Educational Background and Math Anxiety on Teacher Candidates' Pedagogical Beliefs: Surveys

INVESTIGATORS: This research study is being conducted by Theodore Simantirakis and is being supervised by Dr. Blair Niblett and Heather Bourrie from the School of Education at Trent University.

PURPOSE OF THE STUDY: This study is designed to assess how Teacher Candidates' mathematical backgrounds and levels of math anxiety affect their beliefs about how mathematics should be taught. This study is being completed as part of a master's thesis, although the results may be published in the future in the form of a research paper. Raw data from the surveys will not be made available to other researchers and any surveys completed will be destroyed upon completion of the thesis. Participants are considered eligible for the study if they are Teacher Candidates who will teach mathematics in the future.

WHAT YOU WILL BE ASKED TO DO: If you agree to participate in this study, you will be asked to do the following:

1. Complete this consent form (~5 minutes).
2. Select your level of educational experience with mathematics (~1 minute).
3. Complete a survey which assesses your pedagogical beliefs about how mathematics should be taught (~ 10 minutes). You will be asked to rate your level of agreement with 22 different statements about teaching on a scale from 1 to 5.
4. Complete a survey which assesses your level of math anxiety (~5 minutes). You will be asked to assess your level of anxiety on a scale from 1 to 5 in response to 9 different situations involving mathematics.
5. If you are interested in the possibility of being part of a follow-up interview for this study, you will have an opportunity to provide your email address. Please note, that this step is completely optional and does not affect your participation in this part of the study.

6. Your survey will be collected and analyzed. The results of these surveys will be published in a thesis available to participants through Trent Library. All surveys will be destroyed upon completion of the thesis.

POTENTIAL BENEFITS: This research would fill a current gap in the literature concerning how educational background and math anxiety interact to affect TCs' pedagogical beliefs. This study could help to highlight new avenues of potential research and could also provide more insight into how TCs' beliefs form. The beliefs of teachers and TCs is a focal point of educational research right now as beliefs play an important role in fostering changes to teachers' pedagogy and educational reform. As such, this research would help to contribute to researchers' understandings of beliefs and could provide new insight to this area. I cannot guarantee, however, that you will receive any benefits from participating in this study.

WHAT ARE THE POTENTIAL RISKS TO YOU AS A PARTICIPANT: There is minimal risk to participation in this study and the risk should be no greater than the risk that you experience in a mathematics pedagogy/teachable course. One potential risk is that you may encounter feelings of math anxiety from the situations outlined in the survey. If these feelings become too uncomfortable for you, you may either skip that particular scenario and complete the rest of the survey or stop participating in the survey, either temporarily or permanently.

CONFIDENTIALITY: To ensure confidentiality, all surveys will be completed anonymously. For people who provide their emails, the data will be anonymized after the selection stage for the interviews has taken place. All surveys will be destroyed following completion of the thesis, which is estimated to be in August 2024. The surveys will be handled solely by Theodore Simantirakis and only anonymized data will be published or provided to Heather Bourrie and Dr. Blair Niblett.

INCENTIVES AND/OR COMPENSATION FOR PARTICIPATION: There is no paid incentive/compensation for completion of this section of the study (i.e., for completion of the surveys). However, upon completion of this section, participants can express interest in follow-up interviews, which will delve deeper into the themes discussed in the surveys. Participants who are selected for the interviews will be given a $25 honorarium.

COSTS TO PARTICIPATION: There are no additional costs associated with this study.

COMPENSATION FOR INJURY: By agreeing to participate in this research, you are not waiving any legal right in the event that you are harmed during the research.

VOLUNTARY PARTICIPATION AND WITHDRAWAL: Participation in this study is completely voluntary. You can choose whether to participate or not. If any question makes you uncomfortable, you can skip that question. You may stop participating at any time and you will still be given the incentives and reimbursements described above. If you choose to stop participating, you may also choose not to have your data included in the study. However, due to the anonymous nature of the surveys, once you have submitted your data, it will not be possible to withdraw it from the study. Your choice of whether to participate will not influence your future relations with Trent University or the investigators (Theodore Simantirakis, Heather Bourrie, and Dr. Blair Niblett) involved in the research.

QUESTIONS ABOUT THE STUDY: If you have any questions or concerns about the research now, please ask. If you have questions later about the research, you may contact:

Mr. Theodore Simantirakis at theodoresimantirakis@trentu.ca
Mrs. Heather Bourrie at heatherbourrie@trentu.ca or 705-748-1011 ext. 7712, Lecturer at Trent's School of Education
Dr. Blair Niblett at blairniblett@trentu.ca or 705-748-1011 ext. 7052, Associate Professor at Trent's School of the Education

This study has been reviewed by the Trent University Research Ethics Board, the study number is 13564. If you have questions or concerns that you don't wish to share with the researchers, please contact:

Anna Kisiala
Coordinator, Research Conduct and Reporting
c/o Office of the Vice President, Research and Innovation
Trent University
1600 West Bank Dr
Peterborough, ON K9L 0G2
705-748-1011 ext. 7866
annakisiala@trentu.ca

CONFIRMATION OF AGREEMENT:

☐ I have read, or have had read to me, the information in this agreement;
☐ I have asked any questions I have about the study;
☐ By signing, I agree to participate in the study;
☐ I am aware I can change my mind and withdraw consent to participate at any time;
☐ I have been given a copy of this agreement; and
☐I am not giving up any legal rights by signing this consent agreement.

____
Name of Participant (please print)

____________________________________ ____________________
Signature of Participant Date

An Investigation into the Effect of Educational Background and Math Anxiety on Teacher Candidates' Pedagogical Beliefs: Interviews
Consent Agreement

You are invited to participate in a research study. Before you agree to participate, please read this form carefully and ask any questions you may have to be sure that you understand what your participation will involve.

<u>An Investigation into the Effect of Educational Background and Math Anxiety on Teacher Candidates' Pedagogical Beliefs: Interviews</u>

<u>INVESTIGATORS</u>: This research study is being conducted by Theodore Simantirakis and is being supervised by Dr. Blair Niblett and Heather Bourrie from the School of Education at Trent University.

<u>PURPOSE OF THE STUDY</u>: This study is designed to assess how Teacher Candidates' mathematical backgrounds and levels of math anxiety affect their beliefs about how mathematics should be taught. This study is being completed as part of a master's thesis, although the results may be published in the future in the form of a research paper. Raw data from the interviews will not be made available to researchers outside of this study and any transcripts and recordings will be destroyed upon completion of the thesis. Participants are considered eligible for the study if they are Teacher Candidates who will teach mathematics in the future.

<u>WHAT YOU WILL BE ASKED TO DO:</u> If you agree to participate in this study, you will be asked to do the following:

1. Complete this consent form (~5 minutes).
2. Decide how it is best to receive your honorarium (e.g., via cash, e-Transfer, etc.) and inform Theodore Simantirakis (~5 minutes).
3. Arrange a convenient time and date to do an online interview via Zoom with Theodore Simantirakis (~5 minutes). The Zoom meeting will be recorded for data analysis.
4. You will be sent a copy of the interview questions ahead of the interview time for you to review at your own leisure (~1 hour).
5. Complete an online interview via Zoom (~1 hour). The interview will be semi-structured and ask you about your experience with mathematics, your educational background, your feelings towards mathematics, what your beliefs about how mathematics should be taught are, and what has influenced these beliefs.

6. After the interview has been transcribed, the recording of the interview will be deleted. You will be sent a transcription of the interview and you can decide to modify your transcript or have it removed from the study any time prior to the completion of the thesis in August 2024. You will also receive an identification number under which your data will be referenced and quoted in the thesis. The identification number will be a randomized 2-digit number in order to ensure your anonymity.
7. The result of these interviews will be published in a thesis available to participants through Trent Library. All transcripts will be destroyed upon completion of the thesis.

The total time commitment is estimated to be 2.5 hours.

POTENTIAL BENEFITS: This research would fill a current gap in the literature concerning how educational background and math anxiety interact to affect TCs' pedagogical beliefs. This study could help to highlight new avenues of potential research and could also provide more insight into how TCs' beliefs form. The beliefs of teachers and TCs is a focal point of educational research right now as beliefs play an important role in fostering changes to teachers' pedagogy and educational reform. As such, this research would help to contribute to researchers' understandings of beliefs and could provide new insight to this area. I cannot guarantee, however, that you will receive any benefits from participating in this study.

WHAT ARE THE POTENTIAL RISKS TO YOU AS A PARTICIPANT: There is minimal risk to participation in this study and the risk should be no greater than the risk that you experience in a mathematics pedagogy/teachable course. One potential risk is that you may encounter feelings of discomfort from the interview questions as they will ask you about your experiences with mathematics and teaching. If these feelings become too uncomfortable for you, you may either skip that particular question and complete the rest of the interview or stop participating in the interview, either temporarily or permanently. You are also free to withdraw your data from the study at any point prior to its estimated completion in August 2024.

CONFIDENTIALITY: All interviews will be audio and video recorded on Zoom. The recordings will be stored on Theodore Simantirakis' personal laptop and will not be shared with anyone else. Following transcription, all transcripts will be assigned an identification number to ensure the participants' anonymity. Once transcription is complete, all recordings will be destroyed. The transcripts will be shared with participants so that they can make any appropriate modifications or choose to have their data removed from the study. Transcripts may be referenced and quoted by the participant's identification number in the final thesis and may also be shared with the thesis supervisors (Heather Bourrie and Dr. Blair Niblett). After the completion of the thesis in August 2024, all transcripts will be destroyed.

INCENTIVES AND/OR COMPENSATION FOR PARTICIPATION: There is a $25 honorarium for your participation in these interviews. If you choose to stop participation, you will still be given the full honorarium.

COSTS TO PARTICIPATION: There are no additional costs associated with this study.

<u>COMPENSATION FOR INJURY</u>: By agreeing to participate in this research, you are not waiving any legal right in the event that you are harmed during the research.

<u>VOLUNTARY PARTICIPATION AND WITHDRAWAL:</u> Participation in this study is completely voluntary. You can choose whether to participate or not. If any question makes you uncomfortable, you can skip that question. You may stop participating at any time and you will still be given the incentives and reimbursements described above. If you choose to stop participating, you may also choose not to have your data included in the study. You may also choose to view, modify, or remove transcripts of your interview from the study at any time prior to the completion of the thesis, which is estimated to be for August 2024. Your choice of whether to participate will not influence your future relations with Trent University or the investigators (Theodore Simantirakis, Heather Bourrie, and Dr. Blair Niblett) involved in the research.

<u>QUESTIONS ABOUT THE STUDY</u>: If you have any questions or concerns about the research now, please ask. If you have questions later about the research, you may contact:

Mr. Theodore Simantirakis at theodoresimantirakis@trentu.ca
Mrs. Heather Bourrie at heatherbourrie@trentu.ca or 705-748-1011 ext. 7712, Lecturer at Trent's School of Education
Dr. Blair Niblett at blairniblett@trentu.ca or 705-748-1011 ext. 7052, Associate Professor at Trent's School of the Education

This study has been reviewed by the Trent University Research Ethics Board, the study number is 13564. If you have questions or concerns that you don't wish to share with the researchers, please contact:

Anna Kisiala
Coordinator, Research Conduct and Reporting
c/o Office of the Vice President, Research and Innovation
Trent University
1600 West Bank Dr
Peterborough, ON K9L 0G2
705-748-1011 ext. 7866
annakisiala@trentu.ca

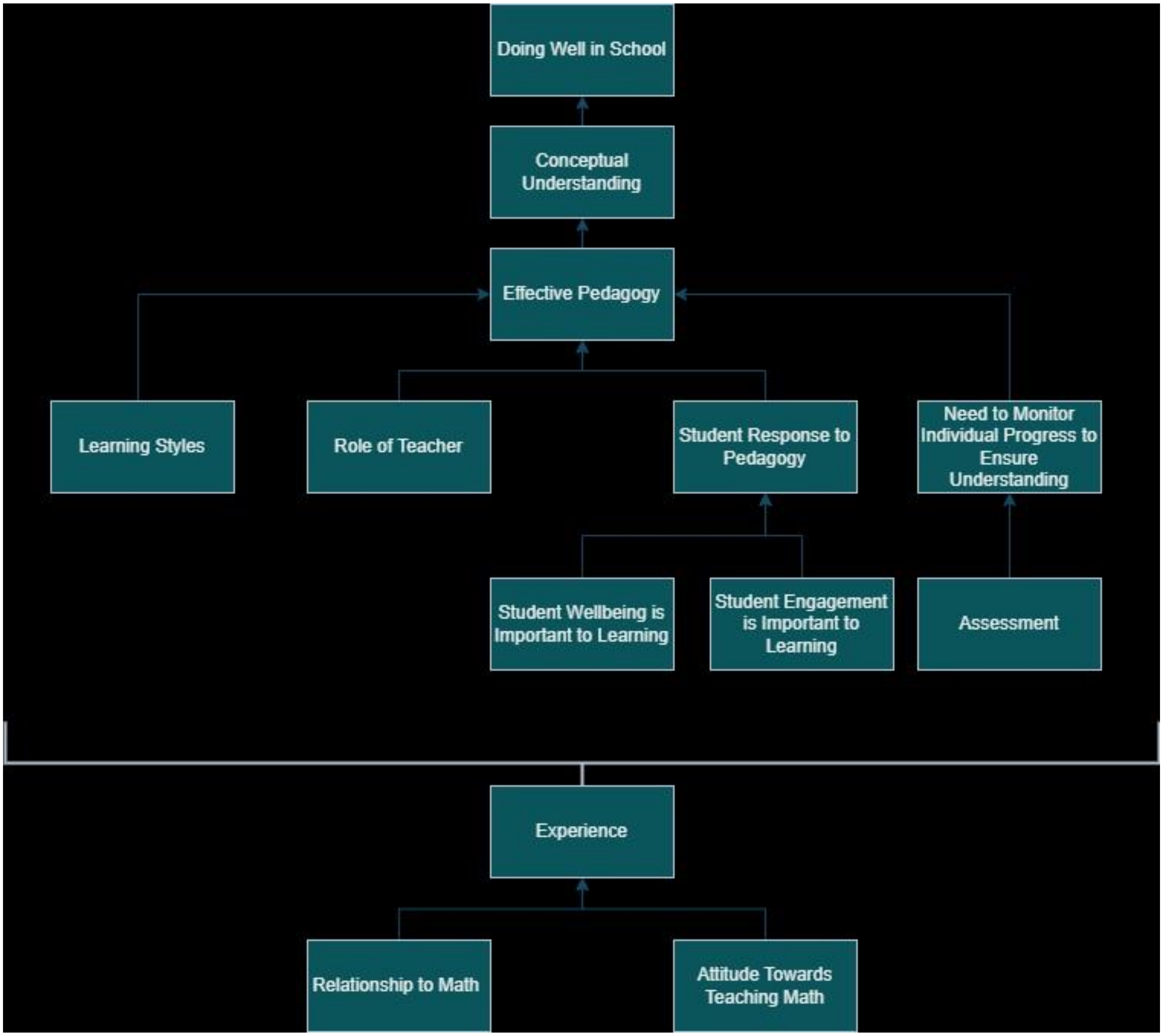
<u>CONFIRMATION OF AGREEMENT</u>:

☐ I have read, or have had read to me, the information in this agreement;
☐ I have asked any questions I have about the study;
☐ By signing, I agree to participate in the study;
☐ I am aware I can change my mind and withdraw consent to participate at any time;
☐ I have been given a copy of this agreement; and
☐I am not giving up any legal rights by signing this consent agreement.
☐ I am aware that the researcher will use my identification number when discussing my contributions in their report;
☐ I agree to be video and audio recorded for the purposes of this study. I understand how these recordings will be used, stored and destroyed.

____
Name of Participant (please print)

____________________________________ ___________________
Signature of Participant Date

Appendix E: Code Tree



Category	Subcategory	Codes
Relationship to Math	Appreciation	Enjoy Doing Math Like Problem-Solving and Puzzle Elements of Math Enjoy Understanding How the World Works Confident About Math
	Approach to Math Classes	Pragmatic Approach to Math Classes
		Idealist Approach to Math Classes
	Aversion	Dislike Math Dislike Tests Dislike Textbook Work Dislike Worksheets Anxious About Math Test Anxiety More Abstract Math Equals Less Understanding Feelings of Inadequacy Difficulty Detracted from Math Enjoyment
	Math Teacher Played a Key Role in Their Relationship to Math	Pedagogy Fostered Math Anxiety Mismatch Between Pedagogy and Learning Style
Attitude Towards Teaching Math	Affinity	Enjoy Teaching Math Excited to Teach Math Teach Like They Wish They Had Been Taught Confident in Teaching Math
	Neutral	Neutral About Teaching Math
	Uncertainty	Uncertainty About Pedagogy Open to Other Pedagogies
	Concern	Concern About Their Teaching Ability Concern About The Teaching Method
	Anxiety	Anxious About Teaching Math Due to Stigma Anxious About Teaching Math Due to Their Ability Nervous About Re-Learning Curriculum
Experience	Personal Education Experience	Educational Experience Hinders Their Teaching Ability Reflection Impacted Their Pedagogical Beliefs
	Professional Education Experience	
	Academic Education Experience	Math Pedagogy Course Showed Them Other Ways of Teaching Math Reflection Impacted Their Pedagogical Beliefs Math Pedagogy Course Has Been Validating
Role of Teacher	Teacher as Guide	

	Teacher as Expert	
	Teaching and Doing Are Different Things	
Student Wellbeing	Minimizing Anxiety	Experiencing Math Anxiety Makes Them More Receptive to Students Tests Foster Anxiety Non-Traditional Assessments Provoke Less Anxiety Struggling with Math Would Foster a Negative Relationship with it Math Anxiety Turns People Away from Math Safe Environment Vulnerability Respect Learning from Mistakes
	Preparation	Students Need to Be Taught How to Learn Structure Soft Skills
Student Engagement	Applied Math	Applied Math Makes Learning More Relevant and Engaging
	Collaboration	Collaboration Helps Students Learn Whiteboards Grouped Desks
	Differentiation	Student Interests Student Expression Visuals Manipulatives Accessibility Students Have Different Learning Styles
Assessment	Tests	Tests Are a Good Way to Measure Student Learning Tests Are Not a Good Way to Measure Student Learning Tests Foster Anxiety
	Projects for AofL	

	Worksheets Can Be Effective Tools When Used Properly	Worksheets for Practice Worksheets for Aof L Worksheets for Notetaking
	Textbooks Can Be Effective Tools When Used Properly	Textbooks Are Often Misused Textbooks as an Additional Support for Students Textbook as Teacher Support Textbooks for Practice
	Non-Traditional Assessments are Effective	Observations for AforL Self-Assessment is Effective
Learning Styles		Visual Learner Mismatch Between Pedagogy and Learning Style Students Have Different Learning Styles
Effective Pedagogy	Traditionalism	Mimicking Helps Them Learn "Thinking Classroom" is not an Effective Method "Thinking Classroom" Takes More Effort than Traditional Pedagogy
	Constructivism	The GRRM is an Effective Method Problem-Based Learning is Effective Problem-Solving Tasks Learn better By Learning from Mistakes "Thinking Classroom" is an Effective Method Mimicry is Not Very Effective for Teaching Students
	Eclecticism	Environment Affects Pedagogy Diversity of pedagogies is Effective
Conceptual Understanding		Conceptual Understanding is Helpful for Learning Thinking Traditional Math Teaching Did Not Encourage Conceptual Understanding