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Factors influencing productive teaching experiences of early career mathematics tutors in higher education: A case study of a professional development programme

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Abstract. Graduate teaching assistants are often tasked with teaching large groups of students, commonly in workshops or tutorials, a number of times per week in each semester of the academic year. This paper discusses a case study on the challenges faced by early career mathematics tutors while learning-to-teach and the factors that shape their teaching experiences in higher education. These factors were identified from the analysis of data that was collected during a professional development (PD) programme centred around a community of practice, whose participants were a group of mathematics/statistics PhD students ($n = 7$). The factors that emerged from the sessions were 'Teaching', 'Concurrent and Post Teaching Reflection', the 'Affective Domain', 'Students', 'Past Experiences', and 'External Factors'. Each of these factors have multiple subcategories which are described in this paper. The findings also indicate that the PD programme played a meaningful role in alleviating the challenges that the tutors in this study faced by increasing their confidence and supporting their pedagogical development and perseverance. Considerations for future PD programmes are also discussed.

1. Introduction

Much research has been conducted into the learning and teaching of mathematics at primary- and post-primary levels of education. By comparison, there is less research on the same issues in higher education (HE) [14, 31]. However, it has been found that many students experience difficulty in transitioning from post-primary education to HE, including those who were high achievers in mathematics at post-primary level. Factors that negatively affect students' transition from post-primary education to HE include: changes in instructional practices in HE, shifts in the nature of the curriculum, changing assessment practices, changes in students' emotional disposition towards mathematics, increased speed of the introduction of new topics, a greater diversity of tasks, increased autonomy in the solving process, a new balance in the 'tool' and 'object' dimensions of mathematical concepts, and the increased role of definitions [1, 4, 10].

Compounding these issues is the so-called 'mathematics problem', i.e. the finding that the mathematical standards of beginning undergraduates have been in decline for many years in various countries around the world [16, 33, 34]. It is apparent that mathematics educators in HE need to possess teaching skills and knowledge of a very high level to help them to facilitate a positive and successful HE mathematics experience for their students, particularly during the transition phase when students' issues have been found to be most intensive. In contrast to this finding, new academic staff (including lecturers at various levels) in HE have been found to experience difficulty in

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terms of their self-confidence and preparation for their teaching roles [2, 39]. These difficulties are also evident amongst graduate teaching assistants (GTAs) in mathematics [11, 36, 39] and research suggests that the issues persist should GTAs become teaching staff in HE institutions [2]. It has been stated that the "impact of [teacher] experience is strongest during the first few years of teaching; after that, marginal returns diminish" [29, p.1]. Rice [29] further suggests that the quality of a teacher's training and preparation programme may have a greater influence on their effectiveness than teaching experience itself. Based on these findings, providing HE mathematics instructors with a teaching preparation programme during the early phases of their careers may be critical in terms of positively influencing their future teaching. However, some GTAs' research supervisors deem that professional development (PD) of GTAs' teaching skills does not warrant the time that it takes away from their research, and in some cases the supervisors do not permit, or do not buy-in to, GTAs' engagement with training [8, 14]. This is despite the finding that GTAs' participation in teaching PD does not change the length of time it takes them to complete their studies [5]. Our case study investigates the research questions:

- What challenges do GTAs encounter in their early teaching experiences?
- Does participating in a PD programme centred around community of practice (CoP) help to alleviate these challenges?

2. Literature Review

2.1. **Students' Cognitive and Emotional Difficulties Related to HE Mathematics.** The transition from post-primary education to HE can present significant cognitive and emotional difficulties for students in their mathematical studies, particularly in first year [4]. Difficulties have been reported for students undertaking degrees in mathematics [10], as well as for students taking service mathematics modules (i.e. students who take mathematics modules as part of their degrees, but whose degrees are not in mathematics, such as science/engineering students) [34]. The cognitive challenges stated in the literature include difficulties with the increased use of symbolism and generalisation, the role of definitions, formal reasoning and proof, abstraction, modelling, and the faster pace and changed expectations of HE mathematics [10, 13, 24, 32]. These challenges are compounded by students' prior exposure to more routine or procedural approaches in post-primary education and lecturers' assumptions about students' mathematical preparation [13, 24]. Furthermore, the 'mathematics problem' (see Section 1), has long been recognised as a detrimental factor for students transitioning to HE and its effects have been observed in Ireland, the United Kingdom, and internationally [12, 16, 18, 34]. Alongside these cognitive challenges, students may experience affective/emotional difficulties such as anxiety, insecurity, low confidence, fear, frustration, and negative self-perceptions of their mathematical ability [4, 10]. High levels of mathematical anxiety and low mathematical self-efficacy have been reported among specific groups of HE students, including engineering students, psychology students, and mature students [17, 23, 25, 35].

2.2. **The Role and Challenges of GTAs.** GTAs form the majority of future mathematics lecturing staff and their preparation for teaching roles does, and will, impact mathematics education in HE both now and in the future [6, 9, 11, 21]. Nearly all mathematics PhD students teach at some point during their postgraduate studies [8] with nearly two-thirds of this teaching in the USA being in first-year modules such as calculus or below that level [9]. They have important roles in module delivery, including having more contact with students than the module lecturers [27], and impacting on students' mindset and decisions about which major to pursue [8, 28, 37]. Despite this, they

typically have very little teaching experience and/or education or training on teaching [11]. While they have been found to have strong subject matter knowledge, they have also been found to teach in a didactic, lecture-type, way with limited opportunities for student engagement [9, 36]. It has also been found that fundamental teaching skills such as voice projection, board work, checking for understanding, responding to different student learning styles and fostering participation and engagement among students all required improvement in GTAs' teaching skills [9, 36]. This highlights the fact that even though a teacher's knowledge of the subject matter is clearly vital and impacts on their acquisition of all other teaching skills [30], they do need guidance on teaching. Wood et al. [39] investigated the teaching and learning challenges that early career teachers (lecturers and tutors) in HE in Australia faced when teaching mathematical sciences. Respondents ($n = 111$) to a survey in Wood et al. [39], listed management of large classes, gaps and diversity in student knowledge and abilities, negative attitude of students, and lack of knowledge of effective and contemporary teaching methods as challenges that they faced in teaching. They also reported that the use of technology and presentation skills were areas in which they would like training.

2.3. **Professional Development for GTAs.** Despite the fact that many GTAs only teach in departments for a relatively short period of time, their participation in PD on teaching can "pay out-sized dividends in undergraduate teaching" [8, p.687]. In relation to previous PD for GTAs on teaching mathematics, most of the research is descriptive (i.e. the types of training/PD undertaken) [7]. Ellis [11] describes three models for GTA PD on teaching: (i) The Apprenticeship Model, which emphasises mentoring, observation, and progressive responsibility as tutors transition into their new role; (ii) The Coordinated Innovation Model, which combines pre-semester preparation, ongoing coordination around student-centred teaching, teaching observations, and weekly meetings within the teaching team; and (iii) The Peer-Mentor Model, which utilises experienced GTAs to support newer tutors and foster communities of practice. Murdoch et al. [20], in their project with GTAs in a school of criminology in Canada, also state four recommendations to enhance GTAs' training for teaching. They recommend that GTA training should be mandatory, discipline-specific, varied, ongoing, and that participants should be compensated.

A study with 253 STEM GTAs in the USA showed that more time engaged in PD on teaching and learning was correlated with higher teaching self-efficacy [6]. A similar finding is reported in [5]. Musgrave and Carlson [21] studied the effects of an intervention targeted at 19 precalculus and calculus GTAs in the USA. The intervention was designed to incorporate pre-semester workshops and weekly 90-minute seminars during the academic term where they prepared upcoming classes, discussed what was involved in understanding the upcoming concepts and practiced delivering mini-presentations on how they would support their students' learning in the class. The intervention focused on what was needed to understand and learn the key ideas of each lesson and encouraged the tutors to focus on mathematical meaning and precise communication. They found that while the GTAs had deficiencies in their understanding of average rate of change pre-intervention, mostly focusing on it in terms of computational or geometric interpretations, after the intervention 15 of the 19 GTAs attempted to give an explanation of it with a more conceptual focus. Although research on the experiences of GTAs has been carried out in other countries, there is a shortage of research in the Irish setting.

Deshler et al. [9] state that changes in knowledge, changes in beliefs about learning and teaching, increases in student success, and the analysis of student surveys, interviews, teaching observations and portfolios are some of the factors that can be analysed to determine how effective a PD programme is for GTAs.

The literature above indicates that GTAs occupy a significant position in undergraduate mathematics education, often teaching a large number of students, some of whom are experiencing substantial cognitive and emotional challenges related to mathematics in HE. Also, GTAs may begin teaching with limited preparation for teaching, low confidence, and uncertainty about how to support student engagement and understanding. These findings suggest a need for discipline-specific, ongoing professional development that supports GTAs at the outset of their teaching roles.

3. Methodology

3.1. **Sample.** The participants in this case study consisted of 7 PhD students (denoted P1 - P7) with teaching responsibilities (preparing and delivering tutorials and marking coursework and examinations) in the Department of Mathematics and Statistics in an Irish HE institution. The attendees at a tutor training day (Section 3.2.1) were asked to complete consent forms, as well as pre and post tutor training questionnaires which were completed immediately prior to and at the end of the training day (Appendix A). Participation in this case study was voluntary. Our sample consists of the participants, hereafter referred to as 'tutor(s)', who completed all of these forms during the tutor training day. The sample of 7 PhD students represented approximately 30% of the population of PhD students with teaching responsibilities in the department. As the case study took place prior to the second semester of the academic year, all of the tutors had some prior teaching experience (Table 1). Ethical approval was granted from the university's research ethics committee. The previous teaching experience of the tutors, in addition to any prior teaching training they received, is shown in Table 1.

Tutor	**Length of time teaching prior to this research**	**Previous tutor training**
P1	6 semesters	Yes. 1 tutor training day*
P2	1 semester	No
P3	2 years	No
P4	3.5 years	Yes. 1 tutor training day*
P5	1 semester	Yes, 2 years initial mathematics teacher training course
P6	7 years on an irregular basis	No
P7	1 semester	Tutor training (1 week) for teaching English to children. Sport coaching course (1 week)

Table 1. Teaching background of tutors in the sample (*The tutor training day these tutors previously completed is as described in Section 3.2.1, excluding Workshop 4).

The average length of time that six of the tutors had been teaching was 3.33 semesters (one tutor who stated a length of time, stated they only taught irregularly so was omitted in the calculation of this average) and so can be deemed to be in the early stages of their teaching career. Three of the tutors had received tutor training in the past in the form of a tutor training day, one tutor had completed two years of initial post-primary mathematics teacher education before changing their course of study to mathematical sciences, whilst the last three tutors had not received any training prior to this research. The average amount of time tutors spent teaching at the time of this case study was 3.6 hours per week (tutors met with students between 3 and 6 times a week for an hour to two hours at a time, with class sizes of approximately 20 - 50

students). The tutors stated that, on average, they felt that students would rate their teaching as 6 out of 10 (range 2.5 - 7.5), they rated their own confidence in teaching as 6 out of 10 (range 3 - 8) and rated their positive feelings towards teaching before the semester began as 8 out of 10 (range 3 - 9). The tutorials that the tutors were teaching were timetabled from Weeks 2 - 12 or Weeks 3 - 12 (inclusive, starting in Week 2 or 3 depending on the module they taught) of the semester.

3.2. **Professional Development Programme for Tutors.** The PD programme developed for the tutors in the sample was motivated by the National Forum for the Enhancement of Teaching and Learning in Higher Education's Professional Development Framework for all staff who teach in HE [22]. It consisted of a tutor training day, reflective practice and community of practice (CoP) sessions.

3.2.1. *Tutor training day.* Prior to the semester in which the case study commenced, tutors participated in a five-hour training day comprising four workshops whose activities addressed all five domains in the National Forum PD Framework [22].[1]

The workshops focused on several key areas of tutor development. Workshop 1 introduced tutors to their role, the characteristics of the students they would teach, and challenges associated with supporting mathematics learning. Workshop 2 developed communication skills, including explaining concepts, questioning techniques, listening skills, and the effective use of technology to support student understanding. Workshop 3 encouraged tutors to critically reflect on teaching practice through the analysis of recorded teaching examples and discussion of tutorial planning. Workshop 4 provided opportunities for tutors to apply their learning by planning and delivering short teaching sessions, engaging in self-reflection, and receiving feedback from peers and facilitators.

Collectively, the workshops were designed to support tutors in developing the knowledge, skills, and reflective practices required for effective mathematics tutoring, while aligning with the domains of the National Forum PD Framework.

3.2.2. *Written reflections.* In alignment with elements of domains 1 and 2 of the National Forum PD framework, the tutors were requested to write reflections on their tutorials during the semester on a prescribed reflection document (Appendix B). The decision to complete each reflection point in the document was left to the discretion of the tutors. The primary aim of the written reflections was to provide a platform for tutors to reflect on their teaching: to identify and analyse aspects of their teaching that went well, aspects that could be improved, and to formulate and implement methods to alleviate any difficulties they experienced. The reflections were also used to provide material for the facilitated CoP sessions (Section 3.2.3).

3.2.3. *Community of Practice (CoP) sessions.* Following the tutor training day, the authors held CoP sessions with the tutors twice over the course of a twelve-week semester (in the fourth and seventh weeks). The objective of the CoP sessions was to facilitate the sharing of common concerns and best-practice experiences among tutors, with the aim of co-creating new knowledge to advance their collective teaching practices. These CoP sessions were guided by a list of open questions (Appendix C) in order to identify those experiences the tutors were having during their teaching, and to provide a space for them to discuss teaching and their written reflections with each other if they were comfortable doing so. During the CoP sessions, concurrent feedback and advice, including teaching

[1]The five domains are (edited for brevity): 1. Personal development; 2. Professional identity, values and development; 3. Professional communication and dialogue; 4. Professional knowledge and skills; 5. Digital capacity.

demonstrations, were given by the authors who acted as mentors[2] during these CoP sessions. The tutors also shared best practice and created new knowledge with their peers and with the authors. They did this through discussing problems they experienced in their teaching, and questioning and reaching consensus on potential solutions raised.

3.3. **Data Analysis.** The data sources as described above were (i) pre and post tutor training day questionnaires (ii) transcriptions of CoP sessions and (iii) tutors' written reflections.

(i) Pre and post tutor training day questionnaires. The tutors' rating of their confidence, positive feeling towards teaching and any comments made were compared from the pre to post tutor training day questionnaires. The findings and comments made by the tutors on these questionnaires were listed under the domains of the National Forum's PD framework that they corresponded to.

(ii) Transcriptions of CoP Sessions. The CoP sessions were audio recorded and transcribed verbatim. Six tutors attended the Week 4 session and five attended the Week 7 session. Inductive thematic analysis, using line-by-line open coding [3, 19], was conducted in NVivo 11. The authors and a colleague independently analysed the transcripts without pre-defined codes, identifying factors that influenced tutors' early teaching experiences. Codes and themes were developed inductively from the data using the six-step process of Braun and Clarke [3, p.87]:

(1) Familiarizing yourself with your data
(2) Generating initial codes
(3) Searching for themes
(4) Reviewing themes
(5) Defining and naming themes
(6) Producing the report

Following their individual analyses, a meeting was held to discuss and agree upon the final themes relating to factors affecting tutors' early teaching experiences. After coding the data into primary categories, a second round of analysis was undertaken to identify secondary categories. Comparisons of tutors' verbal interactions within each primary category informed the development of these secondary categories, which also emerged inductively from the data.

(iii) Tutors' Written Reflections. Similar to the CoP sessions, inductive thematic analysis was used to examine the tutor's reflections. Also, the reflections completed by the tutors were examined as follows:

- Data from the tutors' reflections after their first tutorial were examined to determine whether the tutor training day impacted on their teaching and if yes, then how.
- Data from the tutors' reflections after subsequent tutorials were examined to view the tutors' teaching and learning experience, to determine whether the CoP sessions affected anything in their teaching, and to determine if there were any developments in their reflective approaches.

The data provided in the pre and post tutor training day questionnaires, the tutors' written reflections and the CoP sessions were combined as shown in Table 2 to address each of our research questions.

3.4. **Limitations.** This study has several limitations. As a small-scale qualitative case study involving a voluntary sample of seven PhD tutors from one Irish university, the findings are not generalisable to the population. Participants may also have

[2]The terms authors/mentors are used interchangeably depending on their appropriateness.

Research question	Data sources
What challenges do GTAs encounter in their early teaching experiences?	Reflections + post tutor training questionnaire + transcriptions of CoP sessions.
Does participating in a PD programme centred around CoP help to alleviate these challenges?	Reflections + pre and post tutor training questionnaires + transcriptions of CoP sessions.

TABLE 2. The data sources used to address each of the research questions

had more positive dispositions towards teaching and professional development than non-participants, introducing a degree of self-selection bias. The collected data also relied largely on self-reported surveys and reflections. In addition, variation in tutors' prior teaching experience and inconsistent completion of reflective journals limited the extent to which the participants' learning to teach trajectories could be analysed and/or compared. Finally, while the study provides insight into tutors' perceptions of factors which influenced their teaching experience and some insights into their perceived changes in their teaching, it does not include any classroom observations or student outcome data, which constrains claims about the impact of the programme on the participants' teaching practice or on their students' learning.

4. Results

This section presents the findings from the data analysis. First, we compare the pre and post tutor training questionnaires, examining tutors' self-reported changes in confidence and positive feelings towards teaching, what they learned from the training day and intended to implement, and any remaining questions or concerns. Second, we present themes from the post tutor training questionnaires and tutors' reflections after their first tutorial to explore perceived impacts of the tutor training on practice. Finally, we present the themes that emerged from the CoP sessions.

4.1. **Pre and Post Tutor Training Day questionnaires.** The tutors' rating of their confidence on a scale of 1-10 (1-not confident at all; 10-very confident) increased from a median of 6 prior to the tutor training day to a median of 7 afterwards. The median rating of the tutors' level of positive feelings towards teaching on a scale of 1-10 (1-I am dreading it; 10-I can't wait) decreased from a median of 8 to a median of 7 from pre to post tutor training questionnaires. Three tutors (P2, P3, and P5) reported an increase in their positive feelings towards teaching, two tutors (P4 and P7) reported no change, and two tutors (P1 and P5) reported a decrease.

No responses were given by the tutors to the question "Any additional comments" on the pre tutor training day questionnaire. In response to the question "state three things that you have learned from the tutor training day that you plan on implementing into your teaching?" on the post tutor training day questionnaire, the tutors listed the elements shown in Table 3. The domains of the National Forum's PD framework that these elements correspond to are also shown in Table 3.

In response to the question "state three issues/questions that you still have, that you feel were not addressed in the tutor training course?" on the post tutor training questionnaire, the tutors listed the issues in Table 4. The domains of the National Forum's PD framework that they correspond to are also shown in Table 4.

4.2. **Themes from Reflections and CoP sessions.** A total of 30 reflections were completed by the tutors. Given the difference in the number of reflections completed

Domain	Findings and Comments
Personal Development: the 'self' in teaching and learning (Domain 1).	Increased confidence and increased level of positive feelings towards teaching as detailed above.
Professional communication and dialogue in teaching and learning (Domain 3).	Speak slower; more awareness of my speed of writing and talking, in addition to organising the writing on the board better (e.g. divide the space on the board into three equal parts by drawing two vertical lines). Summarise important points at the end of the tutorial.
Professional knowledge and skills in teaching and learning (Domain 4).	Ask more guiding questions. Try to facilitate students' completion of questions during tutorial (as opposed to just writing up the solution). Try to cover less material to allow for increased student participation. Walk around the room while students are attempting tutorial problems. Show students why their suggested and/or completed solution may not be correct. Planning – spend more time thinking about different ways to explain.

TABLE 3. Learning experienced by the tutors and their links to the National Forum's PD framework

Domain(s)	Findings and Comments
Professional communication and dialogue in teaching and learning (Domain 3). Professional knowledge and skills in teaching and learning (Domain 4).	Maybe more practical advice on how to engage 1 to 1 with students in a very large class. How to phrase and pick precise English statements to describe each step in a solution.
Personal and professional digital capacity in teaching and learning (Domain 5).	How to use technology – projector, acetate sheet etc.

TABLE 4. Issues raised by the tutors and their links to the National Forum's PD framework

across participants, analysis of the tutors' first tutorial experiences was based on reflections from tutors P1–P5, while longitudinal analysis was based on tutors P1, P2, and P5, who provided sufficient data across multiple weeks (Section 4.2.2).

4.2.1. *Reflections completed after the tutors' first tutorial (P1-P5) and common themes noted in the post tutor training day questionnaires.* In the post tutor training questionnaire (Q1), tutors were asked to list three things that they have learned from the tutor training day that they plan on implementing in their teaching, while the reflection document (Q3) asked if the tutor training course had impacted on their teaching and (Q2) to list three things that they felt could have been improved and/or did not go well in their first tutorial. Each of the tutors who completed a reflection after their

first tutorial mentioned at least one common item in their responses to these questions (Table 5).

Tutor	**Post-training day questionnaire (Plan on implementing in teaching)**	**Reflection after first tutorial (Impact of tutor training on teaching)**	**Reflection after first tutorial (Things that could have been improved/did not go well)**
P1	Speak slower.	Slowed down – students not getting too much information too quickly.	Was too quick to respond and said 'no' to incorrect responses to questions.
	If someone gives an approach to a question that is incorrect, go through it to help students to see why it is incorrect	Made sure students had time to take things down from board.	
P2	Ask more guiding questions.	Students were interactive, students answered questions posed and asked questions.	
	Summarise important points at the end of the tutorial.		Because I ran out of time at the end, I didn't get the chance to summarise what we went through in the tutorial
P3	Try to cover less material to allow for increased student participation.	The tutor training day emphasised the importance of clarity and understanding over quantity of material covered. As such I spent considerably more time on each question than I would have previously. Had multiple questions from students, questions were tackled slowly with students and motivation outlined at start of each question. Encouraged those who asked questions, a point that was raised at the training.	Too much time dedicated to one question.
	Try to get students to tackle questions in tutorial.	The tutor training day highlighted that ideally students should be attempting questions themselves in the tutorial, this is something I hope to implement, I indicated this to students in the first tutorial.	Students did not attempt questions themselves today.
P4	Explain when you've stopped writing (i.e. give students time).	Conscious of not blocking board as I write and explaining when students aren't writing.	May cover the board when I write. Explain when I've stopped writing.
P5	Students should be attempting questions	Asked more probing questions, tried to get students more involved. Answered students' questions and ensured they understood the answer.	Silence when I asked questions, blank faces and no answers. No answers to questions posed.

TABLE 5. Common items listed by tutors in the post tutor training questionnaires and in their reflections after their first tutorial.

Comparison of the post tutor training questionnaires and the reflections after the tutors' first tutorial indicated that tutors attempted to implement many of the practices emphasised during the training day, including questioning, encouraging student

participation, greater lesson preparation, covering less material in greater depth, and allowing students time to process information. Difficulties reported included limited student participation, timing, and balancing the quality of the content taught with the quantity of content to be covered.

4.2.2. *Overview of learning journey of P1, P2 and P5.* Tutors P1, P2 and P5, who completed reflections across multiple weeks, showed evidence of developing reflective practice over time, moving towards a more proactive and adaptive approach to teaching. Common themes included increased use of questioning, greater attention to student participation and understanding, adaptation of teaching approaches, and an increasing emphasis on quality of learning over quantity of content covered. Their reflections also indicate increased confidence, such as taking time to think before "jumping into an explanation I haven't thought through", and a greater willingness to implement ideas raised in the CoP sessions in their teaching and classroom management.

4.2.3. *Transcriptions of CoP sessions.* Six factors (hereafter referred to in this subsection as 'primary categories' for the purpose of analysis) that shaped the tutors' experiences of teaching mathematics in HE were identified from the thematic analysis of the transcriptions of the CoP sessions.

(1) Teaching - skills in teaching and teaching approaches.
(2) Concurrent and post teaching reflection – the tutor documents what they do in their own teaching and reflects on the means and purpose of what they do. Identifying and analysing this information may lead to changes and improvements in their teaching practice.
(3) The affective domain – the tutor's own confidence, motivation, and patience, and the concern they have for their students.
(4) Students – the knowledge and behaviour of the tutor's students.
(5) Past experiences – the prior teaching experience of the tutor, the tutor's knowledge of the module they are teaching and the tutor's preconceptions of students in general.
(6) External factors – factors to do with resources (size of room, technology etc.) and knowledge of university procedures and management.

These six primary categories, were subdivided into secondary categories (Table 6). For example, the primary category of teaching is subdivided into two secondary categories: teaching skills (planning, explanation, and adaptive practice), and teaching approaches and pedagogical orientation. Themes within the secondary categories are included in (Table 6) alongside the corresponding secondary category.

4.2.4. *Themes within the primary categories from the transcriptions of the CoP sessions and reflections.* This section outlines the challenges experienced by tutors, viewed in relation to how frequently they were referenced in the CoP sessions and reflections. It was observed that tutors did not always mention all challenges in their written reflections; some were identified only through discussion during the CoP sessions.

Themes within the primary category of 'teaching'.

In the CoP sessions, the primary category of 'teaching' accounted for the highest percentage of all coded statements (48.9% by 5/6 tutors, and 34.4% by all 5 tutors, in the first and second CoP sessions respectively), with most of the statements falling in the secondary category of 'teaching skills (planning, explanation, and adaptive practice)'. The dominant themes within this secondary category based on both frequency and the proportion of tutors who mentioned them, are shown in Table 7.

Primary Category	**Secondary Category**	**Secondary Category Themes**	**Number of coded Statements**
Teaching	Teaching skills (planning, explanation, and adaptive practice)	Teaching Abstract Concepts. Quality versus Quantity. Difficulty with changing own behaviour. Motivating Students. Knowledge of Students. Facilitating Students' Input. Planning. Questioning. Mixed-Ability Teaching. Conscious Awareness.	$n = 37(41.1\%)$ CoP1 $n = 26(27.1\%)$ CoP2
	Teaching approaches and pedagogical orientation	Teaching Style and associated opinion on benefit to students. Outlining expectations. Contextualising. Perseverance in new approaches.	$n = 7(7.8\%)$ CoP1 $n = 7(7.3\%)$ CoP2
Concurrent and Post teaching Reflection	Reflective practice on teaching and student learning	Ability to acknowledge what went well. Perception of student learning. Learning from reflection.	$n = 14(15.6\%)$ CoP1 $n = 29(30.2\%)$ CoP2
Affective Domain	Affective dispositions towards teaching and students	Confidence. Motivation. Patience. Concern for Students.	$n = 4(4.4\%)$ CoP1 $n = 11(11.5\%)$ CoP2
Students	Students' engagement and behaviour	Engagement. Misbehaviour.	$n = 4(4.4\%)$ CoP1 $n = 5(5.2\%)$ CoP2
	Students' knowledge	Prior knowledge and preparedness	$n = 3(3.3\%)$ CoP1 $n = 10(10.4\%)$ CoP2
Past Experiences	Prior experience and assumptions	Prior teaching experience. Knowledge of module. Preconceptions of students.	$n = 7(7.8\%)$ CoP1 $n = 5(5.2\%)$ CoP2
External Factors	Institutional and resource factors	Classroom. Technology. Tutorial Sheets content and amount to complete. Class size. Knowledge of university procedures and management.	$n = 14(15.6\%)$ CoP1 $n = 3(3.1\%)$ CoP2

TABLE 6. Primary and Secondary Categories Identified as Factors that Shape the Teaching Experiences of Early Career Mathematics Tutors in Higher Education (with n = number of statements coded, and % = percentage of overall statements coded. CoP1 and CoP2 = Community of Practice Session 1 and Session 2 respectively.)

Across reflections following their first tutorial and during the first CoP session, tutors consistently identified three key areas of development: 'questioning', 'conscious awareness'[3], and 'facilitating student input'. The themes of 'questioning' and 'conscious

[3]Conscious awareness refers to tutors becoming more reflective about their teaching behaviours (e.g. pacing, clarity, repetition, and interaction with the class).

First CoP session	Second CoP session
Conscious awareness (*1)	Questioning (1)
Questioning (2)	Quality versus quantity (1)
Facilitating students' input (2)	Conscious awareness (2)
Planning (3)	Mixed-ability teaching (2)
	Motivating Students (2)

TABLE 7. Themes coded within the secondary category of 'teaching skills (planning, explanation, and adaptive practice)' at each CoP session. *Denotes the order of frequency of codings, note some themes tied in terms of order of frequency.

awareness' also emerged in the second CoP session. These were recognised as important teaching practices that tutors aimed to incorporate into their teaching practices but found difficult to implement effectively.

Questioning emerged as the most prominent challenge. Tutors found it difficult to get students to engage with questions, either because students were reluctant to respond or because tutors felt unsure how to pose effective, probing questions. Practical constraints, such as large class sizes, limited time due to large amount of content coverage requested by the lecturer, and uncertainty about handling unexpected answers further hindered their use of questioning as a teaching tool. In the second CoP session, the theme of 'questioning' was the most frequently coded theme. The tutors continued to experience some difficulties in developing this skill.

The theme of 'conscious awareness' was mentioned much less in the second CoP session than in the first CoP session. An item that was listed in the tutors' reflections after their first tutorial as something that could have been improved on was tutors being too quick to respond 'no' to incorrect answers (i.e. being too blunt and not encouraging students' attempts to contribute). Tutors found it challenging to avoid discouraging students while still guiding them effectively, and to engage quieter students when a few dominated discussions. A discussion on how best to respond to students' incorrect answers (theme of 'facilitating students' input') and on potential ways to engage quieter students occurred in the first CoP session. Additionally, time management emerged as an ongoing issue, affecting tutors' ability to implement planned practices (such as summarising at the end of tutorials). Overall, the findings indicate that while tutors were aware of key pedagogical strategies, translating them into practice proved complex due to both skill-related and contextual factors.

Between Weeks 4 and 7, tutors' focus shifted from their own teaching performance to student-centred concerns, particularly balancing 'quality versus quantity' , 'motivating students', and addressing 'mixed-ability' groups. These themes, absent in earlier discussions, became more prominent in the second CoP session, indicating developing pedagogical awareness. Tutors increasingly reflected on how their teaching impacted student engagement and learning, while also highlighting ongoing challenges, especially in managing mixed levels of student abilities and deciding how to allocate time effectively across learners with varied needs. Examples of some of the statements made by the tutors in the second CoP session are shown in Figure 1.

In the reflections that they completed after their first tutorial, tutors identified an ongoing tension between 'quantity versus quality' in their teaching. While the tutor training emphasised prioritising student understanding, tutors found it difficult to balance this with covering all required material. Slowing down improved student comprehension and satisfaction, but often meant less content was completed. This trade-off left tutors uncertain about the 'right' approach, highlighting a persistent challenge in

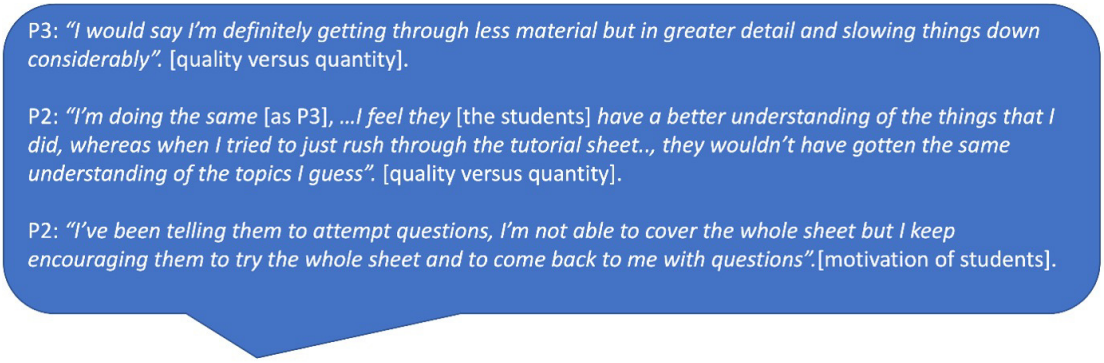

FIGURE 1. Examples of statements made in relation to the secondary category of 'teaching skills (planning, explanation, and adaptive practice)' in the second CoP session (Week 7).

managing instructional priorities.

Themes within the primary categories of 'concurrent and post teaching reflection' and 'external factors'.

In the first CoP session, the primary categories of 'concurrent and post teaching reflection' and 'external factors' each accounted for the second-highest percentage of coded statements (15.6%; 5/6 tutors). In the second CoP session, 'concurrent and post teaching reflection' and 'students' accounted for the second and third highest percentage of coded statements respectively (30.2%; all 5 tutors, and 15.6%; 4/5 tutors). Examples from the first session are shown in Figure 2, illustrating difficulties in relation to the themes of 'learning from reflection', 'perceptions of students' learning', 'tutorial sheet content', 'classroom' and 'technology'. Tutors found it difficult to gauge student progress; for example, P6 asked, "is there a way to measure it?". In the second CoP session, external factors such as pressure to complete lengthy tutorial sheets were seen as limiting opportunities for deeper student engagement through questioning. When expectations around content coverage were relaxed, tutors felt better able to prioritise interaction and understanding. In the second CoP session, reflection itself was viewed as valuable, helping tutors become more aware of their teaching in the moment and more intentional about improving their practice in future sessions.

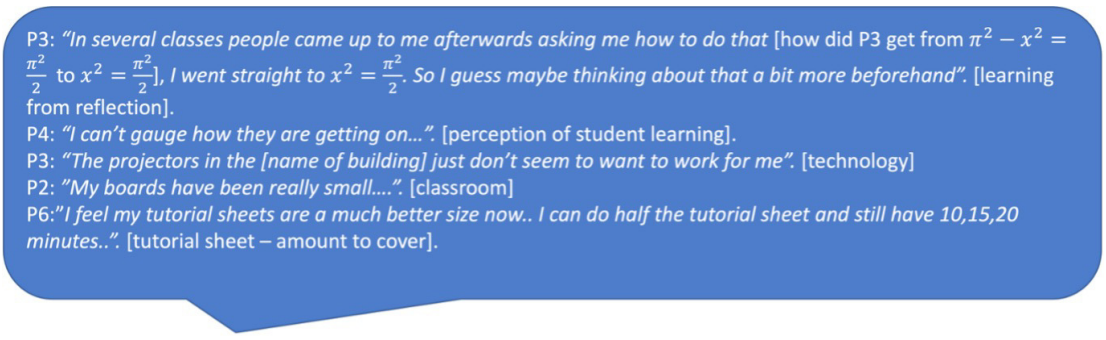

FIGURE 2. Examples of statements made in relation to the primary categories of 'concurrent and post teaching reflection' and 'external factors' in the first CoP session (Week 4).

Themes within the primary categories of 'students', 'past experiences' and 'affective domain'.

Tutors showed an increased focus on 'students', driven mainly by the secondary category 'students' knowledge', which rose from 3.3% of coded statements (2/6 tutors) in the first CoP session to 10.4% (3/5 tutors) in the second. Tutors expressed concern about students' knowledge and their ability to remain engaged when encountering difficulties. They were surprised by some of the challenges students faced and felt that gaps in knowledge and understanding slowed progress through tutorial sheet questions. Examples of statements relating to students' knowledge from the second CoP session are shown in Figure 3.

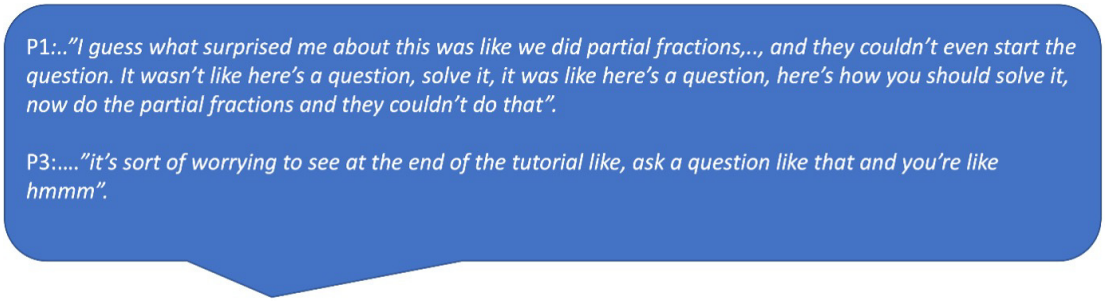

FIGURE 3. Examples of statements made in relation to the secondary category of 'students' knowledge' in the second CoP session (Week 7).

In the first CoP session, tutors' discussions focused on their own 'past experiences' and on their 'students'. Comments about students centred mainly on 'students' knowledge', and their 'engagement and behaviour', while references to 'past experiences' drew on tutors' 'preconceptions of students' and 'prior teaching experience'. Examples of statements made in relation to these themes in the first CoP session are shown in Figure 4.

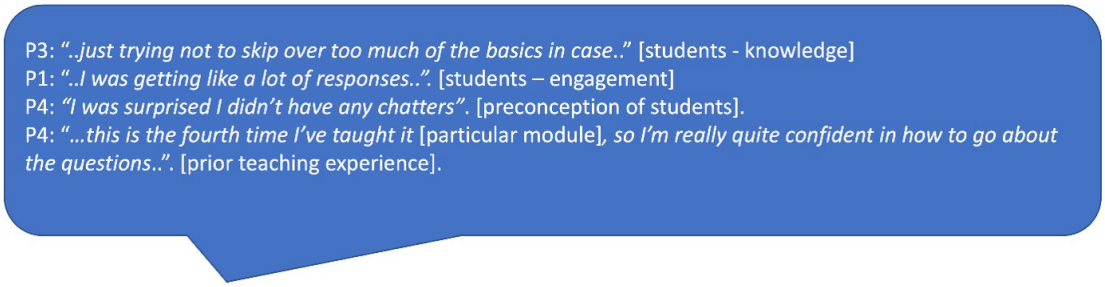

FIGURE 4. Examples of statements made in relation to the primary categories of 'students' and 'past experiences' in the first CoP session (Week 7).

In the second CoP session, tutors' discussions included themes related to the 'affective domain' and 'past experiences' (fourth and fifth highest percentage of coded statements respectively: 11.5% by all 5 tutors and 5.2% by 4/5 tutors respectively). Most affective domain comments reflected 'concern for students', while references to 'past experiences' centred on 'preconceptions of students' and 'prior teaching experience'. Compared with the first CoP session, affective domain themes became substantially more prominent, particularly 'concern for students', 'motivation', and 'patience'. Some examples of these statements made in relation to the primary category of 'affective domain' in the second CoP session are shown in Figure 5.

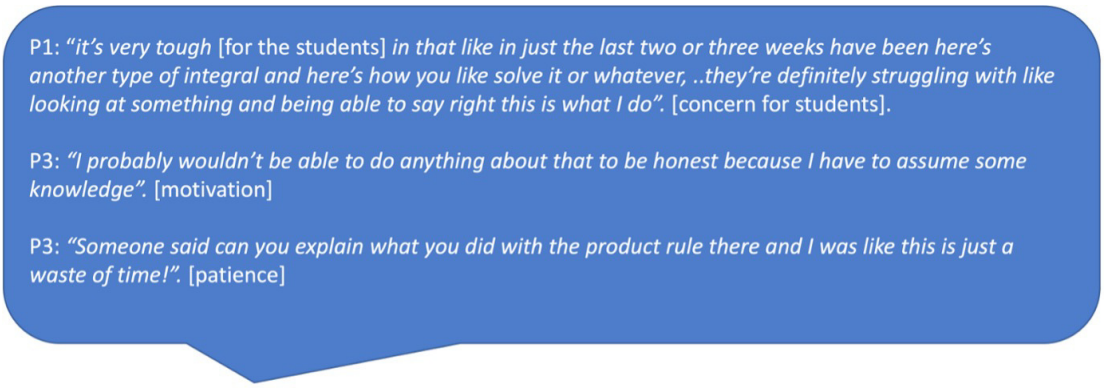

FIGURE 5. Examples of statements made in relation to the primary category of 'affective domain' in the second CoP session (Week 7).

In the second CoP session, the primary category of 'external factors' accounted for the least percentage of all coded statements (3.1% by 2/6 tutors) with the theme of 'tutorial sheet - content and amount to complete' coded highest. There was decreased focus by the tutors in categories 'external factors' and 'past experiences' from the first to the second CoP session.

The challenges that the tutors experienced in their early teaching experiences occurred in the six primary categories as described in Section 4.2.3. The factors that shaped the teaching experiences of the tutors in this case study were seen to remain largely the same from Week 4 to Week 7. The order of frequency of the factor 'external factors' changed from the second highest coded category to the lowest coded category from Week 4 to Week 7, with the factor 'past experiences' changing from the third highest coded category to the fifth highest coded (or second lowest) category.

5. Discussion

Based on findings from the review of literature, the provision of a teaching preparation programme to HE mathematics instructors, particularly during the early phases of their careers, may be critical in terms of positively influencing their future teaching [29]. Both a teacher's experience, and the training and preparation programme they engage with, impact considerably on their teaching practice [8, 20, 21], with teacher training most likely having the greater influence [29]. In our study, the tutors' voices highlighted the importance, necessity and benefit of early PD initiatives on their initial teaching experiences. The authors reiterate that the small sample size limits the extent to which conclusions can be drawn from these findings, and we cannot generalise the results beyond our sample. We structure the discussion around the two research questions guiding the study: (RQ1) the challenges GTAs encounter in their early teaching experiences, and (RQ2) whether participation in a PD programme centred around community of practice (CoP) helps to alleviate these challenges.

5.1. **RQ1: What challenges do GTAs encounter in their early teaching experiences?** Our analysis revealed difficulties related to questioning, facilitating students' input, identifying the source of students' misunderstandings, managing mixed-ability classrooms, and balancing quality of learning with coverage of content. The facilitation of students' input and mixed-ability teaching have previously been highlighted as challenges for tutors [9, 39]. Although the tutors in our study were aware of the benefits of implementing particular teaching skills from the tutor training day in their teaching, and did try to incorporate these, they found themselves sometimes doing the opposite of what they meant to implement and then becoming very aware of this during their

teaching. From the comments made by the tutors in relation to questioning, specifically figuring out what probing questions might help the student to gain understanding, the findings suggest that strong content knowledge does not necessarily translate into pedagogical questioning skills (similar to [30]), reinforcing similar research findings on GTA pedagogical gaps [9, 36]. This may be a result of a combination of never having thought about the need for probing questions, a lack of practice, and being somewhat conditioned to the lecture style of teaching from their own university experience. The lecture style of teaching has previously been found to be favoured by GTAs [9].

Tutors also found it challenging to determine precisely where students were experiencing difficulty. Questions that revealed substantial gaps in prior knowledge were described as "worrying" and tested tutors' confidence and patience. For example, P3 found it concerning that a student asked about how to implement the product rule while they were completing questions which required its use with partial derivatives. As reported in Section 2.1, these experiences align with well-documented weaknesses in undergraduate students' mathematical abilities and the cognitive challenges they face, for both mathematics and service mathematics students [10, 12, 13, 16, 18, 24, 32, 34]. Although discussion of the 'mathematics problem' and common areas of difficulty for students formed part of our Workshops 1 and 2 during the tutor training day, more emphasis on this is required in future PD programmes.

Simultaneously, with the discussion in the CoP sessions suggesting a positive shift in the tutors' focus from self to student (Section 4.2.1), items mentioned also suggests that the tutors were experiencing difficulty in the secondary category of teaching approaches and pedagogical orientation, specifically in the area of 'persevering with new approaches'. The difficulty of persevering with unfamiliar teaching approaches when confronted with challenges related to weaknesses in students' mathematical abilities further compounded tutors' frustrations. The tutors in Wood et al. [39] stated that they lacked knowledge of contemporary teaching approaches and desired training in them. However, based on our study it is noteworthy that the implementation of new teaching methods may come with a degree of difficulty. Tutors also had trouble maintaining patience when faced with "jarring questions" from students, that is questions that indicate severe deficiencies in knowledge of material met earlier in their course/module. In general, the tutors' increased concern for students' knowledge and understanding, coupled with seeing first-hand the benefit of the new teaching approaches to students' understanding, resulted in the tutors wanting to persevere with these approaches in order to benefit students, but they found it difficult. It was also noticed by the authors that, at times, a very literal interpretation of a teaching approach resulted in more difficulty being experienced with respect to levels of frustration and perseverance. For example, tutors were advised that they could complete the initial part of a student's incorrect suggestion for a solution to a problem to allow the student to understand why it was incorrect/not a useful suggestion. P1 interpreted this to mean that they had to proceed with an incorrect suggestion to the point of exhaustion and mentioned that when a student in their class suggested an incorrect substitution for an integrand, following this teaching approach led to a "mess" on the board. P1 stated "I'm not going to keep going and have some sort of mess on the board that I'm going to get flustered with because I don't know how this is supposed to work out". Demonstrations in addition to discussions around teaching approaches will be included in future iterations of the PD programme to alleviate this.

The tutors embraced the idea of providing a quality learning experience for their students and were keen to provide this. However, at times they experienced challenges in trying to achieve a balance of providing a quality experience while also covering all of the content. This was further exasperated if the tutorial sheets provided to

them were particularly long, the lecturer's request was that all material on the sheet should be completed, and/or the students found the content very difficult. Contextual factors, including unfamiliarity with technology and with university procedures and management, added to these challenges and were also found to potentially divert the tutors' attention away from their pedagogical development at times.

5.2. **RQ2: Does participating in a PD programme centred around community of practice (CoP) help to alleviate these challenges?** The findings indicate that participation in the PD programme supported tutors in addressing many of the challenges identified in RQ1. The increase in confidence towards teaching that was self-reported by the tutors was an anticipated outcome of participating in the tutor training day, as a focus on personal development formed part of the design. This is similar to the findings presented in [5] and [6]. Developing confidence, in addition to recognising the role that one's emotions play in any human interaction, forms part of the domain of 'personal development: the self in teaching and learning' of the National Forum's PD framework [22]. The decrease in positive feelings toward teaching reported by the tutors was unexpected. One possible explanation is that participation in the training day increased tutors' awareness of areas in which they may need to improve their teaching practice. At the same time, the increase in self-reported confidence may indicate that they felt they had acquired the knowledge and skills necessary to implement these improvements. The increase in confidence was also of practical importance in reducing anxiety among tutors in this sample and increasing their willingness to implement new teaching approaches (Section 4.2.2).

The CoP sessions provided valuable insights and further elaboration on the difficulties experienced with questioning skills that the tutors mentioned in their reflections. Using the P1 example from Section 5.1, it seems they may not have engaged in reflection to a depth where they was able to gain understanding of potential reasons for an issue occurring and to consider some potential ways to alleviate the issue. In response to the question posed by one of the mentors "after you reflected [...] did you think [...] if something like that comes up again, did you think about what you were going to do?". P1 stated that they "didn't really think, I mean my thought was maybe just not to ask that kind of question but at the same time I don't want to just do out the answers". The CoP session was helpful in providing additional time for tutors to reflect on any difficulties that they were experiencing and to reach an understanding of a possible solution/strategy to use to alleviate these difficulties.

By prompting tutors to consider students' thinking more explicitly, the CoP sessions supported professional growth and heightened awareness of students' difficulties. For example, through mentor questioning, P3 examined whether a student's difficulty stemmed from gaps in prior knowledge or from applying familiar rules in a new context. Such discussions also helped to resolve difficulties arising from literal (and unintended) interpretations of new teaching approaches.

The impact of the tutor training day on the tutors' teaching was discussed in Sections 4.1 and 4.2. A comparison of the post tutor training day questionnaires and the tutors' reflections after their first tutorial revealed that, in general, the tutors did try to implement the items they mentioned in their questionnaires (Table 5). This comparison also revealed several other items that the tutors learned from the tutor training day (not mentioned in the tutors' questionnaires) that they took with them into their teaching (Section 4.2.1). These included questioning to gauge understanding, planning, clearer presentation, encouraging student participation, and prioritising quality over quantity, and monitoring students' progress during class (Tables 3 and 5). The tutors focused on developing various skills and approaches based on what they considered important from what they learned on the tutor training day, and from their own experience as

a learner. They worked on implementing these skills and approaches at times that were appropriate in their learning to teach journey, for example, those with the least teaching experience initially tended to focus on more foundational practices (such as introducing themselves to a group). In the tutors' reflections after their first tutorial, students asking/answering questions was noted as a sign of the class going well by all tutors. This shows that the PD programme had a positive effect on the issues that tutors experience regarding facilitating students' input as found by [9]. Also, tutors asking more probing questions, giving students opportunities to ask questions at the end of problems and/or at several points during more difficult problems, and trying to get their students more involved were all noted as things that went well in the tutors' first tutorial. While 'mixed-ability teaching' and 'motivating students' were not mentioned in the first CoP session, the tutors in the second CoP placed emphasis on motivating students' engagement with the material with continued focus on questioning and managing diverse student needs.

Similar to [39], responses to the post tutor training day questionnaire indicated that some tutors felt the training on technology in Workshop 2 did not address their needs sufficiently, and suggested that more training in this area was necessary. This arose again in the first CoP session. Training on how to use technology and training on any other specific technologies that are available to tutors within an institution should be included within early PD initiatives, specifically before tutors begin their teaching (e.g. checking the classrooms and equipment with each tutor before they begin teaching in order to address any potential issues with classroom resources prior to teaching). In light of the fact that online education is arguably now more prevalent than ever, this training should also include the use of online education platforms. The provision of information on university procedures and management should also be included (e.g. how to change the classroom assigned to a more suitable classroom). By including training on 'external factors' in early PD initiatives, future cohorts of tutors could avoid experiencing difficulty with them and therefore be able to focus more on their teaching without these additional distractions, which may lead to a more productive learning-to-teach experience. The authors would also recommend increased allocation of time where tutors engage in practising their teaching of mathematics, with observation, discussion and feedback by peers and mentors in early PD initiatives – this was highlighted by the tutors as an aspect of PD with which they felt they needed more engagement.

5.3. **Other Outcomes from the PD Programme.** A notable outcome of the PD programme was a shift in tutors' focus from themselves to their students. This included greater recognition of the difficulties that many students, particularly first years [4], experience in their mathematics studies, increased approachability, and adaptive teaching practices aimed at supporting understanding and encouraging engagement. Using the results obtained from this sample of tutors, focusing on external factors in advance of the tutors beginning to teach may have facilitated discussion of mixed-ability teaching at an earlier stage in the CoP sessions. For example, the provision of a session (with discussion) on strategies for mixed-ability teaching could have been included within the first CoP session, or between Weeks 4 and 7. The tutors would then have had the knowledge of some approaches for mixed-ability teaching in advance of them requiring it, providing a more productive learning to teach experience.

The recurring quality versus quantity theme suggests that the tutors were beginning to evaluate teaching success less by content coverage and more by students' understanding of the material. Evidence of the tutors emphasising this was shown by their engagement in practices such as the use of questioning and explaining to promote understanding, and by their inclusion of examples of where the mathematics being learned is applied within the students' chosen field of study. This contrasts with the findings

in the literature which state that students find that classes lack applications [26] and students also have trouble with just accepting content delivered to them in HE and not questioning why it works, along with the findings that mathematics in HE can be very procedural [15, 26, 38].

The increase in references (in the CoP sessions) to concurrent and post reflection and the nature of those statements suggest that the tutors have positive opinions of engaging in reflection. In general, the tutors saw the benefits of engaging in reflective practice in terms of increased awareness of their own teaching and their perception of their students' learning and understanding. In addition, the tutors also acknowledged the benefit of engaging in reflection in terms of improvements in their planning and subsequent improvement in the flow of their lessons and on their students' learning experience. Completing the reflection document after each tutorial was noted as being helpful to the tutors in our study in spotting patterns in their teaching, having time to think about why certain things may be occurring in their teaching and classrooms, and thinking about possible ways in which they could overcome any difficulties. The tutors who completed the reflection document after each of their tutorials over several weeks, showed progression in their reflective practices. As mentioned in Section 4.2.4, in several instances, the information provided by the tutors in their reflections facilitated further insight into a reference to one of the six factors made by that tutor in the CoP sessions.

The tutors reported improvements in their personal development, professional communication and dialogue, and increased knowledge and further development of their skills in teaching and learning after participating in the tutor training day. The CoP sessions were instrumental in supporting the tutors with their engagement of new approaches particularly when they encountered difficulty. The tutors noted that the provision of a safe space to discuss any aspect of their teaching among their peers and mentors, was very helpful in terms of chatting about their teaching experiences, gaining clarification and reassurance on certain aspects of their teaching approaches, reflecting on their teaching, gaining advice on possible ways aspects of their teaching could be improved, discussing new ideas and classroom management issues, acting out teaching approaches, and learning about ways technology could be used to enhance students' understanding. This finding provides further supporting evidence of the benefits of one of the core components in each of the models described by Ellis [11] - Apprenticeship Model (Teaching mentor); Coordinated Innovation Model (Weekly meetings); Peer-Mentor Model (Experienced peer mentor delivering ongoing seminars). The CoP sessions were also helpful in providing another opportunity to engage in reflection with the added benefit of collaborative discussion regarding any issues with peers and mentors.

Overall, while early teaching challenges are unavoidable, the findings from the cohort of tutors in our study suggest that a PD programme centred around a CoP can play a meaningful role in alleviating these challenges by supporting tutors' confidence, pedagogical development, and perseverance during the formative stages of their teaching careers.

6. Conclusion

The tutors in this study highlighted the concerns they had with respect to beginning to teach, in addition to revealing the factors that impacted on their early teaching experiences. It was seen that the prominence of each of the six factors on the tutors' early teaching experience increased/decreased or remained relatively the same between the CoP sessions. This information is useful for individuals who are providing PD

initiatives, in terms of factors to consider for training, discussion and exploration in PD.

The tutors in our study encountered and engaged with many of the challenges identified by past research [39] including management of large classes, gaps and diversity in student knowledge and abilities, lack of knowledge of effective and contemporary teaching methods, and use of technology in teaching within a structured PD context. By engaging early with challenges such as these, the tutors in our study may be better prepared to address these issues should they choose to progress into academic teaching roles.

The tutors in this study reported the importance and benefit of PD initiatives on their early teaching experiences. The authors would recommend the provision of PD programmes for all GTA's who teach mathematics in HE, ensuring that those who teach in HE are given PD from the earliest stage of their teaching career. The authors would also recommend that the duration of such PD programmes be of a sufficient length to cater for the GTAs' PD needs while also taking into consideration both the research and teaching commitments of the GTAs. Following feedback received from the tutors in this study, the authors have extended the duration of the tutor training day in this study to two days. The first day will consist of the four workshops as described in this paper, with further information, training and discussion on the mathematical abilities of students, technology in teaching and external factors. At the end of the first day, the tutors will be asked to plan a lesson, noting that they will be asked to teach part of that planned lesson to their peers and the mentors on the second day. The second day of the tutor training course will consist of the tutors practising their teaching of mathematics with observation, completing a reflection document after their teaching, and then engaging in discussion and receiving feedback by peers and mentors. Following the teaching practice and discussion, tutors will be asked to discuss their completed reflections and to engage in a discussion on the benefits of engaging in planning for teaching and reflective practice. The authors have also refined the PD programme to include two individual meetings with tutors to discuss their reflective practice, in particular areas of growth, implementation of any new approaches, areas of continued difficulty and possible ideas for alleviating any difficulties. These meetings would be held between the first and second CoP session and following the second CoP session. Mathematics education specialists and mathematics support staff are well positioned to offer PD initiatives such as that outlined in this paper. The combination of their mathematics knowledge, pedagogical knowledge, and their experience and knowledge of university students are invaluable in providing early PD initiatives to those who teach mathematics in HE. The provision of such PD initiatives is in line with the National Forum's recommendations for all staff who teach in HE.

The tutors in this study had a strong desire to provide high-quality instruction in mathematics but they required support to aid them in their endeavours. The PD programme outlined in this paper was noted by the tutors as being beneficial and helpful to them in facilitating the provision of such high-quality instruction, as well as leading to increased confidence and reduced levels of stress and anxiety. The CoP sessions as part of the PD programme facilitated meaningful peer discussions on teaching and it is hoped that engaging in PD initiatives as early mathematics tutors may lead to a continuation of peer dialogue on teaching in the future and a continued improvement in the teaching in universities.

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Appendix A. Pre and Post tutor training questionnaires (Note: Format of the questionnaires shortened for publishing purposes)

Pre tutor training course questionnaire

Q1. How long have you been teaching mathematics/statistics? If you have not taught before please just state 'n/a'.

Q2. Have you ever received any teacher training before this (please circle)? Yes / No. If 'yes', please explain below.

Q3. How many hours per week (on average) do you teach/will you be teaching this semester?

Q4. If you have taught before what do you think a student who has attended all of your tutorials would say about your tutorials?

Q5. On a scale of 1 to 10 (please circle) how do you think a student would rate your teaching if you have taught before? (1 = not good; 10 = excellent)

1 2 3 4 5 6 7 8 9 10

Q6. My peers and I discuss teaching and teaching approaches (please circle):

Never Very rarely Rarely Occasionally Frequently Very frequently

Q7. The lecturers and I discuss teaching and teaching approaches (please circle):

Never Very rarely Rarely Occasionally Frequently Very frequently

Q8. On a scale of 1 to 10 (please circle) how would you rate the amount of support available to you with your teaching? (1 = there's no help; 10 = excellent. Everyone is very helpful and help is often offered from staff members.)

1 2 3 4 5 6 7 8 9 10

Q9. On a scale of 1 to 10 (please circle) how confident do you feel about teaching? (1 = not confident at all; 10 = very confident.)

1 2 3 4 5 6 7 8 9 10

Q10. On a scale of 1 to 10 (please circle) how positive are you feeling towards teaching this semester? (1 = I am dreading it; 10 = I can't wait).

1 2 3 4 5 6 7 8 9 10

Q11. Any other comments (worries about teaching/ questions you have etc.)

Post tutor training course questionnaire

Q1. State three things that you have learned from the tutor training course that you plan on implementing/taking with you into your teaching.

Q2. State three issues/questions you still have that you feel were not addressed in the tutor training course.

Q3. On a scale of 1 to 10 how confident do you feel about teaching? (1 = not confident at all; 10 = very confident.)

1 2 3 4 5 6 7 8 9 10

Q4. On a scale of 1 to 10 how positive are you feeling towards teaching this semester? (1 = I am dreading it; 10 = I can't wait.)

1 2 3 4 5 6 7 8 9 10

Any other comments?

Appendix B. Reflection Documents

Reflection after first tutorial

(1) List three things that you felt were good and/or went well in your first tutorial.

(2) List three things that you felt could have been improved and/or did not go well in your first tutorial.
(3) Do you feel that the tutor training course impacted on your teaching in any way (please circle)?

Yes No

If 'yes', please explain in the space provided below.
(4) Any other comments on your first tutorial?

Post tutorial reflection (following each tutorial)

(1) What content did your tutorial cover?
(2) List three things that you felt were good and/or went well in your tutorial.
(3) List three things that you felt could have been improved and/or did not go well in your tutorial.
(4) What will you do to help alleviate the issues you have stated in Q3?
(5) If you feel the past mentoring session(s) has affected anything in your teaching please explain.
(6) Any other comments?

Appendix C. Open ended questions for CoP sessions (semi-structured and subject to change).

(1) How is your teaching going this semester?
(2) Have you experienced any successes? If so, what are they?
(3) Have you encountered any difficulties? If so, what are they?
(4) How have you tried to alleviate the difficulties you have experienced?
(5) Have you noticed any difference in how your tutorials have started this semester compared to in previous semesters?
(6) What do you think a student who has attended your classes might say about them?
(7) Have you had any classroom management issues? If so, what have you done to combat them?
(8) Have you found any of the mathematics you are teaching particularly difficult to explain? Have you resorted to procedural teaching (i.e. teaching the students how to do a problem step by step without effort to teach for understanding)?
(9) If yes to 7, did you change anything in the weeks following the class where you had that experience?
(10) Have you reflected on your classes after they were over? *(NOTE this will be advised in the tutor training day).* If so, what were some points you reflected on? Did it change anything about your teaching afterwards?

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