Barriers to Integration: A Case Study of STEM-Learning in Mathematics and Digital Technology

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Teachers often perceive barriers to integrating technology with Mathematics. In the study, teachers participated in professional development about considerations for and examples of integrating Digital Technologies into Mathematics learning in primary schools meeting the *Australian Curriculum: Mathematics* and *Digital Technologies* requirements. This exploratory multiple case study included pre- and post-surveys, mentoring conversations and interviews to explore their beliefs and perceived barriers to integrating mathematics and digital technologies. This paper provides insights into their perceived barriers to integrating digital technologies.

When teaching STEM, many primary and junior secondary teachers have difficulty including mathematics at the correct curriculum level. The Queensland Government's review of STEM education in state schools found that STEM education could be strengthened by investment in primary teachers and junior secondary teachers (teaching out of field) by providing access to a "range of sustained and specialised professional development to support them to acquire STEM-specific content knowledge and pedagogical practices" (Department of Education, 2018). The review also described teacher confidence influenced the development and delivery of programs in STEM education, particularly in relation to integrated learning.

The *Australian Curriculum (AC): Technologies* is intended to be taught through integration with other learning areas. *AC: Mathematics* and *AC: Digital Technologies* share definitions and content in computational thinking and data collection, analysis, and representation, thus providing avenues for integration.

The project was designed to test the relevance of Ertmer's (1999) framework of first and second-order barriers to technology use in the classroom. The aim was to identify barriers that prevented teachers from implementing integrated mathematics and digital technologies lessons following professional development (PD) in a group of motivated teachers. Findings identified barriers for teachers interested in engaging in STEM-related activities in their classrooms and provided insights for developing and delivering future PD to understand the second-order barriers identified.

Theoretical Perspectives

Curriculum Integration and STEM

Curriculum integration is an authentic and engaging way of weaving across learning area boundaries to apply transdisciplinary skills for learning (Drake & Reid, 2020). An integrated approach to teaching is often complex (Kneen et al., 2020; Venville et al., 2002), and teachers spend hours planning the curriculum and resources to bring together different learning area threads (Nayler, 2014).

Advocacy for STEM education has momentum and support from business, industry, government, and education (Education Council Australia, 2015; Ross, 2022) as STEM is necessary to underpin Australia's economic growth. Knowledge from multiple disciplines is required to solve complex global challenges which are not derived from one area or discipline alone (Keeley & Knowles, 2016); hence students need to be educated in STEM-related areas to promote and foster students' career paths in STEM-related fields (Education Council Australia, 2015).

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Easton et al. (2020) stated that the mathematics component of STEM learning is perhaps the most important. Mathematics is a language that can cross the boundaries of all disciplines through problem-solving, logical reasoning and spatial thinking (Coad, 2016; Ferme, 2014). However, Mathematics is rarely foregrounded in STEM activities (English, 2016). Frequently, the focus of an integrated STEM unit has been derived from one discipline with identifiable connections to other disciplines (Ross, 2022). When these conceptual links are made, they are not at an age-appropriate level, but rather the concepts consolidate prior learning. The question is whether the learning experiences are drawn from mathematics concepts that further the learning expected at that year level or are more aligned to opportunities to consolidate prior learning or numeracy concepts. Mathematics is often the final element considered in the integration puzzle, which is the issue this research aims to address through connection with integrated digital technologies.

Barriers to Integrating Digital Technology

Ertmer (1999) highlighted two categories of barriers to embedding digital technology in classrooms. First-order barriers refer to issues external to the teacher, such as access to the necessary technological devices or software, insufficient teaching time, and inadequate technical support. Second-order barriers are about the teacher, including beliefs about digital technology, appropriate pedagogy, and reluctance to engage with technology (Ertmer, 1999). Ertmer (1999) stated that both first- and second-order barriers hinder teacher efforts to embed digital technology in the classroom. However, she suggested that second-order barriers can be more difficult to overcome. First-order barriers are typically about resourcing; thus, once sufficient resources have been received, the problem has generally been resolved. However, second-order barriers involve personal beliefs and are intrinsic to the teacher.

Ertmer's (1999) study focused on technology use in the classroom. Subsequent research has considered technology integration in the classroom. An & Reigeluth (2012) encountered more first-order than second-order barriers among the teachers surveyed. Attard (2013), considering the use of mobile technologies in primary mathematics classrooms, found that teachers are often provided with the technology and expected to integrate it into their classroom practice without the PD support necessary, meaning that teachers struggled to understand how the technology could be integrated into a primary mathematics classroom to enhance learning. PD that is centred in the school context allows teachers to enact the learning and validate ideas in their own classrooms leading to collaboration, experimentation and reflection, and boosting connectivity between the learning and enactment of the learning (Silver et al., 2007). Teachers in Perienen's study (2020) identified the need for further training to be able to integrate digital technology into their mathematics teaching whilst those in Baya'an et al.'s study (2019) demonstrated how establishing a community of practice enabled mathematics teachers to integrate ICT into their teaching.

Version 9 of the AC makes the connections between *AC: Mathematics* and *AC: Digital Technologies* more explicit to support the integration of the two learning areas. This project included PD that focused on STEM curriculum integration and technological content knowledge to demonstrate connections between the *AC: Mathematics* and *AC: Digital Technologies* in the primary years. The project aimed to determine which first- or second-order barriers existed with the teachers who participated and whether implementing integrated Technology and Mathematics activities in the classroom reduced the number of barriers teachers perceived for integrating technology in mathematics. The research question was:

- What barriers exist for primary teachers when implementing integrated Digital Technologies in Mathematics?

Research Design

Context

This 6-month study is part of a larger study. The smaller study focused on the experiences of two primary school teachers at the same school. Only data from these two teachers were included and pseudonyms used. The teachers attended a PD session where statistical and digital technologies concepts were integrated and used this learning to enact integrated lessons using digital technologies to teach and consolidate mathematics concepts. The teachers were offered two mentoring sessions after trialling integrated lessons and a second PD session which further developed their understanding of integration through geometric visualisation activities. An exploratory multiple-case study design (Yin, 2009) used qualitative methods for collecting data, including surveys and a semi-structured interview.

Participants

The participants were from one independent, high socio-economic status primary school in the western suburbs of Brisbane. The teachers' classes included students from a broad spectrum of academic achievement levels. The school has a reputation for STEM learning and engaging students in advanced learning in digital technologies and robotics. Whilst all teachers in the primary school were invited to participate, only two teachers accepted the invitation.

Abigail had less than seven years of teaching experience. She is keen to use technology in the classroom and assists her peers with technological issues and questions. Abigail has taught mathematics and digital technologies in Australia and the United Kingdom. This is her first school since her return to Australia.

Hillary also had less than seven years of teaching experience. She believes she has only a basic understanding of how technology can be implemented in the classroom. She had not had experience teaching with digital technologies and felt intimidated by the technology available at the school when she first arrived. She recently moved to Australia, having trained and taught in schools in the United Kingdom.

Data Collection

The teachers completed a pre-PD survey to ascertain their *starting* beliefs, and participated in two mentoring sessions, a post-project survey and a final semi-structured interview at the conclusion of the study. The survey included questions from the *Technology Beliefs and Barriers to Creating Technology-Enhanced, Learner-Centred Classrooms* sections of An and Reigeluth's (2012) survey. Additional questions were derived from those sections relating to the study's specific context, i.e., beliefs about and barriers to integrating *AC: Mathematics* and *AC: Digital Technologies*. The survey was distributed again at the end of the school term following all teacher lessons and project mentoring sessions. The mentoring session prompts were based on Rolfe et al.'s (2001) framework for reflective practice asking the teachers to:

- describe the integrated lesson the teacher had completed, including aspects that worked well and challenges (what)
- highlight aspects that the teacher would change, were interesting or surprising (so what)
- outline what they planned to do next (now what).

The mentoring sessions were held through Zoom to enable flexibility. A second PD session was held following the second round of teacher lessons to share practice and provide additional concepts and examples for integrating digital technologies in different conceptual areas of mathematics—visualisation. Final interviews were held with the teachers at the conclusion of the project. Interview

prompts related to their beliefs about teaching and learning mathematics, teaching and learning technology, attitudes toward integration, and barriers they perceive to integration in the classroom.

Data Analysis

Thematic analysis was used to analyse the data collected using Braun and Clarke's (2006) six phases of thematic analysis to identify themes. A comparative analysis considered each case's emerging enablers and barriers (themes) to integrating digital technologies.

Emerging Enablers and Barriers

Key themes emerging from the data were perceived experience and confidence to teach mathematics, perceived experience and confidence to teach digital technologies, and school culture and organisational practices, including access to resources.

Experience and Confidence to Teach Mathematics

While Abigail was educated as a teacher in Australia, most of her teaching experience has been in the United Kingdom but feels confident about teaching the *AC: Mathematics* and *Digital Technologies*. However, Abigail explained that mathematics was stressful for her, and she appreciated that mathematics provided "one right answer", unlike other learning areas.

> I don't think I'm particularly confident in my own ability in maths. It was always a thing that I felt like anxious about. But at the same time, my lack of confidence, I think in like this feeling of anxiety that even I as a person, I think a lot of people feel that maths anxiety around numbers…I've always really liked that there is an answer at the end of the tunnel. Whereas all of those others like, you know, HASS and science, there's no right or wrong answer. It's about where you come through, because I really, I enjoy that part of math. … I definitely, as a person feel math anxiety. (Interview: Abigail)

Hillary described feeling confident about teaching mathematics as the AC is like what she taught in the United Kingdom. Hillary expressed that she initially disliked mathematics, was intimidated by it, and was taught that mathematics was about getting the correct answer. However, she explained that that did not always bring success because having the correct answer does not mean that a student understands the reasoning behind mathematics.

> As a child, I really disliked it [Maths]. And I think it's because we have that, you know, sit down, this is what you need to learn. You repeat it in this way. And you'll have success because eventually, you'll get it right. But that success doesn't really come, and it doesn't last because there's no actual understanding of the reasoning behind it…So I felt very intimidated by maths growing up. And it wasn't until I became a teacher and trained as a teacher that I've realised that the different way to do it, how it should have been taught to myself as a young person. (Interview: Hillary)

Now she feels excited to teach mathematics, particularly when she sees one of her students' faces lights up when they reach understanding.

> And now maths makes me, I don't know, I feel excited, really excited by it. And it's exciting to watch…the children's faces…light up when there is that element of understanding because we use a different way of explaining it or we've got the manipulatives out or we've used a visualisation tool and I got it and there's nothing better than that feeling. (Interview: Hillary)

Both teachers described the importance of real-world, hands-on, problem-solving for developing students' understanding and critical thinking and their preference for pedagogy that reflected this.

> Maths is one of the ones in our curriculum that is connected completely to like real-world situations like money or time or accounts, like just general things like that. And I think so obviously means, like real-world context, I think it also means problem-solving, like critical thinking, and being able to like decode and understand situations, and work our way through it quite systematically. (Interview: Abigail)

> …sometimes I have to ensure that I am going back to my values as a teacher and going back to what I know is the best pedagogy and ensuring that I mix that with what the school's expectations are for how things are taught. (Interview: Hillary)

Experience and Confidence to Teach Digital Technologies

The two teachers' technology beliefs were very similar and did not shift throughout the project. Both teachers supported using technology in the classroom, believing it necessary for student learning. They believed as classroom teachers they needed to keep up with new technologies and embed them into their teaching.

> I feel confident teaching it [digital technologies] and delivering it. (Interview: Abigail, 29 Nov 2022)

In her final interview, Abigail described feeling hampered by the confidence of other staff to teach with technologies in two opposing ways. In her cohort, Abigail felt that she was frequently the teacher who wanted to continue to push forward with technologies but that she needed to be mindful of the confidence and capacity of her colleagues. She described that she is often the person who is called upon to explain the new technology or to support her fellow cohort teachers in teaching the technologies.

But it's hard to do it, I guess in practice sometimes. Because it's not necessarily just me in that room, or me in that cohort, teaching it. So, I think, getting others to be on the same board and teaching them I find that stressful and difficult. Because everyone doesn't have the same kind of like self-efficacy with technology that I do. And then, I have to consider them and what works best in the situation. And I think digital technologies is something that's a challenge for a lot of people. (Interview: Abigail)

In contrast, Hillary initially lacked confidence to teach digital technologies. She stated that she had little experience using digital technologies, particularly as she had taught in low socio-economic schools in the United Kingdom.

> There's something I started off with very, very little confidence...It's something that coming from the UK, in the sort of schools I worked in, we worked in very low socio-economic areas, there just was not the access for the children to digital technologies. So, they weren't used and utilised within the classroom. Because just financially, they couldn't afford that equipment. (Interview: Hillary)

Hillary was initially intimidated by the students' overwhelming access to technology, but her competence was increasing with her emersion. Nevertheless, she needed ongoing support for it to be a natural inclusion.

> Where it's been coming here, each girl has a one-to-one laptop; it was quite intimidating to start with. I will say my confidence has definitely grown. (Interview: Hillary)

School Culture and Organisational Practices

The teachers agreed on several barriers to creating technology-enhanced, learner-centred classrooms. In the survey, the teachers strongly agreed that *Subject culture (the general set of institutionalised practices and expectations which have grown up around a particular school subject)* was a barrier as well as time, assessment requirements and knowledge about ways to integrate technology into learner-centred instruction. Through analysis of the survey and interview data, themes emerged related to school culture and organisational practices.

Abigail and Hillary reported high levels of support for teaching technology at the school with good access to new technology and support for experimenting with its use. There was a technology specialist within the school, however, both teachers reflected on issues relating to this human resource.

> I think because she is so fantastic. And she's got all of those wonderful banks of ideas already. I wonder whether teachers sometimes take it upon themselves to try and learn new things to integrate into their classrooms, or whether there's kind of that reliance on using her to feed ideas into their own rooms (Interview: Hillary)

> We were really fortunate with the tech teacher. … I didn't feel that I could incorporate it [digital technologies] as much, I guess, into my classroom use because she's got it so set up. But we started to do that,

> I think through this programme and have that more confidence to bring it over and to utilise it in the classroom rather than it being quite segregated. So that's definitely good. (Interview: Abigail)

Both teachers agreed that they would like to try using the technology in a more integrated way. While they had almost unlimited access to digital technologies resources, they still felt that they could benefit from PD focussed on using them effectively in the classroom. Abigail explained that the primary school used a timetable to allow students a wide array of specialist teachers, including music, visual art, languages, digital technologies, health, and physical education. The students were provided with learning from subject-matter experts but to the detriment of making clear connections across programs or using integrated learning.

> I think it's been quite hard with a K to 12 school, which is very secondary in terms of the way they timetable. A lot of our subjects are quite siloed, … the primary, they encourage us, and they're willing, they're happy for us to kind of go and integrate because we are stuck to like at a time to go, I found it quite tricky. (Interview: Abigail)

Although the school was supportive of teacher innovation and integration, Abigail found that constraints and expectations of the school environment the lack of flexibility meant that she felt that she was not able to engage in "a big inquiry or big problem-solving" and there was an expectation for more traditional mathematics teaching styles.

Hillary described the volume of content to be taught as well as the expectation to use traditional didactic learning styles when teaching mathematics.

> I think because of the school being the way it is and the sort of girls that come into the school. There is that expectation that the work is that high, high pitch, so I think there's a lot of content to get through. And some of it is set quite a bit higher than the year group expectations. And it just puts a lot of pressure on getting through it all. And whereas I guess I would go slower and deeper is my gut feeling, and to do lots of reasoning and problem-solving, you know, beginning with that fluency and that understanding, but then having time within a lesson or within the next lesson to apply that. (Interview: Hillary)

Hillary expressed a preference for going *slower and deeper* to develop conceptual understanding and allow for application. Both teachers described the broader primary school staff's preference to teach according to the chosen textbook. Abigail described the textbook as quite text-dense, thereby creating issues for students with literacy issues. Abigail described feeling caught between wanting to use the text as a resource with other, more hands-on dialogic learning experiences and feeling the pressure of parent expectations given the purchase of the textbook. Hillary also spoke of the importance of more hands-on techniques supporting student needs, developing from her understanding of mathematics. Further, she described a preference for ongoing monitoring and formative assessment rather than the school's preferred assessment strategies focused on written tests to collect evidence. She wanted to allow the students to explain how and why they got their answer, not just the solution itself.

Discussion

Second Order Barriers

The teachers described in this paper expressed second-order or intrinsic barriers including knowledge of technologies, knowledge of pedagogy, and developing confidence.

Despite including two PD sessions and two mentoring sessions with the teachers, both claimed they needed further support to effectively use of digital technologies in the classroom and integrate technology into learner-centred instruction. As Attard (2013) observed, the teachers in this study were given access to technologies without the necessary PD support for effective inclusion in the classroom. Whilst the school invested in a specialist teacher to support the use of digital technologies they were used as much to deliver the classroom teaching, rather than to support teachers' learning about teaching of digital technologies.

Each teacher described past anxiety relating to the teaching of mathematics and that they perceived their school culture to support more traditional pedagogies and textbook use. As Ertmer (1999) describes, second-order barriers often relate to teachers underlying beliefs about teaching and learning, thus making them harder to shift as sometimes the teacher is unaware that they hold these deep-seated beliefs. During mentoring meetings, the teachers frequently doubted the veracity of their integrated tasks. They suggested that the tasks in their lessons were ill-conceived and did not focus on the areas they aimed to develop. However, with mentored reflection, the teachers realised that their integrated lessons provided mathematics learning opportunities beyond what they had intended and that the additional discussions and engagement for their students provided richer learning opportunities than they had expected.

First Order Barriers

The survey data showed that both teachers identified first-order or external barriers relating to time, assessment, and subject culture barriers to technology integration. The interviews also revealed other first order barriers relating to school culture and organisational practices.

Both teachers described feeling that the culture of the school and expectations for teaching and resources hindered their capacity to engage in further integration of digital technologies in their mathematics classrooms. The requirement to complete high volumes of content contributed to a lack of time to engage in deeper problem-solving and integrated learning. Ertmer (1999) described the perception that first-order barriers were easy to overcome as they frequently referred to barriers emanating from resourcing. These two teachers described here believed they had access to almost unlimited digital technologies resources, were keen to integrate digital technologies in their lessons, and learn more about integration, however, for both teachers overcoming the barrier of school culture felt insurmountable. The teachers felt the pressures of a siloed approach to teaching the learning areas through school timetable restrictions, the expectation that the mathematics textbook would be used, and the perceived expectations to use a more didactic teaching style. A limitation of this study has been the focus on the teachers from the school without further input from the school administration to seek clarification as to the messaging to staff about issues pertaining to integration, timetabling, textbooks, pedagogy, and assessment.

Conclusion

This paper provided a small snapshot of a larger study that explored teachers' perceived barriers to integrating mathematics and digital technologies. In this paper, two teachers' journeys were used to illustrate an exploration of Ertmer's (1999) first and second-order barriers to integration of digital technologies. The teachers, Abigail and Hillary, were similar in all but one aspect of their experience, their confidence to teach digital technologies. Yet both teachers described similar second order (intrinsic) barriers to teaching integrated mathematics and digital technologies in their school, including knowledge of technologies, knowledge of pedagogy, and developing confidence.

Although the study was limited to one school, lessons learned may be useful in considering future PD. The first order (extrinsic) barriers described in the case studies identified aspects of school culture, even within a technologically advanced school, as producing perceived barriers to further technology integration. This is important consideration for schools when new technology is introduced. However, further research incorporating the voices of the school leadership would be beneficial to provide clarity of expectation for teachers.

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