Conveyance Technology in Supporting the Teaching and Learning of Mathematics Through Student Reasoning and Problem Solving

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Technology can play a pivotal role in mathematics education. Qualitative methods were used to report on how a Year 1–2 teacher incorporated *Conveyance technology* (iPads), to support the teaching and learning of mathematics through student reasoning and problem-solving. The study was conducted in Australia. A single case was chosen, reporting a lesson where students engaged with a 12-cube task. The findings contribute to the broader discourse on the role of technology in early mathematics education, suggesting that conveyance technology supported by effective teaching practices and open-ended problems, fosters students' reasoning and problem-solving skills.

Technology is a powerful tool that can be incorporated into mathematics lessons. For meaningful learning, technologies can be used to advance students' mathematical thinking, reasoning, and problem-solving skills (Calder & Murphy, 2018; NCTM, 2014). Other benefits include supporting conceptual understanding, collaborative learning, exploration, assessment, and communication (Cullen & Hertel, 2023). However, some teachers are not convinced of the benefits of using technology as a teaching tool in mathematics classrooms, and others have been slow to adopt its use (Dick & Hollebrands, 2011). This is of concern because not allowing students to use technology could impede their mathematical learning experiences.

In addition to using technology, teachers are encouraged to foster students' mathematical understanding through problem-solving and reasoning as emphasised in the Australian Mathematics Curriculum (ACARA, 2022). When guiding problem-solving strategies, the teacher encourages students to model the problem, check for reasonableness, look for patterns or make conjectures (Van de Walle et al., 2024). Likewise, when supporting students in developing mathematical reasoning, teachers focus on guiding the processes of comparing, contrasting, conjecturing, generalising, explaining, and justifying (Herbert & Williams, 2021; Vale et al., 2017). If teaching with technology is difficult for some teachers, integrating problem-solving and reasoning most likely presents a further challenge.

Few studies have investigated ways technology might support the teaching and learning of mathematics, particularly through student reasoning and problem-solving in the early years. Further research is needed to identify how technology can be used productively, including in primary mathematics classrooms (Boon et al., 2021; Calder & Murphy, 2018; McCulloch et al., 2018). The purpose of this study was to gain a better understanding of the role of technology in supporting Years 1 and 2 students' reasoning and problem-solving skills.

Literature Review

Technology can offer teachers new ways for students to learn mathematics (Calder & Murphy, 2018). Examples of technologies that support teaching and student learning include computers, calculators, tablets, computer algebra systems, dynamic geometry software, online games, recording devices, spreadsheets, and a variety of online tools (NCTM, 2014; Van de Walle et al., 2024). Teachers might choose to use technology with their students in different ways, for instance, calculators when exploring larger numbers, online games to practice fluency of multiplication facts or a smart board to project a mathematics problem.

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Theoretical Framework

A Framework for the Roles of Technology in Mathematics Education (Cullen & Hertel, 2023) draws on previous research and is used to present two uses of technology as a tool in mathematics classrooms (Table 1). Teachers and researchers can use this framework when considering how the role of technology as a tool supports mathematical teaching.

Table 1

Framework for the Roles of Technology in Mathematics Education (Cullen & Hertel, 2023, p. 317)

Roles of technology	Conveyance technology uses	Encouraging collaboration	Encouraging collaboration around mathematical problems
		Sequencing and sharing	Sequencing and sharing work on mathematical tasks
		Orchestrating discourse	Orchestrating mathematical discourse
		Monitoring and assessing	Monitoring and assessing mathematical learning
	Mathematical action technology uses	Serving as a tutee	Decomposing, abstracting, and encoding mathematical procedures and processes
		Promoting cycles of proof	Creating testing, revising and proving mathematical conjectures
		Supporting case-based reasoning	Generating, organising, and analysing data
		Presenting multiple representations	Presenting and connecting representations of the same mathematical object

As shown in Table 1 there are two roles or functions of technology (Cullen & Hertel, 2023). *Conveyancing technology* refers to the use of technology for conveying and transmitting information, such as a PowerPoint presentation. The four categories of Conveyance technology include Encouraging collaboration; Sequencing and sharing; Orchestrating discourse; and Monitoring and assessing, all of which can help to support effective teaching practices (Dick & Hollebrands, 2011). *Mathematical action technology* involves using technology to respond to students' actions, as in the case of GeoGebra and Desmos. For example, action technology, may assist students in generating, organising, and analysing data (Cullen & Hertel, 2023).

The Use of Tablets (iPads)

An affordable and common technology tool used for educational purposes in Australian schools is (iPads), equipped with applications (apps) software programs. Mathematical apps have been classified as those that develop a particular type of knowledge (conceptual or procedural) and mathematical content area (e.g., measurement and number skills) (Larkin & Milford, 2018). Similarly, depending on how students use iPad apps, they could be considered Conveyance technology or Mathematical action technology.

To assess the impact of iPads on student learning in middle-year classrooms, Boon et al. (2020) conducted a systematic review of the literature. The findings of the research studies were mixed. While iPads and mobile technology could motivate students' learning and dispositions, not all studies showed significant differences in student learning when comparing the use of iPads (or not) in mathematics lessons.

The purpose of the study reported in this paper is to extend what is already known by focusing on conveyance technology as a tool in a Year 1–2 classroom when considering how iPads might support students' reasoning and problem-solving. The study sought to answer the following research question:

- In what ways did a Year 1–2 teacher incorporate conveyance technology and support students' mathematical reasoning and problem-solving?

Method

Qualitative methods were used in this single-case study, involving a lesson observation of a Year 1–2 teacher. A single-case design was deemed appropriate for reporting cases that convey stories with messages, aiming to assist others by describing the observed activities within the case (Dumez, 2015). The single-case participant was selected because he had been teaching open-ended problems for several years. Open-ended tasks are characterised by having multiple solutions and/or different possible strategies (Sullivan et al., 2016), which were embedded into his teaching approach. As part of a larger project, (part research and part professional development) the author conducted school visits, each term for one year. These visits involved lesson observations and collaborating with Foundation to Year 2 (students 5 to 8 years old) teachers during the implementation and trialling of sequences of problem-solving lessons. The lesson reported here was the final lesson observation and was conducted in December 2018.

At the time of data collection, Jim (pseudonyms used throughout) was teaching the second lesson from a measurement and geometry sequence (Sullivan et al., 2023). The big idea of the lesson was that the same volume can be used to construct different prisms. The students were asked to solve the following problem:

A rectangular prism is made from 12 cubes. What might the prism look like?

Data Collection and Data Analysis

Data collection included video recordings, field notes, and students' work samples. Audio recordings were transcribed for subsequent coding and analysis. Lesson transcripts were thoroughly read and subjected to thematic analysis, utilising the Framework for the Roles of Technology in Mathematics Education (Cullen & Hertel, 2023). The results section includes vignettes from the lesson, including coding and evidence of *Encouraging collaboration, Sequencing and sharing, Orchestrating discourse, and Monitoring and assessing* (see Table 1). Additional coding showed evidence of the teacher supporting students' reasoning and problem-solving.

Results

During the lesson, students used the camera app on iPads to capture photographs of their responses to the 12-cube task. The primary purpose of the technology tool was to collect photographs of their constructions [coded: conveyance technology use]. The following vignettes report on the role of conveyance technology as a tool for supporting students' reasoning and problem-solving.

Vignettes of the Lesson

Lesson Launch and Using Technology

The lesson was launched to the class when sitting together on the floor. After reading the problem together, students moved to their tables to solve the 12-cube task (Figure 1).

Figure 1

Students Solving the 12-Cube Task

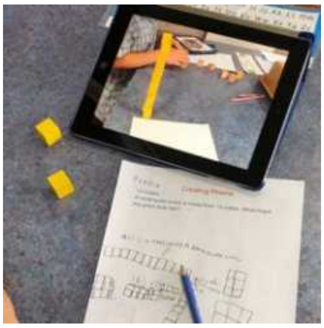
Each student had a set of 12 wooden cubes, the same colour, an iPad, a pencil, and a sheet of paper for recording their solutions (Figure 1). After the students used the 12 cubes to construct different prism, they took photographs, using their iPads. The iPad was useful as a tool for documenting the range of student responses to the task. The photographs were also used by the students to share their responses during the lesson with each other or their teacher [coded: encouraging collaboration; sequencing and sharing].

Teacher Observations

Students were also asked to draw their constructions. Many students had difficulties drawing three-dimensional prisms and instead drew two-dimensional diagrams (e.g., Figure 2).

Figure 2

Student Photograph of Their Cube Construction and Written Working Solution



As shown in Figure 2, a photograph and student's work sample offered insights for the teacher when monitoring and assessing mathematical learning [coded: monitoring and assessing]. Seeing the students' constructions provided immediate visual feedback for the teacher when considering how to respond to student learning. Interpreting only written solutions may have taken longer without the technology to support monitoring and assessing.

There were four solutions to the problem and a rotated prism was not an additional solution. When assessing student responses these were two key ideas that became the focus of the teacher and student one-on-one interactions [coded: orchestrating discourse] (Figure 3).

Figure 3

The Same Rectangular Prism Rotated

As shown in Figure 3, Jim used both the images and the blocks when modelling and exploring the problem with the students. Jim, "Now I am just going to go like this and tip over the rectangular prism." Jim, "What can you tell me?" Jenny replied, "It is still the same, but it is tipped over."

Jim's questioning supported problem-solving by asking questions that helped Jenny to apply her knowledge and other questions focused on reasoning by encouraging Jenny to explain her thinking [coded: problem-solving and reasoning].

Lesson Conclusion

Near the end of the lesson, the teacher asked the students to come together on the floor and sit in a circle bringing their iPads and written solutions. Jim asked the students about the number of different solutions (n = 4). First, he chose to focus on students' understanding and whether a prism rotated was a different or repeated solution [coded: assessing reasoning]. In the ensuing discussion, Peter, explaining his answer, talked about having to "turn it around" as he referred to the rectangular prism.

Jim: Put your hand up if you turned yours around or did what Peter did and popped it down?

Jim: Can I ask you if you were creating one that was the same or one that was different?

Girl: The same (*stating the correct response*).

To help students to visualise this concept Jim asked Peter to come and show the class his photographs on the iPad [coded: encouraging collaboration; sequencing and sharing; orchestrating discourse; monitoring and assessing; problem-solving and reasoning].

Jim: Peter, can you bring your iPad here and explain what you were telling me before? There was one you were looking at and I would like you to explain this … It was the one at the start … wasn't it? It was that one …

After flicking through the photographs Jim then held up one solution (Figure 4: Image 1) to the students

Jim: Let's start with this one … Put your hand up if you had this solution?

Figure 4

Peter's Photographs of the Same Solution Rotated

After sharing the first image (Figure 5: Image 1) Jim flicked to another photograph (Figure 4: Image 2) and asked everyone:

Jim: Is this solution the same or a different solution? Now some people think it is a different solution, but Peter, can you explain why you think it is a different solution? (*Jim had spent time with Peter during the lesson to confirm his new learning before being selected during the whole class discussion to share his correct thinking*).

Peter: (*grinned and said*) It is the same because all you are doing is pushing it up.

Jim: (*repeats what Peter said and then confirms with the whole class*) Did the rectangular prism change?

Maddy: No, it just turned up.

Jim: Did any of the faces change?

Class: No (*all the children responded together)*.

Jim: No, the faces all just stayed the same. Put up your hand if you thought it was a different solution and then you went back like Peter and said hang on it was just a different orientation?

By asking this question, Jim was highlighting to the students that they needed to check which ones were the same or different [coded: problem-solving and reasoning].

At the end of the lesson, Jim asked, “Who can convince me how many possible solutions there are?” [coded: reasoning]. Next, students constructed and shared the four possible solutions in the circle (Figure 5).

Figure 5

Constructing, Sharing, and Discussing all Possible Four Solutions

As shown in Figure 5, students used the data on their iPads to check if any other possible solutions were missing [coded: encouraging collaboration; problem-solving and reasoning]. Finally, students agreed that there were four possible solutions.

Discussion

During the lesson, the iPad served as an invaluable tool for enhancing both teaching and students’ learning experiences. As reported in the results all codes of conveyance technology were demonstrated and the integration of technology was used effortlessly by students and the teacher. The teacher also used the conveyance technology to support students’ mathematical reasoning and problem-solving skills. Next, these findings will be discussed.

The technology proved beneficial for documenting and sharing early years students’ responses. Without this technology tool, some students might have encountered challenges when sharing answers with peers and the teacher, especially those facing difficulties when drawing three-dimensional prisms. In other words, the technology was an efficient tool for younger students to use when recording their solutions. The tool allowed students to capture solutions after constructing each prism, extending their mathematical understanding of the problem, and avoiding prolonged periods spent attempting to draw their answers. This finding suggests that using an iPad to capture images of their constructions was beneficial for Years 1 and 2 students when responding to the 12-cube task.

As reported in the results, the use of technology in Jim’s lesson supported monitoring and assessment. The technology provided visual feedback for the teacher, assisting him when offering feedback to students in the movement of teaching. As Jim has a large cohort of students in his class, developing efficient strategies for supporting all students’ learning is important. Similarly, the images of the students’ constructions most likely provided feedback to students as they compared and analysed their solutions by flicking between responses. Creating opportunities for students to reflect on their learning aims to enrich their mathematical experiences.

Using iPads in the classroom offers the advantage of creating a visual record of students’ achievements and learning. Images of students’ mathematical responses could be added to a portfolio showcasing their progress across the year. In addition, at the end of the 12-cube lesson, Jim could have asked students to take a photograph of their written responses as a digital record of how they drew their prisms. Additionally, students could be asked to use the video app to record a reflection of their learning experiences, providing further evidence of student learning and the benefits of conveyance technology.

The use of conveyance technology played a crucial role in facilitating collaborations, enabling the sharing of student solutions, and fostering discussions related to the 12-cube task. Furthermore, the teacher's discussion and questioning approaches when using the images on the iPad during the lesson supported student reasoning and problem-solving. In particular, the students were encouraged to justify and explain their solutions and thinking and make a conjecture by explaining all four possible solutions when responding to the problem. The open-ended nature of the problem provided opportunities for students to record and discuss all possible solutions including developing mathematical vocabulary related to the properties of prisms such as faces and orientation. The images assisted students when pointing and justifying their thinking, especially during whole-class discussions at the end of the lesson.

Without technology, the teacher may have primarily relied on student work samples and the physical construction of three-dimensional prisms (12 cubes) to support students' mathematical reasoning and problem-solving skills. However, the combination of the technology tool and the quality of the teacher's pedagogical approaches in this study supported students' learning. The technology served as a tool for fostering collaboration, sharing solutions, promoting discourse, monitoring, and assessing. The technology was also useful in supporting the teacher when posing questions to extend students' reasoning and problem-solving skills. Although not explicitly addressed in this study, it is also plausible that incorporating technology could have further engaged students and fostered positive learning dispositions.

The findings of this study highlight one approach for using conveyance technology with early years students to support their reasoning and problem-solving skills. Most likely the learning in this lesson was attributed to the teachers' pedagogical actions, the task and technology. Calder and Murphy (2018) would agree that when teaching with iPads the quality of the teacher's pedagogy is influential in supporting student learning. In other words, a good teacher is needed to support learning with technology. In addition, Cullen and Hertel (2023) cautioned that when assessing technology as a tool we need to consider if student learning is attributed to the teacher or the technology. Further studies could explore this idea by interviewing teachers and students after using technology as well as teaching the same lesson with and without technology to compare how students learn.

Conclusion, Implications and Recommendations

This study investigated the use of conveyance technology, specifically iPads, to support mathematical reasoning and problem-solving through a single case study. The Year 1–2 lesson, centred around a 12-cube task, providing a platform for students to engage with technology. The incorporation of iPads was beneficial for sharing and recording student responses, supporting the teacher when monitoring and assessing, and providing opportunities to support students' reasoning and problem-solving. A short video capturing this lesson is available on the Monash University *TeachSpace* website (Livy, 2019).

Implications of this study suggest that integrating conveyance technology in early years' mathematics lessons when teaching with open-ended problems can support teaching practices for problem-solving and reasoning. Additionally, the study highlights the importance of teachers' pedagogical approaches when using technology to support student learning. Teachers, like Jim in this case, played a pivotal role in guiding students' mathematical reasoning, addressing misconceptions, and fostering mathematical discourse. Likewise, the use of iPads to document and share solutions supported peer learning and collaboration. Students benefited from seeing and discussing each other's approaches, leading to a deeper understanding and the development of conjectures and strategies. Overall, these findings contribute to the broader discourse on technology's role in the early years of mathematics education suggesting that the integration of conveyance technology when supported by effective teaching practices, and open-ended problems can foster students' reasoning and problem-solving skills.

This study was conducted before the onset of COVID-19. Conducting a follow-up study with the teacher could offer valuable insights into the evolution of the use of conveyance technology. Given the widespread shift to online teaching during the pandemic, exploring how teachers, including the one in this study, have adapted and grown in their use of technology would provide a timely and relevant perspective, contributing to further understanding of productive and unproductive uses of technology tools in the early years.

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