Teachers' Views of the Challenging Elements of a Task

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The findings discussed here are a small part of a larger study entitled, *Encouraging Persistence Maintaining Challenge*. The paper reports five teachers' observations of the implementation of a task which was new to them. The teachers were asked to identify aspects of the task which they perceived as challenging for the Year 6 students. The teachers' responses are discussed using a framework of features of challenging tasks proposed by Sullivan et al. (2011). The findings show that teachers identified the challenges involved as demanding mathematical reasoning, interpreting complex mathematics and in expecting students to create their own solution pathways.

The *Encouraging Persistence Maintaining Challenge* project[1] (EPMC) is researching a range of issues including the kinds of teacher practice which might encourage students to persist when working on challenging tasks in mathematics. It is a complex project with many important elements that are not included in this paper, including teacher interviews, student observations, and different survey instruments completed by teachers and students. The particular research question addressed in this paper is: What do teachers see as the extent of challenge in selected tasks and activities?

Sullivan et al. (2011) characterised challenging tasks as those which require students to:

- plan their approach, especially sequencing more than one step;
- process multiple pieces of information, with an expectation that they make connections between those pieces, and see concepts in new ways;
- engage with important mathematical ideas;
- choose their own strategies, goals, and level of accessing the task;
- spend time on the task;
- explain their strategies and justify their thinking to the teacher and other students; and
- extend their knowledge and thinking in new ways (p. 34).

In this paper, these features will be used to structure the observations made by teachers after they had observed a "modelled lesson".

Most curriculum guidelines in mathematics education stress the need for teachers to extend students' thinking, and to pose extended, realistic and open-ended problems (see, e.g., City, Elmore, Fiarman, & Teitel, 2009). To do this, it is also critical for teachers to understand the motivational characteristics of their students, particularly those characteristics that contribute to increased persistence, valuation of mathematics as a useful domain, and an orientation towards taking on challenging tasks (Middleton & Jansen, 2011).

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A framework that guided our thinking about using challenging tasks to build student persistence was proposed by Stein, Grover, and Henningsen (1996) who argued that the consideration of classroom tasks by teachers goes from the …

> Mathematical task as presented in instructional materials
>
> which, influenced by the teacher goals, their subject matter knowledge, and their knowledge of students, informs …
>
> … mathematical task as set up by the teacher in the classroom
>
> which, influenced by classroom norms, task conditions, teacher instructional habits and dispositions, and students learning habits and dispositions, influences …
>
> … mathematical task as implemented by students
>
> which creates the potential for …
>
> … students' learning.

The research indicated that student persistence is a key variable in understanding how to improve the learning of mathematics. Further, teachers may have an orientation to reducing the level of the demand of tasks. For example, Sullivan, Clarke, and Clarke (2013) in a study of the ways teachers implemented a range of types of tasks, reported that many of their project teachers seemed reluctant to pose challenging tasks to students. Stein and Lane (1996) also found that teachers had an orientation to reducing the cognitive demand of tasks. Tzur (2008) argued that the two key times that teachers modify tasks are at the planning stage if they anticipate that students cannot engage with the tasks without considerable assistance, and once they see student responses if these are not as intended.

Methodology

The EPMC is a collaborative project involving university researchers and classroom co-researchers. The study can be considered design research; described by Cobb, Confrey, DiSessa, Lehrer and Schauble (2003) as "engineering particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them" (p. 9). The characteristics of design research were further elaborated by van den Akker, Gravemeijer, McKenney and Nieveen (2006) as:

> Interventionist: the research aims at designing an intervention in the real world;
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> Iterative: the research incorporates a cyclic approach of design, evaluation and revision;
>
> Process oriented: … the focus is on understanding and improving interventions;
>
> Utility oriented: the merit of a design is measured, in part, by its practicality for users in real contexts; and
>
> Theory oriented: the design is (at least partly) based on theoretical propositions, and field testing of the design contributes to the theory building (p. 5).

Each of these characteristics is a feature of the EPMC research project methodology. As well as *practical results* and *theoretical results*, the design had the potential to contribute to the *professional development* of its participants (McKenney & Reeves, 2012). In the part of the project reported here, all three of these elements were apparent, however, the most substantial contribution was possibly to the professional development of its participants. A classroom intervention was undertaken by university researchers who took responsibility for instruction. We chose design research to examine the complexity of the classroom including students' persistence, the approaches students took to finding solutions, the challenging aspects of the task, and the classroom discourse. It was conceived as an opportunity to investigate teachers' observations of the practice of others with a focus on behaviours that encourage persistence and maintain the challenge. We acknowledge that design research is a highly interventionist methodology and a "test-bed for innovation" (Cobb et al., 2003). In this case, it also drew on our prior research because the researchers have been involved in creating demonstration lessons to promote teacher learning (Clarke et al., 2013). The intention was to free teachers to observe a challenging task that they had not seen before, implemented with children they knew, with a focus on the behaviours that encourage persistence and maintain the cognitive challenge. We were interested to answer the following question:

- If shown a lesson that presents students with a challenge and supports them in persisting, what do teachers see?

The process

The lesson was developed to incorporate the features of challenging tasks as listed by Sullivan et al, (2011). It connected to the mathematical content the students had been studying (understanding, interpreting and using data) and their broad interests. It was adapted from Thompson, Battista, Mayberry, Yeatts and Zawojewski (2009). In essence, the students were required to work in pairs to use the "fitness data" in Table 1 to divide the class into three teams of five competitors, attempting to ensure that the teams were likely to be of roughly equal ability when competing in a future Fitness Fest competition.

Table 1
Class data to be used by students in creating three teams of roughly equal ability

Student	Fitness Test (30 push ups, 50 jumping jacks, and 20 sit ups)	100m Run	800m Run	High Jump
Betsy	Pass	17.3 sec	3 min 38 sec	140 cm
Caroline	Fail	16.0 sec	3 min 1 sec	84 cm
Daniel	Pass	19.89 sec	2 min 42 sec	145 cm
Dick	Pass	18.52 sec	2 min 55 sec	112 cm
Jason	Pass	16.48 sec	2 min 55 sec	94 cm
Judi	Fail	17.2 sec	3 min 22 sec	87 cm
Linda	Pass	20.2 sec	4 min 0 sec	132 cm
Mack	Pass	18.25 sec	3 min 16 sec	148 cm
Manuel	Fail	17.1 sec	3 min 11 sec	107 cm
Margret	Pass	20.32 sec	2 min 51 sec	150 cm
Michelle	Fail	16.44 sec	2 min 45 sec	115 cm
Rob	Fail	19.2 sec	3 min 12 sec	127 cm
Sandra	Fail	17.34 sec	3 min 50 sec	135 cm
Scott	Pass	17.0 sec	3 min 30 sec	130 cm
Susan	Pass	18.3 sec	3 min 0 sec	140 cm

Before the lesson, there was a briefing session to clarify the roles of the teacher and observers and to provide the observers (5) with a notebook containing the focus question: “Make a note of anything [the teacher] does that encourages students to persist.” Subsequently they were asked, “What were the features of the task that made it challenging?” The written data were collated and an audiotape of the discussion was transcribed to create the data set reported here. An analysis of the observers’ perceptions of the challenging features of the task follows.

Findings and discussion

A summary of the written data is presented first, after which findings were considered in the light of the characteristics of challenging tasks described in Sullivan et al. (2011). Categories which emerged from the written data are shown in Table 2 and give a sense of the challenges of the task noted by teachers.

Table 2
Summary of written responses to: What aspects of the task make it challenging for students?

Categories of response	Frequency
Mathematical reasoning demands	*(19)*
Requirement to record thinking process, justify reasoning, notice important details	9
Expressing thinking/articulation of ideas	6
Turning verbal argumentation into written ideas	4
Interpreting data	*(17)*
Interpreting of complex data and making a judgement as to the quality of the data	7
Making judgements based on evidence	4
Multiple variables in the data set – statistical and affective considerations	3
Defining terms (e.g., “good”, “average”)	3
Solution strategies	*(10)*
Many solution methods and no teacher example solution was given	7
Student choices/decisions and negotiations to be made	2
Requirement to pre-plan - “early thoughts”	1

The features of the task which were described as challenging for students principally centred on the mathematical reasoning required by the task (19), the interpretation of a complex data set (17), and arriving at possible solution strategies (10). The mathematical reasoning in the task called for higher order thinking skills, expecting students to think independently, to conjecture, to reason, and to justify their mathematical thinking (Russell, 1999). In addition teachers recognised the challenge for the students in the requirement to turn verbal explanations into written mathematical argumentation (Smith & Stein, 2011). The final cluster of “higher cognitive demands” noted by the teachers concerned the problem solving nature of the task where complex thinking was required and no pathway was given (Smith & Stein, 2011, p.16).

While these data are interesting because they reveal the challenges noted most often by teachers, those related to the entire data set will be reported now under headings created from the features of challenging tasks listed at the beginning of the paper (Sullivan et al., 2011).

Plan their approach, especially sequencing more than one step

Completion of the task required the students to: consider ways of proceeding, to choose a strategy, to use it, and to record their thinking so that another person could use their approach to the problem. Each of these elements involved planning and evaluation of mathematical reasoning. As one teacher noted, the relevant challenges were:

> Articulating, recording precisely what decisions are made, making notes along the way of their thoughts, and recording important details.

Another teacher distinguished between procedural and conceptual sequences in discussing challenges:

> There was one group that was quite good at step by step recording – we looked at this and we looked at that - they weren't actually recording important information. So that idea of what is important information and what somebody else could then follow is hard.

Process multiple pieces of information, with an expectation that they make connections between those pieces, and see concepts in new ways

Teachers commented on the problem solving nature of the task:

> It involved a lot of reasoning and problem solving. It was very open, so students didn't have to find one answer. This can be daunting for some students.

Teachers were aware that the way in which complex data are presented to students can impact on their ability to read and to handle it mathematically.

> For some of my boys, there was a lot of data; it was a bit overwhelming for some of the kids. I was thinking, for my kids, I would have cut off the maybe last five names or one of the columns or something to reduce the amount of data. It could be a bit overwhelming for some of my kids. Some of my kids struggle, not so much with the maths side of it, but just the amount of information there.

Engage with important mathematical ideas

Teachers discussed the need for the students to interpret a large amount of complex data and grapple with multiple variables in context. Students were also asked to decide whether some statistics were more salient than others. There were also mathematical skills to be applied such as ordering "ragged" decimals (Roche, 2011). One teacher commented:

> A certain level of knowledge was assumed e.g., how to read time[s], how to order number to hundredths, how to compare data etc. The task allowed for great exploration of these concepts, but it was not the children's initial or 'early stages' exposure to these. It has made me wonder about persistence and how it can rise and fall. If the students didn't know how to order numbers to hundredths, would their level of persistence have been as high? How do we as teachers deal with these peaks and troughs in persistence?

This reflection offers insight about creating challenge at the boundaries of students' mathematical content knowledge and about the challenge requiring application and transfer of content knowledge.

Choose strategies, goals, and level of accessing the task

The students had to decide on a solution method and make judgements based on evidence. For example,

> I thought one of the challenges of the task was the need to devise a method. You know - in most maths classes the kids are given a method for doing something. In this case, they had to devise a method and I think that was one of the complexities and challenges of the task.

Spend time on the task

In the lesson, the students were given 32 minutes to work on the task uninterrupted. During this time, the teacher listened to pairs of students and gently probed and shaped their thinking to ensure that they were on a productive solution path. The prolonged time spent on task and the lack of early opportunities for students to share methods which could then be used by others, was raised in discussion after the lesson:

> Observer: There was no point where anyone shared anything sort of to enlighten anybody. I was not sure … sometimes there can be a block and sharing of that "hot spot" can just actually get them over that [block]. And I realise that you were keeping them ongoing.
>
> Researcher: One of the choices that we did discuss was when they have got their early thoughts; do you get them to share them? And I think [we] felt that if we did that early, a lot of kids would think "Oh okay we will do that too" and so it's always a tension, yes.

Explain their strategies and justify their thinking to the teacher and other students

In the context of the *Fitness Fest* task, teachers noted that students were required to be conscious of their thinking processes, to record those processes, and be prepared to describe and justify their reasoning to their partner and possibly other students. It was mentioned that the students needed to distinguish which were important details of their decision-making processes. The requirement to turn these ideas into written records was recognised as an additional challenge for students.

> That ability to almost debate with your partner, to get your views heard, and come to some consensus with your partner, is quite challenging. And there was quite a bit of literacy in that task as well. I am thinking of some of the boys in my class now. They probably have loved looking at the data and they would orally have had lots to say about the task, but, when it came to recording, that would have turned them right off because they have trouble writing words.

Teachers also noted that one of the challenges for students is "listening to others' reasoning". This comment highlights an awareness of the complexity of listening. In their examination of listening behaviours, Davies and Walker (2007) described three different types of listening.; *evaluative listening* - listening for something specific, *interpretive listening* - requiring more sense-making, and *hermeneutic listening* - characterised as complex and dynamic interactions where learning is seen as a social process ... of participating, interpreting, transforming and interrogating. It seems that students in the lesson in question were at the least expected to engage in interpretive listening and possibly the more sophisticated hermeneutic listening in this lesson. Teachers recognised the demand implied in this expectation. One conversation between teachers also acknowledged the effects of not being listened to by others:

> I heard what [one student] was saying at the start and he was already talking averages and he had his grand plan about how he was strategically going to go about it but it fell on deaf ears. I could see he was becoming disengaged. … I felt he could attack it on his own [Subsequently, this student was offered the option of working on his own.]

Extend their knowledge and thinking in new ways

Glimpses into the extension of the knowledge of the students were seen in the report-back session at the end of the lesson where the teacher selected three pairs of students to describe their approach to the task to the class. The selected students' presentations were targeted and sequenced to create a flow of mathematical thinking. The "home room" teacher of the students remarked that she was "impressed" that two girls in particular were chosen to describe their thinking and that she would not have anticipated that they would have found a solution or been able to report it together at the conclusion of the lesson. This teacher, at least, felt her students had extended their thinking in new ways.

The Reflections of the Fourth Author

The School Mathematics Leader (the fourth author) had a key role in the project, providing an important link between the research team and the classroom teachers. In the following paragraphs, she reflects upon the experiences of the teachers in the project generally, and the lesson in particular:

> Early in the project, teachers had expressed concern about students' ability to complete or stay engaged in the task. As the university researchers had no preconceived notions about individual student abilities, their expectations were fairly high and consistent. As observers, the teachers were able to watch the ways in which some students were encouraged and supported to persist with the task without significant intervention or scaffolding. This reinforced a conjecture that at times we are reluctant to give such challenging tasks to students for fear that they will struggle significantly and therefore not maintain engagement.
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> Through careful observation, all of the teachers involved in this task were able to identify key strategies that were employed to encourage persistence. Through the identification of these strategies, reflective practices were encouraged, as teachers considered their own strengths and possible changes in practice. Discussion immediately following the lesson cultivated professional dialogue and the sharing of expertise. Teachers were able to identify key strategies that encouraged students to persist. These included:
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> - The importance of a collaborative environment that allowed for discussion and clarification
> - Acknowledging to students the challenge ahead and the existence of more than one solution
> - The importance of observation before intervention
> - The openness of the task to ensure engagement for all
> - The expectation of the recording of thoughts and strategies throughout the investigation

The detailed analysis of teachers' reflections reveals a sophisticated understanding of factors that create challenge in mathematical tasks and the ways in which students can be encouraged to persist. Although the findings reported in this paper are based on the observations of a small number of teachers, they indicate that teachers are able to articulate the features of a task (one previously unknown to them) which make it challenging, as they observe a skilful teacher use that task in a lesson.

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