Primary Pre-Service Teachers' Beliefs About Challenging Mathematical Tasks

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We explored primary pre-service teachers' beliefs about challenging mathematical tasks and the role they perceived their initial teacher education played in influencing those aspects. Fifty-seven pre-service teachers completed an online questionnaire, and four participants were individually interviewed. Results showed that most participants recognised the importance of teaching with challenging mathematical tasks even prior to exposure to such content in their teacher education program. The teacher education program was perceived to have positively impacted final year pre-service teachers' perspectives about challenging tasks. Implications for teacher education regarding challenging tasks are discussed.

Challenging mathematical tasks are usually thought-provoking problems that are cognitively demanding and initially difficult to solve (Sullivan et al., 2016). Emerging research indicates that challenging mathematical tasks are important for all students in the primary mathematics classroom because they promote conceptual understanding, learner autonomy and mathematical reasoning (Bobis et al., 2021; Russo et al., 2020; Sullivan et al., 2016). Thus, there is an important need to encourage and support teachers' use of challenging mathematical tasks. Previous research has shown that many primary teachers are reluctant to implement challenging mathematical tasks because of their own beliefs surrounding such tasks including a fear that if students struggle doing mathematical tasks, it will lead to poor engagement (Cheeseman et al., 2013; Ingram et al., 2020). Understanding what beliefs primary pre-service teachers' (PSTs) hold is essential because it is these beliefs that may influence their instructional practices in their future classrooms. Previous research has explored the beliefs of prospective teachers and practicing teachers towards mathematics and teaching mathematics more generally (Grootenboer & Marshman, 2016; Maasepp & Bobis, 2014). However, little research exists specifically on primary PSTs' beliefs on challenging mathematical tasks. Identifying such information is vital for PSTs to reflect and change their beliefs to create classrooms where all students can engage in challenging mathematical tasks. There is a significant need to study what prospective teachers think or believe about challenging mathematical tasks and whether initial teacher education (ITE) courses have an impact on reshaping or changing their beliefs.

The aim of the study reported here was to explore (1) primary PSTs' beliefs about challenging mathematical tasks, and (2) their perceptions of how their ITE courses impacted their beliefs and knowledge about such tasks.

Literature Review

Two areas of research provide the background to this study: teachers' (including PSTs') beliefs about the teaching and learning of mathematics, and research about challenging mathematical tasks.

According to Maasepp & Bobis (2014), beliefs refer to an individual's opinion on a specific issue or practice that is considered true. Regarding PSTs' beliefs about mathematics, research indicates that they are quite narrow and rigid and can have a negative impact on their future teaching and students' learning (Liljedahl, 2009). Maasepp and Bobis's (2014) research showed that PSTs' beliefs affected the way they felt, acted, and thought about mathematics and could impact their knowledge development and future experiences with mathematics. The study also confirmed that experiences provided within ITE programs have the potential to reshape PSTs' beliefs about key aspects of teaching and learning mathematics.

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Challenging tasks provide students with the opportunity for prolonged thinking and reason promoting rich student-centred learning involving productive struggle, persistence and risk-taking (Russo et al., 2019; Clarke et al., 2014). Risk-taking resonates with Growth Mindset theory, where taking risks and making mistakes is part of learning by persisting and making the effort to gain deeper understanding (Dweck, 2008). Challenging tasks generally involve open-ended designed tasks or tasks that have more than one solution or solution strategy for all students to access tasks starting from a "low-floor" to their "high-ceiling" potential and take time to solve with limited teacher instruction (Bobis et al., 2021; Ingram et al., 2020).

The very nature of challenging mathematical tasks could be the reason why teachers are reluctant to pose challenging tasks to their students. For example, open-ended tasks are not always readily available to teachers. They may not know how or be confident to design such tasks themselves. Teachers may not understand the benefits of productive student struggle or have limited knowledge of appropriate instructional strategies to deliver and support students as they work on challenging tasks. Research surrounding teachers' beliefs about challenging mathematical tasks indicates that they generally reserve such tasks for highly mathematically capable students (Cheeseman et al., 2013; Russo et al., 2020).

Acquiring new knowledge or experiences may assist a teacher's beliefs to change. Changing beliefs relating to challenge in mathematics can help reshape teacher practices to include those that encourage students to productively struggle and persist working on challenging mathematical tasks (Clarke et al., 2014; Maasepp & Bobis, 2014). Notably, literature surrounding teacher beliefs about mathematics, challenge and challenging tasks reveals the effect that such beliefs can have on their instructional practices and ultimately on their students learning of mathematics. To date, there is little research that explores primary PSTs' beliefs relating to challenging mathematical tasks.

Research Questions and Conceptual Framework

This study was guided by the research questions:

- What beliefs do primary PSTs hold towards challenging mathematical tasks?
- How do primary PSTs perceive that their initial teacher education program impacted their beliefs and knowledge about challenging mathematical tasks?

The study was designed from a constructivist theoretical perspective (Cobb, 1994). Namely, the construction of primary PSTs' beliefs about challenging tasks was viewed as being influenced by a range of factors and experiences. In accordance with this view, we used Maasepp and Bobis' (2014) adapted framework of primary PSTs' mathematical beliefs to structure the survey items and interview questions. The framework represents how various elements can impact PST's beliefs, including their prior schooling, current ITE courses, their knowledge and confidence of mathematics, and experiences teaching with challenging mathematical tasks.

Methodology

All students enrolled in The University of Sydney's Bachelor of Education (Primary) ITE program across years one to four of the degree were invited to participate in an online survey via an email sent from the university's online Learning Management System. Respondents to the questionnaire consisted of 57 adults (49 females, 7 males and 1 other), representing approximately 13% of the total number of PSTs enrolled in the program. Of the 57 participants, 53 were aged between 18-24, one was aged between 25-34, two were aged between 35-44 and one was aged between 45-54. Across the four year groups, 18 from year one, nine from year two, 13 from year three and 17 from year 4 students responded to the questionnaire. All participation occurred on a voluntary basis and participants were able to opt out at any time. Participants who indicated their

willingness on the questionnaire to participate in phase two were contacted and invited to an interview.

Questionnaire. The questionnaire was conducted via the platform Qualtrics and took participants 15 to 20 minutes to complete. Part A asked for biographical information of participants such as their age range, mathematics level in high school and year level of the course. Part B contained 14 closed response items adapted from a previous survey designed to assess inservice teachers' beliefs about challenging tasks (Russo et al., 2020). Using a 5-point Likert scale (1 Strongly Disagree to 5 Strongly Agree), PSTs were asked to respond to measures of beliefs about mathematics (e.g., *I believe if I work hard, I will be able to perform better in mathematics),* about challenging tasks *(e.g., Challenging mathematical tasks enable me to think more creatively),* their learning about challenging tasks *(e.g., My university units have helped me to understand challenging mathematical tasks),* and of teaching students with challenging tasks *(e.g., It is important for my students to struggle in mathematics before I intervene).* Part C required an open-ended response asking PSTs to elaborate on why they had or had not changed their views about challenging tasks in the past few years.

Interview. Participants from each year level were invited to a semi-structured interview that was guided by open-ended questions and discussion prompts to further understand participants' beliefs towards mathematical tasks. Semi-structured interviews have in-built flexibility during data collection to adapt to respondents and situations to elicit the PSTs' beliefs among different year levels of the degree (Punch & Oancea, 2014).

Pseudonyms are used to report the interview data. No student in the second year of the program accepted the invitation to be interviewed. The interviews were conducted via zoom, which allowed for scheduling flexibility and availability of participants. All interviews were audio-recorded with participants' consent then transcribed by the first author.

Analysis. Descriptive statistics were used to summarise the biographical information collected from Part A in the questionnaire. Part B also used descriptive statistics such as percentages, mean scores and measures of frequency to analyse items requiring quantitative responses. The interview recordings were re-visited multiple times to ensure accuracy of transcripts and obtain a better understanding of participants' thoughts and beliefs. Participant responses were coded using a deductive coding process to account for information relevant to each element in the conceptual framework and corresponding interview questions (Braun & Clarke, 2013). The analysis was approached with pre-empted responses and anticipated themes relevant to the beliefs of PSTs. An inductive analysis followed to apprehend unexpected codes that emerged in the data and connecting it to prior research (Fereday & Muir-Cochrane, 2006).

Results

Questionnaire. Table 1 summarises participants' responses to item 6 (prior learning relating to challenging mathematical tasks) in Part A of the questionnaire. Other information gleaned from Part A was included in the description of participants.

Table 1 data reveals that nearly 30% of PSTs had no prior experiences learning about challenging tasks. Of the 71% who had prior experience, over half of them had some form of exposure as part of their ITE course. Approximately 35% of respondents have either read or had experienced PL about challenging tasks when on their professional placements in schools. These findings correspond with the fact that over 31% of respondents were in their first year of their ITE and had not yet undertaken any mathematics education courses.

Table 1

Questionnaire Participants' Biographical Data (N=57)

Item	Questionnaire Item	Responses	No. (%)
6	Prior learning relating to challenging mathematical tasks	No prior experiences	25 (29.4)
		PST education Unit of Study	28 (32.9)
		Professional readings	17 (20.0)
		Mathematics teacher conferences	2 (2.4)
		School-based PL	13 (15.29)

Of the 71% of the respondents who had prior experiences with challenging tasks, sixteen elaborated on their reasons in the open response section of the questionnaire as to why their beliefs about them had changed in the past few years. Four PSTs specifically referred to a mathematics education unit of study or the readings associated with a unit as having helped develop more positive beliefs towards challenging tasks. These changes were associated with a deeper knowledge of what challenging tasks are, how "they can be beneficial to students' learning" of mathematics and feeling "more equipped to teach" and "confident" with challenging tasks. Three respondents described how their beliefs about challenging tasks had changed because their view "of maths has changed". For instance, one respondent claimed she had "started to see mathematics as a creative subject that allows for open exploration rather than having a single answer". Several PSTs reported changed beliefs because they had changed their beliefs about how students learn mathematics and referred to "student participation", "engagement" and the "importance" of challenge when learning mathematics for conceptual understanding. Overall, survey respondents who reported changes to their beliefs about challenging mathematical tasks in the last few years, indicated that these changes were mostly because of new knowledge acquired either from their ITE course, professional readings or other PL that helped them recognise the benefits of challenging tasks hold for students' conceptual understanding of mathematics.

Table 2 summarises participants' beliefs about mathematics, challenging tasks, learning, and teaching challenging tasks from Part B of the questionnaire. The data shows that participants generally possess a growth mindset in terms of their own learning of mathematics as indicated by the high and low mean scores of items 16 and 8 (3.68 and 1.74 respectively). Responses to the three items (9, 13, 17) intended to measure participants' beliefs about doing challenging mathematical tasks indicated that most held moderate to moderately high positive beliefs. Similarly, in terms of PSTs' learning about challenging tasks during their ITE course, responses were moderate to moderately high. This is a positive result given that almost 30% of respondents were yet to experience any mathematics methods courses. It seems that ITE units have assisted PSTs' understandings of what challenging tasks are and helped them appreciate their affordances (e.g., item 14, mean 3.42).

PSTs' beliefs about personally teaching challenging tasks also reflect a growth mindset as shown in responses to items 15 and 20, which acknowledge the importance of challenging tasks and students need to expend effort to perform better in mathematics. Most respondents disagreed with item 11, indicating that they believed challenging tasks were not just for gifted and talented students. However, most respondents agreed with item 21, which is the opposite belief to what would be expected of someone comfortable using challenging tasks to teach mathematics to all students. This ambiguity in the findings could be explored in future research.

Table 2

Participants' Mean Responses to Part B of the Questionnaire

Item	Questionnaire Item	Mean
Beliefs about mathematics		
8	There will always be some people who will never 'get' math concepts no matter how hard they try. *	1.74
12	I consider myself to be a 'maths' person.	2.12
16	If I believe I work hard, I will be able to perform better in mathematics.	3.68
Beliefs about challenging mathematical tasks		
9	I like solving mathematics problems that can be solved in many different ways.	3.33
13	I like tasks where I do not know the answer straightaway and need to spend time to solve.	2.67
17	Challenging mathematical tasks enable me to think more creatively.	3.23
Beliefs about the learning of challenging mathematical tasks		
10	My university units have helped me to understand challenging maths tasks.	2.89
14	My university units have helped me see the benefits of teaching with challenging mathematical tasks.	3.42
18	My personal experiences of learning with challenging mathematical tasks have shown me that they are too difficult and unnecessary in learning mathematics. *	1.44
Beliefs about personally teaching challenging mathematical tasks		
11	Challenging maths tasks should be reserved for gifted and talented students. *	0.70
15	It is important for my students to struggle in mathematics before I intervene.	3.37
19	I think implementing challenging tasks will be difficult as students will become disengaged and struggle. *	2.47
20	It is important to teach primary school students with challenging maths tasks.	3.96
21	I think students should master basic mathematical facts before they tackle challenging tasks. *	4.14

*Reverse-scored item.

Interviews. Interview data were first categorised under three domains relevant to the conceptual framework: beliefs, ITE, and implementing challenging tasks in the classroom. Table 3 summarises the codes and themes identified during analysis and provides illustrative quotes. Due to page limitations, interview data are interpreted in the Discussion section.

Table 3

Codes and Themes Identified During Analysis of Interviews

Domain	Theme	Code	Sample quotes
Beliefs	Growth mindset vs. Fixed mindset	Struggle	"productive struggle came about by the challenge question—students had to figure out a method" (Casey year 3)
		Challenge	"There are certain people who are predetermined to enjoy a challenge more than others … there are others who may or may not enjoy the challenge and would prefer it to be something easier" (Anthony year 1)
	Past experiences in teaching / learning mathematics	Gifted and talented students, enrichment—for everyone	"I think all of them. There's no reason why not everybody could be involved in something" (Anthony year 1)
	Beliefs about teaching practice	Teaching for understanding	"I think there may be some problems in comprehension if you do it, especially with early stage 1 or maybe stage 1… especially like big-worded questions" (Anthony year 1)
			"When it comes to the elements in mathematical concepts, the key underlying concept has to be clear… the other elements can be challenging" (Lexi year 4)
Impact of initial teacher education (ITE)	Exposure to challenging mathematical tasks	Primary Education Degree	"I haven't heard of challenging tasks, but it sounds interesting" (Anthony year 1)
			"I have heard of challenging tasks during the course of my degree in Primary Education… over the years, I realise the fact that its open-ended nature actually helps every student" (Susan year 4)
	Mathematical knowledge for teaching	Using representations, confidence	"if you use a wide range of fraction models, like the area model or the discrete model, it helps the knowledge be more solid and its consolidated" (Lexi year 4)
Implementing challenging tasks	Students' disengagement	Not enjoyable, too challenging/ difficult	"Challenging tasks can possibly negatively impact the kids who are struggling just maybe going I can't, I give up, this is way too hard" (Casey year 3)
	Teacher guidance and differentiation	Teaching strategies (enabling/extend prompts)	"you can use a wide range of fraction models, like the area model or the discrete model" (Lexi year 4)

Discussion and Conclusion

Regarding RQ1 and PSTs' beliefs about challenging mathematical tasks, questionnaire results showed participants generally had confidence in themselves to succeed and expend effort to perform better in mathematics revealing a growth mindset towards their own learning (Dweck, 2008). However, interview data revealed that a fixed mindset was present in some PSTs in terms of student learning with challenging tasks. Anthony (year 1) believed that some students may be "predetermined to enjoy a challenge more than others…". Similarly, Casey (year 3) expressed a belief reminiscent of some practicing teachers that less able students might become disengaged by challenging tasks (Ingram et al., 2020). Nevertheless, questionnaire data revealed most PSTs

recognised the importance of teaching with challenging mathematical tasks. This belief is also reflected in the final year PST interviewees' responses.

In terms of RQ2, and if PSTs perceived their ITE had impacted their beliefs and knowledge about challenging tasks, questionnaire data highlighted that overall, participants held positive beliefs towards challenging mathematical tasks even though nearly 30% had not had any prior learning experiences with them. Meanwhile, 32.9% of participants have been exposed to challenging mathematical tasks in their ITE unit/s of study contributing to their belief about the teaching and learning of challenging tasks. These findings resonate with interview data, where the first year PST reported that he had "not heard of" or had limited exposure to challenging tasks. In contrast, PSTs in the final year of the program indicated familiarity with them and could relate implementation strategies to differentiate learning involving challenging tasks (e.g., using representations, and extending and enabling prompts). Through the ITE, PSTs like Susan recognised the benefits of such tasks for "every student". Corresponding with what Maasepp and Bobis (2014) and Lijedahl (2009) stated, ITE can impact PSTs' beliefs.

One interpretation of the variation between first and final year PSTs' beliefs and knowledge relating to challenging tasks is that exposure to the ITE methods courses and information about challenging tasks had positively impacted the perspectives of final year PSTs. The revised perspectives of challenging tasks were more notable in final year PSTs' responses. For instance, Susan noted that "over the years, I realise the fact that its (challenging tasks) open-ended nature actually helps every student". These findings emphasise the potential impact ITE can have in reshaping PSTs' beliefs and reveals the importance of explicitly addressing the use of challenging mathematical tasks in ITE.

Limitations of this study include the fact that the sample size was quite small and non-representative of the majority of primary PSTs in Australia. Namely, PSTs were from only one university. Nonetheless, PSTs from all year levels of the program were represented in the questionnaire. Future studies with a greater number of questionnaire respondents would increase the reliability of results. Similarly, the interviews were conducted with only four participants, one from each year group except for a second year primary PST. Whilst not a broad cross section of students in the primary ITE course, the number was sufficient to reveal PSTs' beliefs about challenging tasks and how their ITE has the potential to impact their beliefs and knowledge.

The aims of this study were to explore primary PSTs' beliefs about challenging mathematical tasks and their perceptions of how their ITE courses have impacted their beliefs and knowledge about such tasks. The findings indicate that primary PSTs in this study generally held positive views towards the teaching and learning of challenging mathematical tasks. These are important findings because new curricula around the globe focus on the skills of problem solving and reasoning—processes inherent when working with challenging tasks. ITE can change or reshape beliefs by raising awareness of the importance and affordances of including challenging mathematics instruction.

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