Hitting the Conceptual Knowledge Wall: Pre-Service Teacher Responses to High-Stakes Mathematics Testing Failure

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Abstract

The research reported here is part of a larger study and examines the cases of two individuals who were initially unable to achieve the required 60% passing grade on a Mathematics for Teaching Exam at the end of their first enrolment in an intermediate-level mathematics methods course. The exam is a graduation requirement of the teacher education program at a specific university in Ontario. The two individuals reacted in markedly different ways to the news that they had not met the mathematics requirement: one took it as an opportunity to grow and learn the mathematics she was aware she had never learned

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in her past; the other became angry and hostile, blaming his professor for his lack of success. In this article, we present the contrasts in approach between the cases, and how the responses influenced the participants' further mathematics learning. As well, the somewhat unexpected impact that these responses had on the subjects' peers is explored. Finally, we document concerns that were raised from the use of a high-stakes exam as a mandatory graduation requirement and consider reasons for the differing reactions.

Keywords: pre-service education, mathematics education, mathematics for teaching, high stakes examination

Résumé

Les résultats présentés ici font partie d'une plus vaste étude qui examine les cas de deux personnes qui n'ont pas réussi à atteindre le seuil de réussite de 60% à un examen de mathématiques pour les futurs enseignants à la fin de leur premier cours de méthodologie des mathématiques de niveau intermédiaire. Les deux personnes ont réagi de manière nettement différente à la nouvelle qu'elles n'avaient pas satisfait aux exigences en mathématiques : l'une d'entre elles l'a vu comme une occasion de grandir et d'apprendre les connaissances en mathématiques qu'elle savait n'avoir jamais acquises par le passé; l'autre s'est quant à elle mise en colère et a démontré de l'hostilité, rejetant la responsabilité de l'échec sur son professeur. Dans cet article, nous présentons les contrastes d'approche entre les deux cas, et la manière dont leur réponse a influencé leur apprentissage ultérieur des mathématiques. Nous explorons aussi l'impact quelque peu inattendu de ces réponses sur leurs pairs. Enfin, nous examinons les préoccupations soulevées par l'utilisation d'un examen à enjeux élevés comme condition d'obtention du diplôme et les raisons possibles des différentes réactions obtenues.

Mots-clés : formation initiale, enseignement des mathématiques, mathématiques pour l'enseignement, examen à enjeux élevés

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Introduction

Since the work of Shulman (1986), researchers have examined the knowledge teachers require in order to teach effectively. Ma (1999) used the term *profound understanding of fundamental mathematics*, and Ball and her colleagues (e.g., Ball et al., 2008) gave these understandings the broad umbrella term of *mathematics knowledge for teaching*. Our work follows these scholars in examining the mathematics knowledge for teaching of pre-service teachers. Given the links that have been established between teacher knowledge and student achievement (e.g., Baumert et al., 2010; Hill & Ball, 2004; Hill et al., 2005), we decided to make attaining a minimal level of mathematics knowledge for teaching a graduation requirement in our (then one-year, post-degree) Bachelor of Education program. Although from an academic and research position we felt that this mathematics requirement was critical, we encountered some interesting and unintended consequences as a result of the policy.

This research study focuses on some of these consequences, and, in particular, examines the parallel journeys of two pre-service teachers who struggled with mathematical understandings. Both were initially unsuccessful in achieving the minimum mathematics knowledge requirement on either the original or the supplemental Mathematics for Teaching Exam during the one-year program. Thus, both were required to retake the mathematics methods course the following year, and thereby have the opportunity to write the Mathematics for Teaching Exam again. Although both participants were ultimately successful in the second year, how they chose to perceive and react to the initial knowledge of the exam and not passing it the first time were markedly different. One student gained a deeper understanding of the mathematics and showed herself to be a leader while repeating the course, becoming more self-assured, whereas the other student became a toxic presence in the repeated class, bringing a negative attitude and the idea that the whole purpose of the program was "just to pass the exam."

We first look at the literature that helps to provide context for our study. Then we examine our data and present the results for the two participants. In the end, we discuss what we have learned from observing and working with the two participants during the process with regard to the possible concerns in using a high-stakes mathematics exam in a teacher education program.

Literature Review

"Teachers must know and understand deeply the mathematics they are teaching and be able to draw on that knowledge with flexibility in their teaching tasks" (National Council of Teachers of Mathematics [NCTM], 2000, p. 17). Research has identified links between stronger mathematics knowledge for teaching and teachers' capacity to use more cognitively demanding tasks in a classroom (e.g., Charalambous, 2010; Walkowiak, 2010). Such research supports the idea that teachers need to have a strong understanding of mathematics for teaching in order to support the type of mathematics classroom that is advocated by the National Council of Teachers of Mathematics (NCTM, 2000) and by our provincial curriculum (Ontario Ministry of Education, 2005). Characteristics of the classroom environment advocated by the NCTM and the Ontario Ministry include the use of problem solving to teach mathematics, the use of concrete materials and models, and a shift away from teacher-directed instruction.

Some researchers have shown links between mathematics knowledge for teaching and student achievement (e.g., Baumert et al., 2010; Hill et al., 2007; Hill et al., 2005) while other researchers did not draw the same conclusions (e.g., Kersting et al., 2010; Kersting et al., 2012; Shechtman et al., 2010). Although the existing research may not be conclusive on the direct link between mathematics knowledge for teaching and student achievement, the research is clear that a stronger knowledge of mathematics for teaching allows teachers to implement more cognitively demanding tasks and to support students in their development of mathematics skills.

Our previous research discussed the connections between teachers' understanding of mathematics and their associated beliefs in their own abilities in mathematics (Holm & Kajander, 2012). Jacobson and Kilpatrick (2015) define a productive disposition for teaching mathematics as "mathematics teachers' malleable orientation toward—and concomitant beliefs, attitudes, and emotions about—their own professional growth, the subject of mathematics, and its teaching and learning that influences their own and their students' successful mathematics learning" (p. 402). Looking at how pre-service teachers felt about mathematics was important in understanding how they approached the exam, as well as how they might approach a future in teaching.

McGraw and Fish (2018) looked at qualitative data related to the stories of Australian pre-service teachers who had lower scores for entry into a program and likely would not have entered a different program because of the Australian Tertiary Admission Rank and Literacy and Numeracy Tests for Initial Teacher Education Students scores. In their examination of the high-stakes tests, they cautioned that using these scores in isolation as a gatekeeper was not ideal. Instead they stressed focusing on the pre-service teachers' developing qualities and academics during the program. In alignment with this research, we made the decision that using the Mathematics for Teaching Exam as a gatekeeper for entry into the teaching program was not the intention. We referenced the research of Ball et al. (2005) and noted that the system we are attempting to improve would be the system of learning that these teachers were graduates from, so using this system as the deciding factor of whether or not they were accepted into a teaching program seemed unethical. Instead, we followed the ideas of Hoffman and Nottis (2008), who suggested that different factors motivate students to perform and stressed that a focus needs to be placed on strategies designed to increase self-efficacy and personal motivation. Within the program, we focused on class discussions regarding developing strategies for learning the mathematics and implemented supplemental workshops to increase understandings. Our goal was to provide support during the program for development of the mathematical models and understandings needed for teaching, and to then use the Mathematics for Teaching Exam to monitor how much of the mathematics that teachers require to support teaching the Ontario curriculum had actually been learned. In order to alleviate stress as much as possible, opportunities for test re-taking and, if needed, course re-taking were made available.

An additional element of high-stakes testing that was pertinent to our study was around the use of *fear appeals*. Fear appeals are messages that arouse fear around the negative consequences for a particular course of action countered with the positive consequences of a differing course of action (Witte & Allen, 2000). Putwain and colleagues (2017) examined the impact of fear appeals on student engagement. They discovered that in certain circumstances a fear appeal "serves to enhance the growth and mastery-focused mindset characterised by a challenge appraisal" (p. 80). For those who are not confident in their own academic success, a fear appeal "serves to enhance the self-protective and avoidance-focused mindset characterised by a threat appraisal" (p. 80). Although unintentional, the course instructors and Bachelor of Education program administrators did discuss the consequences of failure with incoming candidates, and thus used fear appeals with all of the pre-service teachers. Following the research of Putwain et al. (2017), the ways that these fear appeals were interpreted would likely have varied among the population.

In designing the mathematics methods course, we aimed to support pre-service teachers by following the work of Morris and Hiebert (2017) in that we felt teacher education programs needed to focus on breaking down the mathematics that prospective teachers are expected to teach—in other words, supporting the development of "useable knowledge" (p. 528), rather than focusing on more advanced mathematics. This approach was supported by the work of Morris and Hiebert (2017), who found that the deeper the focus on mathematics content in education programs was explored, the more deeply a topic was learned in the program and the more it was developed in lesson plans up to six years after the course was taken.

Based on the literature weighing the pitfalls of high-stakes testing with the benefits for teacher development (and potentially student learning), we proceeded with the program requirement of the Mathematics for Teaching Exam as a Bachelor of Education degree requirement in our program for upper elementary teacher candidates. In an attempt to ameliorate some of the tension, participants had two chances to write the exam at the end of the mathematics methods course (the initial sitting and a possible supplementary exam). If a participant was not successful on either attempt, they had the opportunity to retake the methods course one time the following year, and then write the exam once again.

Context

This research was conducted in a mid-sized Ontario university within the Junior-Intermediate education program (teaching Grades 4–10). At the time of the research in Ontario, the teacher education program was a one-year program that was completed *after* receiving a degree in another subject area. One difficulty that we determined in our program was that the vast majority of our education candidates had a degree in something other than mathematics, and that the majority had not taken a mathematics course since high school. As a result of previous research (see Kajander, 2007, 2010), we realized that we needed to do more in order to support our future teachers in ensuring that they knew the mathematics that they would be required to teach. Since we had to work within only a single 36-hour mathematics methods course, we had limited opportunities to ensure that our future teachers were getting the content, as well as pedagogical knowledge, needed to teach mathematics.

We worked within our institution to set up a compulsory mathematics exam that focused on the specialized content knowledge of mathematics for teaching at the Grades 4–9 levels. At the time of this research, this exam was held at the conclusion of the methods course as the final exam within the course. This exam focused on the work of Ma (1999), and the more recent work of Mitchell et al. (2014) in ensuring that pre-service teachers were modelling and explaining the mathematics, not just answering typical classroom questions. In order to pass the course (completion of which was required to receive the Bachelor of Education degree), all pre-service teachers had to earn at least 60% on this final examination as a separate graduation requirement. The exam was held in March of each year at the conclusion of the methods course. Anyone not receiving the required 60% on the exam was given an optional second opportunity in May of the same year to write the exam again prior to graduation. Anyone not receiving the 60% required to graduate was required to re-enrol in the methods course in the following school year, at which point they would have one more opportunity to take the exam again at the conclusion of the second year in the methods course. Pre-service teachers who were successful in receiving the minimum exam grade of 60% at this time would be allowed to graduate with their Bachelor of Education degree. The research discussed within this article looks at the cases of two individuals who were unsuccessful in passing the Mathematics for Teaching Exam at the conclusion of their first year, and the unexpected effects that their different responses had on the classes in which they participated during this repeated course.

Both years of the course used a problem-solving and inquiry pedagogy for teaching the mathematics. The goal of the course was to teach by example, showing how the mathematics could be taught in schools by allowing students to explore the concepts through the use of models and reasoning, often with manipulatives. Within the course, the instructors (referred to as A and B) worked to not only help the pre-service teachers learn the mathematics deeply, but also consider how mathematics could be taught in a way that did not use direct instruction and memorization. Since both pre-service participants had to re-take the course and exam, Instructor B made sure to meet with both individuals early in their second year of taking the course to set goals and discuss strategies for being successful, as well as offer meetings throughout the year in order to support the participants and monitor their progress.

Framework

In order to create the Mathematics for Teaching Exam, several key pieces framed our understandings of what we included in the exam. We first used the Ontario mathematics curriculum (Ontario Ministry of Education, 2005) as the starting place for deciding what mathematics content needed to be included in the examination. The work of Davis and Simmt (2006) guided our efforts in that we agreed with their conclusions that what "the mathematics teachers need to know is qualitatively different than the mathematics their students are expected to master" (pp. 315–316). We referred to the items that Ball and her colleagues have termed *mathematics for teaching*, as well as those used in the Ma study, in order to create the Mathematics for Teaching Exam questions (Ball et al., 2008; Hill, 2010; Ma, 1999). The items on the exam focused on the models, reasoning, and explanations that a teacher would need to know in order to support a student in learning the concept. Following the ideas presented in Ball et al. (2005), we focused on their ideas of what it means to know mathematics in a way that would support student development of understanding: multiple representations, alternative algorithms, and identifying student errors. We agree with researchers (e.g., Ball et al., 2005; Ball et al., 2008; Davis & Simmt, 2006) that this type of knowledge is both crucial and specialized to teaching. We did not attempt to pull apart the different constructs within the broader umbrella of *mathematics knowledge for teaching* and instead attempted to examine the plurality of the term in the examination.

In order to understand the phenomenon of what was happening with the reactions of our participants (and the other pre-service teachers), we referred to the research around *fear appeals*. According to Putwain and Remedios (2014), fear appeals are the "persuasive messages designed to facilitate a course of action so as to avoid a negative outcome" (p. 504). Although the Mathematics for Teaching Exam was not intended to be used as a fear appeal since the focus of the discussions was focused on success (e.g., passing the Mathematics for Teaching Exam as a graduation requirement and as a basis for effective teaching), the research around how students (in our case, student teachers) responded to this type of high-stakes messaging served as a framework for our research. We acknowledge that to many of the pre-service teachers, the message they would have heard was, "If you fail the Mathematics for Teaching Exam, you will not graduate and get to be a teacher."

Research has divided fear appeals into two broader categories: *threat appraisals* and *challenge appraisals* (Putwain et al., 2016; Putwain et al., 2019). Putwain and Remedios (2014) found that when students heard more fear appeals and perceived these messages as "threatening," their performance on the examination was lower. Their research raises concerns that fear appeals are not an effective motivational strategy (Putwain & Remedios, 2014; Putwain et al., 2019) unless they are viewed as a challenge (Putwain et al., 2017). Putwain and colleagues (2017) determined that when moderate-high challenge of activity was combined with moderate-high threat appraisal of fear appeals, there was a lower engagement of the students. The highest engagement scores in their study came from students who felt there was a high level of challenge and a low level of threat in the fear appeal. Research indicated that threat appraisals were linked with avoidance-type behaviours and mindset; whereas challenge appraisals were associated with a growth mindset focusing on results-oriented approaches (Putwain et al., 2016; Putwain et al., 2019). Putwain and colleagues (2016) determined that for individuals, the perception of threat appraisals was related to "lower academic self-efficacy, higher attainment value and higher extrinsic value" (p. 1,681). Given that Putwain and colleagues (2016) noted that there was a discrepancy in the frequency reported between teachers and students in the number of challenge and threat appraisals, we posited that pre-service teachers may also perceive a difference in whether something was a challenge or threat appraisal leading to different behaviours.

Methods

This research used narrative inquiry to investigate the journeys of two individuals, Grace and Richard[1], as they attempted to complete the mathematics component of their Bachelor of Education degree. This narrative inquiry relates to the stories of the individuals

1 Pseudonyms were used for both participants, and the dates of the research have also been removed to protect the participants' anonymity.

as the focus of the research, and these stories should be merged with the story of the researchers as they interact in the social situations of the research (Chase, 2005; Clandinin & Connelly, 2000). In order to understand the individual journeys of the two pre-service teachers, narrative inquiry was used to relay the individual stories within the same context. As is important for a narrative researcher (Chase, 2005), we attempted to respect the stories and the journeys of each of the pre-service teachers as they worked within the Bachelor of Education program, and not just discover themes that link the stories of the individuals together. The actual words, thoughts, and feelings of the participants were used to describe their journeys throughout the two years each spent in the Bachelor of Education program.

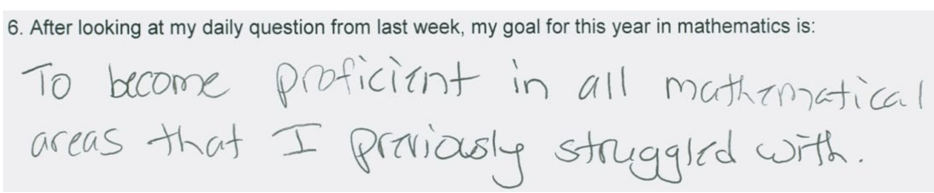
Data collected during the first year of the study included the *Perceptions of Mathematics* survey (Kajander, 2007), other survey questions asked during the course, and work on assignments and exams. These two participants were part of a larger study at that point. The second year of data included interviews conducted at the beginning and end of the repeated methods course, as well as assignments, grades, and exams. Interviews were fully transcribed by a research assistant and then read for accuracy by the authors following the conclusion of the (repeated) methods course. In order to create the report, the transcripts of the interviews were read while the tapes were played in order to find quotations and common ideas within the individual stories, as well as to hear the voices and emotions of the participants. Course work was used to provide further evidence and to support the comments made by the participants, as well as to give additional information about their understanding of mathematics during different points of the two-year journey. Both individuals were enrolled in sections of Instructor A's course in their first year of study, and both were enrolled in sections of Instructor B's course for the second year. Although neither was in the same section, the two participants both entered and exited the program at the same time. Typical university ethical guidelines were followed, ethics approval was obtained for this research study, and neither participant chose to withdraw. Interviews were not conducted by Instructor B, nor was any information that was gathered from the interviews shared with instructors until after the final grades were submitted.

Results

In order to convey the results and to stay true to narrative inquiry, the stories of the individuals are first separated, and then discussed together in order to draw some conclusions. Quotes are selected from participant interviews unless otherwise noted. Actions or motivations were not interpreted by the researchers in this section of the report. Only descriptions of the story as presented through conversations, observations, and assignments are provided. Interpretation about the responses to the mathematics questions is included in order to give some clarity to the reader.

From the very beginning of taking the course the first time, Grace shared her fear of mathematics. In her first interview, Grace shared that her struggles with mathematics began in Grade 7 and she was never able to recover from them. "Right at the beginning I thought, 'Oh…I'm not going to be able to do this.' I was so stressed out."[2] In the second week, she was asked to set a goal for the year, and her goal (Figure 1) focused on her concerns over the mathematical understandings she brought to the course.

Grace's First Attempt at the Methods Course


6. After looking at my daily question from last week, my goal for this year in mathematics is:

To become proficient in all mathematical areas that I previously struggled with.

Figure 1. Grace's goal for the math course

Throughout the semester, Grace received intensive one-on-one support and encouragement from Instructor A, yet her insecurities and fears remained constant and she was ready to quit the program at the halfway point. "I was shocked at how fast it was. I would leave class every week thinking, 'I have no idea what's going on.'" Grace received a 26% mark on her midterm exam, which included some of the type of mathematics content

2 As a reminder, interviews were conducted at the start of the second year and participants were asked to reflect on the previous year. These quotes are interspersed where appropriate to add narrative to the mathematics work of the first year.

found later on the final Mathematics for Teaching Exam. Figure 2 shows a sample solution from her midterm exam. Her solutions showed a clear lack of understanding of the content despite the additional support she was receiving.

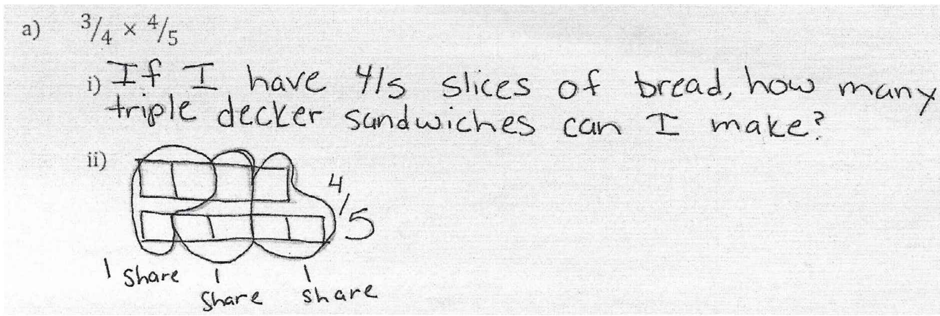
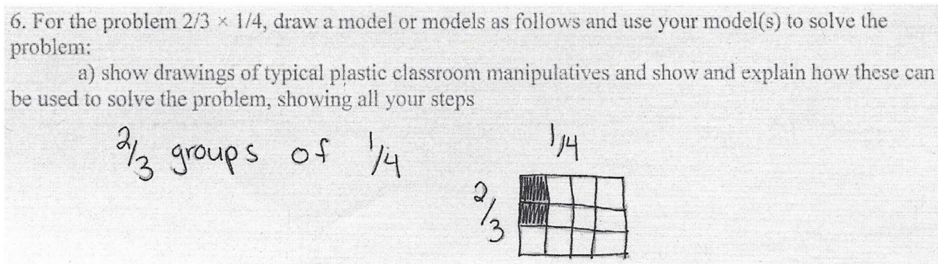


Figure 2. Question from Grace's midterm exam

"I got really discouraged in the first semester, I just kinda gave up." … "At this point I was so discouraged that I don't want to complete this degree, I don't want to be a teacher." Grace's lack of mathematics understanding led to a compromised math placement during the first year. In the end, Grace failed the final Mathematics for Teaching Exam with a mark of 31%. Figure 3 shows a sample question from her final exam. The solution shows that Grace has gained an understanding of fraction multiplication as "groups of," which differs from the response on her midterm in Figure 2. The question, however, asked her to use fraction bars or circles in order to model the question (the area was to be used in part b in order to build to a justification of the formula). She was also unable to give an explanation of the model that would support student understanding. We saw it as a promising step that Grace was gaining understandings, but she still had some room for improvement in her confidence related to explaining her answers. At this point, she decided not to attempt the supplemental exam and opted just to re-take the course in the following year. "I didn't have any time to prepare and I wasn't looking at any math. Well I'm not going to go do it and fail it again and still have to take the course again. I know it will benefit me to take the course again as a very part time student."


6. For the problem 2/3 × 1/4, draw a model or models as follows and use your model(s) to solve the problem:

a) show drawings of typical plastic classroom manipulatives and show and explain how these can be used to solve the problem, showing all your steps

2/3 groups of 1/4

1/4

2/3

Figure 3. Question from Grace's final Mathematics for Teaching Exam

Grace's Second Attempt at the Methods Course

Grace entered the class with Instructor B in positive spirits, but still very concerned about her compromised placement and about learning the mathematics. She was dedicated to learning the content in the second year and really put a lot of effort into the readings and work. "I still feel like I had, already, an advantage coming in." Grace saw it as a benefit to her that she was only taking the math methods course, rather than all the other courses that she had last year on top of the math methods course. As she noted, "I'm actually having the time to focus on this math and to keep up with all the readings and I'm understanding and I'm actually enjoying it." The reflection that she completed near the end of the first half of the course showed that she was beginning to increase her confidence level, as well as her understanding (see Figure 4).

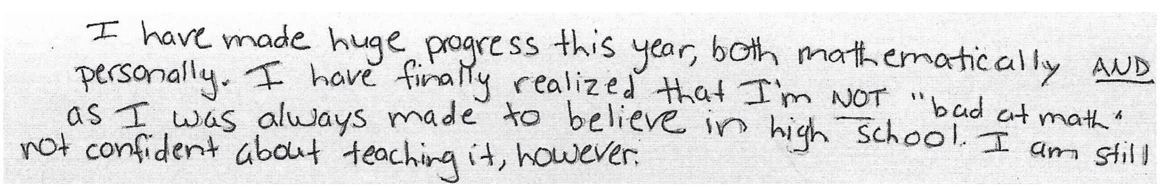

I have made huge progress this year, both mathematically AND personally. I have finally realized that I'm NOT "bad at math" as I was always made to believe in high school. I am still not confident about teaching it, however.

Figure 4. Reflection midway through year 2

Throughout this second course attempt, Grace was observed by Instructor B to be a leader in the course who was constantly helping her peers at the table. "And when we first started the fractions this year doing the modelling I was the only one on my table that got this one right… I feel like I'm looking at it from a different way now." She received a 68% on her midterm exam, and her solutions showed her increased knowledge of mathematics (see Figure 5). Grace was able to model the idea that division by a fraction such as

¼ meant counting all the parts of ¼ within the total volume of paint. She was even able to note that the final section (or remainder) should be interpreted as how much of the next section of ¼ it was. However, there were still some errors in the execution of the reasoning, as is evident in Figure 5. As she noted, "My confidence in it for myself right now is much more than it has been in any other time in my life, actually." She also felt that there was a different environment in the class that contributed to her success: "I find them to have a more positive attitude towards the class in general than the people last year. A lot of people in the class last year were very negative."

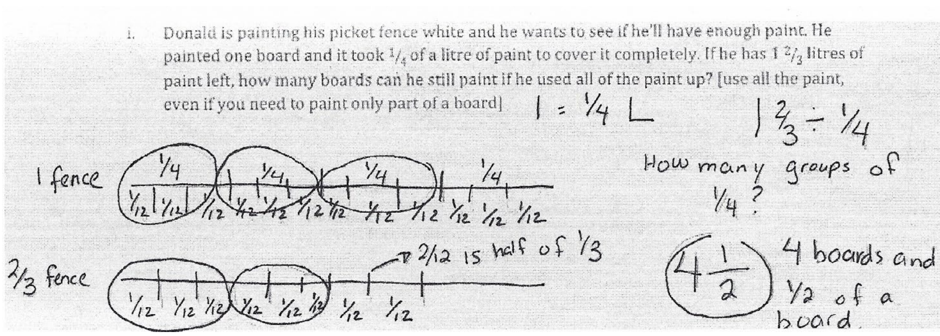


Figure 5. Question from Grace's year 2 midterm

In her opinion, her growth was attributed to having the time to concentrate on mathematics, as well as a slightly different approach to the course. As Grace noted,

> We have a lot of time to work with our groups on modelling with manipulatives in each class and we didn't take such a big portion of time to do that last year, and I think that really helps because you learn so much from your peers and people in your group too.

It is unclear whether the small group explorations were indeed longer with Instructor B, or whether Grace herself was able to draw more fruitful learning from these experiences at this point. Grace's understanding continued to increase throughout the semester, and she truly started to see the value in what she interpreted as the new way she was being taught. Grace even expressed the desire to use models and manipulatives in teaching, although she did not feel confident yet that she could do it herself. Her attitude continued to show a change from the previous year: "There were some things that were very positive along the way. Some of it was negative, but that doesn't matter. You can learn from the negative too."

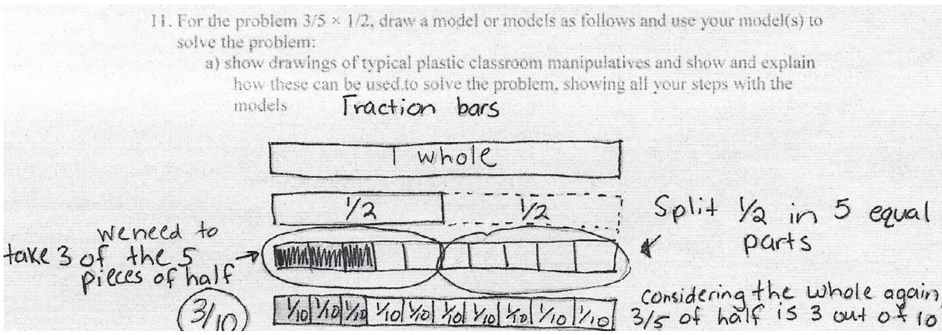


Figure 6. Question from Grace's year 2 final Mathematics for Teaching Exam

Grace was able to achieve a final mark of 71% on the Mathematics for Teaching Exam (see Figure 6 for sample response which demonstrates she can now use fraction bars with multiplication, as well as how much more she understands about fractions from the initial response in Figure 3), so she was successful in passing the mathematics course and mathematics requirement during the second attempt. "I loved the fractions unit. That's still my favourite… I realized that I'm really good at patterning too." She also shared that she did pass her final placement, so was able to graduate with her Bachelor of Education at the end of the second year. She summarized her overall experience by saying, "My attitude towards math has changed and I'm not afraid of it anymore."

Richard's First Attempt at the Methods Course

At the beginning of the methods course, Richard showed that his understanding of mathematics was limited to being able to use formulas to compute answers. Figure 7 shows a *Perceptions of Mathematics* survey question that was given to Richard on the first day of the methods course, and his response. Richard was able to find the correct answer for the question; however, he was unable to give any understanding of why his formula would work to solve the problem.

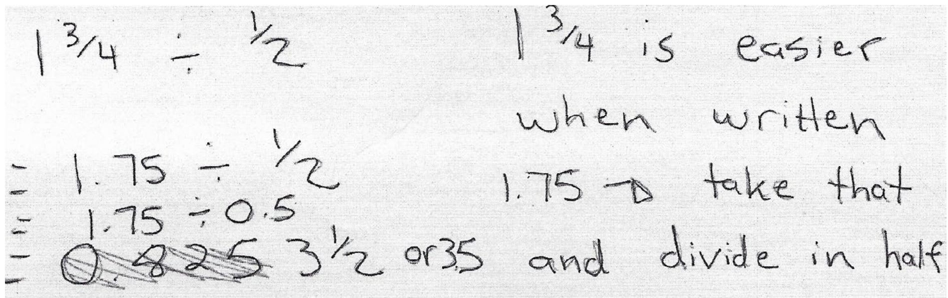


Figure 7. Richard's solution for the question, "Solve 1 ¾ ÷ ½. Then explain how and why your method worked, using pictures, diagrams, explanation, etc."

In the second week of the class, Richard was asked to consider a goal for himself for the course (see Figure 8). At this time, he acknowledged that he had not studied math in many years and had some difficulty in remembering much of it. In describing his past experiences with mathematics, he did admit they were not overly positive and stated that "it wasn't a lack of effort, just some people understand math and some don't." He did feel that mathematics in school should not be put on a "pedestal" as he felt the Mathematics for Teaching Exam did because "it's definitely not as important as English." Indeed, he requested a meeting with Instructor A at the beginning of the course to express his concerns about the mathematics requirement, asking that she "just give me whatever I need to pass the exam."

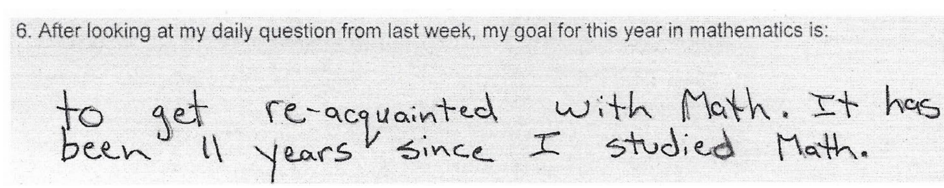


Figure 8. Richard's goal for the course

After nine weeks in the methods course, Richard took the midterm exam, which was a similar exam to the one Grace took, to show his understanding of the mathematics that he had learned in the first half of the course. Richard received a 50% on his midterm exam. Figure 9 gives a sample response from his exam. It appears from this solution that Richard lacked a deep understanding of multiplication. His initial answer showed that he thought that multiplication was "how many groups of" something, but he did change his answer to show that he knew that another way to think of the problem would be ¾ of ⁴⁄₆.

By this point, he was becoming overwhelmed with the entire program and noted, "a lot of things are getting thrown at you and it's the way you are being taught [in the methods course] that kinda, it's kinda screwing up the way we were taught about math."

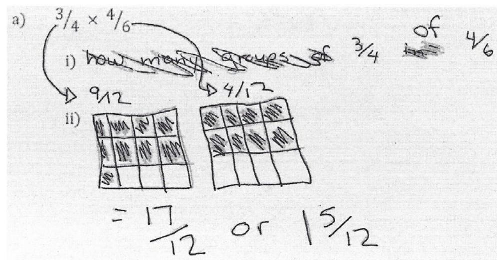


Figure 9. Sample question and response from Richard's midterm exam. Students were asked to solve the question, and also provide a model with explanation of why the method worked.

When Richard came back from his placement and break to start the second half of the course, he again wanted Instructor A to "just tell me what I have to do to pass." During his practice teaching placement he felt that "none of these methods were used," so this reinforced his distaste for the approach to mathematics learning used in the methods course, which he mentioned multiple times in his interview. In discussing his placement experience he reported, "It was the traditional way. I kinda gravitated toward that because it was easier." Understanding that he was in danger of not passing the course, he said, "that's when I paid more attention to math and less in the other subjects" and "that's not right." At this point, he leaned heavily on the graduate assistant for help on all of his assignment work. Though he attended multiple meetings for help, most did not involve any deep engagement with content and instead involved Richard reiterating that he just wanted to pass. He claimed that Instructor A was never available and that she was "hard to get ahold of for extra help," adding "well, we didn't really get along either." Richard expressed anger and a strong objection to the idea of a math assessment that he would have to pass in order to get his teaching degree. "So I don't know what to tell you guys—there is a disconnect here, 'cos I live in [major city about 900 km away] and what's going on down there isn't happening in this class."

His failure to engage in the content within the course showed in his achievement on the final Mathematics for Teaching Exam. Richard scored a 54% on the final exam;

however, as mentioned, the score required for graduation was a 60%. In looking at his final exam, it appeared that Richard had not engaged deeply with the content and showed a lack of understanding of what was required to explain or model concepts. Figure 10 shows a question from this attempt on his final exam. Although the question asks Richard to derive the formula, he starts out with stating the correct formulas and draws an image that would potentially help him derive the formula, but does not do so. The response shows that he sees what is needed but does not explain his solution fully. This could be a result of seeing the answers when engaging with the graduate assistant and just looking for what the solution should be or what he thinks he should know to pass the exam. Partially correct solutions were common on his final exam.

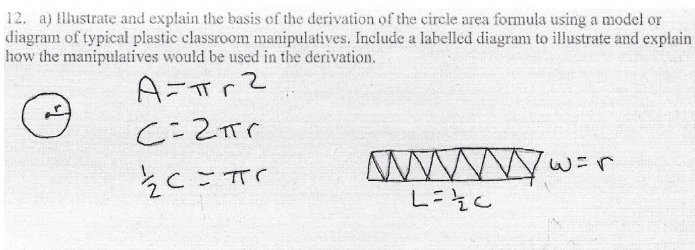


Figure 10. Question and response from Richard's final Mathematics for Teaching Exam

Since it was a graduation requirement, and we wanted to support as many pre-service teachers as possible in graduating, we allowed for a supplemental Mathematics for Teaching Exam to be written prior to graduation two months later. Richard chose to attempt the supplemental exam and received an even lower grade of 50%. Figure 11 shows the same question as Figure 10, but with Richard's solution on the supplemental exam. Based on the scoring rubric for the exam, this response shows an expanded knowledge of the answer but still does not show a depth of knowledge that would allow him to convey this to students. At this point his reaction to the news was to blame the university program, saying, "Forgive me for being disappointed because if I went anywhere else I'd already be working."

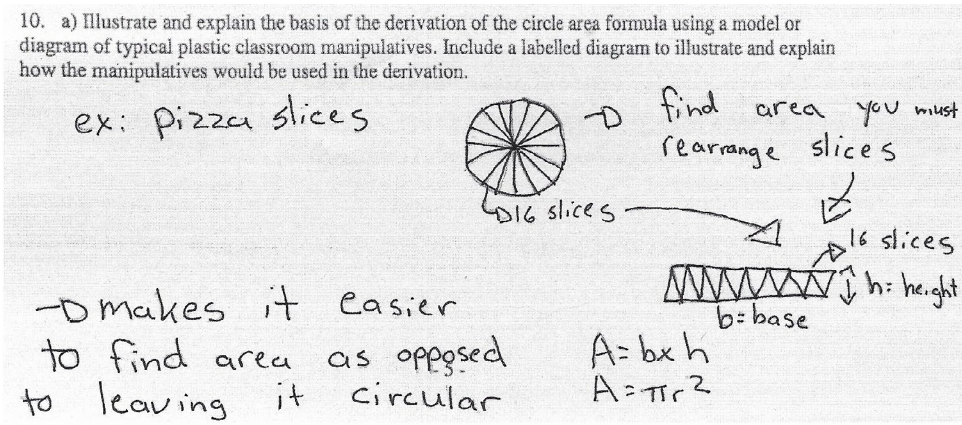


Figure 11. Richard's response to the same question on the supplemental Mathematics for Teaching Exam

Richard's Second Attempt at the Methods Course

Richard was incredibly angry[3] about having to come back for the second year in order to pass the course: "You're setting people up for failure, in my opinion." He was determined to avoid retaking the course and talked to the Chair about other options. In all meetings with Richard during his second attempt at the course, he continued to blame Instructor A for failing, and noted, "I don't think I deserved to have to come back." He blamed the program for his difficulties, remarking, "You guys have a lot of problems here [at the university] you have to fix. I'm paying for it, but that's life."

In the first week he met with Instructor B in order to discuss how many classes of the repeated methods course he absolutely had to attend (and which ones) since he decided to commute a great distance to complete the course. In the end, he attended the absolute minimum number of classes to pass the course. Throughout the course he was observed by Instructor B to share his anger with his classmates, although he claimed the opposite, saying, "I just try to be positive to the other new students." Despite the appearance of anger and frustration in every conversation, he noted that, "Everything is a little bit more open and positive this year than it was last year." He did maintain that it was Instructor B's purpose to help him be successful: "[Instructor B], you're all I got…you

3 Richard used more colourful language, but we did not feel it was appropriate to use his exact wording in the report, but rather have used a synonymous phrase that we felt was more appropriate.

are the one that has to help me get over the hump. I can't keep looking at other students. You're the teacher, you're the coach."

He did show improvements in his understanding and was able to achieve a 75% on his midterm exam (see Figure 12, which demonstrates his improved conceptual understanding), noting that, "So far I'm feeling good about math."

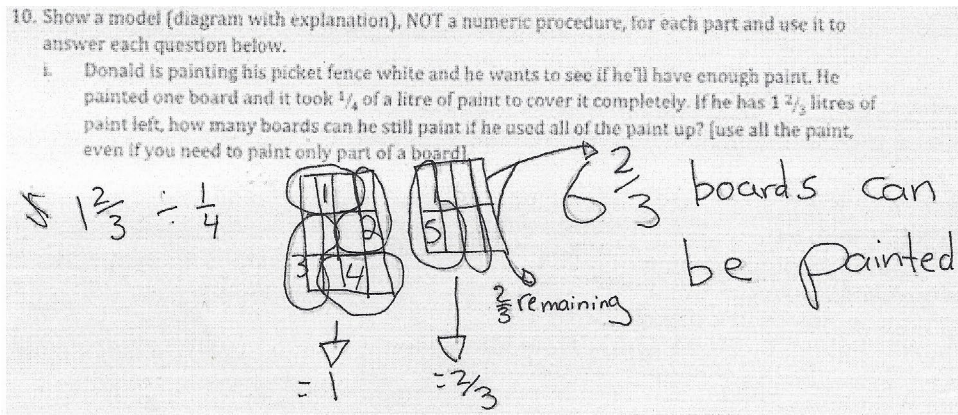


Figure 12. Question from Richard's year 2 midterm exam

Although he did finally appear to learn the content more effectively, he maintained that the course was not representative of what was needed for teaching in the field. In referring to his placement, he said, "I mean I did fractions and you explain to them the rules that we learned… The way we learn then would have been fine and I do teach math quite easily, but now it's this new wave of trying to teach… We are smart in other areas and then you come to math and you feel dumb and that's the worst feeling." However, he added, "It took a while, but at least I get it now. Like, there's different ways of multiplying, and uh…area models, and fraction manipulatives, and all that." See Figure 13.

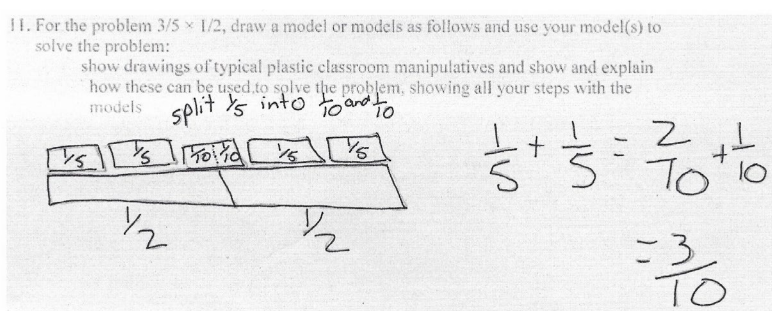


Figure 13. Question from Richard's year 2 final Mathematics for Teaching Exam

Richard added that failing "made me feel so dumb and ruined a lot of my confidence. I got it back this year because there was only one class. I was able to channel all of my energy into it. But, it's frustrating." In the end, we feel he missed the entire message of the course by believing that what he was taught was to throw away the old and focus on the new, despite the assurance of both instructors that a balanced approach was needed. (It is also possible that his self-expressed anger kept him from hearing the messages.) In the end, he passed his final exam with 72% (see sample response in Figure 13, which shows that Richard is still not entirely confident in his models but is able to solve the questions without reliance on a formula), but still maintained that Instructor B held the keys for his success: "[Instructor B] was unbelievable!... She was just supportive through and through, wanted to see me do well, and I did! So, that was good on her!" Although he was successful in passing the course, he remained adamant that the traditional method of direct instruction is best for teaching mathematics. He even mentioned that if he taught he would, in fact, focus on the teacher's manual, which he believed would give him all the information that needed to be conveyed to students, because that was "the best way to teach," adding "I'm just going to follow suit the best I can. I'm just happy I survived it."

Discussion

Reporting the participants' comments and feelings about the program without discussion was not meant as a way to blame either participant for behaviours or expressed feelings, but to present how two individuals who were facing the same struggles at the same time responded in different ways. Although both pre-service participants were provided with extensive supports and meetings from Instructor B, they chose to see the program in different ways. These differing perceptions of their experiences are important in discussing the implications of including a high-stakes examination in mathematics in a Bachelor of Education program. Both Grace and Richard entered the Bachelor of Education program with weak knowledge of the mathematics that they would need to understand in order to teach well. However, their initial attitudes were very different. Grace was fully aware of her deficits and knew that the year was going to be a struggle, while Richard just felt he needed a refresher and that there was a problem with the program. Richard maintained, throughout his journey, that the problem was the way math was being taught in the methods course, whereas Grace shifted both her beliefs about herself, and her beliefs about teaching mathematics. Since beliefs are the biggest determinant of how a teacher teaches (Wilkins, 2008), Richard's maintenance of his ideas about mathematics is a cause for concern as he enters the profession.

The institution of the mandatory Mathematics for Teaching Exam was intentional at the university in order to ensure that there was at least a minimal understanding of mathematics for teaching (cf. Ma, 1999; Silverman & Thompson, 2008) when the pre-service teachers graduated. Although both participants were able to meet the required 60% score at the conclusion of the two years, based on participant comments, it was clear that Grace truly embraced the process of ensuring that her own knowledge grew; whereas Richard decided it was just about getting through the program and planned to stick with his traditional views of mathematics teaching.

McGraw and Fish (2018) suggest that it is better to focus on developing qualities and academics during a program instead of using testing as a gatekeeper for program entry. We agree with findings that previous academic experiences should not be used as a way of denying entry into the program, but instead focused on increasing mathematics knowledge for teaching during the program, and ensuring (with support) that a suitable level of knowledge was achieved before graduation. We take the stand that such mathematics knowledge is essential for effective teaching, based on the work of numerous researchers (e.g., Hill et al., 2007) who were able to show that student achievement differs based on the depth of a teacher's knowledge of mathematics for teaching.

The unintended consequence of ensuring that all pre-service teachers met the exam mark requirement was the impact that the two students had on their classmates. Grace's peers ended up benefitting from her increased knowledge and confidence as she shared her understandings and growing enthusiasm with her peers. The groups always seemed to enjoy working with and learning from Grace throughout the course. The peers in Richard's class, on the other hand, appeared negatively affected by having him in the course with them. Instructor B noted a change in the atmosphere of the class whenever Richard was absent. Richard himself admitted that he made sure to tell his classmates that it all is about the exam and just getting through it.

It is possible that Grace and Richard perceived the high-stakes nature of the exam as a "fear appeal," since a failure would be detrimental to their futures (Witte & Allen, 2000). Although the exam was not designed as a fear appeal, there was definitely the negative consequence that a teacher education degree would not be granted if the Mathematics for Teaching Exam was not passed with a minimum of 60%. As Putwain et al. (2017) noted, not all fear appeals have a detrimental effect. In the first year, it seemed that Grace's lack of confidence led to her "self-protective and avoidance-focused mindset" (p. 80), but as her confidence increased, she became focused on a growth mindset. Richard also did not perceive the fear appeal as motivating, and exhibited his own self-protective behaviours through anger.

Jacobson and Kilpatrick (2015) focus on teachers needing a productive disposition but that "there must be a compelling theoretical rationale and empirical evidence that it influences mathematics learning" (p. 403) when exploring new ways of teaching. This aligns with Elwood et al. (2017) in that students are trying to find ways to cope with the reality of the testing situation and to do well within it. Richard chose to narrow the curriculum to focus on only what he felt he would need to succeed, whereas Grace embraced the entirety of what was missing in her understandings of mathematics. Both, in the end, did feel that they had learned more about mathematics. Richard chose to say it was thanks to Instructor B, and Grace seemed to appreciate that she just needed more time with the material in order to feel confident. This is an important finding in that dealing with Richard could be perceived as being "unpleasant," but he did end up learning the mathematics he would need to be an effective teacher. The fact that his beliefs did not change could be a result of the forced nature of the examination, instead of truly being able to just engage in the course and appreciate the nuances of what was being taught. Grace saw these changes as having a positive impact on her own learning, so that her understanding of mathematics would, in turn, support the learning of her students. If the goal was simply to increase teacher knowledge, then the institution of the examination was a success. If the goal was bigger, and involved beliefs around embracing such deep conceptual and specialized learning, and the development of positive attitudes toward it, then perhaps broader experiences need to be explored moving forward.

Since researchers (e.g., Hill et al., 2005) have shown that an increased knowledge of mathematics for teaching affects student achievement, we maintain that ensuring this knowledge is learned during a pre-service program is vital. What this study has additionally suggested, however, is that there can be consequences of taking a hard line in terms of high-stakes assessments, depending on how the participants view their initial failure.

In future research we would like to examine the effects of different program structures that would further explore and support dealing more broadly with student failure.

Regardless of the structure that future iterations of such an assessment might take, we remain fully committed to the idea that evaluating mathematics knowledge for pre-service teachers must include specialized content knowledge. As well as having the support of the literature related to the relationship of this knowledge with student achievement, this study provides further evidence of the importance of beliefs and attitudes of teachers, as we have also previously argued (Holm & Kajander, 2012). Grace's change in attitude and mathematical capacity began when she started to "see the mathematics in a new way." The models and reasoning approach gave her an important new understanding, which both helped her knowledge of teaching and gave her the tools to develop confidence in herself as a teacher. Richard, on the other hand, struggled to change his beliefs from those strongly tied to traditional values, and a test focused on computational skill and traditional procedures would only have underscored his lack of interest in learning any new mathematical understanding.

As provincial ministries of education consider mandating high-stakes testing of graduating mathematics teachers, we continue to argue strongly for the need to support—and test—*much more* and *other than* procedural curricular skills. Teaching is a highly specialized field—and so is the mathematics teachers need to teach well.

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