Australian Secondary Mathematics Teachers' Conceptions of Mathematical Challenging Tasks

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Despite their well-documented academic, motivational and affective benefits, challenging tasks remain underutilised in Australian secondary mathematics classrooms. This raises questions about whether Australian secondary mathematics teachers' conceptions of challenging tasks influence their decisions to implement them. In this exploratory study, 59 responses to one open-ended survey question were analysed thematically to understand these conceptions. Findings indicate that although most teachers' conceptions generally aligned with characteristics identified in the literature, some specific characteristics were often overlooked.

Challenging Task in Mathematics Education

Although mathematics education has traditionally entailed a passive acquisition of knowledge (Bird, 2023), this teaching and learning approach no longer meets the needs and demands of a world described by the OECD as "increasingly volatile, uncertain, complex and ambiguous" (2018, p. 3). These profound and ongoing changes are reshaping how we live, learn and work, prompting the OECD to deem it "appropriate that [both international and national] curricula should continue to evolve... in radical ways" (OECD, 2018, p. 3; OECD, 2023). Over the last few decades, mathematics education has responded to these changes through reforms in mathematics curricula both nationally and internationally to emphasise 21st century priorities such as reasoning, critical thinking and problem solving (Goos et al., 2020; Szabo et al., 2020). This has led to the emergence of and increased interest in teaching practices and pedagogies that address more contemporary needs and demands.

One mathematical task recognised for its ability to help foster 21st century skills in students is challenging tasks (or rich tasks). Challenging tasks are usually thought-provoking problems that are cognitively demanding and initially difficult to solve, requiring students to:

- plan their approach, especially sequencing more than one step
- process multiple pieces of information, with an expectation that they make connections
- 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
- extend their knowledge and thinking in new ways (Sullivan, 2017)

This study draws on Sullivan and colleagues' pioneering model of challenging tasks because it is widely accepted and used in Australian primary classrooms and mathematics education research. It underpins the current priorities of Australian mathematics education by addressing national curricula and syllabi reforms to 21st century changes (ACARA, 2026; Sullivan & Davidson, 2014). Moreover, the model comprehensively outlines the definition and seven characteristics, clearly communicating what students engage in during challenging tasks. Therefore, the model offers a useful data analysis framework for cross-checking Australian secondary mathematics teachers' conceptions of challenging tasks with the published definition

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and characteristics. In addition, for this study, Philipp's (2007) definition of conceptions is used to describe mental structures "encompassing beliefs, meanings, concepts, propositions, rules, mental images and preferences" (p. 259) that shape what a secondary mathematics teacher considers a challenging task to be and how it should be implemented.

Research findings have consistently demonstrated that challenging tasks in mathematics education are an effective medium for developing higher order thinking skills, while preparing students both academically and holistically for the workplace, world and life (English & Gainsburg, 2015). A possible reason for their effectiveness is that when tackling challenging tasks, students productively struggle and persist through the cognitive challenge (Sullivan et al., 2012). Struggle can support students to make mathematical connections and develop conceptual understanding, while failure can elicit hidden self-efficacy in students (Kapur, 2008). Moreover, challenging tasks require high cognitive demand and higher order skills, with students encouraged to explain, describe, and justify; make decisions, choices, and plans; formulate questions; apply existing knowledge and create new ideas; and represent their understanding in multiple formats (English & Gainsburg, 2015). Challenging tasks emulate both familiar and unfamiliar demands that can be found in the real world, so these tasks foster 21st century skills that students learn to apply beyond the mathematical classroom and in the real world (English & Gainsburg, 2015).

While there is strong evidence that challenging tasks are effective in helping to foster higher order thinking skills in students, their implementation is not widespread in secondary mathematics classrooms as their importance would seem to warrant (Wilkie, 2016). Research has identified enablers and barriers of challenging task implementation in both primary and secondary contexts, with reported barriers including student fear of taking risks and failing; classroom management; teacher knowledges; lack of support, resources and time; and student unwillingness to persist due to their cultural background, mathematical ability and/or language level (Ingram et al., 2020; Sullivan & Mornane, 2014). At a fundamental level, a teachers' decision to implement or not implement challenging tasks may be informed by their conceptions of what challenging tasks are. Yet, little research has investigated what mathematics teachers conceive a challenging task to be in terms of how it is defined and what its characteristics are, as studies have often been conducted within the context of an intervention involving teacher professional development that assumes correct conceptions already or that conceptions are influenced by participation already. Instead, some studies have focused on what teachers conceive the challenging elements of a challenging task to be or the elements that contribute to cognitive demand. For example, while Cheeseman et al.'s (2013) study found conceived challenging elements to be: level of mathematical reasoning demanded by the task; interpreting complex mathematical data; and creating multiple solution pathways, Parrish and Bryd's (2022) study found that the challenging task characteristics that contribute to cognitive demand level to be: multiple solution strategies; multiple representations; and incorporation of explanation and justification.

Evidently, there has been minimal focus on mathematics teachers' conceptions of what a challenging task is in an exploratory way outside of an intervention. Addressing this gap in the literature is important because conceptions may influence teachers' pedagogical decisions to implement or not implement challenging tasks (Lee, 2012; Schweig et al., 2020). Given the benefits of challenging tasks and the noted lack of implementation in high schools, this study aims to investigate Australian secondary mathematics teachers' conceptions of challenging tasks to understand whether their conceptions influence decision making around challenging task implementation. Hence, the research question is "What are Australian secondary mathematics teachers' conceptions of challenging tasks?"

Methodology

Participants were 59 Australian secondary mathematics teachers who opted in to participate in an online questionnaire about their conceptions of challenging tasks and use (or non-use) of challenging tasks. In this paper, the findings from one open-ended question "What do you know about challenging tasks?" are reported. Thematic analysis of this qualitative data was first conducted deductively, drawing on Sullivan's (2017) definition and characteristics of a challenging task. Then, thematic analysis was conducted inductively using new codes on characteristics developed from the data. Each author independently reviewed and discussed the themes and codes prior to collaboratively refining the thematic structure through iterative comparison and discussion. This process supported credibility and dependability by allowing themes to be reviewed and refined. The aim of the analysis was to develop a comprehensive understanding of teachers' conceptions of challenging tasks in relation to the Sullivan's (2017) framework. This process is intended to be recursive rather than linear, as researchers can flexibly return to earlier steps given new data and/or themes. Moreover, themes can be coded regardless of the number of times the theme appears in the data and will contribute to the emerging conclusions. Three researchers including the PhD student and two supervisors contributed to the coding process for inter-rater reliability.

Results and Discussion

Alignment With Definition of Challenging Tasks

When responding to the question "What do you know about challenging tasks?", a diverse range of responses were collected from teachers (Table 1).

Table 1

Higher to Lower Alignment With Sullivan's (2017) Definition

Higher	"A challenging task in math education is a complex, absorbing problem designed to be accessible to students of all ability levels through enabling and extending prompts, requiring them to engage in sustained thinking, planning, and risk-taking to foster a deep understanding of mathematical concepts, problem-solving, and a growth mindset. These tasks encourage exploration, provide multiple pathways to solutions, and promote the productive struggle necessary for genuine learning and the development of resilience."
	"Nothing really! I can assume what is meant by the term, but haven't any particular knowledge on what makes a challenging task and the benefits of them."
Lower	"I don't know what you mean by this term 'challenging tasks'"

The wording of the question meant that responses ranged from definitions, characteristics, benefits, enablers and barriers of challenging tasks. For this paper, only the responses that referred to the definition and characteristics were analysed. The responses gathered suggest that although many participants did not directly refer to Sullivan and colleagues' model, their interpretations mostly aligned.

For the responses that were more closely aligned, teachers were able to state definitions and characteristics that emulated Sullivan and colleagues' model even when no direct references to the researchers were made. Most teachers know that challenging tasks fall under the category of problem-solving tasks, by describing them using adjectives including "non-routine", "complex", "open-ended", "multi-layered" and/or tasks that tackle "familiar and unfamiliar [situations]". Two teachers were able to provide an alternative term for challenging tasks: they are "rich tasks" and "[cognitively] demanding and thought provoking [tasks]". References were also made to other types of mathematical tasks such as "low floor high ceiling tasks" and

"inquiry tasks" which do overlap with the offerings of challenging tasks as those that enable inquiry and differentiation. As a result, challenging tasks were seen as distinctly different from textbook, fluency-focused questions characterised by "repetition" and "familiar situations". One teacher commented that challenging tasks "often require students to probe further to understand concepts rather than simple mimicking". Another teacher pointed out how challenging tasks are not immediately solvable because "they are tasks in which there are no clear immediate solutions and require thinking beyond ordinary classroom routine problems to solve".

In terms of the responses that did not have significant alignment with the definition and characteristics of challenging tasks, teachers were either: (1) unfamiliar with the term completely and could not offer a definition; (2) unfamiliar with the term but could assume its meaning; or (3) familiar with the term but their definition did not really align. This shows that most teachers possess a broadly accurate conception of challenging tasks, but specific characteristics were often overlooked. This suggests that there are some gaps in teachers' understanding of challenging tasks, which may have implications for their decision making around challenging task implementation.

Teachers' Conceptions of Challenging Task Characteristics

In teachers' responses, key characteristics of challenging tasks were noted. When analysing the responses, characteristics can be divided into those that are listed as part of Sullivan and colleagues' seven published characteristics and those that are not but are still considered characteristic of challenging tasks. Overall, six out of seven characteristics by Sullivan and colleagues were directly stated by the participants, excluding the 'Spend time on the task' characteristic (Table 2).

Table 2

Alignment With the Seven Published Characteristics of Challenging Tasks

Plan their approach, especially sequencing more than one step (*n*=1)	"I've never used that term before. I assume it means tasks that… require students to develop their approach to solve the task… Tasks that require numerous interconnected steps"
Process multiple pieces of information, with an expectation that they make connections between those pieces, and see concepts in new ways (*n*=3)	"Highlight the connection between pieces of knowledge and concepts in topics, for example, the connection between graphical features and algebraic expressions" "Makes connections between strands and maths concepts"
Engage with important mathematical ideas (*n*=12)	"Tasks to challenge students' cookie-cutter thinking to improve understanding" "Students engage with tasks that are non-routine, which despite being accessible extend their critical thinking of mathematical content"
Choose their own strategies, goals, and level of accessing the task (*n*=16)	"They are accessible to students i.e. not requiring unreasonable prior knowledge, but difficult enough to make students stop and think" "There are often many ways to approach a challenging task, so they are often cross-topic."
Spend time on the task (*n*=0)	N/A
Explain their strategies and justify their thinking to the teacher and other students (*n*=2)	"My understanding is challenging tasks encourage approaching problems in unfamiliar contexts, generally requiring reasoning to be applied and conceptual understanding to find efficient solutions."

	"These challenging tasks allowed students to start to work mathematically and explain their thinking of the mathematics they were implementing."
Extend their knowledge and thinking in new ways (*n*=23)	"Developing critical thinking skills in students and push them to think out of the box"
	"They are often non-routine, so different from 'textbook' questions in that they require more creative or conceptual thinking."

Sullivan and colleagues' characteristic of 'Spend time on task' seems to be overlooked in the teacher responses and is typical of tasks requiring higher cognitive demand and higher order thinking skills, which were still mentioned by teacher participants (Table 3). One teacher response suggested this characteristic but did not explicitly refer to time as a factor, as they described challenging tasks as "complex tasks that requires higher skills, significant efforts, determination and strong focus in solving". One reason for this oversight may be because the mathematics education landscape has come to value the correctness of answers in preparation for assessment and the product of the learning experience over the process. Challenging tasks, being a non-routine task that some participants describe as "not repetitive textbook questions", appear different to the routine mathematics that students may be more familiar with, as students need to "draw on a variety of skills and apply knowledge to less familiar situations."

In addition to these seven characteristics, other challenging task features were noted by the teachers. These features included higher cognitive demand, application to the real world, multiple solution pathways and solutions, and collaboration (Table 3 & 4).

Table 3

Characteristic of Challenging Tasks: Higher Cognitive Demand & use and Development of Higher Order Thinking Skills

Higher order thinking skills & Cognitive demand, with some references to educational theories (*n*=9)	"Providing students with non-routine problems that allow them to think beyond their regular questions. It allows them to treat numbers and concepts like puzzles and figure solutions out."
	"Bloom's taxonomy. How to create challenging tasks"
	"One that is at the very edge of the students' zone of proximal development. In practice, this often includes some element of far transfer, where they need to apply their knowledge in a new setting or context."

It is interesting to note that some teachers related their definition and characteristics of challenging tasks to educational research and literature such as Vygotsky's *Zone of Proximal Development* (1978) and *Bloom's taxonomy* (1956). With the *Zone of Proximal Development* related to challenging students and *Bloom's taxonomy* related to engaging in higher order skills, this can be likened to the characteristic of "Extend their knowledge and thinking in new ways", especially in both familiar and unfamiliar situations. These references to theories in educational research, although not explicit in the definition and characteristics of challenging tasks, show how some Australian secondary mathematics teachers are familiar with the theory and practice of challenging tasks, highlighting the teaching praxis they possess.

Table 4

Characteristic of Challenging Tasks: Application of Challenging Task Experience to Real World

Real life applications / connections (*n*=3)	"Allows for real world connections"

	"These are tasks where students are encouraged to apply maths to solve real life problems"
21st century skills such as critical thinking, reasoning and problem solving (*n*=16)	"They are tasks in math that requires investigation and requires student to work collaboratively through critical thinking and discussions"
	"They promote the integration of topics, critical thinking, perseverance, and sometimes collaboration if structured well."

The responses in Table 4 suggest that teachers recognise that challenging tasks foster real life connections and 21st century higher order thinking skills in students. Challenging tasks are often designed and implemented in ways that make the task more relevant and meaningful to students. This may be achieved by incorporating real life examples and modelling in the challenging task. More generally, with the 21st century skills developed from the challenging task experience, students learn to apply these mathematical skills to other disciplines and in the real world. They even learn skills such as productive struggle, persistence and collaboration as students practise thinking, exploring, taking risks and failing, often in a group setting. After all, challenging tasks require students to face a problem they cannot immediately solve so students must participate in the critical process of solving such tasks, which cultivates a persistent disposition underpinned by a growth mindset in students (Boaler, 2016). Application to the real world is thus a characteristic of challenging tasks that the teacher participants acknowledge.

Another characteristic that teachers recognised in challenging tasks is multiple solution pathways and solutions of challenging tasks, as challenging tasks are not immediately solvable.

Table 5

Characteristic of Challenging Tasks: Multiple Solution Pathways and Solutions

Multiple solution pathways and solutions (*n*=10)	"Challenging tasks in mathematics would require students to explore and utilise multiple strategies, drawing from a wide repertoire of mathematical knowledge, skills and techniques."
	"They require critical thinking or problem solving, not immediately solvable by an algorithm, encourage creativity and possibly open-ended with multiple 'correct' answers."

Lastly, a small group of teachers (*n*=2) characterised challenging tasks in ways that did not quite align with Sullivan and colleagues' model. While many teachers conceive challenging tasks to be in-class tasks or activities, two teachers conceive challenging tasks to be investigative tasks for assessments or competition style problems (Table 6).

Table 6

Different Conceptions of Challenging Task Definition

Investigative tasks (*n*=1)	"For me it's all in the rubric! How to structure and use them well"
Competitions (*n*=1)	"There are a lot of competitions to get included in."

Further alternative responses are outlined below in Table 7.

Table 7

Different Conceptions of Challenging Task Characteristics

Teacher quote	Analysis / Comment
"I've never used that term before. I assume it means tasks that either lack scaffolding and have more of a modelling approach and require students to develop their approach to solve the task."	While students should plan their approach when tackling challenging tasks as challenging tasks tend to be open-ended and non-routine, scaffolding should still exist to enable differentiation. For example, students can be supported through the task using enabling and extending prompts.
"Tasks that require numerous interconnected steps and associated	While the first half of this statement is true as challenging tasks tend to be multi-step, the second half of this statement

concepts that may extend slightly outside of the typical scope of the syllabus that is usually taught and assessed.	is debatable. Depending on the Australian state, different teaching strategies may be called for by curriculum, but the underlying skills remain applicable. For example, General Capabilities from the Australian Curriculum and Working Mathematically processes from the NSW mathematics syllabus target the higher order thinking and skills fostered by non-routine tasks like challenging tasks.
"HPGE, HSC, Practical Scenarios, Multiple Solutions, Cross Curriculum."	Most of what is written here is correct but HPGE, which stands for High Potential and Gifted Education, seems to suggest that challenging tasks are limited to students excelling academically when they should be accessible by all students as challenging tasks support differentiation.
"Well-designed challenging tasks will have a low floor, generally allowing guess and check or simple applications of routine procedures for easy but potentially less accurate answers, also becoming a discussion point when analysing the problem"	Since challenging tasks are good for differentiation, the task should be accessible for all students, meaning it is low floor, high ceiling. This response suggests that challenging tasks tackle lower order skills and routine problems, which is not exactly the case.

Given some variability in teachers' conceptions, these alternative responses offer insight into current teacher knowledges around challenging tasks and the implications this may have on professional learning. There is opportunity to create a discourse on challenging tasks and establish a consistent understanding of its definition and characteristics.

Conclusion

This study aimed to investigate Australian secondary mathematics teachers' conceptions of challenging tasks. When teachers were asked about what they know about challenging tasks, a key finding in this paper is that most teachers held broadly accurate conceptions of challenging tasks, but specific characteristics of such tasks were often overlooked. Even if teachers are not familiar with Sullivan's (2017) published model of challenging tasks, they are able to articulate the key concepts underpinning the definition and characteristics of challenging tasks in their responses. Many teachers summarise challenging tasks to be open-ended, non-routine tasks that foster different higher order thinking skills in students. However, teachers who were less familiar with challenging tasks had different conceptions of challenging tasks in terms of how they can be situated within the syllabus and curriculum, how accessible they are to all students and how much cognitive demand is required to tackle one.

The findings from this exploratory study contribute a richer understanding of what Australian secondary mathematics teachers conceive a challenging task to be. It is these teacher conceptions that may influence decisions surrounding challenging task implementation in secondary mathematics classrooms. Potential future directions include comparing teachers' conceptions with their actual implementation of challenging tasks in classrooms. This could be achieved by analysing teachers' classroom practice and challenging task examples. Another interesting avenue for research would be to investigate teachers' responses to the similarities and differences between their own understandings of challenging tasks and Sullivan and colleagues' model. This could be a professional development intervention to help enhance teacher knowledge and practice around challenging task implementation.

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