Primary Students' Responses to a Cognitive Activation Lesson

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Cognitive activation is an approach to instruction associated with increased mathematical achievement and engagement. However, researchers have questioned its effectiveness for students with different learner characteristics. A Year 6 class participated in a lesson designed using cognitive activation practices. Interviews with ten case study participants, comprising varying achievement and engagement levels, revealed that practices such as collaborative learning and the use of cognitively demanding tasks evoked positive student responses. The findings highlight the instructional potential of cognitive activation across heterogeneous learner profiles.

Cognitive activation, an element of the Three Basic Dimensions framework posited by Klieme et al. (2009), has garnered attention for its relationship with improved mathematical performance (Le Donné et al., 2016; Lipowsky et al., 2009). Defined by Klieme et al. (2009) as "any observable pedagogical practice and pattern … of instruction that encourages students to engage in (co-)constructive and reflective high-level thinking and thus develop an elaborated, content-related knowledge base" (p. 140–141), cognitive activation is recognised by the Programme for International Student Assessment (PISA) as an instructional practice for enhancing mathematical literacy (OECD, 2013). In the context of primary mathematics education, there exists a broad consensus that sole reliance on a singular pedagogical approach is insufficient for a deep, holistic understanding of mathematical concepts. Instead, it is recommended that educators draw upon a diverse range of instructional practices to enrich their repertoire. As cognitive activation continues to be explored as one of the many instructional practices that teachers can employ, there is a growing need to enhance our understanding of how different students respond to its implementation.

Literature Review

Cognitive Activation

Although cognitive activation was conceptualised by Klieme et al. (2009), the construct was unpacked in greater detail by Lipowsky et al. (2009). Lipowsky and colleagues conceptualised cognitive activation as a multi-dimensional construct comprising three sub-elements: instruction for conceptual understanding, the cognitive level of students' activities, and the quality of interaction and participation in the classroom.

Instruction for conceptual understanding centres on the development of conceptual knowledge. Conceptual knowledge is defined as knowledge rich in relationships where teachers encourage students to develop meaningful connections between procedures and apply this understanding to novel situations (Brophy, 2000). Key features of conceptual understanding include explicit attention to concepts, the activation of prior knowledge and productive struggle (Hiebert & Grouws, 2007). The cognitive level of students' activities, the second sub-component, is closely linked to the first as facilitating productive struggle requires tasks demanding complex thinking. Lipowsky et al. (2009) found that cognitive activation is less likely when students solve mathematical problems in a standard manner. Therefore, tasks necessitating intricate, non-algorithm cognitive processing and decision-making are critical to

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this type of instruction. Such tasks require deep, sustained mathematical thinking and should be suitably challenging, falling within the learner's zone of proximal development (Vygotsky, 1931/1978). Vygotsky's research identified a zone just beyond what an individual can do independently where students can perform with the guidance and support of a more knowledgeable person, such as a teacher or peer. It includes scaffolding, challenge level, social interaction and cognitive development to support students to optimise their learning through challenge while providing the necessary support for growth. Finally, Lipowsky et al. (2009) also found the quality of interaction and student participation as an important factor of cognitive activation. They outlined practices such as questioning and student related discourse as facilitators for the construction of deeper meaning. Other research into student participation favours practices that encourage students to articulate ideas and engage in constructive dialogue, such as collaborative learning.

Table 1 provides a synthesis of the key practices/strategies outlined in Lipowsky et al.'s (2009) conceptualisation as well as integrating relevant theories.

Table 1

List of Cognitive Activation Pedagogical Strategies and Contributing Theories

Cognitive activation pedagogical strategies	Contributing theories
Activation of prior knowledge	Zone of proximal development
Explicit attention to mathematical concepts	Theories of student engagement
Productive struggle	
Cognitively demanding tasks	
Classroom discourse	
Collaborative learning	

Importantly, Lipowsky et al. (2009) acknowledged that "instructional features do not impact students' achievement in a direct manner; rather, the uptake of learning opportunities is thought to depend on various learner prerequisites" (p. 529). In their discussion, they argued the need for further examination of the interaction between cognitive activation strategies and learners' characteristics. This is of particular importance as "the classroom learning community is neither static nor linear" (Anthony & Walshaw, 2009, p. 149) and students arrive at any learning situation with a range of different learning characteristics. The focus characteristics selected for this paper include student achievement and engagement.

Achievement and Engagement Learner Characteristics

Student achievement is defined by Hattie (2013) to encompass their accomplishments. In this study, achievement refers to students' performance within the context of mathematics learning goals. Achievement has been an ongoing area of interest for mathematics educators. However, within student-centred and problem solving-based pedagogies, educators have expressed reservations about incorporating demanding or challenging tasks for students of low achievement backgrounds. A study by the National Foundation for Educational Research (NFER) in the UK (Burge et al., 2015) revealed that cognitive activation practices were less frequently observed among low-achieving students compared to their high-achieving counterparts. Notably, high-achieving students reported a 23% increase in situations where teachers presented problems where the solution was not immediately apparent. Although a nascent link exists between cognitive activation strategies and academic achievement, uncertainty persists regarding whether this discrepancy stems from high-achieving students witnessing more of these practices from their teachers than their lower-achieving peers. Furthermore, as evident from the updated New South Wales K–10 mathematics syllabus (New South Wales Education Standards Authority (NESA), 2020), students across all achievement levels should have opportunities to be creative and critical when solving complex tasks. There is a need to understand more deeply how students respond to moments of instruction that centre on students making connections, discussing key mathematical concepts and attempting cognitively demanding tasks; all key elements within a cognitive activation approach.

Student engagement has garnered significant attention due to its potential impact on positive educational outcomes (Fredericks et al., 2004). Engagement is well established as a multi-dimensional construct, encompassing behavioural, emotional and cognitive sub-constructs, all which play pivotal roles in fostering student involvement in their learning (Fredericks et al., 2004). Within their multidimensional framework, Fredericks et al., (2004) suggest authentic and challenging tasks can be associated with heightened behavioural, emotional and cognitive engagement. However, the authors acknowledge a gap in literature concerning how individual differences such as achievement levels, moderate the relationship between challenging tasks and engagement. Over the past two decades, researchers have continued to explore this gap. For instance, Bobis et al. (2021) explored instructional strategies to facilitate increased engagement in mathematics learning when challenging tasks were involved. Insights gleaned from teacher interviews highlighted the efficacy of using open-ended tasks as catalysts for enhancing student engagement. The present study aimed to capture student perspectives on teaching practices aligned with a cognitive activation approach that sustains or promotes engagement in their learning. Given the association between student engagement and achievement, understanding student responses to cognitive activation practices may be useful. Insights from this study can inform classroom practices and guide further investigations into the use of these teaching strategies across diverse student populations.

The present study aimed to address the following research question: How do Year 6 students with different engagement and achievement learner characteristics respond to components of a lesson designed using cognitive activation practices? For the context of this paper, 'respond' refers to students' reactions including their enjoyment and engagement.

Methodology

An exploratory case study methodology was used to investigate student responses to a lesson designed using cognitive activation strategies and contributing theories, hereafter referred to as a cognitive activation lesson. This paper is affiliated with a larger study comprising a series of six intervention lessons, all constructed around cognitive activation teaching strategies. The findings in this paper report on student responses of 10 subset case study participants gathered during the semi-structured interviews following the first cognitive activation lesson. Previous mathematics lessons were teacher-directed and students had minimal experience with cognitive activation practices prior to the intervention.

Intervention

A 60-minute lesson was led by the researcher, who was not the regular class teacher. The content focus of the lesson was on addition. A warmup activity was designed to activate prior knowledge where students were tasked to find multiple strategies to solve a three-digit additive number sentence. Students worked collaboratively with a peer using a mini-whiteboard to record their working. Solution strategies were shared and evaluated in a whole class discussion. The body of the lesson centred around a cognitively demanding 'Charity' task that posed the following question: Three schools raised $125,750 for charity. Each school raised a different amount. What amount might each school have raised? The open-ended nature of the task offered the possibility of stimulating higher-level thinking. It allowed students to generate their own strategies and apply their understanding of addition in a novel context. These key elements align with existing literature, which suggests that such tasks can enhance cognitive demands and challenge students intellectually (Dyer & Moyinhan, 2000; Sullivan, 2018). Support and extension prompts were pre-devised, adopting an approach recommended by Sullivan (2018) when providing students with challenging tasks. A support scaffold reduced the total to $25,750 while an extension scaffold challenged students to find multiple solutions where the total for each school was within $3,000 of each other. Students had a choice in the last few minutes of the task to use a calculator to help find more solutions. After completing the task, some student solutions were discussed. Students also had an opportunity to reflect on the strategies they used during the problem-solving process.

Participants and Data Collection

A heterogenous Year 6 class participated in the study. The school was an independent, co-educational school located in metropolitan Sydney. Students came from mid- to high-socioeconomic backgrounds. This age range was selected as it is a stage often linked with declining mathematical engagement (Skilling et al., 2020). Prior to the intervention, baseline data were collected to help select the subset of case study participants. Students' achievement and engagement characteristics were evaluated using Martin's (2007) Motivation and Engagement Scale (MES), Progressive Achievement Testing (PAT) and a researcher-made assessment on addition and subtraction. Results were ranked using a tripartite approach to determine low, moderate and high achievement and engagement. A subset of ten case participants, comprising five males and five females, represented a broad spectrum of achievement and engagement levels.

Each lesson was video recorded and researcher/teacher field notes were logged. Student artefacts including work samples and photographs of whiteboard work were collected. Individual student semi-structured interviews were conducted immediately following the first lesson. Interviews were video recorded and transcribed.

Data Analysis

A hybrid thematic approach was employed to discern patterns of significance within the semi-structured interview transcripts (Braun & Clarke, 2006). The initial phase of analysis involved a comprehensive review of the transcripts to obtain a holistic understanding of the students' reactions to the lesson. Deductive coding was primarily used to tag quotations when students alluded to a particular cognitive activation practice (refer to Table 1 for an overview of the cognitive activation practices). Inductive codes were also annotated when students mentioned other instructional components of significance. Following this, an inductive strategy was employed to detect patterns pertinent to the research question. These findings were further scrutinised, and categorised into sub-themes and major themes for this paper.

Results

Due to space constraints, a comprehensive coverage of all cognitive activation practices is unfeasible. Instead, the results in this paper hone in on four principles frequently underscoring students' responses: cognitively demanding tasks, zone of proximal development, productive struggle and collaborative learning. The findings are organised into two primary themes extracted from data analysis. Students' names are pseudonyms for confidentiality in the study.

Student Responses to Challenge

During the semi-structured interviews, students frequently discussed the cognitively demanding task or the associated challenge level. More than half of the students referenced the level of challenge, the majority in relation to the cognitively demanding 'Charity' task. Most students spoke negatively about the level of challenge because the cognitive demands of the task were excessively high. Oscar, a low achievement and engagement student, accounted for almost half of the negative responses, "I just don't know how to work out the question … I didn't get how to find the amount that each school raised. And I didn't get just what the question meant."

Similarly, Leah, a moderate achievement and engagement student, also found the main task too challenging, "I got confused on this task and I got quite stuck … I just didn't understand … With the other ones, I know how to do the strategies and I knew what to do."

Victor, a high achievement low engagement student, also found the challenge level for the 'Charity' task not suitable. He perceived part of the task too easy because the openness of the task meant answers could be derived by "coming up with random numbers". Victor did, however, show an increase in his cognitive engagement when afforded the opportunity to solve the extension prompt, "I think it was better when there was a bit less freedom … when it had to be a little closer together because you can't just do anything."

A similar sentiment was observed from Edward, a low achievement high engagement student, when referring to the opportunity to use the calculator towards the end of solving the main task, "well, when we started using the calculators, that wasn't as fun because it was giving us the answers. I like to work it out."

Both Edward and Victor reported diminished enjoyment when they perceived the task as straightforward, with answers readily available. Victor expressed greater enjoyment upon successfully completing the extended prompt, while Edward experienced a similar effect when he avoided using a calculator, as both instances required more effort in solving the cognitively demanding task.

Among the students who provided positive feedback regarding the cognitively demanding task, Maddie, a student with moderate achievement and low engagement, explicitly acknowledged the suitability of the challenge level, "it was pretty fun because the questions weren't too hard or too easy."

Almost all the students recognised the beneficial role of challenge for their learning. Sally, a low achievement and engagement student spoke positively about the role of productive struggle in the lesson, also noting the importance of scaffolding in responding to challenges:

> I think it can be sort of helpful because you get to challenge yourself and try. If it is something easy a lot of the time, I think you don't actually learn anything … I do like having that challenge but I also think it would be helpful … getting more help with challenging ones if it gets too challenging.

She also found interest in attempting struggle within the lesson and challenging herself not to only find easy solutions:

> It was fun to do different things and correct myself because I know I got a few wrong. I checked them and it was fun to redo it and do different examples instead of just having really easy ones the whole time.

Many high-achieving students exhibited favourable responses when confronted with challenges during the lesson. For example, George, a high achievement and engagement student, and Victor, both expressed enjoyment and a feeling of victory upon successfully solving complex problems:

> When I complete something hard, it just brings me joy. (George)

> When you're trying to figure out something and then at the very end or at the start of the next lesson, you finally figure it out, it gives you a sense of accomplishment and it feels good. (Victor)

Classroom Participation During the Lesson

Collaborative learning emerged as the predominant cognitive activation practise discussed in the student interviews. The majority of students spoke about their enjoyment engaging with a peer to solve the warmup task. For example:

> I really enjoyed it because we could work with new people and share our ideas and listen to each other. (Leah)

> I think my favourite part was when we were all sitting down on the carpet and we were working together with a partner because we could figure out who was going to do what and we could work more efficiently and we could understand what each other were doing. And we could also learn more ways to figure things out or be remembered. (Laura)

Sally, a low achievement and engagement student, expressed unfavourable sentiments regarding the collaborative learning activity. She highlighted a lack of collaboration with her partner and conveyed low enjoyment because she was not able to actively contribute to the shared learning experience, "I was with someone who understood math a lot better than I did and who knew lots of different strategies so it ended up being she did most of the work."

Similarly, when queried about her lowest engagement moments during the lesson, Sally attributed it to the collaborative activity, asserting "because my partner did most of the work." When prompted to identify a part of the lesson she would like to do again, she responded, "I'd probably do the warmup again and try and challenge myself to do some other things … instead of just letting my partner do it."

During the analysis of student responses, it became evident that collaborative learning was not the sole factor contributing to heightened classroom participation. Many students attributed their increased behavioural and cognitive engagement to the cognitively demanding task. Specifically, Laura, Edward and Connor reported that the open-ended task extended their involvement in the lesson, as they found the exploration of multiple solutions intellectually stimulating and intriguing:

> I enjoyed it because there were multiple answers … it was interesting to see how many answers you could come up with. (Laura)

> I enjoyed it because there wasn't one answer, because if there was one answer, it would just be like a boring lesson. We would figure out one and it would be over, but this there's multiple answers and multiple ways to figure out your answer. (Edward)

> I enjoyed it because it was a problem where you didn't just work it out and then you were done. You could have multiple answers, like lots of them, so you could sit there for a long time working out new answers. (Connor)

Discussion

The prominence of responses relating to the challenge level underscores the significance of Vygotsky's Zone of Proximal Development theory (1931/1978) in the context of cognitive activation instruction. Positive reactions, particularly in terms of engagement and enjoyment, were consistently observed when challenge levels aligned with students' academic capabilities. Conversely, excessively demanding challenges led to decreased engagement and enjoyment. When the challenge level was perceived as 'optimal' from the student's perspective, cognitive engagement appeared to increase. Although this study drew insights from a limited sample size of student voices, an interesting observation emerged: challenge level played a critical role in utilising Lipowsky et al.'s (2009) second sub-component of cognitive activation. The potential implications of this finding are promising, yet further investigation is warranted.

Furthermore, the observation of heightened negative reactions to challenging tasks among low-achieving students reinforced the importance of scaffolding. This finding aligns with Bobis et al.'s (2021) research, where teachers emphasised the effectiveness of a differentiated approach, including extending and enabling prompts, to engage a diverse student population. Student perspectives indicated that suboptimal challenge levels led to reduced engagement and enjoyment. It is acknowledged that this is one of many factors which may have influenced the way students engaged with the task, and further exploration of these factors is needed in larger-scale studies. Cognitive activation, which centres on the utilisation of cognitively demanding tasks, reveals the need for teachers to possess a deep understanding of their students. Student responses in this context highlight the role of teacher-student familiarity in optimising cognitively demanding activities. Specifically, awareness of students' achievement characteristics during the design and creation of cognitively demanding tasks could assist teachers to tailor differentiation effectively. By doing so, educators can aim to engage a wider student population. Further research should continue to explore this relationship and refine instructional strategies within cognitive activation teaching.

In the analysis, classroom participation emerged as a salient theme, with numerous students attributing heightened engagement to collaborative learning experiences and the solving of an open-ended cognitively demanding task. Sally's perspective illuminated the detrimental impact of ineffective collaboration on her learning. Her negative reactions stemmed from her lack of active contribution to the collaborative process, resulting in decreased task engagement and enjoyment. The large number of positive reactions, coupled with Sally's negative response, showed there may be a possible association between increased engagement and enjoyment with opportunities for collaborative learning, so long as the collaboration is shared equally and is productive. Finally, a potential link between cognitively demanding tasks and classroom participation was revealed. Notably, student perspectives demonstrated alignment with Frederick et al.'s (2004) findings, which associate challenging tasks with increased behavioural, emotional and cognitive engagement. Student responses to this lesson highlighted increased participation and heightened cognitive stimulation from both collaborative practices and open-ended, cognitively demanding activities as reasons for enhanced engagement and enjoyment in the lesson.

Conclusion

The objective of this study was to investigate how students with varying achievement and engagement profiles respond to different practices and aspects of a cognitive activation lesson. By analysing student feedback, we explored the potential of cognitive activation instruction. Notably, students reported heightened engagement and enjoyment when the challenge level aligned with their individual achievement characteristics. While these preliminary findings warrant further scrutiny, they hold implications for instructional practice. Student voices serve as a call for educators to incorporate opportunities for struggle and cognitively demanding tasks into teachers' teaching repertoires. A possible link between cognitively demanding tasks and increased cognitive engagement and participation emerged. Additionally, responses related to collaborative learning underscore heightened student participation, transcending engagement and achievement levels. In this lesson, successful collaboration not only facilitated peer learning but enhanced overall participation, with students appreciating the social dynamics inherent in this learning approach. This study sheds light on how learners with different characteristics engage within a cognitive activation framework. The hope is that these findings will encourage teachers to embrace this instructional practice, with the intent of elevating student engagement and the potential to foster a deeper enjoyment of mathematics learning.

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References

Anthony, G., & Walshaw, M. (2009). Characteristics of effective teaching of mathematics: A view from the west. *Journal of Mathematics Education*, *2*(2), 147–164.

Bobis, J., Russo, J., Downton, A., Feng, M., Livy, S., McCormick, M., & Sullivan, P. (2021). Instructional moves that increase chances of engaging all students in learning mathematics. *Mathematics*, *9*(6), 582. https://doi.org/10.3390/math9060582

Braun, & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Brophy, J. E. (2000). *Teaching: Educational practices (Series–1)*. Brussels, Belgium: International Academy of Education (IAE)/UNESCO International Bureau of Education (IBE).

Burge, B., Lenkeit, J. and Sizmur, J. (2015). *PISA in practice: Cognitive activation in maths.* Slough: National Foundation for Educational Research (NFER). https://www.nfer.ac.uk/media/vmtj0jne/pquk04.pdf

Dyer, M., & Moynihan, C. (2000). *Open-ended questions in elementary mathematics: Instruction and assessment.* Larchmont: Eye on Education.

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, *74*(1), 59–109. https://doi.org/10.3102/00346543074001059

Hattie, J., & Anderman, E. M. (Eds.). (2013). *International guide to student achievement*. Routledge. https://doi.org/10.4324/9780203850398

Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In J. Frank & K. Lester (Eds.), *Second handbook of research on mathematics teaching and learning* (pp. 371–404). Information Age.

Klieme, E., Pauli, C., & Reusser, K. (2009). The Pythagoras study: Investigating effects of teaching and learning in Swiss and German mathematics classrooms. In T. Janik & T. Seidel (Eds.), *The power of video studies in investigating teaching and learning in the classroom.* New York, NY: Waxmann Publishing Co.

Lipowsky, K., Pauli, C., Drollinger-Vetter, B., Klieme, E., & Reusser, K. (2009). Quality of geometry instruction and its short-term impact on students' understanding of the Pythagorean Theorem. *Learning and Instruction*, *19*(6), 527–537. https://doi.org/10.1016/j.learninstruc.2008.11.001

Le Donné, N., P. Fraser & G. Bousquet (2016). *Teaching strategies for instructional quality: Insights from the TALIS-PISA link data.* OECD Publishing, Paris. https://doi.org/10.1787/5jln1hlsr0lr-en.

Martin, A. J., (2007). Examining a multidimensional model of student motivation and engagement using a construct validation approach. *British Journal of Educational Psychology*, *77*, 413–440, http://dx.doi.org/10.1348/000709906X118036

New South Wales Education Standards Authority (NESA). (2020). *Nurturing wonder and igniting passion, designs for a new school curriculum: NSW curriculum review*. NSW Education Standards Authority. https://nsw.gov.au/sites/default/files/2023-04/NSW-Curriculum-Review-Final-Report.pdf

Organisation for Economic Co-operation and Development (OECD). (2013). *PISA 2012 assessment and analytical framework: Mathematics, reading, science, problem solving and financial literacy.* https://doi.org/10.1787/9789264190511-en

Skilling, K., Bobis, J., & Martin, A. J. (2020). The "ins and outs" of student engagement in mathematics: Shifts in engagement factors among high and low achievers. *Mathematics Education Research Journal*, *33*(3), 469–493. https://doi.org/10.1007/s13394-020-00313-2

Sullivan, P. (2018). *Challenging mathematical tasks: Unlocking the potential of all students*. Oxford University Press.

Vygotsky, L. S. (1931/1978). *Mind in society: The development of higher psychological processes*. In M. Cole, V. John-Steiner, S. Scribner & E. Souberman (Eds.), (A. R. Luria, M. Lopez-Morillas & M. Cole [with J. V. Wertsch], Trans.) Cambridge, Mass.: Harvard University Press. (Original manuscripts [ca. 1930–1934].