Examining the Impact of Lesson Structure when Teaching with Cognitively Demanding Tasks in the Early Primary Years

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The current investigation systematically contrasted teaching with cognitively demanding (challenging) tasks using a task-first lesson structure with that of a teach-first lesson structure in a primary school setting (Year 1 and 2). The findings indicate that there is more than one way of incorporating challenge tasks into mathematics lessons to produce sizeable learning gains. Analyses of interviews with teachers and students regarding their perceptions of learning with challenging tasks suggest that each type of lesson structure has distinct strengths. It is concluded that teachers should consider varying the structure of the lesson to provide a range of learning experiences for students.

Over the past few decades, there have been calls to reform mathematics education in Australia to increase the amount of time students spend engaged in deep problem solving and cognitively demanding mathematical tasks (e.g., Hollingsworth, McCrae, & Lokan, 2003). As part of this reform process, it has been argued that traditional lesson structures (i.e., teacher explanation, followed by student practice and correction) are inherently inadequate for meeting contemporary mathematical learning objectives (Sullivan et al., 2014). Instead, reform-oriented teaching approaches have frequently employed a triadic lesson structure: Launch, Explore, Discuss (Stein, Engle, Smith, & Hughes, 2008). Considerable empirical evidence is emerging as to the efficacy of reform-oriented approaches. To summarise, classroom climates perceived by students or expert observers to be more reform-oriented appear to foster students who are more intrinsically motivated to learn mathematics (e.g., Middleton & Midgley, 2002) and perform better mathematically (e.g., Jong, Pedulla, Reagan, Salomon-Fernandez, & Cochran-Smith, 2010).

However, from the perspective of cognitive load theory, launching a lesson with a cognitively demanding activity, which is not explicitly linked to teacher instruction and prior learning, may be problematic (Kirschner, Sweller, & Clark, 2006). This argument is based on the idea that working memory has limited capacity to process novel information and is easily overloaded when required to solve an unfamiliar problem (Sweller, Kirschner, & Clark, 2007). Consequently, it may be that an alternative lesson structure which adopted the same reformist content and pedagogy, but began with a less cognitively demanding activity, would result in even larger gains in mathematical performance.

Given these contrasting evaluations, there is a need to disentangle the various elements of a reform-oriented lesson and to empirically investigate the impact that systematically varying one aspect, such as lesson structure, has on subsequent student learning outcomes and the learning experience of students. To address this issue, the current investigation contrasted teaching with cognitively demanding tasks (challenging tasks) using a task-first lesson structure (Task-First Approach) with that of a teach-first lesson structure (Teach-First Approach), through the delivery of two programs of mathematics instruction to Year 1 and 2 students. The aim was to investigate how varying lesson structure impacts teaching and learning with challenging tasks. The central question was:

What are the advantages of using cognitively demanding tasks to launch lessons and support subsequent instruction and discussion (Task-First Approach) compared with using

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cognitively demanding tasks to extend understanding, following instruction and discussion and the completion of several more routine tasks (Teach-First Approach)?

This question was explored from a variety of different perspectives. Study One considered the question from the point of view of evaluating the impact of lesson structure on student outcomes, including mathematical performance, task-based persistence and intrinsic motivation to learn mathematics. Study Two examined teachers' confidence and competence in teaching with cognitively demanding tasks, and whether lesson structure impacts teacher willingness to incorporate such tasks more comprehensively into future instruction. Study Three explored student perceptions of learning with cognitively demanding tasks and whether students prefer a given lesson structure.

Method

Participants

Participants included Year 1 and Year 2 students (n = 75), and their respective teachers (n = 3), who attended a primary school located in Melbourne. In Victoria, students typically turn seven years of age during Year 1, and eight years of age during Year 2.

Procedure

The first author was responsible for designing and teaching two units of work in number and algebra across two school terms. The first unit of work related to number patterns (Patterning Unit), and comprised 16 lessons. The second unit of work related to addition and missing addend problems (Addition Unit), and comprised 12 lessons. The three classes of students included in the study were composite classes of Year 1 and Year 2 students.

Figure 1. Contrasting the Task-First Approach with the Teach-First Approach.

Each lesson involved four aspects: work on a challenging task (15 minutes), a teacher-facilitated discussion (15 minutes), work on consolidating worksheets (15 minutes), and a teacher-led summary of the lesson (5 minutes). Whereas the Task-First Approach occurred in this order (i.e., Challenge, Discussion, Worksheets, Summary), the Teach-First Approach began with the teacher-facilitated discussion, proceeded with work on the consolidating worksheets, then shifted to work on the challenging task, with the teacher-led summary again concluding the lesson (i.e., Discussion, Worksheet, Challenge, Summary). Figure 1 summarises these two approaches.

Each of the three classes were initially randomly allocated to one of three intervention conditions: Task-First Approach, Teach-First Approach or the Alternating Approach (two lessons task-first, two lessons teach-first, two lessons task-first etc.). Across both units of work, Class C remained in the Alternating condition, whereas Class A and Class B were inverted (see Table 1).

Table 1
Structure of the Overall Research Program

Unit of Work	Task-First	Teach-First	Alternating
Patterning: Term 2	Class A	Class B	Class C
Addition: Term 3	Class B	Class A	Class C

The researcher (first author) was responsible for developing the units of work and the respective lesson plans, and for leading the teaching during the sessions. By contrast, the regular classroom teacher acted as a relatively passive co-teacher, assisting with classroom management and providing occasional support and guidance to students to assist with the smooth running of the lessons (under the assistance of the researcher).

Summary of Results and Discussion

Study 1

In Study One (see Russo & Hopkins, 2017a), a series of mixed randomized-repeated design analyses of variance (Mixed Design ANOVAs) were employed to explore the relationship between participation in the program and student outcomes, including mathematical fluency, problem-solving performance, intrinsic motivation to learn mathematics and task-based student persistence. For each analysis, the within group factor was time (i.e., pre-, post-program) and the between group factor was lesson structure (i.e., Task-First Approach, Teach-First Approach, Alternating Approach).

There was evidence that a Teach-First Approach improved mathematical fluency more than a Task-First Approach. Specifically, growth in mathematical fluency in the addition unit was highest for the teach-first group [$F(2, 70) = 3.913$, $p < 0.05$, $\eta^2 = 0.101$], whilst a combined analysis which pooled data from both units of work suggested that participants improved their mathematical fluency more in the teach-first condition than in the task-first condition [$t(47)= -2.05$, $p <0.05$ ($d = 0.30$)]. It is worth noting that the main effect for time (i.e., pre vs. post) was notably larger than the effect of lesson structure. This suggests that participation in any form of the program when challenging tasks are used was more important than the manner in which the respective lessons were structured for improving mathematical fluency. By contrast, there was no evidence that lesson structure resulted in differential improvement in students' problem-solving performance. However, again it was apparent that participation in the program overall had a large impact on problem solving performance. Finally, both intrinsic motivation to learn mathematics and task-based student persistence appeared wholly unrelated to lesson structure, although this may have been in part a consequence of limitations regarding the specific instruments employed to measure these constructs. In particular, students in the study demonstrated very high levels of intrinsic motivation to learn mathematics prior to participation in the program, and the associated ceiling effect may have undermined the capacity of this measure to detect group differences.

It is necessary to try and explain why lesson structure was found to impact fluency but not problem-solving outcomes. Spiro and DeSchryver (2009) have argued that more explicit approaches to teaching may be more effective for learning in well-structured domains, and that inquiry-based methods more appropriate for learning in ill-structured domains. Although this position is contentious (e.g., Clark, 2009), it may explain the differential findings in the current study. Perhaps most obviously, the skills and knowledge that facilitate fluency performance are almost by definition more clearly structured than the equivalent skills and knowledge that facilitate problem solving performance. Whilst developing mathematical fluency involves acquiring and flexibly applying algorithmic-type knowledge, problem solving ability necessarily involves contexts where the individual is assumed not to know how to solve the problem a priori. Consequently, if we adopt the position of Spiro and DeSchryver (2009), it is perhaps not surprising that whilst the Teach-First Approach resulted in greater relative improvements in fluency performance, the Task-First Approach was equally effective when it came to problem solving performance.

Study 2

Study Two (see Russo & Hopkins, in press) employed interpretative phenomenological analysis to examine teacher-participant interviews following each unit of work. The findings revealed that teacher-participants perceived that students responded positively to learning with challenging tasks. Teacher-participants described students as autonomous, persistent and highly engaged. Such positive student reactions were attributed by teacher-participants to a variety of factors, including a classroom culture which embraced struggle, high teacher expectations, and consistent classroom routines. However, other previously identified barriers to teaching with challenging tasks, including time and resource constraints (e.g., Sullivan et al., 2014) and possessing the relevant mathematical knowledge (e.g., Charalambous, 2008), remained (to varying degrees) a concern for teachers. In addition, teacher-participants differed in their views of whether challenging tasks were a suitable means of differentiating instruction, with such evaluations apparently linked to how they defined student success.

With regards to lesson structure, teacher-participants perceived both the Task-First Approach and the Teach-First Approach to teaching with challenging tasks to have particular strengths. Teacher perceptions uncovered in the current study were highly consistent with the arguments and evidence contained within prior research. Specifically, it was found that the Task-First Approach was perceived by teachers as better able to (i) foster mathematical creativity as students had the opportunity to 'discover' idiosyncratic, and often more than one, solution methods (e.g., Leikin, 2009); (ii) promote meaningful discourse amongst students (e.g., Forman, Larreamendy-Joerns, Stein, & Brown, 1998); (iii) build student persistence (Sullivan et al., 2014); and (iv) effectively engage students through challenge (e.g., Sullivan, Clarke, Michaels, Mornane, & Roche, 2012). Conversely, there was also some support for the postulation that a lesson which begins with some form of explicit teaching, such as the Teach-First Approach, constitutes a more focussed, efficient approach to instruction (e.g., Kirschner, et al., 2006). Teachers also perceived that the Teach-First Approach was more supportive, particularly for lower-achieving students (Westwood, 2011) – although this latter view was not supported by student outcome data. Overall, these findings imply that framing the Task-First Approach or Teach-First Approach as an either/or proposition is perhaps overly simplistic, as both approaches were perceived by teachers to have distinct advantages in terms of student learning outcomes.

The central tension identified by teacher-participants in the current study between wanting students to discover and subsequently own their personalised solution method and teachers leading students towards the most efficient (or mathematically important) solution method has been revealed in previous research. For example, Star and Rittle-Johnson (2008) found that encouraging Year 6 students to discover their own methods for solving linear equations led to them demonstrating a broader variety of problem solving strategies, however directed teaching in how to solve such equations resulted in students incorporating more efficient strategies. This tension has been described elsewhere by Baxter and Williams (2010) as "managing the dilemma of telling", and is the central theme of their paper which observes the classroom practice of two teachers who are attempting to employ problem-based approaches to learning mathematics (Baxter & Williams, 2010, p. 7).

A corollary of the finding that the Task-First Approach and the Teach-First Approach have distinct strengths is that a particular teacher's preference for one approach over another will likely depend in part on what student learning outcomes she prioritises as a teacher. For example, a teacher who is strongly focussed on meeting the needs of the three or four students in her classroom who have severe difficulties with mathematics may be inclined to embrace the Teach-First Approach. By contrast, a teacher who views mathematics learning as being principally about struggle and discovery will likely embrace a Task-First Approach. The notion that the idiosyncratic values that teachers hold regarding what they believe should be the primary learning objective impacts on their subsequent approach to instruction has been raised in a variety of other primary education contexts, including foreign-language learning (e.g., Pichon, 2014) and the use of technology in classrooms (e.g., Warwick & Kershner, 2008).

Study 3

Study Three (see Russo & Hopkins, 2017b) was divided into two sections. The first section used the Constant Comparative Method to analyse the interview responses of 73 young students regarding the work artefacts they were most proud of creating and why. Five themes emerged which characterised student reflections: Enjoyment, Effort, Learning, Productivity and Meaningful Mathematics. Whereas Enjoyment reflected a single category, Effort encompassed the categories of having a go, conscientiousness and persistence. Learning described students either learning something new or trying something new, and disproportionately reflected the views of female participants [X^2 (1, 73) = 3.895, p <.05]. Productivity captured three interrelated categories, specifically the notion of taking pride in a work artefact because the task was completed, because a large quantity of work was produced or because the work was produced quickly. Meaningful Mathematics was the final theme discussed, and reflected students valuing work because it was presented in a rich context, or because the challenging task involved doing 'real maths', as opposed to more routine mathematical work. Overall, there was evidence that students embrace struggle and persist when engaged in mathematics lessons involving challenging tasks, and moreover that many students enjoy the process of being challenged.

The second section considered the lesson-structure preferences of a subset of participants (Class C; $n = 23$) when learning with challenging tasks. Most students (58%) in the study preferred the Teach-First Approach when learning mathematics in lessons involving challenging tasks. According to these students, this was primarily because the teacher-facilitated mathematical discussion and the consolidating worksheets served as cognitive activators, effectively 'warming up their brains' so students were ready to work through the challenging task. Lower-performing students were disproportionately inclined to indicate that they preferred the Teach-First Approach, which provides further validity for the cognitive activation explanation offered by students. These observations are consistent with Pekrun's (2006) control-value theory of emotions in an achievement setting. When students are simultaneously given substantial autonomy over how they approach a task and provided with opportunities for cognitive activation, they are likely to experience a high level of control. When accompanied with a high level of value, this is theorised to generate academic enjoyment. By contrast, the comparative expertise of higher-achieving students implies that their sense of control is less likely to be undermined when confronted with a challenging task prior to any instruction (i.e., Task-First Approach). For these students, the activation of knowledge held in long-term memory may effectively substitute for knowledge provided from an external source (e.g., a teacher), which may explain their greater relative preference for the Task-First Approach.

Still, a considerable proportion of students (42%) indicated that the Task-First Approach was their preferred lesson structure. Several students with this preference indicated that they valued the fact that the focus of the lesson was very much on the challenging task. This appeared to partially relate to students acknowledging that they have finite mental resources available, and would rather use their available 'energy' to work on the challenge. However, most compellingly, three students specifically indicated that they found discussing the mathematics after exploring the challenging task particularly important, as it provided them with an opportunity to learn from other students.

The potential power of the discussion component of the lesson following work on a cognitively demanding task to build students' mathematical understanding has been noted elsewhere (e.g., Stein et al., 2008). Indeed, ensuring that teachers possess both the pedagogical and mathematical knowledge to value (in the first instance) and facilitate (in the second instance), such a discussion has been viewed as a critical aspect of converting a task into a "worthwhile learning experience" (Sullivan, Clarke, & Clarke, 2009, p. 103). However, the notion that students as young as seven or eight years old can identify that they themselves benefit directly from participating in such discourse is noteworthy, and contrasts with teacher concerns that even much older students struggle to meaningfully engage in whole-of-class discussions around mathematics (e.g., Leikin, Levav-Waynberg, Gurevich, & Mednikov, 2006).

The other theme to emerge, Cognitive Demand, can be considered the antithesis of students preferring the Teach-First Approach because it supported Cognitive Activation. Specifically, it appears that that some students preferred the Task-First Approach precisely because the lack of discussion beforehand made it more challenging. This notion that 'hard is good', which exists in juxtaposition to the idiom 'help is good', is a reminder that one size is unlikely to fit all within the context of mathematics education (Ridlon, 2009), and suggests that teachers may contemplate varying the structure of lessons on equity grounds.

Implications

A key implication to emerge from this suite of studies is that the findings do not support the assumption that for students to learn from cognitively demanding tasks, lessons must begin with these tasks. They instead suggest there is more than one way of incorporating challenge tasks into mathematics lessons to produce sizeable learning gains. However, this does not imply that the Task-First Approach and the Teach-First Approach generate equivalent learning experiences for students. Specifically, taken together, the three studies provide distinctive, contrasting portrayals of the two approaches. The teach-first lesson structure can be described as a highly focussed, efficient approach to learning that effectively activates prior knowledge and provides opportunities for students to be successful and to feel suitably supported. On the other hand, the task-first lesson structure can be described as a highly dynamic, explorative approach to learning that effectively maintains a high level of cognitive demand and provides opportunities for students to be mathematically creative and to feel suitably challenged.

It appears that teaching with more cognitively demanding tasks in any capacity constitutes a significant departure from how mathematics is typically experienced in schools, at least for participating students and teachers in the current investigation. Moreover, teaching with more cognitively demanding tasks improves both mathematical fluency and problem-solving performance, regardless of how the corresponding lesson is structured. Consequently, teacher-educators should continue to encourage and support teachers to incorporate such tasks into their mathematics instruction, even in the early years of primary school. Part of the role of outside expertise, such as teacher-educators, would appear to be to design suitable cognitively demanding tasks, whilst perhaps initially allowing teachers to structure lessons around these tasks in a manner in which they are most comfortable. Although there seems little doubt that the task-first and teach-first lesson structures have distinctive strengths and generate different learning experiences, it is difficult to prescribe one particular structure over another based on the results of the current investigation. Such a determination likely depends on the skill, personality and knowledge of the teacher, the nature of the mathematical material to be learnt, the specific learning objectives emphasised during the particular lesson (or suite of lessons), and the preferences, personalities and mathematical ability of students. Ideally, teachers should strive to provide students with opportunities to experience both types of lesson structures when planning lessons incorporating challenging tasks.

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