Experimenting with Reform-Orientated Approaches: Difficulties and Advantages Experienced by Primary Mathematics Teachers

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There have been many attempts to reform mathematics teaching in Australia to encourage teachers to use more cognitively demanding tasks that focus on problem solving and reasoning. However, there is limited specific advice for teachers on how best to do this. This paper reports on one set of survey items that examines 52 teachers' responses to experimenting with a reform-orientated approach and challenging tasks through the EPMC project. Findings indicate that the EPMC approach was different to most teachers practice, and despite the difficulties experienced by both students and teachers, both responded positively and reported the approach effectively supported student learning and in developing growth mindsets.

With growing evidence supporting the notion that students learn best when they are presented with academically challenging tasks that focus on problem solving and reasoning (NCTM, 2014; Kilpatrick, Swafford, & Findell, 2001) many countries around the world have made curricular changes to give problem solving a more central role. However, despite reforms in mathematics education and resources that encourage teachers to utilise more cognitively demanding problem-solving tasks, it appears that many teachers are reluctant to use such tasks and experience difficulties incorporating problem solving into classroom practice (Sullivan, Clarke, Clarke, & O'Shea, 2010). In exploring the reluctance of teachers to pose more cognitively demanding tasks, literature suggest it may arise from fear of student reactions to being challenged and a lack of time to plan such lessons (Sullivan et al., 2014). Stacey (2016) described the difficulty experienced by teachers as not only mathematical, but as pedagogical and personal; as teachers strive to meet a range of student learning needs, take appropriate risks and invite more student autonomy. Furthermore, Stein, Grover and Henningsen (1996) found that when teachers incorporate cognitively demanding tasks, they are often transformed into less demanding tasks during instruction. Consequently, it appears that teachers may need more support and opportunities to incorporate challenging problem solving tasks in their classroom.

The data reported below were collected as part of the Encouraging Persistence Maintaining Challenging (EPMC) project (Sullivan, Borcek, Walker, & Rennie, 2016). This project was a teacher professional learning (TPL) initiative based on the notion that one way to encourage innovation is to offer teachers specific suggestions of learning sequences involving engaging and challenging problem solving experiences that prompt the experimentation of alternate approaches.

The EPMC Project as a form of Reform-Orientated Approach

It is acknowledged that tasks play a vital role in student learning (Anthony & Walshaw, 2009). However, as Stein and Lane (1996) found, engaging students in high levels of cognitive thinking and reasoning is dependent on the how problems are set up and implemented in the mathematics classroom. Furthermore, Marshall and Horton (2011) concluded after examining the order of instruction of over 100 lessons, that students thought more deeply about the content when given the opportunity to explore the concepts prior to any explanation (whether this be by the teacher or students). The implication is that teachers should provide students with opportunities to develop ideas for themselves to maximise

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learning opportunities. Despite consistent advice to incorporate more challenging problem solving tasks that teach through problem solving, there is limited specific advice for teachers on *how* best to do this (Sullivan et. al., 2016).

One example of a TPL initiative that attempted to support learning through problem solving is the EPMC project. The project encourages teachers to consider an alternative approach premised on the assumption that students learn mathematics best when they engage in building connections between mathematical ideas for themselves, prior to any instruction, by working on unfamiliar challenging tasks. Essentially the EPMC approach facilitates students in moving from initial confusion, to eventual clarity and understanding. As a result, the EPMC approach is quite different to traditional approaches that utilise more explicit approaches to instruction, such as 'teacher telling'. Supported by empirical, conceptual and theoretical developments in mathematics education over the past three decades, the following key aspects of the EPMC approach (often described as a reformist approach) were summarised by Sullivan et. al. (2016) to involve:

- Approaches that teach *through* problem solving that use problem solving as a context for learning new concepts and developing the four proficiencies (understanding, problem solving, reasoning and fluency). Problem tasks are presented with minimal instruction from the teacher (and no explicit instruction) where students learn through the problem-solving experience, as well as from listening to others justify and explain their solutions and strategies. (see Schroeder & Lester, 1989)
- Adaptations of the task to differentiate the learning experience, including enabling and extending prompts that support students' thinking and to access the main learning task. (see Sullivan, Mousley, & Jorgensen, 2009)
- Approaches to reviewing student work including anticipating students' mathematical responses, monitoring student responses, purposefully selecting students' responses to display and have them explain their solutions and thinking, purposefully sequencing those responses so that the reporting is cumulative and connecting the student responses. (see Stein, Engle, Smith, & Hughes, 2008)
- Providing opportunities to consolidate the learning by posing further tasks that are appropriately varied. (see Dooley, 2012; Kullberg, Runesson, & Mårtensson, 2013)
- Tasks that are open-ended, have multiple entry points, allow varied solution strategies, require the students to justify and explain their solutions, require complex and non-algorithmic thinking, involve some level of anxiety for the students due to the unpredictable nature of the solution process required, and demand considerable cognitive effort. (see Stein, Grover, & Henningsen, 1996)
- Developing classroom cultures that fosters growth mindsets, where effort is valued and recognised to lead to success, mistakes and confusion are promoted as part of learning, challenge is welcomed, and persistence encouraged. (see Dweck, 2000)

The research reported in this paper is one aspect of my research exploring the factors that influence teachers to utilise reform-orientated approaches and challenging tasks. Teachers knowledge, beliefs, opportunities and constraints (including professional learning opportunities) are examined to explore teachers decisions on tasks and approaches that influence student thinking and learning. The theoretical model by Carpenter and Fennema (1991) provides a framework for this study emphasising that tasks and instructional approaches do not directly influence student learning, but instead influence student thinking and behaviour, which in turn, influences student learning.

In acknowledgement that practising teachers often find it challenging to implement reform-orientated approaches that encourage teaching through problem solving (Sullivan et al., 2009), the present study explored the following research question through the EPMC project: *When experimenting with a reform-orientated approach as part of a project, what*

are the difficulties and advantages experienced by primary mathematics teachers that can influence their decisions to incorporate reform-orientated approaches?

Data Collection and Analysis

The data reported below were collected as part of the EPMC project that adopted a design research approach which "attempts to support arguments constructed around the results of active innovation and intervention in classrooms" (Kelly, 2003, p.3). The intervention involved the suggestions of challenging tasks with a specific approach to teaching, and the innovation was the notion of activating cognition through embracing confusion. The project was iterative for two reasons: (1) up to 14 suggestions were implemented sequentially by teachers and (2) this approach was repeated to involve different mathematical content and demographic of teachers. The current paper focuses on one iteration of the project relating to geometric reasoning tasks, with an emphasis on the learning of angles.

As part of the TPL initiative, there were two professional learning days (at the start and end of the iteration) where teachers completed an online survey using Qualtrics (2015) at the beginning of each day. Whilst survey items for this study were incorporated into both days, only data from the second professional learning (PL) day are presented in this paper, after the implementation of the EPMC tasks and approach. Open response items were incorporated into the EPMC survey and designed to prompt self-reports of instructional practices and experiences implementing the EPMC approach. Participants involved 54 Australian teachers of Years 4, 5, and 6 classes (students aged 9-12 years old) from both public and catholic schools in rural and metropolitan areas. Teachers were from a range of socio economic backgrounds and years' experience teaching. Survey responses were analysed using inductive methods and Braun and Clarke's (2016) six phases of thematic analysis. Through Excel, data were inspected, coded, themes identified and reviewed for later refinement. Themes for survey item (a) were compared to the EPMC approach, reinspected and refined.

Results

The set of survey items presented to teachers on the second face to face PL day were:

> The set of angles suggestions asked you to:
>
> - Present students with tasks prior to any explicit instruction on the underlying concepts or without explaining how students should approach the tasks;
> - Differentiate the experience for students who need it;
> - Review students' strategies drawing on suggestions from various students;
> - Pose further similar tasks to consolidate the students' learning.
>
> a) In what ways is this approach similar to what you usually do?
>
> b) Assuming that you use the suggestions in this way, what difficulties did you experience?
>
> c) Assuming that you use the suggestions in this way, what do you see as the advantages of this approach?

Survey results are presented in three section according to survey item (a), (b) and (c). Note that due to teachers often describing more than one theme, the number of themes exceed the number of teachers in each section.

Reported Problem-Solving Practice

The survey item initially present instructional practices consistent with the EPMC approach and item (a) asked teachers to compare and identify similarities to their own

approach, prior to their exposure to the EPMC professional learning. The most frequent practices reported by the 54 teachers were differentiating the learning experience with 31 teachers describing *differentiation* (e.g., grouping, offering different tasks, enabling and extending prompts), and reviewing students' solutions and strategies with 28 teachers describing *reviewing student work* (either throughout the lesson or more commonly at the end of the lesson).

There were 17 teachers who stated their approach was *completely different* and described explicit approaches. Some representative responses were:

> I would usually provide some form of explicit teaching of skills/concepts before sending them off to do challenging tasks. Having completed this work over the past little while with Peter, I have a much greater appreciation for the way of presenting tasks without explicit instruction on the underlying concepts allows students a better opportunity to construct their own understandings allowing for a far richer learning outcome.

> I find I usually do more explicit teaching with teacher modelling… I found this approach to be really uncomfortable for me to stand back and just watch and not help those who were struggling. But I got used to it and I saw they weren't really struggling, they were problem solving and thinking! I don't give enough think time. I was amazed to see how well my students did using this approach.

Interestingly, some teachers reported using explicit approaches prior to the EPMC project, however, appear surprised when describing the EPMC approach to be effective without explicit approaches. There were an additional nine teachers who described *explicit approaches* with differentiation and/or reviewing.

There were 12 teachers who described *open-ended problem solving tasks* and 11 teachers described using *consolidating tasks*. Interestingly, of the 11 teachers who described using consolidating tasks, most of these teachers were familiar with the project and approach, having previous involvement in the project or other PL experiences. One teacher explained: *we have been implementing Challenging Tasks for two years now and this style of lesson is becoming our regular practice for all topics.* Ten teachers who described *no explicit instruction or modelling* also stated previous involvement in the EPMC project or related PL.

Overall, there were nine teachers who described their practice to be the same as listed in the survey item and who were also familiar with the EPMC project. One teacher commented *It is the same approach to many of my lessons but not all. This is mainly due to the Masters I have been involved in with Peter and so therefore my approach has changed to include more of these types of lessons.* It appears that the EPMC project and other professional learning opportunities have had an impact on some teachers' practice in that they describe using this approach in their classrooms. In contrast, some teachers new to the project described quite a different approach and reported a change in their practice, knowledge and dispositions.

Difficulties Experienced when Implementing a Reform-Orientated Approach

Consistent themes surfaced when analysing question (b) exploring the difficulties of a reform-orientated approach, and findings are presented in Table 1. The most common difficulty reported by 17 teachers was refraining from telling the students how to solve the task, including deconstructing the problem and 'teacher telling' of the procedures and concepts. Some responses include:

> I did find it difficult to not really get in there and support some students. But when I didn't, I found they often figured things out on their own. Or, after 5 minutes' think time, when they shared ideas, the kids just learned from each other

> The complete lack of explanation at first, many students want or are used to being told what to do at first. Students didn't like that feeling of not knowing what to do at first. But they got used to it relatively quickly

Despite teachers reporting it difficult to refrain from using explicit approaches, teachers reported that students responded productively to the EPMC approach.

Table 1
Themes from Survey Item (b) Exploring the Difficulties of the EPMC Approach

Themes	Total
Not telling	17
Fixed mindsets	15
Tasks	11
Differentiation	9
Time	8
None	5
Reviewing	4

The next prevalent difficulty reported by 15 teachers was related to fixed mindsets and trying to establish a classroom culture that promotes a growth mindset. Representative responses include:

> Tackling the fixed mindset of some of my students. They have a very fixed idea about their abilities. They have become so used to maths sessions being structured a certain and very traditional way that to be asked to solve problems without some time dedicated to explicit teaching was highly unusual to them.

> Some of the difficulties experienced included getting the students to adjust and have a go at these tasks without the fear of making mistakes.

These responses connect to the lack of teacher telling and students' response to feeling confused, challenged and having to find solutions for themselves. It is reasonable to assume that students' fixed mindsets were connected, in part, to teacher telling.

There were 11 teachers who reported difficulties related to tasks, with some teachers reporting them as too hard for their Year 3 students (which can be expected due to half the tasks being targeted for Years 5 and 6), and other teachers reporting *ambiguous wording of some of the tasks*, or *the tasks were too easy for my high achieving students*.

Differentiation was another theme described by nine teachers. Some teachers were not sure how long to wait before giving the enabling prompts and others stated they experienced: *difficulty in extending kids that needed a really deep extension, due to my own weakness in maths*. Time was also a prominent theme. Eight teachers reported that the end of year was too busy with little time to complete all the tasks due to reporting and assessment. Teachers also stated that the lessons required more time than they were accustomed to.

There were five teachers who reported they experienced no difficulties and four teachers who described difficulty with choosing when to review students' work, and how to draw out the learning as some students *struggled to explain* their thinking, solutions and strategies.

Advantages Experienced when Implementing a Reform-Orientated Approach

Table 2 presents the findings to survey item (c) exploring the advantages experienced by the teachers when implementing a reform-orientated approach. When asked to describe the advantages experienced when using the EPMC approach, majority of teachers (33) described students engaged and effectively learning. Representative responses include:

> Great for students in helping make connections between different concepts

> Critical thinking. Students are building the knowledge for themselves

> Allowing students to authentically construct their own deep understandings of the concepts

One of the key aspects of the EPMC approach is providing opportunities for students to connect ideas for themselves and constructing knowledge, and it appears most teachers saw the value in this approach and experienced students learning this way.

Table 2
Themes from Survey Item (c) Exploring the Advantages of the EPMC approach

Themes	Total
Effective learning and engagement	33
Growth mindsets	32
Reviewing students' work and students learning from others	22
Differentiation	19
Challenging problem-solving tasks	19
Student led learning and independent thinking	13

The next prominent theme was related to growth mindsets. Some responses include:

> Students did become more persistent with each lesson and not giving up after the first few minutes.
>
> Once the students adapted to the process and understood this method they were very enthusiastic about the approach and became confident sharing their responses whether they were right or wrong.
>
> I felt a shift in some students in their mentality towards challenge and confusion. Many students realised their potential as problem solvers through this approach.

Many teachers reported difficulty supporting students who had a fixed mindset. Despite this challenge, it appears most teachers experienced success with shifting students' fixed mindset to a growth mindset after some time. It appears that teachers perceive the EPMC approach to be effective in supporting their students to build persistence, welcome challenge, see mistakes as part of learning, and build confidence in the process.

Reviewing students' work and students learning from one another was also a common theme among the teachers, with 22 teachers describing this theme. One teacher reported it was *Amazing to see when reviewing students' strategies how many students went back and understood the task.* Another teacher commented that *students listened to the suggestions of others and this helped them to deepen their own understandings.* It appears these teachers experienced the process of reviewing students' work a valuable aspect of student learning, with students learning through each other and the problem-solving experience, rather than explicitly being taught the concepts and procedures.

Differentiation, including the use of enabling and extending prompt that differentiated the learning experience, was described by 19 teachers. Some representative responses include:

> Enabling and extending prompts allowed me to cater for all students and they all experienced success.
>
> I liked how all students began the task and then could either be supported or challenged. This built confidence in the students as they were happier to work through the challenges.
>
> The high-end students didn't have an end point, they were consistently extended through the prompts and it challenged the students that always "get it" to explain their thinking deeper.

Despite concerns related to teachers experiencing difficulty meeting a range of student needs (Stacey, 2016), it appears that these teachers perceived the EPMC tasks and approach to be effective in differentiating the learning experience. Teachers often described the use of enabling and extending prompts to facilitate differentiation whilst also highlighting the advantages of all students working on the same task and beginning at the same level. Overall, teachers described the approach to differentiation to be effective at catering for all students, promoting successful learning and encouraging positive mindsets (including confidence and enjoyment) among their students.

There were a further 19 teachers who described advantages related to the use of open-ended challenging problem solving tasks. Some responses include:

> The tasks were clear and easy to teach, despite the initial feelings of confusion students were all able to contribute and learn no matter their level, the tasks were non-repetitive and engaging.

> It enabled students to be challenged and find a variety of ways to solve the problem.

Not only did teachers report ease of implementation when using challenging and open-ended problem solving tasks, but they saw advantages in tasks that prompted a variety of solutions and strategies to explore the underlying concepts. Teachers also reported that students *enjoyed the challenge* and *embraced the challenges and wanted to find the answer.* Interestingly, when using cognitively demanding tasks, teachers described positive responses from the students in that they were not fearing challenge, but rather welcoming it. These findings conflict with the concerns related to teachers fearing student negative reactions to challenge and that students prefer to be told what to do (Sullivan et al., 2014).

Connected to the above themes was the final theme *Student led learning and Independent thinking*. 13 teachers used words that described students' thinking *for themselves* and building their *own understanding*, describing students having ownership over their learning.

Discussion and Conclusion

Extending from previous research that explored the cognitive demand and features of problem solving tasks in primary mathematics classrooms (McCormick, 2016), this paper sought to gain an insight into teachers' experiences implementing a reform-orientated approach. Overall, many teachers described a different approach to teaching mathematics with some similar themes (but commonly a different approach) including differentiation and reviewing students' work. There were some teachers who described a similar approach to teaching who had previous involvement in the project and related professional development opportunities. When experimenting with a reform-orientated approach, many teachers reported difficulty refraining from telling the students what to do or teaching the concepts, and encouraging students who had a fixed mindset. When reflecting on the advantages of the EPMC approach most teachers reported the approach to be engaging and effectively support students develop deep understanding of the concepts and procedures. Furthermore, the teachers reported that the EPMC approach helped to develop growth mindsets with their students, including students welcoming challenge and confusion, encouraging persistence and seeing mistakes as part of learning. Despite concerns related to the reluctance of teachers to incorporate challenging problem solving tasks and constraints experienced (Sullivan et al., 2010), it appears that the EPMC approach supported teachers to experiment with alternate approaches, and both students and teachers responded positively to the EPMC approach. Some teachers reported that their *students also commented they prefer to do Maths this way.*

Interestingly, the EPMC project appears to have had an impact on some teachers practice in that they described incorporating reform-orientated approaches in their mathematics classrooms after involvement in the project. Previous EPMC survey items explored this phenomenon, and unpublished findings suggest that teachers reported the documentation (that detailed the tasks and approach) was well organised, thorough, high quality, well linked to the curriculum, and easy to implement and incorporate into planning. Some teachers also stated that they found modelling and trialling the tasks during the first day to be effective in preparing them for trying the new approach and tasks. These finding could be of interest to schools and systems in designing professional development programs for significant and sustained improvement in student learning. For a more accurate portrayal of teacher practice this research will augment survey data with case study data, to further explore teachers'

beliefs, knowledge, opportunities and constraints related to problem-solving practice and factors that influence effective practice, including professional development opportunities.

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