Best practice models for the use of digital technologies in mathematics teaching and learning

Final Report

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Executive summary

The Australian Government commissioned dandolopartners to identify contemporary opportunities for the use of digital technologies in maths teaching and learning.

There were three key drivers for the project:

1. A sustained decline in student maths and numeracy performance across Australia
2. The increased adoption of digital tools for maths teaching which occurred during the COVID-19 pandemic in some states and territories
3. An interest in identifying effective online teaching methods that have improved student outcomes in maths that can be applied more broadly

Australian students' maths performance has been steadily declining since 2003 with nearly half of all students not meeting the OECD's minimum standard in numeracy.[1] We know that maths is essential for education and broader life outcomes.[2] Maths outcomes have been particularly poor for some cohorts. For example, students from the lowest socio-economic quartile are about three years behind students in the highest socio-economic quartile.[3]

Extended periods of remote teaching in locations such as Victoria, NSW and the ACT led to many schools embracing digital tools for teaching, including the teaching of maths. However, we found that the impact of COVID-19 varied significantly across the sector depending on:

- Level of school closures in the jurisdiction
- Teachers', students' and parents' confidence in using technology
- Access to devices and reliable internet connections

School uptake of digital technology was less evident where there were minimal school shutdowns. We also heard that in some schools there has been a reversion away from use of digital tools now that COVID-related school closures have passed. Although COVID-19 was a disruptor to Australian education systems, it did not result in a fundamental change to the major challenges faced by maths teachers.

Methodology overview

In the first stage of the project, we prepared an Interim Report undertaking these research and analysis steps:

- We conducted interviews with system level stakeholders to gain an understanding of the key challenges facing maths teaching and learning, and the current state of technology use in maths classes. We spoke to stakeholders in state and territory departments of education, Catholic Dioceses, and Independent Schools.

[1] OECD, "Country Note: Australia – Programme for International Student Assessment", 2018.

[2] Productivity Commission, 'Literacy and Numeracy Skills and Labour Market Outcomes in Australia', 2014; OECD, 'Skills Matter: Additional Results from the Survey of Adult Skills', 2019.

[3] OECD, "Country Note: Australia – Programme for International Student Assessment", 2018.

- We conducted desktop research to identify examples of maths teaching using technology and evidence of effectiveness.
- We engaged an Expert Panel of maths education researchers and innovators and ran workshops to capture their input on key questions for the project.[4]
- We partnered with the Melbourne Graduate School of Education to complete a literature review on best practice online teaching of maths.

In the Interim Report, we outlined a series of drivers of improved maths performance including:

- Improving maths teacher capacity
- Improving maths teacher capability
- Improving access to maths specialists
- Differentiating student learning
- Enabling new ways of student learning

We also profiled a range of models for technology use which contributed to progress on one or more of the drivers of improved maths performance, cited above.

Our Expert Panel then reviewed our Interim Report and, using their feedback, we refined the scope for the Project's Final Report. The Final Report was to focus on three key challenges that schools face in improving students' maths performance, namely:

1. Improving maths teacher capacity and efficiency
2. Improving teacher capability and confidence
3. Differentiating student learning

The Final Report would complete 'deep dive' analysis on eight of the models for technology use in maths teaching and learning that we identified in the Interim Report. These eight models were assessed by our Expert Panel to have the highest potential for contributing meaningfully to addressing one or more the three key challenges cited above.

In drafting the Final Report we completed fieldwork involving:

Type of stakeholder	Number of consultations
Maths teachers (public, Independent and Catholic schools)	90
Vendors of digital tools for teaching and learning of maths	8

[4] The members of the project's Expert Panel are listed in Appendix 3.

School leaders and teachers	9
Managers of programs for digital teaching and learning of maths	4
Online class observation	1
Expert panel interviews	7
State and Territory Department of education STEM policy and program staff	6

The eight technology models profiled were:

Model	Summary
Maths lesson plans	Providing maths teachers with banks of high quality, curriculum aligned lesson plans to increase the effectiveness of their classroom teaching and to reduce their preparation time for teaching each unit or topic.
Digital observation and remote coaching	Teachers record their lessons for self-reflection or to share with professional development coaches. Coaches can be remote or in-person, pairing less confident or experienced maths teachers with experienced maths teachers.
Remote learning delivery	Using video conference technology, experienced maths teachers can reach students that do not have access to local maths experts. Video conference technology can also be used to group students from multiple schools in virtual classes to receive maths teaching.
Online tutoring	Students are provided with one-on-one or small group online tutoring sessions with qualified maths teachers familiar with the Australian Curriculum. These sessions are additional and complementary to in-class maths learning.
Fully featured teaching and learning platforms	Fully featured teaching and learning platforms are software products providing comprehensive and integrated libraries of maths exercises, lessons and/or videos for use with students, as well as automated grading and individual or cohort analytics.

Digital exploration, investigation & game environments	This model encompasses platforms that use contemporary graphics, visualisation tools, mini-games or play-based interactions to develop understanding and proficiency with maths concepts, both simple and complex.
Cohort-specific culturally relevant content and lesson plans	Digital teaching tools that are designed to use culturally relevant pedagogies to engage and improve student outcomes in maths for culturally and linguistically diverse students.
Teacher-recorded worked examples	Teachers record short, 2-5 minute, videos of their handwritten completion of maths problems on screen with their own voice-over commentary. They distribute this recording to individual students or cohorts of students who have the same misconception or learning challenge.

It is clear that the use of digital tools in maths teaching and learning can make a substantial contribution to address the three key challenges that schools face in improving students' maths performance

Teacher capacity and efficiency

We heard from maths teachers that they are time-poor and may have insufficient capacity to complete the range of preparation, administration and classroom tasks needed for optimal student outcomes. A lot of time is spent on administrative tasks, limiting time available for high value activities improving student performance.

Digital technologies can improve maths teachers' capacity by helping them to complete tasks more efficiently, allowing them to reallocate this time to higher value activities that are more likely to contribute to improved student performance. It can also reduce the overall burden on maths teachers, decreasing burnout and enabling them to operate at full capacity more often.

Teacher capability and confidence

Supporting inexperienced and less confident maths teachers to build the skills needed to teach maths well. We heard from teachers and system level stakeholders that inexperienced or less confident teachers need support around content and teaching practice.

Differentiating student learning

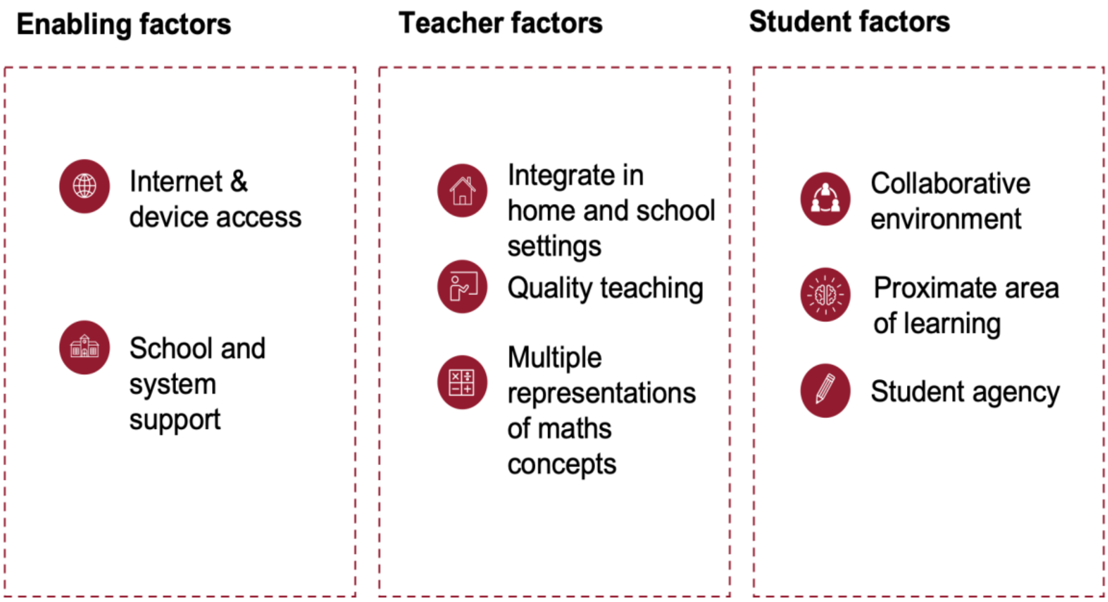
Supporting teachers to effectively manage maths classes with a wide range of ability levels and learning styles. Teachers have significant differentiation in student level within one class. Supporting all student levels can be difficult and time consuming.

Key factors for success and some cautions

Success factors

There are **three types** of factors that support successful adoption of digital tools for maths teaching and learning:

Figure 1: Key factors for success



Alternative text: Figure 1 presents the three types of factors that support successful adoption of digital tools for maths teaching and learning. The first category is 'enabling factors'. Within 'enabling factors' is internet and device access, and school and system support. The second category is 'teacher factors'. Within 'teacher factors' is integration in home and school settings, quality teaching, and multiple representations of maths concepts. The final category is 'student factors'. Within 'student factors' is collaborative environment, proximate area of learning, and student agency.

Enabling factors support the uptake of digital tools as they allow students and teachers to reliably access online and digital materials. Having school and system support encourages teachers to integrate the use of digital technologies into their maths teaching practice and assist them in implementing new tools.

Teacher success factors support digital technology use in the classroom and for at home learning. These factors are required for model implementation to be successful.

Student success factors are essential to utilising digital technologies well. Students learn best using digital technologies when these factors are present.

Caution factors

Five factors warrant caution in the adoption of digital tools to enhance maths teaching and learning:

1. Improving teacher capability and confidence in maths is the key to improving student performance. Technology is not a panacea.
2. Digital literacy is not universal amongst students, and sensitivity to this aspect of learning context is critical.
3. Before embracing digital tools to enhance maths teaching and learning, schools should first reflect on precisely why they are doing so and what benefits they are seeking.

4. Student facing technologies appear to be better suited to secondary school maths.
5. eSecurity and privacy considerations are critical for the emerging range of online, collaborative, and multi-user platforms used in maths.

There are opportunities for the Australian Government to support best practice models for the use of digital tools in maths teaching and learning.

States and territories and the Australian Government both play a role in supporting maths teaching. The states and territories implement education policy while the Australian Government is uniquely placed to support wider uptake of digital maths teaching models by acting as:

- A coordinator and linker- connecting stakeholders with resources or organisations
- An evaluator and assessor- commissioning evaluations and assessments of maths activities
- A capability builder- providing funding or commissioning resources and PD around maths teaching

Figure 2: Potential Australian government roles

Potential role	What does it mean?	Example
Co-ordinator and linker	Acting as the coordinator between different parties (e.g. schools and industry partners, or states and territories) to: • Improve STEM networks in education. This will allow more parties to collaborate on new ideas and approaches. • Inform the sector of existing initiatives. This helps avoid 'reinventing the wheel' with new initiatives.	• Raising awareness of existing initiatives e.g. through mechanisms such as the Digital Technologies Hub • Linking organisations who are thinking of doing similar activities (e.g. two states who want to set up an engineering academy) • Bringing together and building consensus between different stakeholders

Evaluator and assessor	Evaluating and assessing initiatives to: • Better understand impact and opportunities for future improvement • Share lessons learned with the sector • Build an evidence-base about what success looks like to inform future policy decisions	• Evaluating, or funding the evaluation of, individual or packages of initiatives • Facilitating evaluation activities (e.g. by developing or promoting resources to help others run evaluations)
Capability builder	Focusing on building system capability to: • Providing funding to schools, school leadership and teachers to provide high-quality maths education • Ensure the system maintains relevance and remains up-to-date with evolving leading practice	• Professional development or online resources for schools on new maths strategies or best-practice evidence

1 Introduction

1.1 Project context

Mathematics is critical…

Mathematics and numeracy are critical for education outcomes, as well as broader life outcomes:

1. Literacy and numeracy skills are associated with better labour market outcomes.[5]
2. An increase of one standard deviation on the numeracy scale is associated with an almost one percentage-point increase in the likelihood of being employed rather than unemployed, and a 7% increase in wages.[6]
3. For women in particular, low numeracy can have a greater negative effect on life outcomes than low literacy.[7]

Australia needs a workforce with specialist mathematics skills for future economic prosperity. STEM skills are a requirement in 75% of the fastest-growing occupations.[8] This makes mathematics especially critical, given it is not just a discipline in its own right, but also underpins success in science, technology and engineering.

…but Australian student performance in mathematics is in decline.

Average Australian student performance in mathematics has been declining in real terms since 2003,[9] according to PISA test results. The average 15-year-old student is more than one full year behind in mathematics compared to their 2003 equivalent.

Australian student performance in maths is also declining relative to other OECD countries. In the most recent round of testing in 2018, Australia fell below the OECD average for the first time. Nearly half of all Australian students did not meet the OECD's minimum standard in mathematics.[10]

Underperformance in mathematics is worse for students from certain demographic cohorts. Strengthening mathematical performance is therefore important for equity, as well as overall education excellence. According to 2018 PISA results:

- There is a gender gap, with female students scoring lower than male students on average, and a lower proportion of high-performing female students than male students.
- Students in remote schools were one-and-a-half years behind students in metropolitan schools on average, with only 34% achieving the OECD's minimum standard.

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[5] Productivity Commission, 'Literacy and Numeracy Skills and Labour Market Outcomes in Australia', https://www.pc.gov.au/research/supporting/literacy-numeracy-skills/literacy-numeracy-skills.pdf, 2014

[6] OECD, 'Skills Matter: Additional Results from the Survey of Adult Skills', https://www.oecd-ilibrary.org/sites/1f029d8f-en/index.html?itemId=/content/publication/1f029d8f-en, 2019

[7] Bynner & Parsons, 'Does Numeracy Matter More?', National Research and Development Centre for adult literacy and numeracy, 2005

[8] PwC, "A smart move: Future-proofing Australia's workforce by growing skills in science, technology, engineering and maths (STEM)," PricewaterhouseCoopers, Sydney, 2015.

[9] OECD, "Country Note: Australia – Programme for International Student Assessment", 2018, https://www.oecd.org/pisa/publications/PISA2018_CN_AUS.pdf

[10] Ibid.

- The mathematical literacy of Indigenous students was around two-and-a-half years behind that of non-Indigenous students.
- Students from the lowest socio-economic quartile were about three years behind students in the highest socio-economic quartile.

Student participation in mathematics is also declining. In NSW in 2020, almost one quarter of HSC students did not take any maths course, compared to 6% in 2000. There has also been a sharp decline in the proportion of Year 12 students choosing advanced maths subjects over the past 20 years.

There are contested views as to why Australian students' performance in maths is in decline.

The second Gonski review, for example, argued that Australia's outdated 'industrial model of school education' treats all students the same and does not differentiate learning to achieve maximum learning growth for each individual student.[11] It also argued that too many schools are 'cruising' – they maintain average achievement from year to year but do not improve.[12]

There is strong evidence that teacher quality is the most important in-school driver of student performance, including in maths and numeracy. The best-performing systems in the world emphasise teacher quality in three main areas: *who* becomes teachers (teacher selection and training), *what* they teach (curriculum) and *how* they teach it (teacher practice).

There are specific challenges in each of these areas relating to mathematics and numeracy, for example:

- There is a shortage of high-quality maths teachers in secondary schools across many state and territory education systems. As a result, many teachers are teaching maths 'out of field', without the necessary knowledge, skills and experience. There is also a lack of experienced maths teachers to coach or mentor early-career maths teachers.[13]
- This year ACARA reviewed the Australian Curriculum, including the teaching of maths and numeracy. The review identified areas of improvement including embedding mathematical reasoning and problem solving and streamlining content to key areas.
- There are contested, passionate and ideological views on the best way to teach mathematics – for example, direct instruction or inquiry-based approaches.
- Expectations on teachers are higher than ever, given the emerging focus on individualisation of teaching to students.

The Australian Government has long recognised this challenge and sought to address it. For example, it led the development of the National STEM School Education Strategy with states and territories and funded a number of STEM programs through the 2020-21 Budget, including Mathematics by Inquiry.

COVID-19 disruptions compounded the challenge – and created opportunities.

[11] Australian Government, 'Through Growth to Achievement'. 2018, p27.

[12] Ibid, p10.

[13] Australian Institute for Teaching and School Leadership, Australian Teacher Workforce Data: National Teacher Workforce Characteristics Report, 2021.

COVID-19 school closures sparked deep concern in Australia and internationally, in that the rapid pivot to remote learning would result in students falling behind on key indicators such as literacy and numeracy. For example:

- Research commissioned by the Australian Government Department of Education toward the start of the pandemic assessed that while remote learning had the potential to work well for some students, for others it would present major challenges.[14]
- Teachers reported feeling concerned for the educational and psychosocial welfare of students, particularly those in early primary school.[15]
- A recent study in the US, which also experienced extensive periods of remote learning, found that by the end of the 2020-21 school year students were on average five months behind in mathematics.[16]

We are still working to understand the full impact of the COVID-19 disruption on student learning in Australia, including through further qualitative testing on student performance. There are early indicators that students may have fared better than expected (for example, the 2021 NAPLAN results showed no significant decline in students' numeracy performance between 2019 and 2021).

However, it is too soon to conclude that COVID-19 school closures did not have an overall negative impact on student performance. The challenges of remote learning were particularly acute for students from certain cohorts:

- Remote learning increased gaps in achievement and engagement for students who were already vulnerable or disadvantaged. This was due to a number of factors, including lower parent engagement in learning and no appropriate places to study.
- Remote learning was particularly challenging for students without access to the internet or required technology (the 'digital divide').
- Some school students who were at risk of disengaging from education prior to the pandemic disengaged completely during periods of remote schooling.[17]

While moving to remote learning created challenges, it also fostered a new era of innovation in schools. Online platforms for teaching had been in use in many contexts prior to the pandemic. In particular, there has been a shift from 'ed tech', which focuses on content, to online platforms that focus on a particular pedagogical approach to teaching (which one expert referred to as 'ped tech'). During the pandemic online platforms expanded greatly in usage and prominence. Students and teachers were required to quickly adapt to using these new technologies.

We don't yet have a full understanding of which models worked, for which cohorts of students, and in which contexts. But there are important reasons to reflect on and learn from experiences using online models for teaching mathematics during COVID-19 related school closures:

[14] Department of Education, 'New Research to examine the potential impact of remote learning', https://www.dese.gov.au/about-us/announcements/new-research-examine-potential-impact-remote-learning, 2020

[15] Flack et al, 'Educator Perspectives on the impact of COVID-19 on teaching and learning in Australia and New Zealand', Pivot Professional Learning, 2020

[16] McKinsey, 'COVID-19 and education: The lingering effects of unfinished learning', https://www.mckinsey.com/industries/education/our-insights/covid-19-and-education-the-lingering-effects-of-unfinished-learning, 2021

[17] DESE, Emerging Priorities Program Guidelines, The Smith Family https://www.thesmithfamily.com.au/-/media/files/about-us/media/the-smith-family_insights-snapshot_may-2021.pdf

- While students have now returned to the classroom, schools may continue to close intermittently over the short to medium term as a result of further COVID-19 disruptions, or natural disasters requiring remote learning.
- More fundamentally, reflecting on our experience using online models may provide insights into how to address Australia's declining student performance in mathematics and numeracy – either across the board, or for particular cohorts of students.

The aims and context of this report

The Australian Government commissioned dandolopartners (dandolo) to identify and explore best practice digital maths teaching and learning models that were in use during the COVID-19 pandemic (COVID), particularly when many jurisdictions across Australia experienced significant school closures or disruptions to regular classroom-based teaching.

This work will help the Government and other actors in the Australian education system to better understand what worked and why, with a view to:

- Ensuring school education delivery can meet education needs during future disruptor events, whether caused by public health challenges or other challenges such as natural disasters.
- Enhancing teachers' capability to deliver quality maths education.
- Supporting improved student performance in maths across Australia.

2 Project methodology

2.1 Project scope

Given the breadth of potential issues and opportunities arising in relation to mathematics teaching and learning, we have defined the scope and focus of the project in relation to ten 'scales' outlined in Figure 3.

Figure 3 - Scope of the project

Scale	Agreed scope
Year levels	Students enrolled in Foundation to Year 12.
Domestic – International	Focus on the domestic use of digital technology for maths and numeracy teaching and learning, considering international examples where relevant.
COVID – Pre-COVID	Consider models developed both during and pre-COVID, with a preference for models that were either developed or came to prominence during COVID.
Online – Digital	Consider digital technology in a broad sense rather than narrowing the project to strictly online teaching delivery.
Maths specific – Broad application	Focus on maths and numeracy specific teaching and learning over broader models of teaching and learning that can be applied to maths, but considering both as appropriate.
Learning – Attitudes	Focus on improving student learning and performance rather than improving their attitudes towards mathematics, with recognition that these may not be mutually exclusive and that improved attitudes can lead to improved learning.
Mathematics – Numeracy	Consider both mathematics and numeracy in this report, when we say 'maths', we are referring to both maths and numeracy.
Virtual classroom – Physical classroom	Consider both virtual and physical classroom learning - acknowledging that many schools will be using blended learning in practice.

Teacher – Student	Focus on both models that support teachers to deliver learning and students to engage in their own learning, with priority on models that support teachers.
Delivery – Professional learning	Focus on the delivery of maths teaching, but acknowledge that professional learning in support of teacher capability is also important.
Peer reviewed academic literature- other data sources	Include peer reviewed academic literature where available and relevant, though recognise COVID pandemic research completed and peer reviewed. Will also consider grey literature, stakeholder consultation and teacher views.

For clarity, the project is not:

- A review of the Australian maths curriculum.
- An investigation into different teaching approaches, such as explicit instruction or inquiry-based learning.
- An examination of the use of digital technology in an early childhood education context.
- A detailed examination of the socio-economic determinants of education outcomes, such as the impact of the home environment and internet connection on learning.

We acknowledge that there are technologies that support the administrative operation of schools and classrooms and that these may also improve teacher capacity, but we have focussed on technologies that have a closer connection to maths teaching and learning.

2.2 Project methodology

The project was completed from March 2022 to October 2022.

In the first stage of the project, we prepared an Interim Report through these research and analysis steps:

- We conducted interviews with system level stakeholders to gain an understanding of the key challenges facing maths teaching and learning and the current state of technology use in maths classes. We spoke to stakeholders in state and territory departments of education, Catholic Dioceses and Independent Schools.
- We conducted desktop research to identify examples of technology being applied to deliver and improve on maths teaching and learning, and to gather available evidence on their effectiveness.
- We engaged an Expert Panel of maths education researchers and innovators and partnered with the Melbourne Graduate School of Education to complete a literature review on best practice online teaching of maths.[18]

[18] The members of the project's Expert Panel are listed in the Appendices.

In the Interim Report, we profiled a range of models for technology use which contributed to progress on one or more of the drivers of improved maths performance:

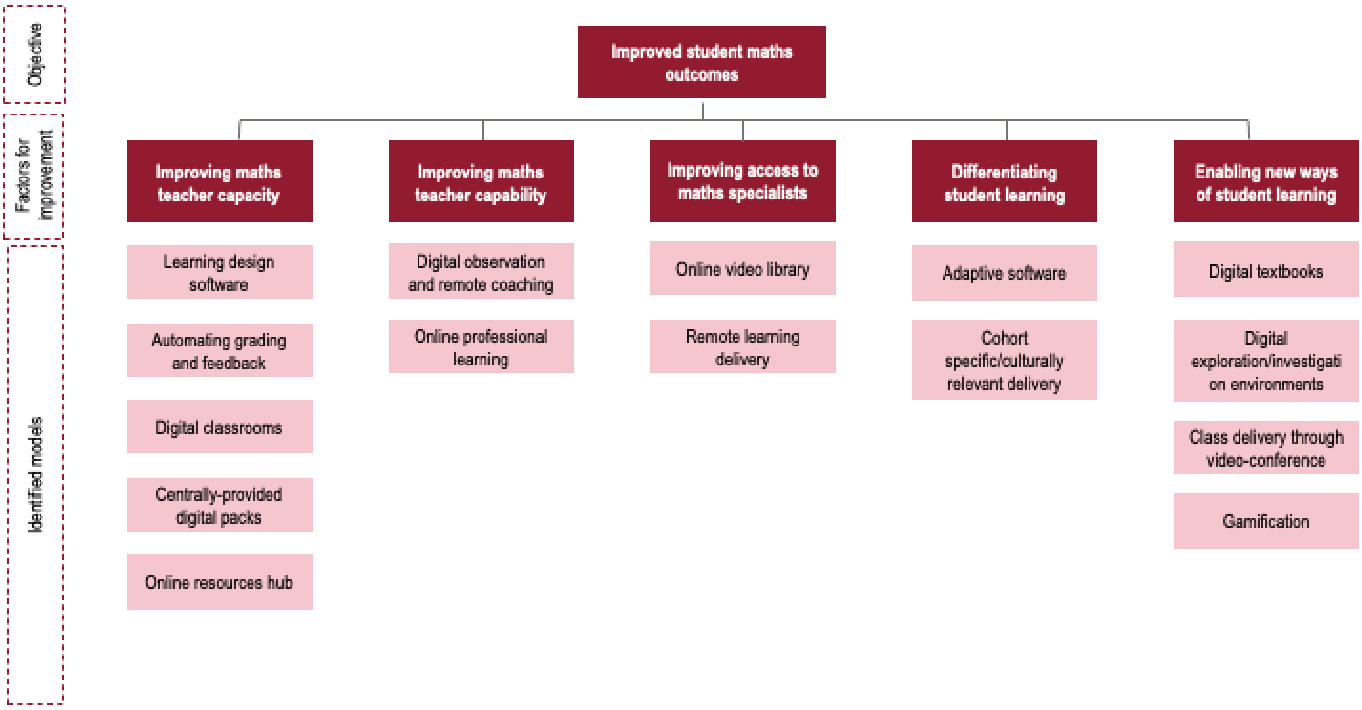
- Improving maths teacher capacity
- Improving maths teacher capability
- Improving access to maths specialists
- Differentiating student learning
- Enabling new ways of student learning.

We evaluated a range of best practice models for inclusion in the Interim Report using the following criteria:

- Innovation
- Recency
- Potential for impact
- Availability of information
- Integration
- Potential for scalability/sustainability.

The models we profiled in our Interim Report were as follows:

Figure 4: Long list of models



Alternative text: Figure 4 presents the models profiled in the Interim Report. A branching diagram represents three horizontal levels. The top level includes 'improved student maths outcomes' as an overall objective. The next level down lists the factors for improvement. The bottom layer lists the identified models beneath each of the factors for improvement. Beneath 'improving maths teacher capacity' includes learning design software, automating grading and feedback, digital classrooms, centrally-provided digital packs and online resources hub. Beneath 'improving maths capability' includes digital observation/remote coaching and online professional learning. Beneath 'improving access to maths specialists' includes online video library and remote learning delivery. Beneath 'differentiating student learning' includes adaptive software and cohort specific/culturally relevant delivery. Beneath 'enabling new ways of student learning' includes digital textbooks, digital exploration/investigation environments, class delivery through video conference and gamification.

Our Expert Panel then reviewed our Interim Report and, using their feedback, we prepared the scope for the project's Final Report. The Final Report considers use of digital technology in maths teaching more broadly (compared with the focus on online maths teaching in the rapid literature review) and focusses on three key challenges that schools face in improving students' maths performance, namely:

1. Improving maths teacher capacity and efficiency
2. Improving teacher capability and confidence
3. Differentiating student learning

The Final Report includes 'deep dive' analysis on eight of the models for technology use in maths teaching and learning that we identified in the Interim Report. These eight models were assessed by our Expert Panel to have the highest potential for contributing meaningfully to addressing one or more the three key challenges cited above and as reflecting one or more of the promising practice framework principles identified through the Literature Review.

To prepare the Final Report we completed fieldwork including:

- A discussion forum with 50 maths teachers from public, Independent and Catholic schools regarding their experience with different software products.
- Engagement and consultations with 40 teachers from the public, Catholic and Independent school sectors at a maths masterclass workshop run by the Teaching Excellence Program of the Victorian Academy of Teaching and Leadership and online discussion forum.
- Interviews with a range of vendors of digital tools for teaching and learning of maths including Swivl, IRIS Connect, Education Perfect, Mathspace, Maths Pathways, Ochre, Cluey Learning, and Desmos.
- Interviews with a range of school leaders and teachers at schools including Whitfield State School (Queensland), Haileybury (Victoria, Northern Territory, China), Melbourne Girls Grammar School (Victoria), Elisabeth Murdoch College (Victoria), Caulfield Grammar (Victoria), Mount Waverley Secondary College (Victoria), Templestowe Heights Primary School (Victoria), Aurora College (Victoria), and Armidale Catholic Dioceses (New South Wales).
- Interviews with managers of programs for digital teaching and learning of maths including the Maths Specialist Teachers (MaST) program (New South Wales), the Rural Learning Exchange, Learning+ (New South Wales), the Virtual STEM Academy (Queensland), and Solid Pathways (Queensland).
- Observations of maths lessons being delivered with digital tools at a range of Queensland primary schools.
- Interviews with members of our Expert Panel regarding research on best practice use of digital tools in maths teaching and examples of innovative practice occurring in Australian schools.
- Interviews with STEM skills policy and program staff at Departments of Education in Victoria, New South Wales, South Australia, Western Australia, Queensland and the Northern Territory.

Our 'deep dive' analysis on each of the eight models addressed target users, evidence of impact, pre-requisites in terms of infrastructure and support, success factors and areas for caution. Drawing on these deep dives, we developed a series of recommendations regarding the most promising applications of the models to tackle the three key challenges for maths education in Australia: teacher capability and confidence, student learning differentiation, and teacher capacity and efficiency. Our Expert Panel then reviewed and validated these conclusions.

3 Academic literature review on online maths teaching

3.1 Introduction

The purpose of this academic literature review was to identify and report on the available research that focuses on online learning in mathematics for primary and secondary school students in an attempt to outline key principles that could inform future online learning programs.[19]

Our intent was to understand the variety of available online learning models, defined broadly to include any digital educational material designed to be accessed outside the traditional in-person school setting.[20] The ability for educators to make use of the variety of available online programs, quickly and adeptly, requires evidence-based policy designed on a deep understanding about not only what online models are effective, but also why these models are effective (characteristics). Added to this, clarity on the contextual factors that may influence the effectiveness in specific situations is also required to ensure the evidence base is nuanced and responsive to local needs.

Educators may wonder if a program offers a full curriculum or is intended to be supplemental. Does it require synchronous or asynchronous interaction with a teacher, or is it fully automated? What kind of personalisation or adaptive capabilities does the program have? Unfortunately, many educators and administrators lack information about the critical characteristics of online learning programs, their quality and effectiveness, and the supporting evidence.[21]

Out of scope for the review were other categories of digital tools such as those supporting maths teachers' professional learning and game and simulation environments.

3.2 Methodology

3.2.1 Our approach to locating, analysing and synthesising the literature

Careful consideration was given to the type of literature review to undertake given the scope of the task and the need to maximise time available for the fieldwork stage of the project. It was determined a 'rapid review' would be the most appropriate literature review to undertake, as one of the core features of this form of review is the ability to "assess what exists about a practice issue".[22] By drawing on systematic review methods to search and critically appraise the existing literature, a rapid review would be the most rigorous, timely, and appropriate method to utilise.

The specific methods of 'rapid review' evolved due to the need for evidence-based decisions within a policy maker's time frame and have gained legitimacy in a range of fields and industries. This method is now proposed as a means of

[19] Full references in the Appendices.

[20] Sahni et al., 2021.

[21] Tosh et al., 2020.

[22] Grant & Booth, 2009, p. 100.

providing an “assessment of what is already known about a policy or practice issue, by using systematic review methods to search and critically appraise existing research”.[23]

Rapid reviews aim to be rigorous and explicit in method and thus systematic, but make concessions to the breadth or depth of the process by limiting particular aspects of the review process.[24] The methodology identifies several legitimate techniques that may be used to shorten the time frame. These include carefully focussing the question, using broader or less sophisticated search strategies, conducting a review of reviews, restricting the amount of grey literature, extracting only key variables, and performing only ‘simple’ quality appraisal.[25]

To identify, analyse, and synthesise relevant research on online models for maths and numeracy teaching in Australia and internationally, the rapid review followed a six-step process:

1. Establish the research question
2. Define eligibility criteria (inclusion and exclusion) – a key feature of a systematic review
3. Plan & execute search for empirical studies
4. Screen, select and quality appraisal
5. Synthesis of the evidence from the empirical studies
6. Develop a Best Practice Framework aligned to the factors that contribute to the success of maths and numeracy teaching models in specific contexts

3.2.2 Limitations

Curtailing the duration of the review process runs the risk of introducing bias. Limiting the time taken to search may result in publication bias. Limiting appraisal, or quality assessment, may place a disproportionate emphasis on poorer quality research, while a lack of attention to synthesis may overlook inconsistencies or contradictions. Producing the evidence within a rapid time frame must be offset against this risk of this increased bias. Documenting the methodology and highlighting its limitations is one way of militating against such biases.[26]

Important evidence may have been excluded because of the necessary constraints of the streamlined approach. The rapid evidence review adopted here has only included studies that (a) were peer reviewed, (b) were in the databases searched, (c) were written in English, and (d) reported results on student outcomes in mathematics.

In addition, the review was intentionally restricted to studies of models and programs that were implemented entirely online; many studies of hybrid programs that include both distance and in-person components were excluded during the screening stages. However, given that many students will experience a combination of in-person and remote instruction in the coming academic years, understanding the efficacy of hybrid approaches is a critical area to explore. While hybrid approaches were out of scope for this literature review, the findings of this review offer useful insights for the online aspects that occur within hybrid models of learning.

[23] Government Social Research, 2008, p. 15.
[24] Butler et al., 2005.
[25] Grant & Booth, 2009.
[26] Grant & Booth, 2009.

Another limitation for this study is the limited amount of high-quality research available focused on online teaching of mathematics. Despite many educational systems pivoting to online teaching and learning models as a response to the COVID-19 pandemic, this widespread practice did not necessarily translate into widespread definitive and rigorous research. The research team outlined four key areas to consider in relation to the limitations of this rapid review:

1. **Lack of rigorous research:** Education systems that moved to online teaching due to COVID often did this quite rapidly and understood the increased workload this placed on teachers. As a result of the complex situation, many education systems (e.g., Victorian Department of Education and Melbourne Archdiocese of Catholic Schools) paused research activities. No new research was approved, and existing research was placed on hold. This may have limited the ability of rigorous research or evaluation being undertaken on promising models that resulted from COVID lockdowns.
2. **Absence of Teacher Professional Learning:** As a result of the rapid transition to online learning and understanding the increased workload pressures placed on teachers and school leaders, many systems paused teacher professional learning. While this policy originated from an empathetic stance on teachers' drastically increasing workloads associated with the changing delivery mode, it also meant the online models that emerged were based on teachers' existing knowledge of online teaching. This may have led to the adoption of models that are not in complete alignment with evidence-based practice, but are more likely a consequence of what was viable and achievable given the extremely complex environment schools were working within.
3. **Research Design:** The rapidly evolving nature of shifting to online models during the COVID pandemic coupled with the ability for research to be responsive (i.e., the slow process of conceptualising research, gaining ethics approval and undertaking research) may have led to some research lacking customary tests of quality that we would normally explore through a systematic review. For example, we found no local randomised control trials to review.
4. **Slow Research Peer Review Process:** Despite the challenges outlined already, even if researchers were able to undertake research on online models of teaching mathematics, their research may still be caught up in the peer review process. It is common for academics and journals to currently be reporting slow peer review processes which may mean critical research is still yet to be published on this area.

3.2.3 Search strategy

Seven databases were searched to identify the key literature related to teaching mathematics online (see Appendix 2). The initial searches returned 39,494 references. After removing duplicates and screening on title and abstract, 196 references were labelled for inclusion. Of these 196 initial references, 79 studies met the inclusion criteria and were clustered into primary, lower secondary, and upper secondary studies for deeper analysis.

3.2.4 Inclusion and exclusion criteria for the rapid review

To be included in the evidence map, studies needed to meet all the following inclusion criteria:

1. *Publication Year:* We restricted our search to studies that were published between January 2020-present (date of the search was 22/04/2022). This search is intended to capture what has emerged in online teaching of mathematics since the emergence of COVID.

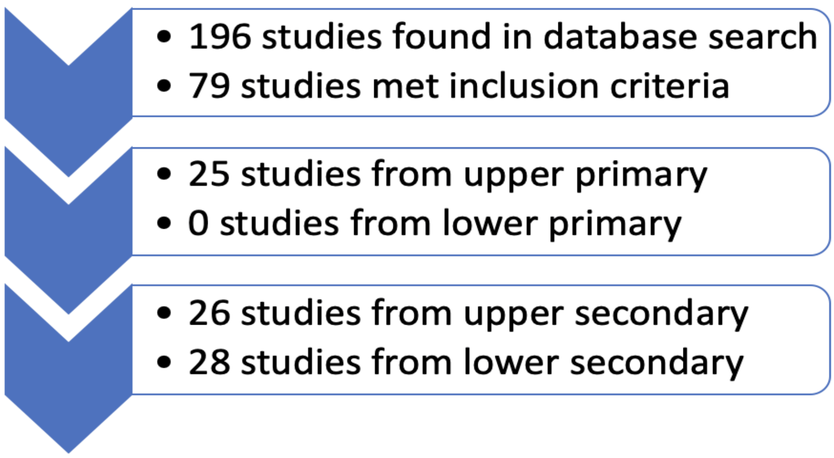
2. *Language:* Studies that are in English; exclude studies published in languages other than English. This is necessary due to resource constraints.
3. *Reporting:* Peer reviewed literature. This includes black and grey literature, such as journal articles, working papers, dissertations, extended abstracts, and public research organisation (PRO) research. Conference papers were excluded. The rationale is that short versions do not contain enough information to assess quality or to extract information about components of the intervention that support or hinder effectiveness.
4. *Intervention population:* Include studies of qualified teachers working in formal settings (i.e., primary school and secondary school). These settings can be either domestic or international. Early childhood settings will not be included.
5. *Design:* Studies of models and programs that were delivered fully online and measured the impact on student mathematics outcomes.
6. *Outcomes:* Include studies that measure pupil achievement using tests of mathematics.

3.2.5 Findings

The search and screening procedure identified 196 studies that were potentially eligible for analysis (Figure 5). Of the 196 studies, 79 were included and a secondary screening process was undertaken. This consisted of 25 studies related to primary school, 28 related to lower secondary and 26 related to upper secondary. It is worth noting there were no eligible studies undertaken specifically in Foundation to Year 2 (5–8-year-olds).

All studies were written in English, relevant to online learning of mathematics for primary and secondary students and published between January 2020 and April 2022. These were identified using searches of electronic databases, the reference lists of the literature itself, and our own and colleagues' knowledge of the literature. See Appendix 2 for search terms, databases and initial results.

Figure 5: Studies included in the DD



3.2.6 Evidence Mapping

Evidence maps involve a systematic search of a broad field, followed by the coding of the studies identified based on study characteristics. Although there are different approaches to analysing qualitative data, the approach in this review was built on the broad principles of Grounded Theory.[27] Grounded Theory is an approach to qualitative research that embraces both the rigor of 'science' and procedure, and the 'creative' elements of emergent discovery, remaining faithful to the interpretive nature of qualitative analysis.

First, three researchers undertook vertical analysis of the studies to deeply understand the key characteristics that lead to success in each individual study. This data was coded and displayed in matrices so it could be compared systematically in Phase 2.[28] Phase 2 of the analysis, the horizontal analysis, explored the comparison among the among the studies. That is, what themes were emerging among the eligible studies. The typical patterns found in the vertical analysis were compared with the other subgroups (upper primary, lower secondary and upper secondary) to discover whether a pattern in one was observed in another and to identify key differences that might exist related to age and context of the studies. This was an iterative and recursive process, where interpretations are developed, reconsidered, and modified as necessary.

3.2.7 Review of theory

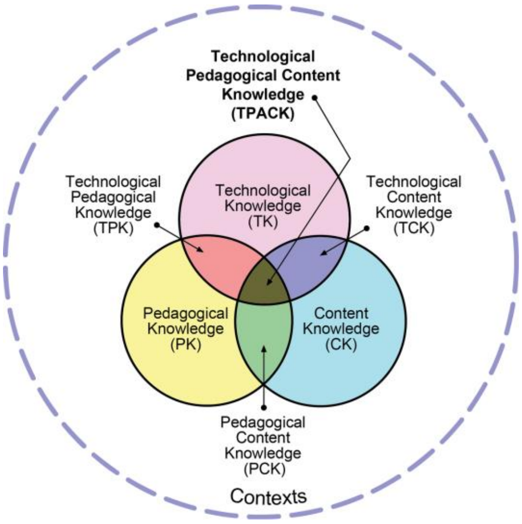
Our review of theory was intended to develop a coding frame that will be used to capture the principles from each of the included studies. This information was then used in the horizontal analysis, where principles across studies were synthesised.

Our review of theory began with the TPACK framework that can be utilised to describe the types of knowledge that teachers need to teach effectively while integrating technology.[29] The TPACK framework is based on Shulman's (1986) Pedagogical Content Knowledge model and contains seven constructs arising from the intersection of the three major knowledge constructs: Technology Knowledge, Pedagogical Knowledge, and Content Knowledge (Figure 6). The intersection of these three knowledge constructs is identified as Technological Pedagogical Content Knowledge.

TPACK can be described as an understanding of how teaching and learning changes when technologies are utilised and includes knowing the pedagogical affordances and constraints of a range of specific discipline technological tools and resources and knowing developmentally appropriate pedagogical designs and strategies.

[27] Hennink et al., 2010.
[28] Miles & Huberman, 1994.
[29] Koehler & Mishra, 2005.

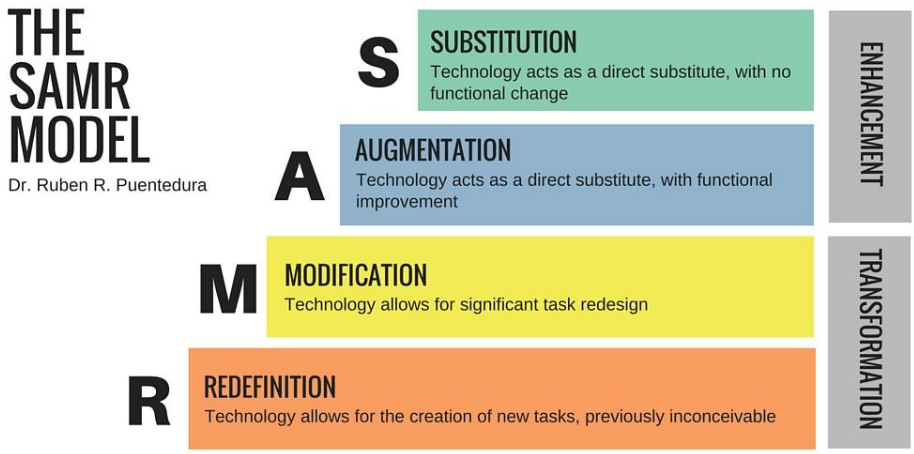
Figure 6: TPACK Framework[30]



[30] From *Wikimedia Commons*, by tpack.org (2012). (https://commons.wikimedia.org/wiki/File:TPACK-new.png). In the public domain.

An additional theoretical framework utilised to inform the coding was the Substitution, Augmentation, Modification, and Redefinition (SAMR) model (Figure 7), conceptualised by Puentedura (2006). This model describes the ways teachers can use technology in a range of educational settings. The SAMR model consists of four hierarchical levels of technology integration and use for teaching and learning. The four discrete SAMR categories are divided into two main classifications; Enhancement, which encompasses the lower levels of Substitution and Augmentation, and Transformation, which incorporates the higher levels of Modification and Redefinition.[31] The focus for this rapid review was to highlight characteristics of online teaching that would be considered in the augmentation, modification or redefinition level.

Figure 7: SAMR Model[32]



Alternative text: Figure 7 defines each of the four layers of the SAMR Model. Substitution is defined as 'technology acting as a direct substitute, with no functional change'. Augmentation is defined as 'technology acting as a direct substitution, with functional improvement'. Modification is defined as 'technology allowing for significant task redesign'. Redefinition is defined as 'technology allowing for the creation of new tasks, previously inconceivable'.

3.3 Findings: Towards a promising practice framework

Through analysis of the 79 studies included in the rapid evidence review the research team was able to establish important principles that emerged across the studies. In the following sub-sections, each principle will be outlined to give insights into how it was implemented, a brief explanation about the research base aligned to each principle, and finally some practice examples to highlight how the principle could be implemented in classrooms.

3.3.1 Key principles of online learning in mathematics from Year 3 – Year 12

The analysis identified six principles for teaching online mathematics. These are outlined below, in no particular order.

Principle 1: Minimise cognitive load through coherent learning resources

[31] Hand, 2016.

[32] From *Wikimedia Commons*, by Puentdura (2006). (https://commons.wikimedia.org/wiki/File:The_SAMR_Model.jpg#/media/File:The_SAMR_Model.jpg). In the public domain.

The core of any online learning is the learning resources provided by teachers to students. Learning resources refer to the digital learning materials (readings, slides, images, websites, audio, videos) provided to students, as well as the learning and assessment tasks designed for students (what they do with the materials).

The critical thing to keep in mind when it comes to learning resources is that they are coherently organised for students over the weeks of the course. There must be a predictable pattern for students and parents, especially at the primary school level. That is, there needs to be a coherent logic or narrative to what materials are introduced when, and what individual or team-based activities go with what resources. It is also important that these materials and activities are aligned with the identified mathematics learning outcomes.

The literature did not highlight an overly technological approach to the development and use of online learning resources. Many of the effective online programs were supported by relatively modest digital resources. What was clear is the learning resources followed a consistent logic across a week, or unit of study, that enabled students to focus their intellectual resources on the mathematics they were engaging in, rather than trying to understand how to locate required digital learning materials.

Evidence base for cognitive load:

Two main theories describe students' multimedia learning. One is the cognitive theory of multimedia learning (CTML)[33] and the other is cognitive load theory (CLT).[34] Both theories are related to the limitations of working memory. Working memory capacity determines how students select information, and information selection is associated with sustained attention. CTLM explains interactions between pictures and text on students' learning,[35] whereas CLT outlines three categories of instructional design to reduce students' working memory load, including extraneous, intrinsic, and germane cognitive load.[36] Within the context of this study, it was apparent that organising learning material in a logical manner could help manage the cognitive load of students as they worked within an online environment.

Practice examples:

- Explicitly teaching students how to navigate online resources and outlining how different learning materials can be used
- Outlining the weekly tasks required to be undertaken
- Utilising frameworks for learning such as the Gradual Release of Responsibility to inform the logic of learning resource design.[37]

Principle 2: Establishing an online presence through clear, regular communications

An important component of clear communications is being very particular about instructions provided to students about the learning and assessment activities they are required to undertake. While educators may constantly do this in face-to-face learning, teaching in an entirely online mode tends to place more pressure on clearly communicating these

[33] CTML, Mayer, 2014.

[34] CLT, Paas & Sweller, 2012.

[35] Mayer, 2014.

[36] Paas & Sweller, 2012.

[37] The gradual release of responsibility framework suggests that cognitive work should shift slowly and intentionally from teacher modeling, to joint responsibility between teachers and students, to independent practice and application by the learner. Cimino, M. (2018). Synthesising the flipped classroom with the gradual release of responsibility model. *Australian Educational Leader*, *40*(1), 40-42.

instructions as they might be misinterpreted without the clarification that would usually take place in face-to-face learning. The way this practice was implemented was varied across the studies (oral, written or video) and was effective synchronously or asynchronously.

Evidence base for establishing teacher presence:

Through deeper analysis of theme 'establishing teacher presence in an online environment', it became apparent this characteristic was closely aligned to the research related to teacher clarity[38] and teacher expectations.[39]

Fendick (1990) defined teacher clarity "as a measure of the clarity of communication between teachers as students in both directions".[40] This was further described across four dimensions: clarity of organisation, clarity of explanation, clarity of examples and guided practice, and clarity of assessment of student learning. Key aspects of establishing your online presence are connected closely the clarity of communication, explanation, guided practice, and assessment. Added to this, the evidence base for establishing an online presence is also aligned with the research on teacher expectations that is known to have a powerful influence on student achievement.[41] Teacher expectations is about establishing and using regular communication channels with students (and parents). In the studies analysed, this appeared to be critically important in an online learning environment to ensure students had a clear sense the teacher was present and available as an ongoing support. This may be even more important when students were working remotely due to lockdowns and possibly feeling more isolated in their learning than would normally be the case.

Practice examples:

- Have an 'announcements' process where you can regularly broadcast messages to all students about expectations
- Use brief asynchronous instructional videos that students can view to clarify expectations
- Build person-to-person interaction into your learning design with the intention to clarify lesson and weekly expectations

Principle 3: Utilise peer support to build an online community

Peer support enables the development of social and academic skills by encouraging collaborative behaviour and active participation in learning. It is commonly used in Direct Instruction and many other teaching models, both as part of teacher instruction and for structuring group activities.

Peer support can take on many forms and requires students to practise and refine negotiating, organising, and communication skills. It may require students to define issues and problems or ask them to develop ways of solving problems, including collecting and interpreting evidence, hypothesising, testing, and re-evaluating.

Interestingly, remote learning due to COVID restrictions may have limited peer support between students, and as a result classrooms that included peer support in their learning design may have felt more authentic for the students involved. That is, students value the interactive nature of face-to-face learning and appreciated the opportunity to engage in this in the online space. Students often appreciated the opportunity to work with peers and expressed that peer explanations

[38] Fendick, 1990.
[39] Hattie, 2009.
[40] p.10.
[41] Hattie, 2009.

were often clearer and more comprehendible than teacher explanations. There were examples of peer support in both asynchronous and synchronous environments. For example, using an asynchronous discussion to build deeper understandings of concepts through collegial discourse.

Evidence base for peer support:

Substantial evidence exists that active and collaborative approaches result in better learning outcomes for students than occur when students are taught in more teacher-centred classrooms.[42] Positive student gains from engaging in peer collaboration can include improved understanding, confidence, and persistence, as well as increased willingness to seek help or consider different perspectives.[43]

The acquisition of domain specific language is acknowledged as a fundamental part of learning mathematics.[44] Doerr and Lerman (2010) describe communication as the driving force behind all learning. Their four-year study provided insights into the role of speaking, writing, and reading within mathematics teaching and learning. Research has noted that as students become more precise in their language use, they equally become more precise in their mathematical concept-based understanding.[45] The teacher scaffolding collaborative discussion leading to this higher 'quality' of talk has become known as a 'dialogic' approach to teaching and learning.[46] The dialogic nature of building an online community where peer-to-peer support and interaction are explicitly involved seems to be an important consideration, particularly for the studies focused on primary schools.

The use of social media as a learning environment has been found to bring about many opportunities, such as encouraging peer collaboration, informal learning and student autonomy,[47] providing ease of communication with instructors,[48] and promoting collaboration between instructors and students.[49] Finally, in relation to problem solving, Perry, et al. (2021) suggest that collaborative problem solving, supported by worked examples with incomplete knowledge can have a positive impact on student outcomes.

Practice examples:

- Provide opportunities for students to collaborate with different users by using breakout rooms and include clear expectations for academic conversations
- Use collaborative tools (e.g., Padlet) to allow students to share their ideas and receive feedback
- Utilise online forums (e.g., Discord) to enable communication and sharing of documents among students
- Provide opportunities for collaborative problem solving

Principle 4: Develop conceptual understanding through multiple representations of mathematical concepts

Benefits related to the use of technological devices in the teaching and learning of mathematics in online environments are often related to the use of multiple representations in promoting student learning and conceptual understanding.

[42] Fairweather, 2008.
[43] Laursen et al., 2014.
[44] Symons & Dunn, 2019.
[45] Ibid.
[46] Alexander, 2006.
[47] Bingham & Conner, 2010; Collins & Halverson, 2010.
[48] Denker et al., 2018.
[49] Harper, 2018.

Conceptual understanding refers to an integrated and functional grasp of mathematical ideas. Students with conceptual understanding know more than isolated facts and methods. They understand why a mathematical idea is important and the kinds of contexts in which is it useful.[50] They have organised their knowledge into a coherent whole, which enables them to learn new ideas by connecting those ideas to what they already know.[51] Using a variety of online tools, students are able to work dynamically with objects, and represent mathematical concepts, procedures, and data in multiple ways.

Evidence base for multiple representations:

As identified by Jonassen (1999), the provision of multiple representations of reality is a characteristic of an effective mathematics classroom. By moving between the concrete, pictorial, and abstract representations, underpinned by purposeful and intentional use of language, students are far more likely to develop the facets of understanding as described in the curriculum.[52]

The multiple interpretations of the basic operations are symptomatic of a general feature of mathematics, the tension between abstract and concrete.[53] This tension is a fundamental and unavoidable challenge for the way mathematics is taught in school. On the one hand, the abstractness of mathematics is an important reason for its usefulness: a single idea can apply in many circumstances. On the other hand, it is difficult to learn an idea in a purely abstract setting; a concrete interpretation must usually be used to make the idea real.[54]

With reference to education at the high school level, many qualitative studies have focussed on the affordances offered by technology to support students' discovery through visualisation and manipulation of representations of mathematical objects (e.g., Hollebrands & Okumus, 2018; Robotti & Baccaglini-Frank, 2017). Such learning processes can involve the generalisation of mathematical concepts through the manipulation of digital artifacts (e.g., Antonini et al., 2020; Santi & Baccaglini-Frank, 2015) to support student understanding. Multiple representations can be a powerful tool for supporting students to engage with mathematical ideas when used purposefully in classrooms.

Practice examples:

- Solve equations using virtual manipulatives
- Solve problems using more than one representation register
- Utilise open-ended questions and encourage students to describe answers using complementary representations

Principle 5: Using worked examples to scaffold student learning

One of the key features of any effective learning design is the ability to be able to model and explain key knowledge and skills that students are expected to exhibit. A key principle from cognitive science is that students learn effectively by studying a series of completed worked examples of problems and gradually fading the scaffold towards independent practice. The rationale for this is that cognitive load is reduced if students are able to learn the method separately from attempting to apply it to a particular problem. Worked examples were used to demonstrate the steps required to

[50] Kilpatrick et al. 2001.
[51] Fennema & Romberg, 1999.
[52] Kilpatrick, et al. 2001.
[53] Stewart, 1989.
[54] Kilpatrick, et al. 2001.

complete a task or solve a mathematics problem. By scaffolding the learning, worked examples support skill acquisition and reduce a learner's cognitive load.

In mathematics, a worked example is introduced by carefully working through the example to produce a model answer. It is important to acknowledge that in face-to-face learning the use of a worked example is usually an interactive experience where the teacher not only models key aspects of the task, but also talks through the steps they are undertaking and cues students into these key processes, while also checking for student understanding. As student understanding increases through a sequence of learning experiences, the teacher may introduce partially worked examples for students to complete, before moving to fully independent practice. Worked examples were used in a variety of different ways in the studies analysed and ranged from synchronous learning experiences, similar to what would normally occur in a classroom, to asynchronous videos students could view in groups or independently. It should also be noted that teachers utilised worked examples, and partially worked examples, to support a fading technique moving from guided to fully independent practice.

Evidence base for worked examples:

Hattie (2009) contends that worked examples are most effective when the teacher explicitly teaches the steps taken to complete the worked example, and when learners use self-explanations to describe the steps to themselves and others.

The evidence suggests that scaffolds, guidance, or schema-based supports effectively support students to solve problems or learn from complex tasks.[55] Utilising worked examples in an online learning environment appears to be in alignment with face-to-face learning and suggests that as learners develop knowledge, only partial supports are required, which supports the fading technique observed in the studies analysed.

Practice examples:

- Teacher modelling fully worked examples in synchronous sessions (i.e video, document camera, other visual software)
- Short asynchronous video recording of the teacher modelling key aspects of a task or problem
- Using partially worked examples to support collaboration and checking for student understanding

3.3.2 Specific considerations for teaching mathematics online for secondary school students

Principle 6: Socially regulated and self-regulated online learning in mathematics

Self-regulated and socially regulated online learning influence students' learning achievements and behaviours in mathematics. Two Taiwanese studies focusing on mathematics teaching in the secondary years point to the positive effects of employing online approaches which provide access to other students' learning strategies and students mutually monitoring each other during the study process.[56] A third study pointed to key design features such as short video lessons which include worked examples and problem-solving as having a positive effect on senior students' attention and engagement.[57]

[55] Perry et al., 2021.
[56] Hwang et al., 2021; Tzu-Chi, 2020.
[57] Li et al., 2022.

However, it should be noted that instructional practices related to self-regulated learning in the primary context were not as positive. Torrington and Bower (2021) explored a possible reason for issues with self-regulation in primary school students could be linked to students being overconfident in their ability. This would align with research on expertise that highlights novices often overestimate their ability making independent self-regulation difficult to undertake.[58]

Principle 7: Supporting student self-efficacy and adaptability

An Australian study explored the importance of student adaptability as a key factor, along with online learning support, in enhancing student self-efficacy and achievement. The study undertaken by Martin et al. (2021) involved 1,548 Australian high school students (in Years 7 to 10) from nine schools and examined the role of adaptability in predicting students online learning self-efficacy in mathematics and their end of year achievement. The authors define adaptability as the capacity to regulate one's behaviours, thoughts, and feelings in response to novel, variable, uncertain and unexpected situations, and circumstances.

Interestingly, higher levels of help from parents at home were associated with lower end of year achievement. This may be explained by the fact that struggling students may be more likely to seek help from parents. This suggests the importance of understanding the nature of and impact of parental involvement. Additional research is needed to explore diverse dimensions of parental involvement in their children's schoolwork during the pandemic and whether this involvement is a help or a hindrance.

Adaptability can be further enhanced when students share learning goals and strategies and discuss learning strategies with other students. In the previously cited study, Hwang et al. (2021) also found that with access to peer support students were more likely to review incorrectly answered questions, read supplementary materials, and make notes of their own. These strategies show how students can adapt their behaviour, thinking and emotion to navigate new and different circumstances; and to recognise the benefits of these personal adjustments.

3.4 Student academic achievement and low socio-economic status

In one of the few Australian studies reporting on how academic achievement of students was affected by the prolonged lockdowns, Gore et al. (2021) in a study of NSW primary school students concluded that "speculation about alarming levels of learning loss for all students has not been demonstrated, arguing that most students are "where they are expected to be".[59] This reassuring reference to "most students" should not distract attention from clear evidence of the adverse effects of the lockdown on the achievements of students from low SES families and other disadvantaged groups.

In the USA, for example, academic achievement of students from low SES families and students from black and Hispanic families was shown to be adversely affected by the shift to online learning. A study, jointly carried out by the Center for Educational Policy Research at Harvard University and the National Center for Analysis of Longitudinal Data in Educational Research,[60] examined testing data from 2.1 million students in 10,000 schools across 49 states. Researchers examined the impact of remote and blended instruction during the pandemic in widening gaps of

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[58] Dunning, 2011.

[59] p. 605.

[60] Goldhaber et al., 2022.

educational achievement. Analysing the results by race and school poverty, they found that remote instruction was a primary driver of widening educational gaps. For example, in low SES schools in the USA that transitioned to online learning for more than half of 2021, there was a loss in achievement equivalent to half a school year. In other words, students in these schools tended to fall further behind. The challenge for high poverty school districts will be how to close the widening achievement gap caused by the pandemic.

This finding is supported by Gore et al. (2021) who make the telling point that:

> "It is worth highlighting that our finding of two months' less growth in mathematics in less advantaged schools was associated with a remote learning period of around two months. In contexts where schools were closed for much longer periods (such as in Victoria, the United States, and many European nations), research is urgently needed to understand and ameliorate the effects of COVID-19 on the learning of vulnerable students."[61]

In Australia, this urgently needed research could be undertaken using NAPLAN results before and after lockdown, with particular examination of the impact lockdowns had on the mathematics achievement of students in low ICSEA (ICSEA<950) schools.

3.5 Conclusion

Learning is the process by which we acquire new knowledge, skills or behaviours and underpins all aspects of education. Understanding how the learning process occurs effectively in online delivery is essential for developing new learning strategies in a targeted manner. One of the key considerations throughout the rapid evidence review was to determine how online learning of mathematics aligns and differs from what we already know about effective face-to-face instruction.

It is important to acknowledge that all the characteristics identified in the findings section aligned closely with what we already know about effective mathematics instruction. As outlined, all key principles can be linked back to an established evidence base about how students learn. As such, it would be prudent to explore other 'high probability' instructional practices that support improved student outcomes.[62] For example, understanding how to undertake instructional practices in an online learning program through key evidence-based practices such as: short cycle formative assessment, retrieval practice, and checking for understanding techniques appears to be a knowledge gap where further research is needed.

In addition to research on how general pedagogical techniques could be used to effectively teach mathematics online, it is also essential to see how proven pedagogical practices in mathematics, Pedagogical Content Knowledge (PCK), translate to fully online models of learning. It would also be prudent to acknowledge it is anticipated that students may be required to revert to online learning within a context of high stress and uncertainty arising from future circumstances that may cause 'business as usual' to cease. It seems logical to design online learning experiences that consider the social and emotional aspects of learning as well as the academic.

[61] p. 632.

[62] Hattie, 2009.

One of the key analytic frames for this rapid evidence review was to consider contextual factors related to online learning of mathematics. While the review closely looked for evidence relating to contextual factors such as socio-economic status, rural, remote, regional, gender, and students with additional needs, there was a paucity of evidence related to these contextual factors in the international literature.

While predicted by many educational researchers,[63] the lower growth in mathematics for Year 3 students in Australian schools might be explained by the greater challenges faced by families in disadvantaged circumstances who are likely to have been disproportionately impacted by the pandemic.[64] In contexts where schools were closed for extended periods (such as in Victoria), research is urgently needed to understand the effects of COVID more deeply on the learning of vulnerable students. Likewise, Mukaka et al. (2021) found that in Africa students living in non-urban settings experienced more difficulties accessing remote learning during the COVID school closure. As a result, students needed enhanced teaching support after returning to school. However, our analysis did not identify examples of rural, remote and regional students' experience in Australia.

Through analysis of the international literature, it has become apparent that many educational jurisdictions are currently exploring how online learning will become an ongoing aspect of how they operate. For example, the New York City Department of Education decided that online learning will be used on snow days and other traditional days off such as Election Day.[65] From 2021, all secondary school students in Singapore will have up to two days per month of online learning (which can take place in school or at home), having been provided with digital learning devices which are connected to the internet.[66] An extension to the primary school sector is being studied. These online learning days can provide teachers with further opportunities to trial and assess online pedagogies.

In the current Australian context, it is foreseeable that schools may increasingly be required to pivot to online learning because of more extreme weather events, such as flooding and bushfires, that have been ever present over the last few years. This research is important as if the need arises in the future, educators may pivot back to online learning to maximise instructional time for students. It also highlights those online models, used in situations such as extreme weather events, will need to have inbuilt mechanisms to support social and emotional learning due to the nature of when they will be drawn upon. It appears that regardless of the current pandemic's longevity, fully online models of learning are likely to continue to be used by educators for a variety of reasons in the future.

Supporting teachers to have a consistent experience with online pedagogies in mathematics, such as the New York City and Singapore examples, would ensure their expertise within this area is continually being developed. Teachers should be able to contribute to policy related to how and when technological devices are used and should be involved in the development of instructional goals.[67] As Andreas Schleicher (2022) noted in his recent presentation on digitisation and inclusion in education, 'where teachers are not at the heart of design they cannot help with implementation'. Highlighting the importance of partnering with teachers to design effective and pragmatic solutions is particularly important for Foundation to Year 2 where there was no literature to inform practice principles.

[63] Brown et al. 2020; Schleicher 2020; Sonnemann & Goss 2020.

[64] Institute for Social Science Research [ISSR] 2020.

[65] Cramer, 2020.

[66] National Center on Education and the Economy, 2021.

[67] Hill, 2022.

One of the strong features of current research into online teaching during the pandemic has been its focus on students' engagement and achievement. By comparison, there has been a paucity of research on the challenges faced by teachers and their role in supporting students' online learning. As teachers faced – and will continue to face – *novel, variable, uncertain and unexpected situations and circumstances*, teacher self-efficacy and adaptability have been under researched in this context. It is widely recognised in the teacher learning literature the need to support teachers to be 'adaptive experts'.[68] Treating teachers as implementers fails to recognise how quality online teaching needs to be cultivated and shared in these novel situations. This remains a key task for ongoing research and for teacher professional learning.

The review did reveal several online learning principles education stakeholders should consider, with regard to their situation and context. Equally important, it found that online learning currently requires much greater investment, study, and rigorous evaluation to fully understand how it can be implemented in a range of contexts and student populations. Through increased resources and a greater understanding of the existing evidence on effective remote learning models, systems may be able to decrease the burden placed on education practitioners as they grapple with an instructional landscape that has shifted dramatically in an extremely short space of time. This is a critical knowledge gap that needs to be explored to ensure we can continue to better support Australian students now and in the future.

[68] Dunn & Hattie, 2021; Wetzel et al., 2014.

4 Introduction – Deep dive analysis of eight technology models

The eight models for use of digital tools for maths teaching and learning on which we have undertaken deep dive analysis are outlined in Figure 8 below.

Figure 8- Models for Deep Dive Analysis

Model for Deep Dive	Description
Maths lesson plan libraries	Providing maths teachers with high quality, curriculum-aligned lesson plans to increase the effectiveness of their classroom teaching and to reduce their preparation time for teaching each unit.
Digital observation and remote coaching	Teachers record their lessons for self-reflection or to share with professional development coaches. Coaches can be remote or in-person to pair less confident or experienced maths teachers with experienced maths teachers.
Remote learning delivery	Using video conference technology, experienced maths teachers can reach students that do not have access to local maths experts. Video conference technology can also be used to group students from multiple schools in virtual classes to receive maths teaching.
Online tutoring for students falling behind	Students are provided with one to one (or in some cases, small group) online tutoring sessions with qualified maths teachers familiar with the Australian Curriculum. These sessions are additional and complementary to in class maths learning.
Fully featured teaching and learning platforms	Fully featured teaching and learning platforms are software products providing comprehensive and integrated libraries of maths exercises, lessons and/or videos for students. They also provide automated grading and individual or cohort analytics for teachers and maths departments.
Digital exploration, investigation & game environments	This model encompasses platforms that use contemporary graphics, visualisation tools, mini-games or play-based interactions to develop understanding and proficiency with maths concepts, both simple and complex. These can be maths-specific platforms – such as Desmos or Prodigy – or more general play based platforms that encourage the use of maths concepts – such as Roblox or Minecraft.

Cohort specific culturally relevant maths content and lesson plans	Digital teaching tools that are designed to use culturally relevant pedagogies to engage and improve student outcomes in maths for culturally and linguistically diverse students.
Teacher recorded worked examples	Teachers using a touchscreen device and screen recording software to share demonstrations of worked examples to individual students or cohorts of students with similar misconceptions or learning challenges.

Models were initially identified through our literature review and environment scan, then refined down to these eight based on the below criteria developed in consultation with our expert panel and stakeholders.

Figure 9 - Detailed description of criteria for selection of the models for deep dive analysis

Criteria	Details
Innovation	A model must be sufficiently innovative to be considered for a deep dive. Using the SAMR model, to be considered innovative a model would need to fall under either Augmentation, Modification, or Redefinition.[69] This is because Substitution models do not use technology in ways that will significantly improve student outcomes, in comparison to the traditional practice. We have weighted the innovation criteria more heavily in our assessment of models because innovation is central to the purpose of this project.
Recency	The model must have been implemented within the last several years, and preferably have come to prominence during the COVID pandemic. We want to examine models that were either implemented during COVID or came to prominence during COVID.
Potential for impact	The model must demonstrate a potential for impact, including by addressing general principles of best practice in digital maths teaching identified by MGSE's literature review: • Minimise cognitive load through coherent learning resources • Establishing an online presence through clear, regular communications • Utilise peer support to build an online community • Develop conceptual understanding through multiple representations of mathematical concepts • Using worked examples to scaffold student learning

[69] More detail about SAMR model in Academic Literature Review- Methodology.

	For models working with secondary students these specific principles will also be considered: • Socially regulated and self-regulated online learning in mathematics • Supporting student self-efficacy and adaptability
Availability of information	There must be sufficient information available about the model in the literature and/or that we can collect through fieldwork.
Integration	The model must ideally be integrated within school practice and/or at a system level. There also must be alignment with the Australian Curriculum and it should be easy for teachers to use.
Potential for scalability/sustainability	The model must have potential for sustainable implementation and scale-up. The scope of this project is to investigate models which can be rolled out Australia-wide. As such, models that are not suitable for a larger scale or are difficult to implement will not be considered. In addition to this, we are looking for a diversity of models to suit different Australian contexts.

The structure we have employed for each deep dive below is:

1. Model summary
2. Which of the three key challenges does the model address?
3. How does the model work?
4. Examples of use
5. Impact – What evidence exists on the contribution of the model to addressing key challenges for maths teaching?
6. Level of use – What is the extent of adoption by maths teachers?
7. Target groups – Which cohorts of students or teachers is the model designed for?
8. Cost
9. Success factors
10. Caution factors
11. Environment and infrastructure pre-requisites
12. Opportunities and implications for the Australian Government

5 Deep Dive 1: Maths lesson plan libraries

5.1 Model summary

Providing maths teachers with banks of high quality, curriculum aligned lesson plans to increase the efficacy of their classroom teaching and to reduce their preparation time for teaching each unit or topic.

5.2 Which challenges does the model address?

5.2.1 Teacher capability and confidence

Teachers with limited experience or confidence in maths teaching can struggle with understanding maths topics and the optimal way to teach them in response to their students' learning context. Teachers in these circumstances may rely on other teachers or resources to support their teaching. We heard that when teachers are less confident with content, they may over-rely on the traditional chalk-and-talk method and textbooks in order to minimise the opportunity for classes to deviate into subjects on which they are not confident.

For maths teachers, textbooks can provide content and teaching support such as exercises or explanations. Teachers that are less confident or experienced can use textbooks to guide their teaching content and practice. System level stakeholders told us that at the primary school level there is a greater challenge for less confident or experienced teachers as there are very few textbooks available to help teachers scope and scaffold the curriculum. 60% of secondary teachers recently surveyed said they lacked resources to support their teaching.[70] As a result, teachers often must come up with their own lessons plans, requiring substantial research and preparation time.

5.2.2 Teacher capacity and efficiency

The practice of each teacher having individual responsibility for designing their own unique lessons for each class they teach places a heavy burden of preparation on to the profession. This preparation time can be extremely taxing and we heard that it is particularly so for less experienced and out-of-field maths teachers.

- A recent Grattan Institute survey found that almost all teachers (92%) said they 'always' or 'frequently' do not have enough time to prepare for effective teaching.[71]
- A UK survey found most teachers spend between one-to-three hours online each week looking for resources. Almost half of primary teachers say they need to plan a lot of lessons from scratch.[72]

Whilst access to a customisable bank of curriculum aligned lesson plans does not eliminate the need for preparation if the teacher is to align lessons to their students' needs and learning context, it does offer a material reduction in the time required to do so effectively.

[70] Oxford University Press, Solving the knowledge and skills gap in Australian secondary mathematics classrooms.
[71] Grattan Institute, Making Time for Great Teaching: How Better Government Policy Can Help, 30 January 2022.
[72] Ibid.

5.3 How does the model work?

Maths lesson plan libraries provide teachers with an online resource bank they can draw upon to prepare their classes. Typically, the libraries include the following features:

- **Scoped and sequenced to the Australian Curriculum year levels –** Most lesson plan libraries are structured to align with the Australian Curriculum or offer rubrics to explain where each lesson plan fits into the Australian Curriculum.
- **Quality assured lessons –** Lesson plans have usually been prepared by groups of highly experienced maths teachers, with peer review to ensure quality.
- Lesson plans include **formative assessments** including starter quizzes and worksheets for maths.
- **Lesson plans and resources are customisable by teachers** – Most libraries allow teachers to access editable versions of each plan so that they can add, remove or edit content to align with class learning context.
- **Videos of lessons being taught accompany each lesson plan** – Some libraries provide videos with each lesson plan showing an experienced maths teacher delivering a class using the plan which provides role modelling of how to present the content to the year level it is designed for.

Examples of maths lesson plan libraries include Ochre and lesson plan libraries built into fully featured teaching and learning platforms such as Atomi, Education Perfect, Mathspace and Maths Pathway.

5.3.1 Ochre

Ochre provides free, adaptable online resources created by expert maths teachers. The resources are aligned to the Years 2-6 Australian Curriculum and follow evidence based pedagogical principles which are outlined on the site. Resources are sorted by year level and include:

- A starter quiz
- Lesson videos by an infield teacher or expert
- Worksheets for students
- An exit quiz

Ochre is designed to fit within an existing school program and provide content to fit a full lesson length of one hour. Ochre products can also be used for homework, consolidation, catchup and as an equitable replacement to private tutoring. We heard from Ochre that there is a strong quality assurance process before materials are published, with a pedagogical underpinning for each lesson.

Ochre leadership claims the following benefits:

- **Differentiation -** Materials are editable to allow teachers to tailor their teaching content to students' level of progress. There are differentiated activities built into lessons, materials and videos.

- **Explicit instruction and evidence-based informed pedagogical approach** – Ochre's pedagogical approach was developed in conjunction with the Australian Education Research Organisation (AERO). It tests student content knowledge at the start of each lesson and teaches in small steps while checking for understanding along the way.
- **Low variation resource –** Ochre resources use consistent terminology and ways of representing numbers to build teachers' and students' confidence with the knowledge base cohesively over time.
- **Process coherence -** The coherence between lessons builds subject area expertise for less confident teachers.

Ochre was launched in February 2022 in conjunction with the Australian Education Research Organisation. It is based on the Oak National Academy in the United Kingdom which is in use in 24,000 schools and has early-stage evidence:

- An independent evaluation by ImpactEd in 2020-21 reported that:[73]
  - 61% of teachers using Oak said that it saved them time, compares with 24% who said it added time to their job.
  - Teachers who used Oak also had a statistically significant higher wellbeing score than non-Oak users.
  - Oak users identified a statistically significant higher proportion of pupils rated as exceeding expectations than non-Oak users, particularly in primary schools.
- In the first 3 months of 2020-21, teachers delivered 20 million lessons using Oak resources. Nearly 40,000 UK teachers currently rely on Oak each week with Oak being known to 97% of teachers.

5.4 Examples of use

5.4.1 Catholic Diocese of Armidale – MaST teachers

The Catholic Diocese of Armidale are running a pilot called Maths Specialist Teachers (MaST). The pilot placed MaSTs in 12 schools across the Diocese of Armidale. These MaST teachers are maths subject matter experts and provide curriculum support and co-teaching for all maths teachers in their schools. They provide modelling for teachers and professional learning support.

The Diocese provides MaST teachers with content written for every unit of work in the Curriculum. The content is created by the Diocese maths team and provides a range of resources that are varied and aimed at engaging students. For example, there are storybook pictures about maths. The activities are available for the K-10 New South Wales syllabus (which aligns with the F-10 Australian Curriculum) and provides differentiation for different student levels. These resources are distributed via Google Drive.

MaST teachers use these resources to support teachers in their schools. The Diocese also provides professional learning for MaSTs weekly to support them in their schools.

Ochre - Victorian Primary School

[73] ImpactEd, Oak National Academy: 2020/21 Evaluation Report, July 2021.

We spoke to a Learning Specialist located at a Victorian primary school that uses Ochre. Ochre has been used by some teachers at the school and, going forward, will be included as a core resource for the whole school.

We heard that using Ochre saved teachers a lot of time in scoping, sequencing and creating lesson plans and having Ochre replaced the need to "reinvent the wheel" each time. Teachers also used Ochre lesson content for students who missed a significant amount of school time due to illness. They were able to share access to Ochre lessons and resources (including videos of the lesson being taught) with parents at home to help the student keep up to date with class work and / or catch up on content they have missed.

We heard that the fact that Ochre lessons were quality assured by 14 leading teachers across all schooling systems and reflected the input of teams of experienced teachers was highly important to teacher users.[74] The starter quizzes provided also allowed teachers to confirm that students understood what they were being taught. The customisable resources of Ochre slide decks and videos were also useful for teachers as they could add or remove content as they needed.

We also heard from teachers reflecting on the COVID teaching experience that had Ochre been around during the extended lockdown periods, it would have been a very helpful resource. We heard that maths was the hardest subject to teach remotely as it requires a lot of hands-on teaching for individual students. The Ochre model, however, showed that more explicit teaching using Ochre meant that hands-on teaching wasn't always needed.

5.5 Target groups

Online lesson plan libraries can be used by any teacher, though they are particularly effective in supporting primary school teachers, out of field teachers, early career and inexperienced teachers, or teachers with limited access to professional networks.

Lesson planning and implementation of the curriculum is one of the key areas of teaching in which graduate teachers report being less effective.[75] This model supports teachers that struggle with how to implement curriculum in engaging lessons as it provides pre-created content from maths experts.

Teachers with limited access to professional maths networks, such as some rural, remote or regional teachers, can use lesson plan libraries to supplement their teaching by accessing high quality resources that other teachers may access through their professional networks.

5.6 Level of use

We heard from interviews with system level stakeholders that uptake of maths lesson plan libraries among secondary school teachers is quite strong with a substantial share of high resource secondary schools subscribing to fully featured teaching and learning platforms with large libraries of lesson plans, typically used in conjunction with textbooks and maths departments' own resource collections.

[74] https://www.edresearch.edu.au/articles/aero-and-ochre-education-launch-free-teaching-resources-help-return-school.

[75] Mayer et al., Studying the effectiveness of teacher education: final report, 2015.

It appears that primary school teachers are less commonly using maths lesson plan libraries, typically because their schools do not subscribe to the various commercial providers in this space. The recently launched Ochre library which targeted primary school teachers attracted strong interest. Ochre reports that it has been used by around 6,000 teachers in the first 6 months of operation, with the following breakdown by year level:

Figure 10 - Number of Ochre users by year level

Year level	Number of unique users (since June 2022)
2	713
3	2,294
4	1,051
5	937
6	962

As reported above, the similar Oak National Academy lesson plan library in the UK, which was launched in April 2020, is now used by approximately half of teachers in that country.

5.7 Cost

Both Ochre and the Oak National Academy are provided at no cost to users.

Commercially provided maths lesson plan libraries typically charge on a per student per year basis. Pricing is usually substantially less than the recommended retail price (RRP) of hardcopy maths textbook costs at the same year level. The cost varies by provider, year level and school sector and can vary with the mix of features and functionality purchased. (See Fully Featured Teaching and Learning Platforms-Cost for more information)

The cost to produce each Ochre lesson, which includes daily reviews, two quizzes, slide deck, worksheets, and a video, is between $2,000 and $2,500.[76]

5.8 Impact

This model could significantly reduce teacher workloads while allowing for teacher autonomy.

- An Ochre survey found almost 70% of teachers are spending more than 5 hours a week developing resources and almost a quarter are spending more than 10 hours a week.[77] There is evidence that workload remains the most important factor influencing teachers' decisions to leave the profession.[78]

[76] Costs information provided by Ochre.

[77] Ochre Survey, conducted 2021 with 226 participants.

[78] Smithers, Factors Affecting Teachers' Decisions to Leave the Profession, 2003.

- There is evidence that effective instructional materials can raise teacher performance and reduce variability. The gain in achievement is as large as having an experienced rather than novice teacher.[79]
- When teachers have great instructional materials, they can focus their time, energy, and creativity on meeting the diverse needs of students and helping them all learn and grow.
- 88% of teachers said having access to common units, plans, and assessments could save them about 3 hours per week.[80] 86% of teachers would find a resource bank 'extremely useful'.[81]
- As a result of COVID, the capacity for schools and teachers to consider and engage with the curriculum is even more limited.

5.9 Success factors

There are a few factors that are essential for this model to be successful:

- **Accompanying videos for resources -** Having videos accompanying resources which outline how the resources can be used and explaining the content is essential for teacher understanding.
- **Curriculum aligned resources -** Content must be aligned to the Australian Curriculum (as applied through a State/Territory syllabus or curriculum where relevant) to be useful for teachers.
- **Implementation support -** Teachers must be supported in understanding how the model works and how it integrates into the classroom before using the content. This support can be from the lesson library provider or from their school.

5.10 Caution factors

- **Appropriate professional development -** The model relies on using lesson plan content as a base for the lessons, which the teacher then adapts to make it optimal for their class. Teachers need appropriate support to know how to do this, for example how to integrate formative assessments into their teaching and address knowledge gaps in the class.
- **Quality Assurance by teachers -** We heard from an experienced Victorian maths teacher that some videos with some lesson plans are higher quality than others in different platforms. Before providing these videos to students or parents, teachers should review them for relevance and alignment with learning objectives.
- **Limits to curriculum coverage -** At the current stage of content development, not all platforms fully cover the maths curriculum at every year level so teachers must assume they will need to generate their own lesson plans to cover some units.

5.11 Environment and infrastructure pre-requisites

[79] Grattan Institute, Making Time for Great Teaching: How Better Government Policy Can Help, 30 January 2022.
[80] Grattan Institute, Making Time for Great Teaching, 2022.
[81] Ibid.

There are limited environmental pre-requisites for this model as it operates at a teacher level and does not require additional resources. Teachers need to have a device and internet to access the online lesson plan library.

5.12 Implications and Opportunities for the Australian Government

There is potentially a role for the Australian Government in:

- Ensuring the full Australian Curriculum is comprehensively covered by lesson plan and lesson video libraries.
- Ensuring ongoing quality assurance and improvement of these resources occurs.
- Helping to promote the availability and appropriate role of the libraries to the target audience of out-of-field and inexperienced teachers of maths.

6 Deep Dive 2: Digital observation and remote coaching

6.1 Model summary

Teachers record their lessons for self-reflection or to share with professional development coaches. Coaches can be remote or in-person, pairing less confident or experienced maths teachers with experienced maths teachers.

6.2 Which challenges does the model address?

6.2.1 Teacher capability and confidence

Shortages of teachers who are confident and highly capable in maths are contributing to declining maths outcomes for Australian students. One factor behind this scarcity is the relatively limited number of teachers with qualifications in maths entering the teaching workforce. Around 40% of those teaching maths in Australian classrooms are out of field.[82]

The current approach to supporting the development of these out of field teachers is typically:

- Sending out of field teachers to traditional professional development courses on maths teaching, and/or
- Leveraging the schools' more experienced maths teachers to provide coaching and informal training to their colleagues who are teaching maths out of field.

Unfortunately, sending teachers to in-person one-off professional development/learning courses can be both expensive and of limited effectiveness. Costs involved include not just the cost of the course, but also travel, which can be particularly expensive for schools located in remote, rural or regional areas, and the cost of casual relief teachers to cover the teachers' classes while they are at the course. Research on effective professional development shows that as few as 10% of participants implemented what they learned during professional development that focused on teaching strategies and curriculum. Implementation of learnings from professional development increases dramatically when teachers were in small groups and focused on analysis of teaching and student responses.[83]

However, many of the schools using out of field teachers for maths classes are small and located in rural, regional or remote locations without experienced maths teachers in staff to provide coaching, observe their lessons and deliver feedback.[84]

The development of maths teaching skills and confidence among out of field teachers is also constrained by factors that reduce the frequency of classroom observations and the effectiveness of feedback and coaching provided based on these observations. These factors include:[85]

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[82] Australian Institute for Teaching and School Leadership, Australian Teacher Workforce Data: National Teacher Workforce Characteristics Report, 2021.

[83] Bruce Joyce and Beverly Showers, The Evolution of Peer Coaching, 1996.

[84] Australian Education Union, State of our Schools, 2020.

[85] From teacher and stakeholder interviews.

- Even when there are suitably experienced maths specialists present in a school, it is typically very hard to juggle schedules to free up the coach at times the teacher is teaching so they occur less often or not at all.
- Reasonably widespread cultural resistance among mid and late career teachers to being observed teaching. Observations can be negatively associated with performance reviews and performance monitoring and can be regarded as disrespecting of the teacher's autonomy to run their class as they see fit.
- Where observations and coaching do occur, they are often provided by a senior teacher who is not a maths teacher. Therefore, the development of maths-specific skills does not occur.

6.3 How does the model work?

Essentially, this model involves the teacher utilising technology to make secure video recordings of their own teaching in actual classes in an unobtrusive, non-disruptive fashion. They then upload these recordings into a private, controlled cloud environment for later viewing and commenting by themselves and their nominated coaches or colleagues at a time and location of their choosing. Remote coaches can view these recordings to provide feedback. This model provides teachers:

- The opportunity to observe themselves and their class from an outside point of view and then reflect on strengths and opportunities for improvement.
- Access to remote coaching from a more experienced maths teacher at a time that suits the coach and teacher. The coach can, at their own pace, review how the mentee teacher executed their lesson plan, how the class responded, and then relay their feedback in written comments, tied to specific reference to points on the video, or verbally in subsequent coaching sessions.

The components and functions of the model using different technology options are outlined in Figure 11 below.

Figure 11: Components and functions of digital observation technologies

	Dimension	General description	Vendor 1 – Swivl	Vendor 2 – IRIS Connect	Basic
Hardware	Devices and stands	Hardware sets include: • 1-2 devices (can be any device with recording capability e.g. phone or tablet) • A stand for each device Sets can be placed at the front and/or back of the classroom and teachers can choose how many devices they have. Having a device at the front of the class, facing the class, allows teachers to see the students' reactions to the class teacher, and the back of the teacher. Having a device at the back of the class allows the teacher to see their teaching from a student perspective.	Swivl is a provider of teacher recording hardware and software. The Swivl stand can track and record chosen people in the classroom. The Swivl is linked to a dongle and tracks the dongle wearer.	IRIS Connect is a provider of teacher recording hardware and software. Their stand can be placed at the front or back of the class. When teachers are using devices in class, the screens turn black to limit student distraction.	Schools can purchase devices such as tablets or mobile devices with recording capability. They can also purchase a stand online to have the same effect.

	Voice recording	The second aspect of the hardware is a microphone that is attached to the teacher or student. This provides high quality audio that accompanies the recording.	Swivl allows for multiple dongles, which includes the microphone, to be used around the classroom in different groups at once. This can capture what different groups of students are saying for later review.	IRISConnect provides a microphone in a dongle that is worn by the teacher.	Teachers can purchase a remote microphone, but the audio quality of recordings will be low as devices often can't pick up sound from across a room, especially when there are competing sounds.
Software	Record videos	Software is used to record the class. The software encrypts the recording and as soon as it is finished, sends it to a cloud server, and deletes it from the device. This ensures that no student footage is stored on teacher devices.	Swivl allows teachers to record both the physical class and screens. For example, if teachers use a PowerPoint presentation, the software can record both the class and the presentation at the same time Additionally, online classes can be recorded through the software.	IRISConnect allows teachers to record from all classroom devices at the same time.	Teachers can use their own devices to record videos.
	Store videos	Software moves video content online in a cloud storage platform. The location of the cloud is important for privacy and security reasons. Some providers have their own cloud storage, though schools can also use their own systems. More information on security is available in Section 5.10.			

		Once videos are recorded, they are automatically deleted from devices and sent to the cloud. They are also encrypted and auto compressed to ensure the video size is small and secure.			
	Rewatch	Videos can be accessed from the cloud and shared by the recorded teacher.	Swivl allows teachers to rewatch content and with audio from multiple sources when multiple dongles are used in the class. The software can differentiate between different dongles and can be labelled to help teachers identify what students are in which groups.	Teachers are the owners of the video content. This means that only they can view, edit or share the video. Teachers can edit their videos through the software to suit their professional development.	Teachers can rewatch recordings through their device and share with colleagues.
	Comment on performance	One of the most useful features is having the ability to make time-stamped comments. This allows coaches or teachers to precisely mark a comment to a time in the video.	Swivl provides automatic insights from recordings such as length of time taken teaching compared to students talking, how fast teachers are speaking and how much students are engaging with content.	IRISConnect allows coaches and teachers to make time-stamped comments on the video to highlight specific teaching.	Teachers can externally comment on videos when re-watching. They can take screenshots of particular aspects of their teaching.
	Mark against rubric	Rubrics or forms can be put into the re-watching software. These rubrics or forms can align to teaching standards or personal standards and are fully editable. The rubrics and forms can be viewed while a teacher or coach is watching the videos. They can then mark a teacher against certain rubrics and add comments that are time-stamped. This allows teachers to see exactly where they are or aren't achieving certain standards.			Teachers can mark performance against rubrics while watching videos.

Coaching	Live coaching	When possible, coaches can watch classes 'live' through the software. This allows coaches to give feedback as teachers are teaching, with minimal disruption to the class.	Swivl's dongles have audio jacks that can have headphones plugged in. These headphones can relay coaches' feedback while they watch the class online. Teachers can then implement feedback instantaneously.	Teachers use an earpiece while teaching and coaches can watch and provide immediate feedback while watching the class through the devices.	N/A
	Remote coaching	Once coaches have received videos, they can watch it at any time. It may be done with the teacher virtually or in person or watched independently with feedback given remotely or in person. There is significant flexibility in this as coaches do not need to be present in the school. For example, for a remote school with no specialised maths teachers, having a coach in a local city watching the footage allows them to receive detail feedback without having to be in the same location. Coaches can also highlight specific aspect of teaching by referring to the videos. We heard that coaches could use videos to watch student expressions, to measure how effective teaching is. These online coaching sessions can be done via any video conferencing software.			
	Teacher self-reflection	Teachers also can observe themselves and their class from an outside point of view, without the pressure of running the classroom. They can use videos to self-reflect highlight areas for improvement. Without recording their performance, this would not be possible in an ordinary professional development course and allows for continuous improvement and reflective practice.			

6.4 Examples of use

6.4.1 Diocese of Armidale

The Diocese of Armidale operates 24 schools in the New England and Barwon River regions of New South Wales. The Diocese's maths team runs a program for maths specialist teachers called Maths Specialist Teacher program (MaST). MaST teachers are placed in each participating school for a minimum of one day a week. Their role is to support maths learning in their schools by role modelling teaching and supporting other teachers with content and advice. MaST teachers co-teach with other maths teachers and model best practice. Currently, the MaST program operates in primary schools with plans to extend to secondary schools in the coming years. The program has been running for three years and will extend to a fourth year. Swivl products are used to support MaST teachers in professional development.

How it works

MaST teachers all have the Swivl in the classroom and use it to record their teaching. For the teachers that were nervous at first about using the Swivl, MaST staff had students use the dongle first to get used to working with the Swivl and being recorded. Once these teachers have seen students using Swivl, they were usually more comfortable using it for themselves. The next stage for teachers is to record themselves and watch back their practice. This gives teachers an opportunity to review themselves in a safe space and get used to seeing themselves being recorded. MaST staff also provide reflection questions to answer while watching back their performance. Once they are comfortable with watching their recordings back, teachers share their videos with their coach.

Teachers then use the videos as part of coaching and as part of self-reflection. All teachers are provided forms to reflect on their teaching while watching their videos. They are given five weeks to use Swivl as they like and encouraged to note where they have grown and improved. During professional development sessions, teachers and MaST staff reflect on their performance while reviewing video recordings.

Use of model

We heard from MaST staff that the model helped during COVID where teachers were often providing online content. They were able to watch back how they were teaching and see where they could improve for example if they were rambling or communicated unclearly. Teachers were encouraged to use short, sharp, mathematical language when explaining concepts to best teach students. Teachers also use Swivl recordings to co-teach where teachers from other schools come into the school and both teach content as a way of practice sharing. The videos and recording allow teachers to monitor the class while not being present.

6.4.2 Elisabeth Murdoch College

IRIS Connect has recently been implemented at Elisabeth Murdoch College, a public secondary school located in Langwarrin, Victoria. It is currently being implemented in a pilot trial with teachers, with an aim to extend it to all teachers.

The pilot trial will incorporate 10 volunteer teachers and will then roll out to around 120 teachers. The intention is to create supporters of the program to get greater buy-in for this form of professional development going forward.

We heard that initially some teachers were apprehensive about being recorded and viewing themselves. Largely, younger teachers were more comfortable because they were used to video recording from their university training.

The IRIS Connect program is implemented as a part of a broader professional development program led by school leadership. Elisabeth Murdoch College has engaged a model called Teaching Sprints which incorporates a model of "agree, build-upon and challenge" for teachers to improve. There is also a framework for discussion feedback with colleagues to encourage non-judgmental and supportive language. IRIS Connect worked with the school to integrate its program with the existing professional development system.

As well as a professional development program, we heard that the school has worked to develop a culture of improvement and acceptance that feedback from peers will improve their teaching. School leadership needs to support the program and drive a plan of action for implementation. Once there was buy-in from some teachers and testimonials, as well as a program that works well, teachers were happier to engage in it.

6.5 Target groups

This model is particularly valuable for out of field or early career teachers of maths who are based at schools where there are no or few colleagues with strong maths experience to provide feedback and coaching. The ability to time-shift and location-shift the observation of their classes gives the coach the opportunity to gain insight into the challenges that the teacher is encountering and provide higher quality feedback, with reference to actual classroom events.

Even for teachers with experienced maths teacher coaches available on staff at their school, the time-shifting aspect of this model helps overcome the cost and timetabling constraints on real-time observations.

There is also a benefit for teachers who are anxious about being observed by a colleague in real-time or who believe the presence of the observer might increase disruptions from students.

6.6 Level of use

There is no clear evidence of uptake in Australia.

Swivl claims that it is used in 4,000 schools across Australia, including purchases by the Victorian and New South Wales Departments of Education. IRIS Connect claims their program is used by over 20% of schools in the United Kingdom and used by a handful of schools in Australia. We were told the Teach for Australia program also uses IRIS Connect in some schools. However, we heard from teachers and school leaders across several Australian jurisdictions that video-based observation is reasonably rare in Australia in their experience.

6.7 Cost

There are three types of cost associated with the model:

- Hardware cost
- Software cost
- Implementation and support costs

There is an upfront hardware cost involved in purchasing a device and stand. If teachers are willing and able to bring their own devices, this cost is significantly decreased. However, devices must have the ability to film and save videos. Under both the Swivl and IRIS Connect models, the hardware cost was a one-off cost. According to these vendors, fixed hardware costs range from $750 to $1200 per set. Software is an ongoing cost that can be charged on a per teacher or per school basis. This allows use of software and in some cases also covers the support costs for setting up and maintaining the software. The cost for software licences ranges from $50 to $150 per teacher per annum.[86] Support and implementation costs vary. Privacy and security arrangements are an additional consideration and depend on existing school infrastructure.

6.8 Impact

We heard from schools using this technology that when combined with a well-led culture of continuous improvement and reflective practice, this model can be highly effective at improving the skills of out of field teachers. Research by Harvard University examined substituting traditional classroom observations for recorded video lessons in professional development. This included feedback from a virtual coach based on the video. That research found:[87]

- 59% of teachers were able to identify a specific change in practice they made because of the coach's feedback
- 50% of teachers found having a camera in the classroom "moderately" or "much" less distracting than having a supervisor physically present
- 63% of teachers reported that video was "quite" or "extremely" helpful in identifying areas where they need to improve

An evaluation of a US-based program that aimed to support teachers through online coaching with video recordings[88] found that the model resulted in substantial gains in student achievement across subject areas. The program model included:

- Regular cycles of coaching with teachers filming a lesson and coaches watching the lesson
- Coaches providing feedback highlighting the strong and weak elements of student - teacher interaction
- Coaches provide teachers with advice on potential improvements for teaching

86 Information from providers.
87 Thomas J Kane et al., The Best Foot Forward Project: Substituting Teacher-Collected Video for In-Person Classroom Observations, 2015.
88 Allen et al. My Teaching Partner- Secondary Programme Evaluation, 2015.

6.9 Success factors

Our interviews with teachers and system-level stakeholders told us there are several factors that are important to ensure success in the implementation of the model:

- There needs to be a 'champion' in the school to lead implementation of the model, typically a school leader or very experienced teacher. The champion must be able to encourage a culture of use and pilot the model to show that it is effective and useful. Champions must also understand how to use the software and act as a guide for when it is being implemented.
- As well as a champion, the school needs to have a culture of accepting observation and feedback for teachers. This can be a large cultural change as many Australian schools and teachers are hesitant about opening their classrooms to regular observations. It should be noted that many new graduate teachers are more used to recording themselves during their studies, so there may be a generational shift towards engaging in recording as part of ongoing professional development.
- Digital observation and remote coaching needs to be embedded within a well-planned multi-faceted professional development program, developed in consultation with the school's teaching staff. The digital observation and remote coaching should be structured for teachers and a program set around it to improve performance and outcomes.
- Timely and responsive IT support is also very important, particularly in the first phase of implementing the model.

6.10 Caution factors

There are three factors to be aware of when implementing the model:

- There are privacy requirements around recording, saving and sharing videos that include students. Vendors are aware of these issues and have designed their products to support schools to be compliant with these requirements. However, schools must typically follow their Department of Education's guidelines and seek prior approval before implementing this model.
- It also requires a substantial proportion of teacher development time to use effectively. This means that schools need to plan when they want to implement this model to build it into their school's ways of working.
- Some teachers are nervous about being filmed and may be resistant to the model initially. They will need support and guidance to start using the model and encouragement in using the model regularly. We heard that starting off with simply recording and watching their own recordings, rather than sharing them with a coach, peer or school leader from the outset, was a useful way to bring more anxious teachers into the program.

6.11 Environmental pre-requisites

This model requires teachers to be able to access a reliable internet connection, though not necessarily in the classroom itself. Uploads to the cloud for review and sharing can be done afterward and in parts or sections where there is limited bandwidth, recognising that this is a slower process. For coaches and teachers to watch back their recordings and engage in coaching sessions, a fast and secure internet connection is essential. Having asynchronous coaching sessions to lesson recording can reduce the need for fast internet as teachers and coaches can watch recordings in their own time.

It is advisable to have IT support available to help teachers use the software and ensure smooth implementation in the early stages of rollout. If this technical support is not available, giving teachers comprehensive training on how to use the software and hardware and leveraging their peers with the strongest technology skills is important to ensure a positive introduction of video-based observation in schools.

6.12 Implications and opportunities for the Australian Government

Using this model to help to build the capability and confidence of out of field or inexperienced maths teachers requires a combination of things, most of which are outside the remit of the Australian Government. School leadership needs to be committed to building and sustaining a culture among their maths teachers of continuous improvement, constructive feedback and reflective practice. Schools need to invest relatively modest sums in the hardware, software and support needed to implement video recordings. They need to encourage and hold their teaching staff accountable for making their recordings and reflecting on them, either solo or with a coach or colleague.

Preparing and publishing implementation guides for a video recording and remote coaching program for maths teachers in an Australian context could be a potential role for the Australian Government. This model appears to have strong uptake and evidence of effectiveness in the UK and the US. Streamlining and encouraging adoption by Australian schools by translating the lessons from this international experience into the Australian context and offering school leaders practical guidance on how to comply with Australian privacy laws and professional standards could be very effective. This also may involve augmenting the reflection questions and prompts, and coaching processes and guidelines that are built into software platforms offered by vendors in this area to align with the AITSL Australian Professional Standards for Teachers.

7 Deep Dive 3- Remote Learning Delivery

7.1 Model summary

Using video conference technology, experienced maths teachers can reach students that do not have access to local maths experts. Video conference technology can also be used to group students from multiple schools in virtual classes to receive maths teaching.

7.2 Which challenges does the model address?

This model addresses two of our key challenges for maths teaching:

- Teacher Capability and Confidence
- Student Learning Differentiation

7.2.1 Teacher capability and confidence and differentiation

Due to the workforce challenges cited earlier in this report, in many schools (especially in regional, rural and remote Australia) there is a shortage of maths teachers. While taking steps to overcome this teacher shortage by training and employing more confident and specialist maths teachers in schools is the optimal objective, progress on this challenge is also attainable via initiatives that bring maths teachers to schools where they are in short supply by leveraging technology.

Low cost and increasingly feature-rich digital tools are now available to allow for remotely delivered maths teaching. While not a perfect substitute for the direct face-to-face learning with a teacher who understands the learning context and can make use of all the additional communication and cultural factors present in a physical classroom, remote learning delivery may be one of the most straightforward to implement and cost-effective means of bridging the maths teacher capability and confidence gap for impacted cohorts of students.

This model also represents an opportunity to address the Differentiation challenge. For example:

- Providing access to highly experienced, specialist maths teachers for advanced students seeking to accelerate their mathematical knowledge beyond the standard which is taught in their year level at their school. This can also include access to Year 11 and 12 advanced maths subjects which may be a pre-requisite for entry into specific degree courses in STEM fields but which may not be offered at smaller, regional or remote schools.
- Providing access to highly experienced, specialist numeracy teachers for cohorts of primary school students whose skills in this area have not developed at the same rate as their peers, and who are struggling to keep pace with the mathematics instruction provided to students at their year level.
- For students whose learning style, health needs and/or career activities in a domain such as the arts or sport means they learn best via a remote learning delivery model. There is anecdotal evidence that the COVID-related remote schooling periods which occurred in Victoria and New South Wales in 2020 and 2021 revealed a small cohort of

secondary students whose academic progress accelerated more rapidly while learning remotely than under traditional face-to-face classroom teaching.

7.3 How does the model work?

Virtual or distance education schools have been part of the education landscape in Australia for many years. Every state and territory runs schools of this kind with jurisdictions such as Western Australia and Queensland particularly active in this space due to the spread of their populations across very large geographies. These schools have built their own teaching models and instructional strategies reflecting academic research and their own institution's experience with what approaches generate the best student outcomes.

For traditional schools, incorporating remote delivery of specific subjects such as maths has not been very common but during COVID, particularly in Victoria and New South Wales, almost every school was forced to adopt this model for periods of time.

Typically, remote learning delivery involves the use of a video conferencing software product such as Zoom, Teams or Google Meets which allows teachers to:

- Deliver one-to-many content and instruction to a class of students who may be in one location or several.
- Deliver one-to-one instruction to individual students to support their learning, provide feedback on assessments, determine and address misconceptions and so on.
- Facilitate students collaborating with one another in pairs or in small groups to work on a shared problem or project and to assist one another's learning by demonstrating tasks and sharing information.

Improvement in the reliability and cost-effectiveness of the video conferencing software products such as Zoom, Teams and Google Meets means that these tools are now in very widespread use in schools and students' homes. They do require reasonable bandwidth and student access to an entry-level or above laptop or tablet which is not universally the case in Australian schools. Stakeholders consulted for this project report that many secondary students participated in remote learning during COVID on their smart phone using their mobile data plan.

This model also typically uses a learning management system (for example, Canvas or Google Classroom) and/or a fully featured teaching and learning platform (see Deep Dive 5: Fully featured teaching and learning platforms below for detailed discussion of these products) in order to host and distribute teaching content, class activities and assessment tasks. These products also allow teachers and students to communicate with one another using text chat services, to manage completion of assessment tasks and marking, and to collaborate on the completion of projects and solving problems.

Remote learning delivery may involve a teacher or teacher's aide being present at the students' location to support classroom management and student engagement for the remote teacher, to reinforce and amplify the content being remotely delivered, and to potentially solve any IT difficulties emerging at the student end.

The extent to which remotely delivered maths teaching follows the contact hours and structure of a traditional in-person maths class does vary. How much virtual classroom attendance occurs versus individual or group work, how often the teacher schedules virtual meetings or check-ins with individual students, and how often and via what means (calls, chats, emails etc) students are encouraged to ask questions of their remote teacher are all parameters that can be adjusted by the teacher or school.

7.4 Examples of use

7.4.1 Rural Learning Exchange

The Rural Learning Exchange (RLE) is an initiative of the NSW Department of Education. It connects classes of students studying maths for the Higher School Certificate in Year 11 and 12 in around 90 regional and rural schools of less than 300 students where the local maths teacher is early career, overseas trained or teaching out of field (often from a science background). RLE's goal is to support these teachers by leveraging remotely located maths teaching specialists, a suite of technology tools and a range of delivery modes to strengthen maths learning outcomes.

Under RLE, every teacher is matched with a maths specialist teacher mentor (known as Subject Coordinator) who typically supports six schools. Once per week, all six schools and the maths mentor come together for a blended live lesson with content delivery from the teachers on site at the schools and the remotely located maths specialist. Break out groups are often used, and these involve a blend of students from different schools to work on activities, problem sets or assignments. Across the rest of the week - in between these live lessons - the teachers draw upon their maths mentors for advice on lesson planning, examples of pedagogical practice, content advice on topics they are unsure of and feedback on different aspects of their teaching practice.

The program uses several technology tools including Microsoft Teams for the video conferencing for live lessons, and software products with learning resources, assessment tasks and class collaboration tools such as Desmos, Stile and Mathspace.

RLE aims to create three main benefits:

- Greater peer interactions: Students can meet like-minded students and have a supportive peer group to improve Higher School Certificate outcomes
- Access to experts and specialist resources: Schools can access resources beyond their region
- Assessment and feedback as a larger class: A greater range of students complete assessments. This means that students can see more worked examples to improve their work.

7.4.2 Haileybury Pangea

Haileybury is a co-educational independent school with six campuses in Victoria, the Northern Territory and China. In 2023 it will launch a virtual school – Pangea – enrolling students from Years 5 to 12. The driver for the establishment of Pangea was the school's observation that around 10% of their students performed better academically during Victoria's extended periods of COVID-related school lockdowns with remote delivery than in traditional face-to-face classrooms. The school will enrol 80 students in Pangea in its first year with the goal of growing enrolment to 800 students. Interest to date has come from students in regional and remote communities, students pursuing sports or arts careers which mean they're on the road a great deal and students who prefer remote learning to face-to-face classroom-based teaching.

The delivery model will leverage a mix of digital tools including a video conferencing platform, the learning management system Canvas, libraries of teaching and learning content created by Haileybury teachers and drawn from a mix of publishers and software platforms. Students will receive live teaching in virtual classrooms of up to 10 students at a time, participate in customised self-directed learning modules, digital break-out groups with groups of 2-5 peer students, view pre-recorded video content delivered by Haileybury teachers, and one-on-one sessions for explicit instruction and feedback on assessment tasks with teachers.

7.4.3 Aurora College

Founded in 2015, Aurora College started as the NSW Department of Education virtual selective school servicing rural and remote students, but has grown to encompass a non-selective Year 11 and 12 cohort, as well as a selective opportunity class cohort for Year 6 students. Its objective is to provide regional and remote students in NSW with access to the extension opportunities provided by selective-entry schools in metropolitan areas operated by the Department.

At Aurora, lessons are delivered online synchronously to students in their local school, by teachers in similar settings. Typically, an Aurora student will have a dedicated space at their local school, often in the library or similar location. They do sport, cooking, art and extra-curricular activities with students at their local school, but the bulk of their learning occurs via remote delivery with Aurora Teachers. Residential camps are held twice yearly to deliver practical lessons, specialist excursions, and provide social opportunities for Aurora students to meet their peers.

Classes run for 100 minutes with a "brain break" of 5 minutes at the 50-minute point to manage student engagement. Aurora uses Microsoft Teams and OneNote video conferencing, collaboration and content sharing tools. Canvas is the Learning Management System used. All students are issued with the same laptop with stylus and have a second screen for admin tasks. Other software products used include Mathspace for pre- and post-testing and homework tasks, Education Perfect for online NAPLAN preparation, and Desmos and Geogebra for graphing, simulations, 3C calculators and geometry tasks.

7.4.4 Queensland Virtual STEM Academy

The Queensland Virtual STEM Academy (QVSA) is operated by the Queensland Department of Education and is designed to expand and enhance STEM opportunities for highly capable student in Grade 5-9 through tightly coordinated, enriching and challenging courses which are delivered remotely using a range of technologies. The learning is aligned to and enriches the Australian Curriculum, but doesn't replace the students' maths teacher on site at their school.

The target cohort is highly capable maths and science students seeking extension opportunities, often from smaller schools in regional and remote Queensland. QVSA courses enrol a high share of regional students, female students and Indigenous students. There are participants from every region of the state. Delivery occurs once per week for 10 weeks for around 90 minutes. A class typically has up to 15 students per remote teacher. Bigger classes (25 students) will typically involve 2 remote teachers and break-out sessions. The technology employed is the iSee platform which incorporates a range of video conferencing tools, content sharing tools, modes for students to interact with one another and their teacher, smart boards for creating content such as charts, posters, images and spreadsheets. Content from Stile, Khan Academy, and Tuva is used in courses. QVSA teachers are trained and participate in ongoing professional learning using the Department's IMPACT pedagogical model for online teaching.

7.5 Target groups

As the examples above illustrate, the most common cohorts of students targeted for this model are:

- Late Primary and Secondary students without access to specialist maths teachers at their local school for extension in the earlier years and for advanced maths subjects in later years
- Students with a learning style that is better suited to online delivery of maths
- Students with arts or sports careers which mean online delivery of maths is more practical and accessible

7.6 Level of use

Long established schools of distance learning in all jurisdictions have provided remotely delivered maths classes to students for many years. More than 16,000 students are enrolled at these schools Australia-wide.[89] Interest in the 80 places to be offered by Haileybury under its Pangea virtual school model in 2023 reportedly exceeds 2,000 potential applicants.

7.7 Cost

We heard that well executed remote delivery by specialist maths teachers with reliable internet connection and a good mix of software tools can achieve high-quality learning outcomes throughout the high school year levels, and for extension students at Years 5-6 in primary schools.

Successful remote delivery of mathematics requires a reliable internet connection for both the teacher and the students, and a mix of software tools including Learning Management Systems, Fully Featured Teaching and Learning Platforms and tools for completing and distributing teacher recorded worked examples. Learning management system such as Google Classroom, Microsoft Teams or Canvas range in price from around $0 to $50 per student per year, depending on the feature mix selected by the school. Fully featured teaching and learning platforms typically cost $5-10 per user per month. Other useful maths content products such as Desmos are free. Products for completing teacher recorded worked examples such as Screencastify or Loom cost from $0-$12 per user per month.

7.8 Impact

[89] Brisbane School of Distance Education reports 3850 enrolments in 2022. Virtual School Victoria reports 4000 enrolments in 2022. Sydney Distance Education High School reported 1500 enrolments in 2021. WA's School of Isolated and Distance Education reported 2300 enrolments in 2021. SA's Open Access College has 4700 enrolments.

Well executed remote delivery by specialist maths teachers with reliable internet connections, a touch-screen device with stylus functionality, and a good mix of software tools appear to be achieving high-quality learning outcomes at Years 7-12 high school year levels, and for extension students at Years 5-6 in primary schools. We heard from Education Departments throughout Australia that they are continuing to invest in provision and expansion of various types of remote delivery for maths and other subjects to meet the needs of the target student cohorts in their jurisdictions, which indicates both evidence of effectiveness and growing student demand for the model.

7.9 Success factors

- Schools such as Aurora College and Haileybury indicated that it is substantially easier for maths teachers to remotely deliver their classes if their students are using the same hardware and software package. This approach reduces wasted time on IT difficulties and builds teachers' ability to confidently troubleshoot any IT issues occurring in their classes.
- Teachers teaching via this model need a high degree of confidence and training in online teaching to build on the skills and pedagogical foundations they have built in their face-to-face teaching careers. We heard a consistent message that online teaching skills require considered effort to acquire and that a great maths teacher in a traditional classroom may not automatically become a great remote delivery teacher.
- Student follow-through and task completion can be an issue with remote delivery because direct observation of work patterns across a whole class of students is harder in remote delivery than in a classroom setting. To overcome this challenge, teachers must communicate consistently and comprehensively with all members of their class, using all the communication methods available to them. Establishing protocols with students about expectations for responsiveness and checking in are also important.
- "Brain breaks" at least every 50 mins are essential. Over-long "chalk and talk" style content delivery often loses traction with students, so teachers need to structure classes with breaks and breakout group activities to maintain engagement.
- Where possible, providing opportunities for students to meet face to face – even for short 'residential camps' – like Aurora College schedules twice per school year – will make a substantial difference to students' engagement, peer relationships and teachers' understanding of the learning context of their students.

7.10 Caution factors

- Remotely delivered maths teaching is very different to traditional classroom teaching. Successful adoption of this model must be grounded in a thorough understanding of this mode. Leveraging the experience and lessons learned by schools and groups of teachers who have done this for some time and have adapted best practice to this new mode will be beneficial.
- For primary school year levels and cohorts of less engaged students, the presence of school support staff or educators alongside remote learners can assist the remote delivery teacher immensely in reaching optimal student outcomes.

- Under preparation can be very detrimental in a remote delivery maths class, NSW Rural Learning Exchange staff emphasised the importance of precise and thorough planning of a remotely delivered maths lesson. Unlike a face-to-face classroom where there can be opportunities to improvise and rely on having taught a topic before, this is harder to achieve in remote class where the logistics of managing the class are more complex and the risk of disengagement higher due to the nature of technology in use.

7.11 Environmental pre-requisites

Findings from our research were that students and teachers in a remote delivered maths classroom need:

- Reliable high-speed internet connections
- Ideally two screens – one for administration and task completion, the other for attending video classroom or breakout groups
- Access to a mix of technology tools including learning management systems, fully featured maths teaching and learning platforms, and various other utilities including graphing and simulation tools.

7.12 Implications and Opportunities for Australian Government

Opportunities for the Australian Government's consideration include:

- Teacher qualifications – Additional skills are needed by maths teachers to effectively deliver teaching remotely. There may be a role for the Australian Government in supporting the codifying of a set of standards for best practice in this area providing structure for professional learning in this domain.
- Building maths participation and skills attainment in remote and regional communities – This model may represent a cost-effective and relatively quick to implement solution to the teacher workforce shortages plaguing schools nationally and particularly in regional, rural and remote Australia. We note that there are in-field teacher shortages in metro areas, however, the issue is most acute in rural, regional and remote settings. This model allows rural, regional and remote schools to tap into the greater number of specialist teachers located in larger cities.
- Software quality assurance– There are many high-quality software products available in the market for use in remote delivery of maths teaching under this model. There are also products of lesser or uneven quality. There may be a role for the Australian Government to commission work to quality assure software products in maths teaching and learning, to assist schools in their decision making about resources in this area.

8 Deep Dive 4: Online tutoring

8.1 Model summary

Students are provided with one-on-one or small group online tutoring sessions with qualified maths teachers familiar with the Australian Curriculum. These sessions are additional and complementary to in-class maths learning.

8.2 Which challenges does the model address?

8.2.1 Differentiation of student learning

This model addresses differentiation, which was identified as one of our key challenges for maths teaching. As teachers have limited resources, they often focus their efforts to the 'middle' ability of classrooms. This is usually the majority of students in a class, though does not cater to the high and low achieving students. High achieving students need stretch exercises to ensure they can reach their full potential. Low achieving students often need support to understand where they are going wrong and help to catch up with their peers.

One-on-one or small group tutoring supports student differentiation by providing them with specific support tailored to their learning level. High achieving students are able to engage in more difficult exercises and concepts to keep them interested and engaged. Low achieving students can be supported by tutors to fill in knowledge gaps and catch up to other students. We heard that often students had a few areas where they needed help and once they had that support they were more engaged in their classes and showed improved maths understanding.

8.3 How does the model work?

The digital technologies used for tutoring programs usually leverage online meeting apps such as MS Teams, Webex or Zoom to run sessions. They may also include the use of learning management systems or content management systems where programs involve lesson plans or pre-developed content. Not surprisingly, using digital tools and technologies to facilitate one-on-one tutoring programs has become easier as students and teachers have become more familiar and confident with using online meetings and tools to support learning, particularly in heavily lockdown-effected states.

From a pedagogical approach, given that Australian education systems have a mandate to provide effective maths teaching and learning for all students, one-on-one tutoring should only ever be an *additive* to in class learning.

The model operates with:

- Tutors who are experienced maths teachers or tertiary students in a relevant degree, from Australia.
- Students are matched with a tutor who works with them on an online one-to-one or small-group basis.
- Students are tutored for a set number of sessions or period of time.
- Tutoring is provided out of school hours, under appropriate cybersecurity controls via an online meeting platform.

- Tutors identify individual student needs and deliver tailored sessions to support academic growth and independent learning.
- In the case of the Learning+ program, a structured interview consisting of 20 questions, developed by the University of Melbourne Graduate School of Education, is used to identify core learning needs and to develop a learning pedagogy for the student and tutor.
- Most programs provide supporting resources. In some instances, tutors draw from pre-set lesson plans.

8.4 Examples of use

8.4.1 Commercial platforms

There are many commercial providers of one-on-one tutoring services and platforms that have been around for a long time. These have largely been the domain of private providers, with decisions made by parents on an individual basis. Some commercial platforms, such as Cluey Learning, have a relatively large footprint in Australia.

In common with other commercial platforms listed below, Cluey operates by employing school graduates who achieved a high ATAR and some qualified maths teachers to provide one on one tailored tutoring on a user-pays basis. Tutors hold working with children checks and police checks. Tuition is based on the Australian Curriculum (as applied in that state or territory) and has proprietary resources supporting learning. It uses a simple online meeting interface for session delivery and all sessions are recorded.

Other similar one to one tutoring platforms include the following:

- Alchemy Tuition
- Kinetic Education
- MathMinds

Its website notes it is an approved NSW Department of Education small group program provider and that it has provided services to Fennell Bay Public School and Bankstown Girls High School.

We caution that for all these platforms there are highly mixed reviews and, for Cluey Learning[90] in particular, there is evidence of an increase in complaints from customers regarding reliability, quality and efficacy, including:

- Issues providing sufficient tutors to meet demand, often resulting in late cancellations of scheduled appointments
- Switching tutors without notice, breaking consistency
- Lack of follow up including failure to set homework or further tasks to consolidate learning
- High costs
- Aggressive marketing strategies

[90] Examples drawn from non-Cluey moderated review sites including https://au.trustpilot.com/review/clueylearning.com.au, https://www.productreview.com.au/listings/cluey-learning, https://au.indeed.com/cmp/Cluey-Learning-Pty-Ltd/reviews?fcountry=ALL. Last accessed 13 September 2022.

8.4.2 Public sector led programs

Learning+ (South Australian Department of Education)[91]

Learning+ was first launched in 2021 as a pilot and was expanded for 2022.

- For the first year, the program targeted years 6 and 8 to encompass primary and secondary school levels
  - Students at all performance levels were included, that is, below, at or above the South Australian Standard of Educational Achievement (SEA)
- In its second year it was expanded to include years 6 to 9 and to trial program modifications for specific cohorts:
  - Small group approaches for above level achievement students
  - Extended length of tutoring for students with below level achieve standards
  - An Indigenous school on the APY Lands

The program enrolled 1200 students in the pilot and was delivered across a range of metropolitan and regional public schools in South Australia. The program was funded by the Department and was free to schools/students.

The program was designed and delivered by the South Australia Department of Education, with support from the University of Melbourne Graduate School of Education (Dr Catherine Pearn and Dr Natasha Ziebell) and is informed by evidence in its approach.

The Department selected year 6 as the youngest level they could feasibly enrol in the program due to a need for users to understand online pedagogy and be able to navigate technology. For risk management, the program required parental supervision of the online tutoring sessions. Sessions were also recorded and audited for quality assurance purposes.

The program had the following delivery parameters based on evidence relating to effective learning and best practice tutoring:

- Short increment sessions – 30 minutes each
- Delivered via Microsoft Teams which was already used across SA schools
- Provided each student with 2 sessions a week, usually over a 10-week term
- Sessions were undertaken out of school hours, during 4-7pm weekdays, 9-5pm on weekends
- IT support was provided to parents, students and teachers to ensure confidence to use technology effectively. Recently the program team introduced an optional IT check session to be undertaken before tutoring sessions commence

Learning+ tutors are qualified maths teachers who:

- Have experience teaching mathematics, and an in-depth understanding of the Australian Curriculum
- Are existing part-time or full-time teachers or retirees

[91] The Learning+ case study has been reviewed and approved by the relevant unit in SA Department for Education.

- Are drawn from across South Australia and provided with flexibility to work from wherever they like in the state
- In addition to PD hours and learning opportunities, are treated as part of the extended delivery team
- Are invited to participate in communities of practice for specialised areas of mathematics teaching and learning
- These are constituted from teachers in the Learning+ program
- Are paid for 40 minutes for each session, including 30 minutes tutoring and 10 minutes preparation

Students are matched with a tutor for the duration of the program and are provided a personalised learning experience.

To facilitate a tailored approach to tutoring, MGSE developed and implemented "Number interviews" for each year level of the program, which consist of 20 questions designed to reflect the curriculum and identify areas where students are at in terms of core concepts, identifies gaps and misconceptions and helps develop progression of learning approaches. The number interviews are a diagnostic tool which enable tutors to develop personalised learning plans mapped to the curriculum.

The number interviews form the basis of the first two sessions for students. After this, tutors use their professional judgement to determine what each student requires and how they will approach the sessions in terms of learning content. Feedback from tutors indicates that many have been able to implement knowledge and experience from the Learning+ program into their classroom teaching practice.

At the commencement of the program, the Department commissioned an independent evaluation using student pre- and post- program surveys measuring self-efficacy, as well as student and tutor focus groups. They found:

- Greatest impact for students below SEA and students above SEA
- Smaller changes for students at SEA

The Department has now commissioned a larger scale independent evaluation to review students' achievement data. We note however that a higher self-efficacy score is strongly correlated to improved performance according to the evidence base.[92] Anecdotally, there is good evidence that the program changes how students feel about maths or themselves as a maths learner. There is also a good indication that Learning+ reduces anxiety around maths learning.

8.5 Target groups

This model best suits the following groups:

- Schools or classes with limited access to specialist maths teachers such as, for example, regional and remote schools.
- Students with specific needs, such as students with Autism spectrum disorder (ASD) or a particular cultural group, noting programs need to be appropriately tailored to the user group and that user-appropriate support for in home use of technology is an essential co-requirement.

[92] Source: Interview, Dr Catherine Pearn, University of Melbourne Graduate School of Education.

- Students performing below standard achievement levels, who are at risk of dropping out, disengaging from learning, not progressing in their education and/or experiencing negative impacts on their confidence and wellbeing.
- Students performing above standard achievement levels who are at risk of disengaging with STEM pathways.

8.6 Level of use

While estimates vary, it seems that at least one in seven (14%)[93] Australian students are currently using some form of tutoring, although the pandemic impact on the sector is still unfolding. The sector is reported to have rebounded strongly after initial declines in market share for private providers.[94] The Australian Government National Skills Commission has predicted 13.6% growth in demand for tutors in coming years.[95]

At a state level, during 2020 and 2021 the NSW COVID Intensive Learning Support Program supported over 300,000 students at primary and secondary schools via small-group online tutoring.[96] A similar program in Victoria enrolled over 200,000 students.[97] South Australia's Learning+ program has supported more than 1200 students to date.

8.7 Cost

One on one tutoring programs are relatively expensive, both to coordinate and to deliver. Historically, one on one tutoring has been available commercially for those who can afford to pay. The ability to access additional services has potentially exacerbated inequity in educational outcomes for children in low-socio economic cohorts.

The Learning+ cost per 30-minute tutoring session delivered is approximately $62, which includes the cost of tutor preparation time. Commercial providers' advertised rates are in the range of $65-$85 for a 30-minute session and most provide tutors with lesser qualifications than Learning+.

8.8 Impact

There is a clear evidence base for the efficacy of one-on-one tutoring in improving student outcomes and student confidence. Evidence for Learning's (E4L) and the Education Endowment Foundation's (EEF) global synthesis of the evidence rates assess one-on-one tutoring to be very effective at improving student performance on average, however it is more likely to have an impact if it is *additional to* normal lessons.[98] The E4L/EEF evidence summary indicates that one to one tuition can be effective, resulting in five additional months' progress on average in 10 weeks. Average improvement in maths performance was approximately 3 months for a student receiving one-on-one tutoring vs a classroom only peer.

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[93] See Australian Financial Review. 2021. https://www.afr.com/policy/health-and-education/tutoring-in-australia-is-a-billion-dollar-industry-20201029-p569mp Last accessed 4 October 2022.

[94] See for example https://www.abc.net.au/news/2021-09-01/tutoring-school-students-covid-19/100424048 and https://www.abc.net.au/news/2022-04-01/demand-for-tutors-skyrockets-as-covid-interrupts-learning/100926366 Last accessed 4 September 2022.

[95] Australian Government National Skills Commission Labour Market Insights report 2022. https://labourmarketinsights.gov.au/occupation-profile/Private-Tutors-and-Teachers?occupationCode=2492 Last accessed 4 September 2022.

[96] Enrolments in the COVID Intensive Learning Support program were reported to exceed 300,000 students.

[97] The Victorian Tutor Learning Initiative enrolment exceeded 200,000 students.

[98] Evidence for Learning, *One to One Tuition,* last accessed 6 September 2022.

In line with E4L findings, outcome data from the Learning+ program indicates the following:

- Significant self-efficacy improvements in both the below SEA group and the above SEA group, though no significant change in the at level group. It was recommended that further work be undertaken to explore this finding.
- Particular value for regional and remote schools with limited access to specialist maths teachers.
- We heard that a higher self-efficacy score is strongly correlated to improved performance. As such it is reasonable to expect the program will demonstrate an improved performance level in maths for those participating.
- Anecdotally, there is good evidence that the program changes how students feel about maths or themselves as a maths learner. There is also a good indication that Learning+ reduces anxiety around maths learning.

Our review indicated several areas where online tutoring has particular advantages for student cohorts, and where programs have delivered successful outcomes:

- Schools or classes with limited access to specialist maths teachers, for example, regional and remote schools.
- Students with specific needs, such as students with ASD or CALD backgrounds, provided programs are tailored and appropriate technical support is provided alongside the program.
- Students performing below standard achievement levels, who are at risk of dropping out, disengaging from learning, progressing in their education and/or experiencing negative impacts on their confidence and wellbeing.

8.9 Success factors

The following factors contribute to model success:

- Having experienced maths teachers as tutors
- Having diagnostic tools to enable curriculum based personalised learning
- Having professional learning communities for the tutors
- IT support for tutors, students and parents

8.10 Caution factors

Some factors to be cautious about when considering using this model:

- Tutor programs should not be considered as an alternative for effective in school teaching. They should be additive and complementary to classroom maths learning.
- Evidence based diagnostics such as the Number interviews developed by the MGSE, and worksheets aligned with curriculum learning, are better than one size fits all resources that are offered in some commercial programs. In particular, it is important that resources assist students to demonstrate their thinking and working such that logic misconceptions are identified and addressed.
- Digital literacy can be an impediment for some students and parents and there is a risk of exacerbating inequalities in learning.

- Many one-to-one programs are run out of hours and outside of school grounds. It is critical that programs maintain appropriate cyber-security to protect student data and access, and also to ensure appropriate checks and balances are in place to provide a safe learning space for children.

8.11 Environmental pre-requisites

In order to operate well, the following features are required to allow students to access tutoring:

- Out of hours device access
- Reliable broadband access
- An appropriate level of understanding of learning online

8.12 Implications and Opportunities for Australian Government

The Australian Government may consider opportunities to support this model via:

- Working with the South Australian Department of Education to scale up the Learning+ Number interview and/or diagnostics for broader use in schools nationally to support maths teaching and learning.

9 Deep Dive 5 Fully featured teaching and learning platforms

9.1 Model summary

Fully featured teaching and learning platforms are software products providing comprehensive and integrated libraries of maths exercises, lessons and/or videos for use with students, as well as automated grading and individual or cohort analytics.

9.2 What challenges does the model address?

9.2.1 Teacher capability and confidence

One of the core challenges for teachers who are teaching out of field or new to the profession is a limited understanding of maths content and pedagogy. These teachers often lack formal training to understand and therefore teach maths concepts. They often also struggle to teach content effectively due to the unique nature of maths content which requires demonstration and practice. From our consultations we learnt that when teachers are less confident or unsure, they can rely too heavily on textbooks to teach and practice. Although this can work for some students, others need more explicit instruction and / or individualised help from teachers. Out of field teachers may also be reluctant to use content or teaching techniques outside of the textbook scope, as they risk being exposed if they cannot answer questions posed from students.

9.2.2 Teacher capacity and efficiency

Workload is a significant issue for all teachers. Two aspects of a teacher's workload that are significantly time consuming are assessment and lesson planning. Participants from our discussion forum reflected that for most teachers, writing and marking assessments takes up most of their time. Assessing students is essential to track their progress and understanding of content. However, marking assessments is time consuming and only provides limited data. Marking is also delayed and teachers can't use the assessment data until after all marking is done. We also heard that there is a stigma that 'good' teachers write and produce all their content. While it is important for teachers to understand what they are presenting to students, often it is unnecessary for them to produce everything from scratch.

9.2.3 Differentiation

In a maths classroom, student ability levels can differ by up to 9 years.[99] Understanding what level students are at, as well as the best way to teach them is a major challenge for teachers. Differentiation is linked with formative assessment to identify student capability. Providing differentiated problems and teaching styles requires teachers to generate greater

[99] Grattan Institute, Targeted Teaching: How to get the best from our schoolchildren, 2015.

quantities of work in the same time. When teachers are unable to do this, they tend to work with the majority of students, often leaving struggling students behind or not catering to higher performing students.

9.3 How does the model work?

Schools purchase licences to use different software within their maths classes. Software products in this category have different features though offer broadly similar functions such as:

- Online maths lessons
- Teaching resources such as exercises, activities and video explanations
- Assessment and grading
- Differentiation
- Individual and cohort analytics

These platforms are all cloud-based software and are typically accessed by teachers and students via PC, laptop or tablet device. Teachers can use this category of software as a supplementary resource alongside, or replacing, traditional hardcopy textbooks. Most brands allow teachers to add in their own material and customise content to suit class needs.

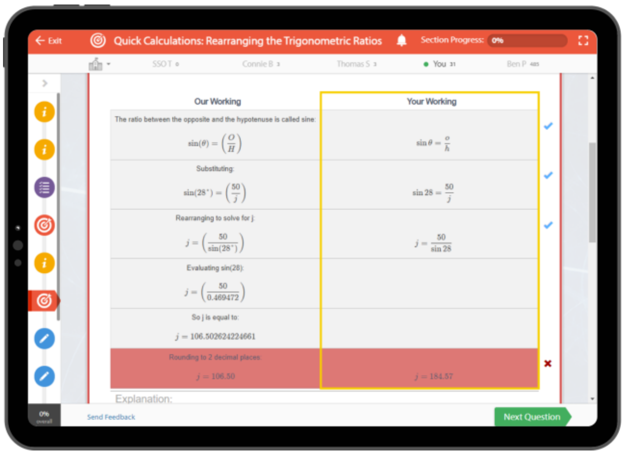
We spoke directly to Mathspace, Education Perfect, and Maths Pathways and will highlight specific features of each program. We also heard from teachers that the following providers were widely used in Australian schools: Edrolo, Maths Online, Atomi, and Prodigy.

9.3.1 Teaching resources

Fully featured teaching and learning platforms provide teaching resources for students such as worksheets, activities, or investigation tasks. They have the functionality to be aligned to the Australian Curriculum. Exercises can include hints and tips for when students are stuck on a problem.

Education Perfect checks all work written by students and provides 'hints' for next steps, as well as worked examples for when students are unable to get the correct answer. It also provides explanations in 'plain English' to help students understands concepts in a straightforward way. Teachers can embed their own content into the platform as they see fit. This ensures that content is aligned to student needs based on the teacher's expertise.

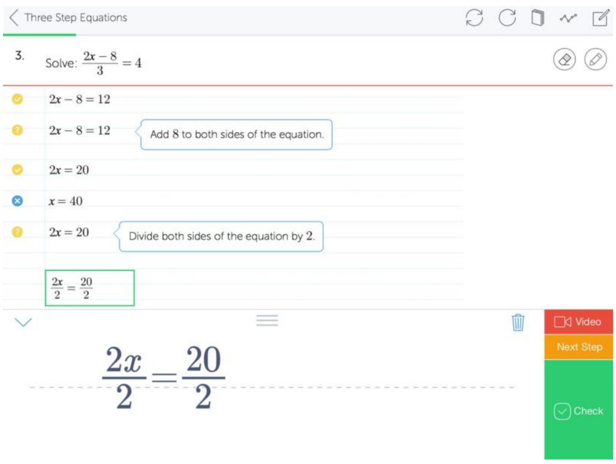
Figure 12: Education Perfect exercise function



Alternative text: Figure 12 is an example of the 'Education Perfect' user interface demonstrating the correct answer on the left-hand side, and a student's work on the right-hand side.

Mathspace allows students to skip questions that they find too difficult to ensure students aren't frustrated by questions that are beyond their level.

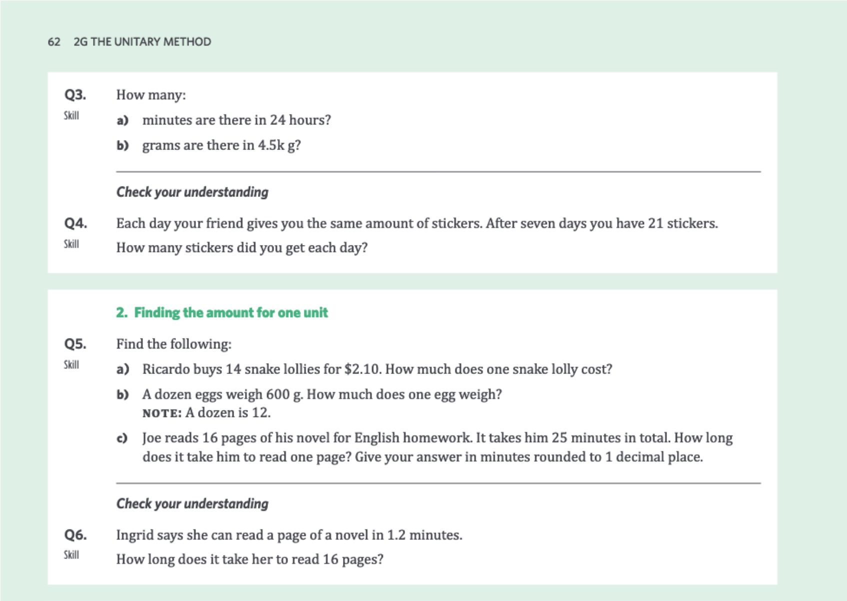
Figure 13: Mathspace exercise function



Alternative text: Figure 13 is an example of the 'Mathspace' user interface with the math question at the top of the screen, the working in the middle, and the student's answer at the bottom.

Edrolo and **Mathspace** provide a suite of print and digital resources, packaged by each topic. There are also video solutions for textbook answers.

Figure 14: Edrolo assessment questions


62 2G THE UNITARY METHOD

Q3. Skill
How many:
a) minutes are there in 24 hours?
b) grams are there in 4.5k g?

Check your understanding

Q4. Skill
Each day your friend gives you the same amount of stickers. After seven days you have 21 stickers.
How many stickers did you get each day?

2. Finding the amount for one unit

Q5. Skill
Find the following:
a) Ricardo buys 14 snake lollies for $2.10. How much does one snake lolly cost?
b) A dozen eggs weigh 600 g. How much does one egg weigh?
NOTE: A dozen is 12.
c) Joe reads 16 pages of his novel for English homework. It takes him 25 minutes in total. How long does it take him to read one page? Give your answer in minutes rounded to 1 decimal place.

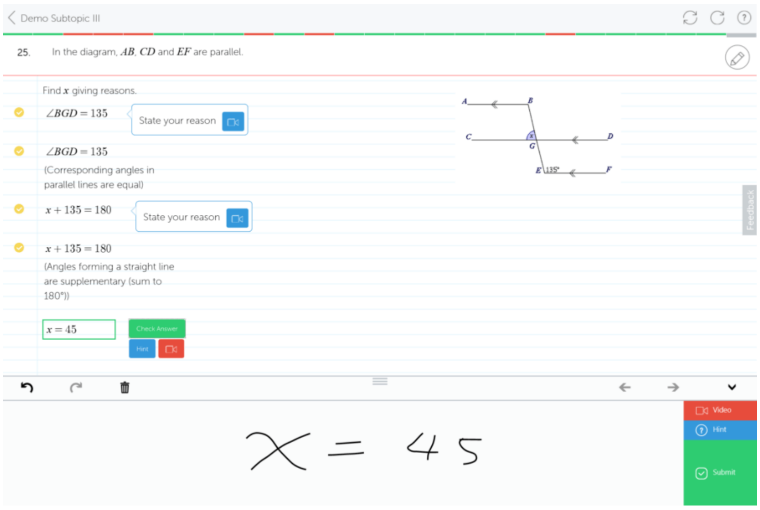
Check your understanding

Q6. Skill
Ingrid says she can read a page of a novel in 1.2 minutes.
How long does it take her to read 16 pages?

Alternative text: Figure 14 is an example of the 'Edrolo' user interface with questions listed sequentially down the screen.

With **Mathspace, Maths Pathways** and **Education Perfect**, students can handwrite their answers on a touch device, rather than typing. We heard that this is especially helpful for maths as many formulae are difficult to type out.

Figure 15: Mathspace example of handwritten work



Alternative text: Figure 15 is an example of the 'Education Perfect' user interface with the question at the top of the screen and a student's handwriting at the bottom.

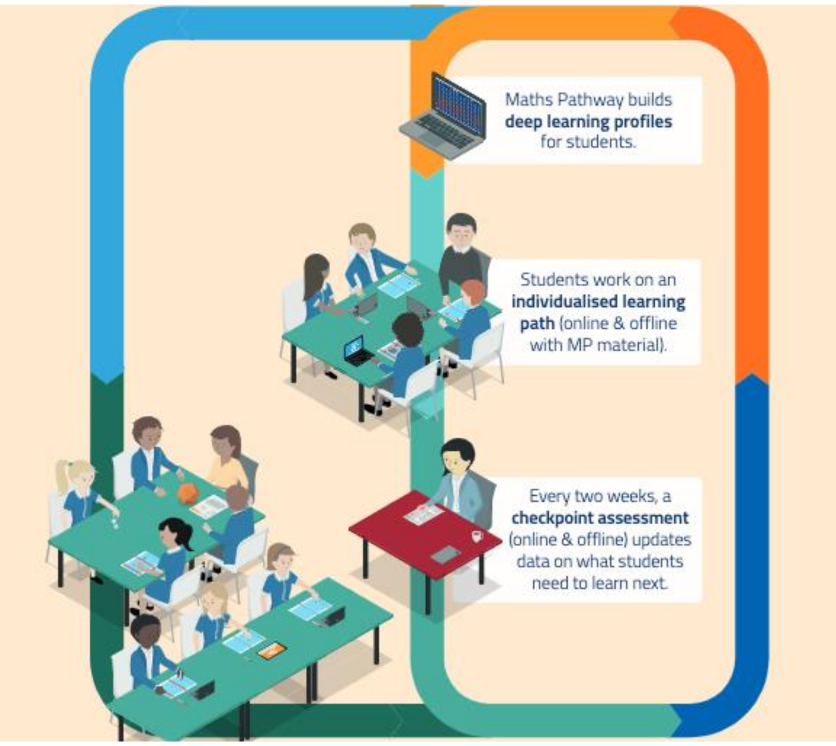
Maths Pathways differs from other online platforms as it encourages student to handwrite their solutions offline and use the software to guide and assess their understanding.

9.3.2 Online maths lessons

Software often includes online maths lessons to help improve students understanding of the content. Lessons can include written or visually represented maths concepts, short videos or interactive diagrams. Lessons may demonstrate how to complete questions or alternative ways of answering questions. Lessons can include diagrams and interactive displays demonstrating different mathematical concepts.

- **Maths Pathways** differs from other platforms as it encourages students to complete exercises through the platform and the teacher then tailors their teaching in response to identified student gaps. This teaching can be done one-on-one with students, in small groups, or to the whole class depending on how many students need the support.

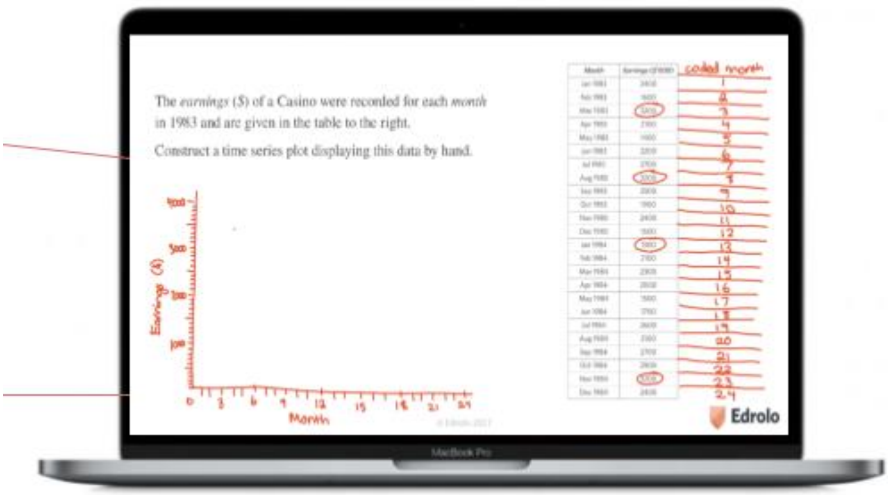
Figure 16: Maths Pathways model



Alternative text: Figure 16 provides a diagram representing the 'Maths Pathways' model process. There are three key stages to the model's cycle. A Maths Pathway builds deep learning profiles for students, students then work on an individualised learning path (online and offline with MP material), then every two weeks a checkpoint assessment (online and offline) updates data on what students need to learn next.

- **Edrolo** provides videos by in-field teachers of 2 - 4 minutes each, as well as a textbook with explanations, examples and questions.

Figure 17: Edrolo example video



Alternative text: Figure 17 is an example of the 'Edrolo' video interface.

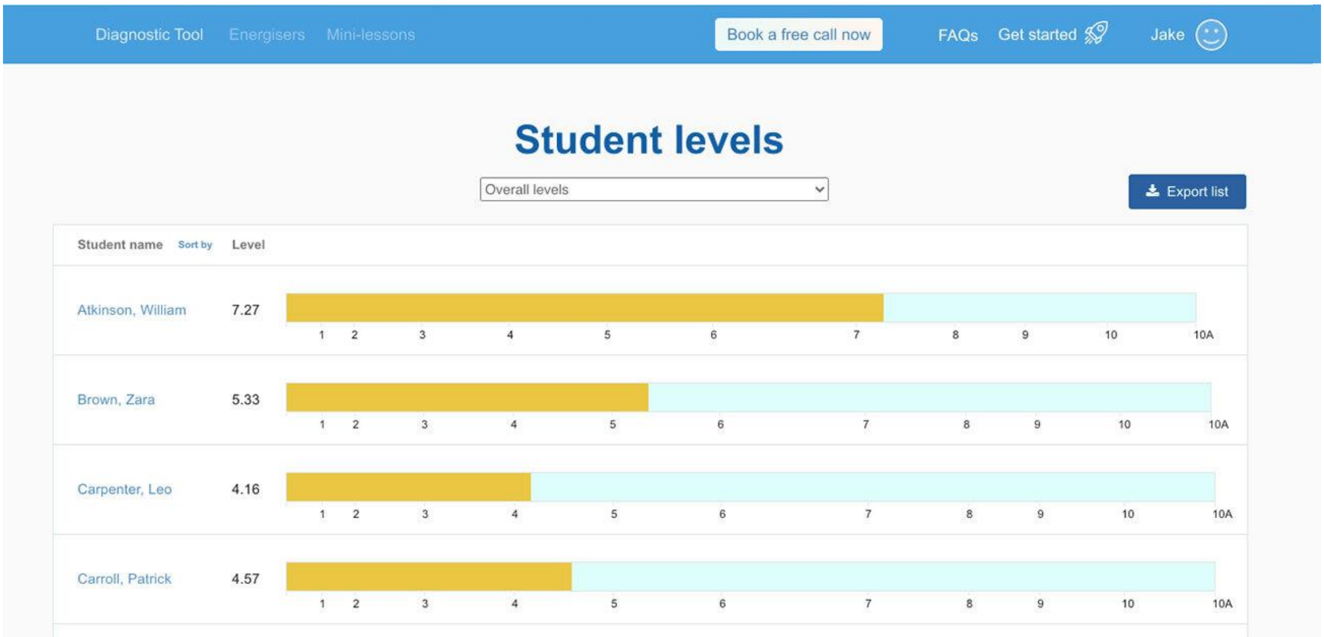
9.3.3 Assessment and automated grading

One of the main benefits of the fully featured teaching and learning platforms is the ability for students to be assessed and receive automatic feedback. All platforms reviewed have this ability and provide formative and summative assessment. Students complete assessments in the platform and the platform either marks a question as correct or incorrect. For practice exercises, platforms provide the solution or hints for where students get stuck. For formative or summative assessments, students do not get hints or solutions. All student engagement with a platform is tracked and reported. For example, if a student finishes a module but used hints for all the questions, the teacher can see this and identify that they need more support in that area.

Each of the software vendors in this category that we reviewed offer teachers tools for undertaking an initial assessment for each topic to identify students' starting ability level. This usually takes around 10 minutes and aims to identify strengths and weaknesses of students. Platforms then offer teachers' guidance regarding the teaching focus for different cohorts of students. For example:

- **Mathspace** uses initial diagnostic tests and input from formative assessments to gauge student level and provide questions tailored to their skill level. Questions become easier or harder depending on how the student answers the questions. Step level feedback is provided to understand at what point the student is struggling. An artificial intelligence (AI) process is used to work out the chance of students knowing future content and provide questions accordingly. It creates a full picture of the student's current knowledge level.
- **Maths Pathways** creates individualised learning pathways for students. Each student is provided with fully differentiated assessments and pathways based on their results collected during formative and summative assessments.

Figure 18: Maths Pathways learning pathways by student

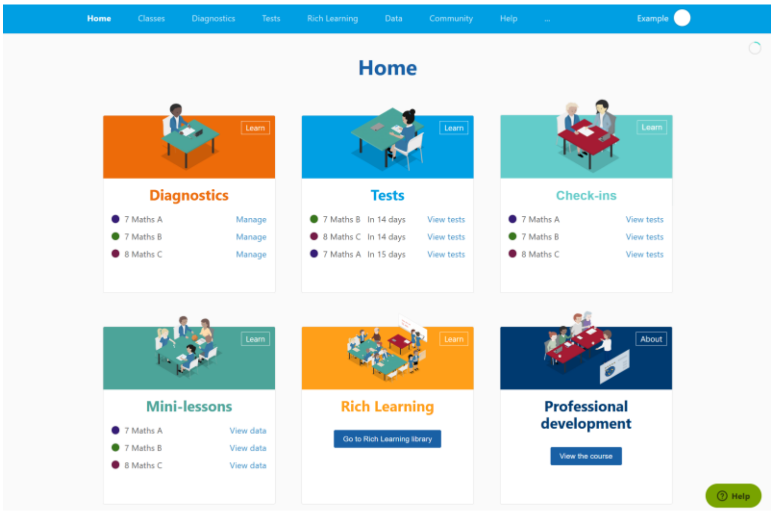


Alternative text: Figure 18 is an example of how the 'Maths Pathways' interface tracks a student's progress. Student's names are listed on the left-hand side of the screen and a bar graph tracks their progress to the right of their name.

9.3.4 Individual and cohort analytics

A unique feature of fully featured teaching and learning platforms is the ability for the teacher to see student, class and year level data. Teachers can see the strengths and weaknesses of each student and easily share this with parents. Platforms spot trends amongst a cohort to help teachers identify what students do and don't understand. They can also identify students ability level at the beginning of a year, term or topic, and create cohort data for maths departments looking to see aggregated student performance. Teachers can see what work students have or haven't completed, as well as their progress in completing work. All information is presented in teacher dashboards with the ability to download and present data as necessary.

Figure 19: Maths Pathways example of teacher dashboard



Alternative text: Figure 19 is an example of the teacher dashboard interface from 'Maths Pathways'. There are links to diagnostics, tests, check-ins, mini-lessons, rich learning and professional development.

9.4 Examples of use

We conducted a discussion forum with 50 maths teachers from across Australian jurisdictions, from government, Catholic and Independent schools, who used one or more of the following products:

- Maths Pathways
- Mathspace
- Edrolo
- Education Perfect
- Atomi
- Prodigy

The following sub-sections summarise our findings about how some of the discussion forum participants use the platforms.

9.4.1 Maths Pathways - Year 7-10 maths teacher, Tasmanian Independent School

Maths Pathways (MP) is used in their maths classroom for all year levels. Maths Pathways is supplemented by weekly direct instruction lessons with a specific focus on what most students are struggling with. Students who are confident with those concepts work independently on their MP modules.

They find the diagnostic tool most helpful as it allows students to work at their own level “without getting too frustrated” and provides specific mini-lessons for students to support their learning. It also allows teachers to access student data to understand what concepts they are struggling with or are confident in. The teacher also liked that with diagnostic tests, they could “tweak them exactly for my students”.

They have found that differentiation is very easy with Maths Pathways and it saves a lot of time as the teacher doesn’t have to plan it. Students are told to do at least six modules of Maths Pathways a week, with eight 55-minute classes a fortnight. Accompanying this are collaborative tasks which are run at the end of the week and allow students to work together.

9.4.2 Mathspace – Year 11-12 maths teacher, South Australian Public School

This teacher found that using Mathspace has increased the impact of their classroom teaching in two ways:

- Firstly, spending less time creating resources or questions to use in the class, leaving more time to plan the use of the resources effectively in class, and differentiating where necessary.
- Secondly, analysis of performance is easier and quicker which makes decision making and lesson adaption quicker.

This teacher found that the time saved by using these platform features has been used to help enrich lessons and support students via differentiation and scaffolding extensions.

In terms of differentiation, Mathspace helps provides manual or automatic differentiation. Manually, teachers “select topics or tasks to assign to students based on their ability or where they are at in their learning and use same to teach or scaffold their learning”. Automatic differentiation occurs by adjusting questions given to students based on their performance as they complete tasks. They recommend using a mix of independent tasks on the platform as well as some practice tasks on paper as an exit task to ensure or assess their mastery.

In their experience, they found that students needed explicit teaching as well as the platform to learn concepts. This was apparent when after students had completed modules, they probed them for further detail and the students failed to show this understanding. They also noticed that to get the best use out of the platform students had to put in “effort to understand the concept or use their critical thinking skill in their problem solving”.

9.4.3 Education Perfect - Year 7-12 maths teacher, Victorian Catholic School

This teacher used Education Perfect in conjunction with presented lessons in class. Education Perfect was sometimes used as a lesson for the entire class, and other times students worked through content individually. The teacher also found Education Perfect to be helpful with online learning as it allowed them to watch what students were doing and send them a message if required. They found that the platform increased effectiveness and impact of classroom teaching by reinforcing what they had taught. The platform also provides more examples for students to work through, highlighting where students need to do work.

They felt resources provided by Education Perfect are less word dense, which was beneficial for students who normally struggle with maths as it supported them to achieve more in a lesson. This teacher valued that Education Perfect provided effective support for visual learners with diagrams and representations. Students enjoyed the quick feedback and accompanying videos with exercises.

The teacher felt the diagnostics were excellent as they were detailed and immediate and were a useful tool for formative assessment to identify which students needed to be challenged or supported. The teacher at times set some extension work for students who needed enrichment.

On implementing Education Perfect in a school or classroom, the teacher recommended being familiar with how the platform works before bringing it into the class. To support this, the teacher advised that watching a tutorial on how it works and / or watching another teacher using it was essential.

9.5 Target groups

Fully featured maths teaching and learning platforms are typically designed to support maths teachers of upper-primary to year-12 students. These platforms have value for:

- **Out of field teachers or less confident maths teachers** - These platforms can provide supplementary content support as well as exercises for students that are automatically marked. Teachers can learn the content alongside their students.
- **Time poor teachers** - These platforms ultimately aim to save teachers time. Time poor teachers can use these platforms to replace traditional assessment and marking. As well as this, platforms can provide instant support and guidance when students are struggling, rather than requiring the teacher's intervention.
- **Teachers with classes with a wide range of maths abilities** - Another feature of these programs is the ability to differentiate work for different students as they can access work on their individual devices. Teachers can also easily identify student skill level allowing them to assign, or have automatically assigned, level appropriate work.

9.6 Level of use

These products are increasingly common in schools across Australia with providers reporting strong growth in their customer base over recent years. In particular, highly resourced independent schools have been using software of this kind in maths classes for over five years with strong renewal rates indicating satisfaction with the quality and value provided to maths teachers.

We heard from program providers that the following number of Australian schools use their products each year:

- Education Perfect claims over 1,600 schools use their platform for maths
- Maths Pathways claims that over 340 schools use their platform
- Mathspace claims 25% of Australian secondary schools use their platform
- Edrolo claims over 1,000 schools use their platform

9.7 Cost

Typically, these platforms are charged on a per student per year basis. The cost ranges from $15-$20 per student per year.[100] Pricing is typically substantially less than the recommended retail price (RRP) of a hardcopy maths textbook at the same year level which can range from $50-$60 per textbook. The cost varies by provider, by year level, by school sector and can vary with the mix of features and functionality purchased. Vendors such as **Education Perfect** and **Edrolo** often bundle their maths product in with other subjects like science, English and languages to provide the school a discount for the maths offering.

9.8 Impact

Fully featured teaching and learning platforms support teachers with maths capability, improving capacity and efficiency in their teaching, and differentiation of teaching for their students.

9.8.1 Teacher capability

When scoped and sequenced to curriculum contexts, these platforms provide ready-made, quality assured resources that align with teaching objectives. These resources include different representations and explanations of maths concepts that can support teachers who are less confident with content or pedagogy. One teacher said platforms "support visual learners really well and some of their diagrams and representations are so much better than I can draw". As well as this, we heard that teachers often learn alongside students and build competencies for future classes. Many of these platforms also provide teaching support resources to assist teachers in communicating content to students.

9.8.2 Teacher capacity and efficiency

We heard from teachers that one of the best features of platforms was their ability to save teachers time in their day-to-day tasks and to improve the efficiency of teaching through easy access to clear data on student progress. Automated features such as formative assessments with instant grading and feedback helped teachers save time traditionally spent creating and marking assessments. One teacher said it allowed them to "quickly check for their understanding and provide on-the-spot support or scaffolding as necessary".

Another time-saving feature is the ability for teachers to identify the ability level students have reached, and which resources are best suited for them. Teachers can then set content for each group and spend time one-on-one with students to answer questions or provide specific support. As one teacher said, the platform "basically takes care of the middle chunk of students freeing me up to spend more 1:1 or small group time with the strugglers and the high-flyers".

9.8.3 Differentiation

[100] Based on information provided by vendors and publicly available pricing information.

Platforms allow for differentiation in teaching by both identifying what level students are at and providing relevant content. Most platforms allow for manual and automatic differentiation for students. Teachers can manually increase or decrease difficulty of work as they see fit to support students, as they know their students best.

Differentiation also allows students to work to their level, and the platform "takes all the guesswork out of the differentiation and allows students choice about the content they cover" as said by one teacher. Identifying student level for teachers helps with what level of content is taught. One teacher said that "through the data collected you can target your teaching for an individual based on their needs…or to a small group who are all stuck … to ensure you are teaching at their point of need."

9.9 Success factors

- **Platforms are integrated in a structured way into the classroom -** The model works best when platforms are integrated into classroom practice. This allows teachers to ensure students know what to expect when using the platforms and understand the purpose of it. Keeping it in a routine also ensures students aren't bored by the software as they know for how long they will be using it and what to expect to get out of it. One teacher stated that "too often we see these platforms not used to their full capacity", and that platforms could "increase the impact of classroom teaching if teachers made a much more conscious effort to embed the platforms into their teaching program".
- **Platforms are used as part of and in conjunction with classroom teaching -** We heard that these platforms are best used when used as part of and in conjunction with classroom teaching. Teachers can monitor, guide and build on what students are learning in the platforms at an individual student level, small group level, or class level.
- **Curriculum aligned platforms work best for classes -** Platforms work best when content aligns to the Australian Curriculum. This saves teachers time tweaking content and ensures that students are learning what is assessable in their context.
- **Enable saved teacher time to be redeployed to focus on individual students and differentiation -** When platforms save teachers time, teachers are able to use their extra time to work more closely with individual students and allocate specific tasks tailored to their learning needs.

9.10 Caution factors

We heard that there are a significant caution factors to consider when implementing this model to ensure it is effective and does not instead result in lower quality maths teaching.

- **Overuse is worse than no use** - We heard that students can easily become bored with completing exercises online or become distracted while using devices and not complete the activities at all. Teachers require a level of trust with their students that they are completing the set exercises and teachers need to play an active role in ensuring students are on task. We heard that, as a general rule, around 30% or less of class time should be spent on the platforms on devices, with the rest on more traditional class teaching.

- **To use data well, teachers need time -** Although the type and quantity of data provided by these platforms is very helpful for teachers, it takes time for teachers to understand and absorb the patterns emerging, and then change practice to respond to them. We heard that teachers can get into the habit of ignoring data and continuing business as usual because of competing demands. As one teacher said, "I believe that platforms help to differentiate … but realistically I am not doing this as much as what would benefit the students… due to time constraints for planning and lack of professional learning".
- **There are significant teething issues involved in implementation of platforms -** To implement platforms well, schools and teachers need to be aware of how to use the platform and how it differs from non-platform teaching. Key aspects of the platforms such as how they work, what students see, what teachers see, and how to troubleshoot basic issues need to be understood before the software is implemented. Teachers also need access to quick and reliable IT support from the school or provider. Initially, setting up these platforms may take more time than previous systems. Maths Pathways recommends a reversed teaching model where students start with the platform and teachers then focus on teaching in areas identified as weaknesses for a particular student or groups of students. This is a significant departure to the traditional method of teaching and requires buy-in and support from school leadership and maths departments.
- **Student motivation affects platform success -** We heard that students who are more independent and motivated learners use the platforms to their full potential and have improved results. However, students who are less self-motivated can tend to 'coast' through the platforms and click through for answers, rather than using the features to improve their outcomes – reinforcing the need for teachers to play an active role in supporting students stay on task.
- **Content must be checked by teachers before use** - Although fully featured teaching and learning platforms are designed to seamlessly integrate into the classroom, we heard that often content needed to be checked before being implemented to ensure it aligns with state and school context. Additionally, the language or solutions used by the platform need to match what the teacher uses so students aren't confused or have right answers marked wrong. Some platforms allow teachers to tweak language, but this is something teachers must do before sharing to students or rely on students to report when the language is different.
- **Some platforms lack higher order thinking and opportunities to show working out -** Some platforms lack higher order thinking questions that help stretch student understanding. In those instances, platforms are better used for homework rather than classwork. Another issue with some platforms is that students don't need to show their working out. We heard that showing how students come to an answer is as important as having the correct answer and teachers often need to direct students to incorporate this when using software.

9.11 Environmental pre-requisites

Fully featured teaching and learning models are resource intensive:

- They require one-to-one devices for students in the classroom and at home. Some vendors cite offline resources students can use, though we heard from teachers that these do not offer the full functionality of the model and are not recommended.

- All platforms also require reliable devices and internet connectivity for students at school and at home.
- Teachers require professional development around how to best use software. They also need quick and reliable IT support when using it in class.

9.12 Implications and Opportunities for Australian Government

The Australian Government may consider opportunities to support this model via:

- Lessening the burden of identifying the highest quality digital maths teaching tools for schools via research, evaluations and collation. For example:
  - Commissioning research and evaluations of tools in this category and sharing the findings with stakeholders to inform decision makers.
  - Developing and publishing standards which resources should meet (e.g., explicit alignment to the Australian Curriculum, provision of 'rich' classroom tasks that support diversified teaching).
  - Incorporating common definitions in these standards that define, for example, what a 'lesson plan' is.
- Initiatives that support teachers to develop the skills needed to effectively utilise these platforms in maths teaching. This may involve both the role of digital maths teaching skills in teaching degree programs and professional learning course offerings.

10 Deep Dive 6: Digital exploration, investigation & game environments

10.1 Model summary

This model encompasses platforms that use contemporary graphics, visualisation tools, mini-games, or play-based interactions to develop understanding and proficiency with maths concepts, both simple and complex.

The term gamification is commonly used in two ways:[101]

1. Adopting video games into everyday use, including to motivate players to undertake tasks such as learning that they may not otherwise feel motivated to do.
2. Using game design elements – or "game mechanics" – to make non-games products more enjoyable and engaging.

10.2 What challenges does the model address?

10.2.1 Teacher capability and confidence

Platforms that use gamification are used by both specialist maths teachers and out of field maths teachers to develop students' understanding of specific tasks in maths. Teachers and experts consulted believe gamified tools are more beneficial to out of field teachers who may otherwise struggle to come up with their own contextualised tasks for teaching.

In Desmos, for example, the task tools which are used for graphing and equation visualisation support the teacher with teacher notes, prompts and guidance as well as real-time data on student progress. These tools are best suited for years 7 and up where there is clear curriculum alignment and tools available.[102,103]

10.2.2 Differentiation

By their nature, platforms that use gamification employ simple language and engaging graphics to convey concepts. Questions and explanations are short, sharp, and clear and often pitched at a low reading level. For this reason, they are suitable for students with lower literacy levels and capture all ranges of achievement within a class.

Stakeholders describe platforms such as Desmos as "low floor, high ceiling" "rich resources", meaning they pitch learning low to be accessible but allow for advanced manipulation and learning at the higher end.

Real-time feedback mechanisms in the platform enable teachers to see progress and data from the back-end and use this to inform personalised learning approaches for their class. For example, for a given task the teacher can see where

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[101] Deterding, S., et al. (2011) From Game Design Elements to Gamefulness: Defining "Gamification". Proceedings of the MindTrek '11. doi:10.1145/2181037.2181040

[102] https://teacher.desmos.com/collection/5e8cc5666b09a173c7377773 Last Acccessed 4 October 2022.

[103] Interviews with Caroline Dean, South Australian Department of Education. Formerly out of stream maths teacher at Wirreanda High School. Now Curriculum Manager SA Aboriginal Science Elaborations, SA Department of Education; and Elijah Kposaftis Maths and Literacy Coordinator Woodville High School SA.

a student has finished early and is ready for discussion, or where a student is struggling to complete a task and precisely where they are getting held up with their working.

10.3 How does the model work?

Digital exploration, investigation and game environments provide students with alternative ways of learning maths concepts and the opportunity to interact with maths concepts:

- Teachers can use these tools in their classrooms to help students understand maths concepts
- Cross-discipline projects can be managed on investigation platforms that include significant maths projects
- Students use individual devices to access online platforms such as Desmos or Prodigy
- Students login with a provided code or credentials. In some cases, teachers establish a session and share the session code with students
- Students work through specific examples or modules within the platform

Gamification approaches and play-based engagement are used extensively across banking, retail, finance, and entertainment sectors to change behaviour. From Frequent Flyer points to internet banking apps, Wordle and Candy Crush, game mechanics, tools and techniques are part of our everyday life.

Gamification can be applied in digital learning environments to increase students' interest in studying and help them better understand learning material.[104] In a virtual setting, gamification can even help influence behaviour and help build a sense of community in the classroom. Stakeholder feedback from the use of Desmos in South Australian schools suggests that use of the platform built greater maths literacy, confidence, and group engagement over maths problems in an otherwise disengaged student group at Wirreanda High School.[105]

Australian schools and teachers have used a variety of gamified online platforms and tools to support teaching and learning. However, there is limited hard evidence on the effectiveness of each and where each has been most effective. This is because there are different elements of games used to add gamification to diverse activities and producing different effects, hampering the process of determining which elements are efficient to promote the engagement and learning for a group or type of user.[106]

10.4 Examples of use

10.4.1 Desmos

[104] Dodson, K. (2021) Can Gamification Drive increased student engagement? https://er.educause.edu/articles/sponsored/2021/10/can-gamification-drive-increased-student-engagement#:~:text=But%20most%20importantly%2C%20gamification%20can,of%20community%20in%20the%20classroom. Last accessed 7 September 2022.

[105] Source Caroline Dean, South Australian Department of Education (see above reference).

[106] Dodson, K. ibid.

Desmos is a US company founded by Eli Luberoff, a math and physics double major from Yale University in 2011. Desmos was acquired in May 2022 by Amplify,[107] another US based provider of K-12 curriculum and tools with more than 10 million students across the US. Following the acquisition, the Desmos calculator will continue to be provided free for students, while the Desmos classroom will continue to be developed with the additional expertise of Amplify.

Desmos provides a suite of maths tools aligned with the Australian Curriculum (years 7 to 12)[108] that can be used to visually represent maths understanding. The tools include:

- A graphing calculator
- Test practice
- Matrix calculator
- Geometry tool

Desmos is constantly updated with new content and new tools and is undergoing more significant iteration as it moves into the Amplify stable.

Desmos is often used within classrooms to teach specific concepts or to undertake specific tasks. It enables open and collaborative learning, where the specific students are de-identified but open to the rest of the class to see how each is approaching solution finding.

As a common example of Desmos use, a teacher would set a graphing task in Desmos for the class to develop axes and a line representing some data. The class can see the approach of their fellow students to setting axes and the representative line and assess their own progress. In the example below (Figure 20), the class is exploring ranges. The screen provides an opportunity for them to play with ranges – and some notes for the teacher to support learning.

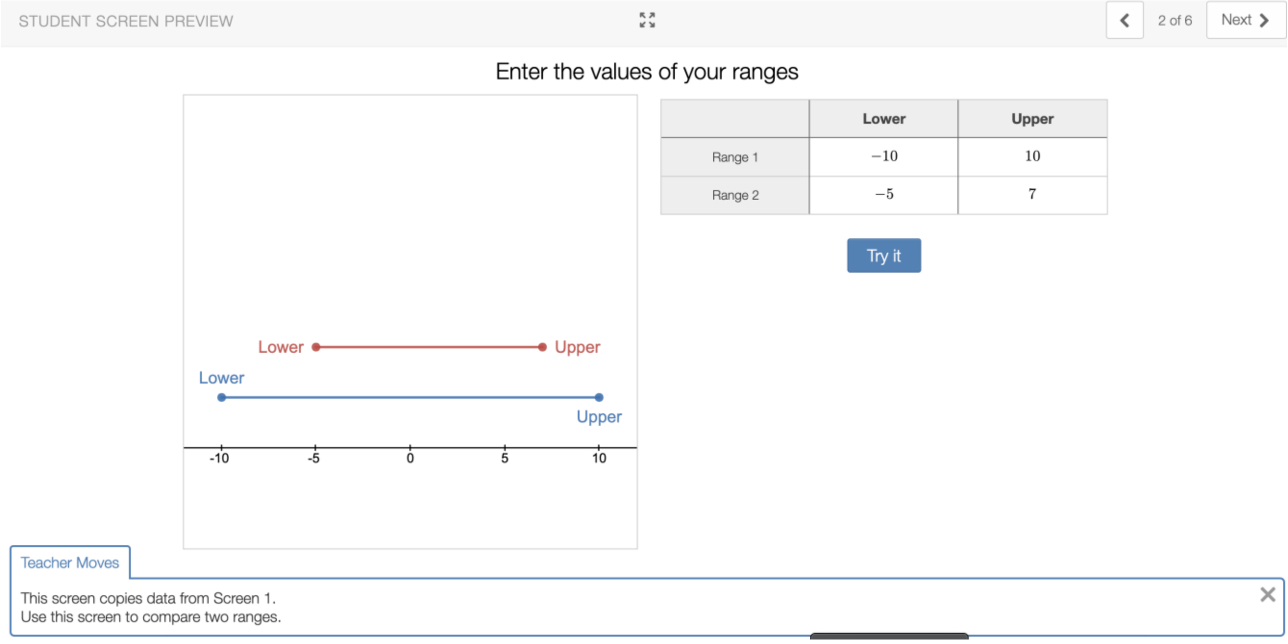
Teachers are also able to develop and set their own challenges, using pop culture or contexts familiar or engaging to their class. John Rowe, a leader in Desmos use in Australia, has developed a range of tools using Star Wars, Mario Kart, and planets for different tasks.[109]

[107] See https://www.businesswire.com/news/home/20220518005797/en/Amplify-Acquires-Desmos-Curriculum-to-Build-the-Future-of-Math-Instruction-Desmos-Calculators-to-Remain-Independent-and-Free-to-All last accessed 13 September 2022.

[108] See https://teacher.desmos.com/collection/5e8cc5666b09a173c7377773 Last accessed 4 October 2022.

[109] https://mrrowe.com/desmos/, last accessed 7 September 2022.

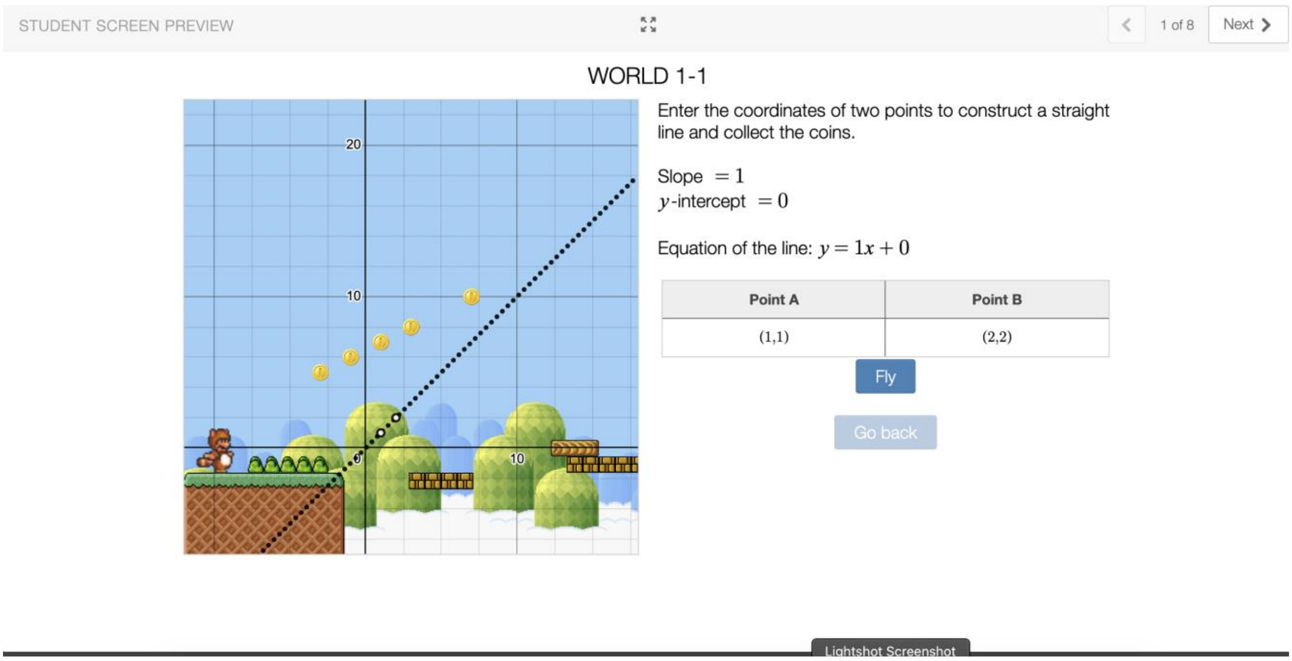
Figure 20: Desmos example screenshot – Graphing task (range)



Alternative text: Figure 20 is an example of the 'Desmos' user interface with a graph on the left-hand side and its corresponding math question on the right-hand side.

The following example uses Mario Kart to encourage students to find the right linear equation for Mario to reach the coins.

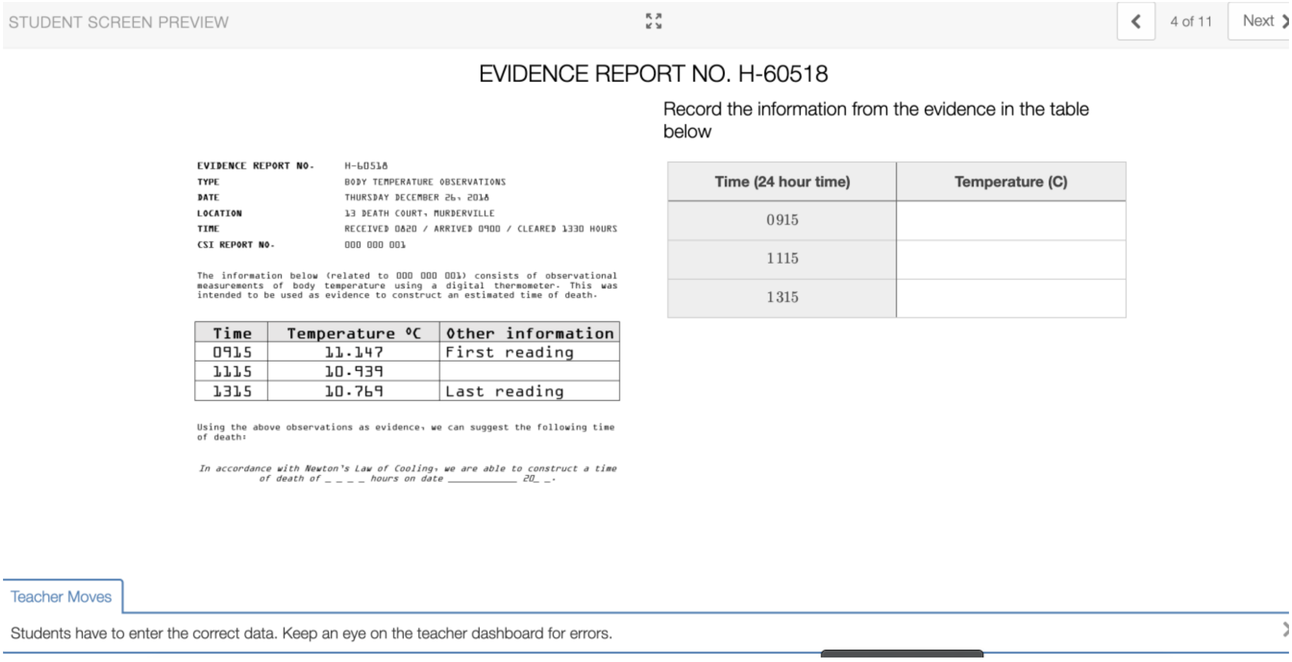
Figure 21: Desmos example screenshot – Mario Kart and linear equations



Alternative text: Figure 21 is an example of the 'Desmos' user interface with a 'Mario Kart' graph on the left-hand side and its corresponding math question on the right-hand side.

The following example (Figure 22) uses a CSI scenario to find and record relevant maths information and to plot a graph.

Figure 22: Desmos example screenshot – CSI



Alternative text: Figure 22 is an example of the 'Desmos' user interface with a fictional report on the left-hand side and its corresponding math question on the right-hand side.

10.4.2 Prodigy

Prodigy Education was founded in Canada in 2011 by Alex Peters and Rohan Mahimker. Prodigy is an application that employs game-based learning for students using adaptive maths problems. Students explore a fantasy world with embedded maths problems. Teachers and parents receive analytics from Prodigy to keep track of student progress. In Australia, Prodigy claims to be aligned to Australian Curriculum for years 1 to 8.

Prodigy has been historically popular in the US and Australia. However, in recent years regulators and media review agencies have stepped in to raise warning about the aggressive marketing that targets children using the platform to access premium levels that require payment to access. Children and Media Australia note "*Aggressive marketing of premium membership is consistently used throughout the game.*"[110]

10.4.3 Minecraft: Education Edition

Minecraft was developed by Swedish programmer Markus Persson and sold to Microsoft in 2014 for USD2.5 billion. Minecraft: Education Edition is a version of Minecraft designed for education in a school setting. According to Microsoft, "*Minecraft: Education Edition is a game- based learning platform that builds STEM skills, unleashes creativity and engages students in collaboration and problem-solving. Minecraft helps educators meet students where they are and inspires deep, meaningful learning across subjects*".

[110] https://childrenandmedia.org.au/app-reviews/apps/prodigy-math-game last accessed 13 September 2022.

Minecraft is a popular game amongst 3-year-olds to adults where players collaborate and build creatively with blocks in immersive 3D worlds. According to the Active Player Minecraft live monthly player count, 173 million players worldwide were on its platform in August 2022.[111] Minecraft won the US Kid's Choice Award for Favourite Videogame in 2020 and 2022.

Although full of unrealistic physics and environments, it gives players infinite possibilities to make tools, build structures and enable them to discover and extract raw materials and other resources in sufficient quantities for their purposes. It also enables players to build up complex systems and higher levels of challenges. Minecraft can be played either online or offline, and as a single-player or multi-player. It is also available on different platforms and devices such as PC, laptop, mobile or via the Microsoft Xbox.

Every player must start with building a new world and these can be chosen from one of five pre-set modes. There are four kinds of difficulties that players need to take up as challenges:

- Peaceful
- Hard
- Increased levels of difficulties
- Difficult specific effects

As Minecraft is an online game it comes with a number of risks common to the online environment and there are also a variety of parental controls that can be applied. The Australian eSafety commission identifies areas such as anonymous communication, online relationships and in-app purchasing as safety areas to consider for Minecraft.[112]

Figure 23: Example of Year 3 Minecraft: Education Edition Maths teaching example – 3D shapes

Alternative text: Figure 23 is an example of the Minecraft interface demonstrating the game's visual 3D design.

[111] https://activeplayer.io/minecraft/ last accessed 13 September 2022.

[112] https://www.esafety.gov.au/key-issues/esafety-guide/minecraft last accessed 13 September 2022.

For maths teaching and learning, we heard from teachers that Minecraft can be useful for learning about concepts like area, volume, perimeter, patterns, ratios, coordinates and algebra which can be laid out spatially and manipulated through the platform.

10.4.4 Roblox

Roblox is an online “open” game platform and game creation system developed by Roblox Corporation that allows users to program games and play games created by other users. It was initially released in 2006 and is available across multiple platforms including Windows, Xbox, Android, and iOS.

In 2021, Roblox ranked as the second most downloaded mobile game globally, with 182 million downloads[113] and 204 million active players in August 2022 (compared to Minecraft’s 173 million).[114]

The Roblox platform is free and open to use in classrooms, though some games may have payment models for use. There are a variety of open-sourced resources to support teaching and learning in Roblox. In 2021, Roblox has moved to create and fund more education specific resources.[115]

In Roblox, kids can create and interact in what its makers describe as "immersive 3D worlds." Players are given the opportunity to create an avatar (player) and select from a variety of different physical features, as well as accessories and outfits that are available to purchase with “Robux” inside the platform’s Catalogue.

As Roblox is an online game it comes with a number of risks common to the online environment and there are also a variety of ‘parental controls’ that can be applied by a student’s guardian or teacher. The Australian eSafety commission identifies areas such as anonymous communication, online relationships and in-app purchasing as safety areas to consider for Roblox.[116]

Maths concepts are present throughout Roblux games. Examples include:

- The incorporation of a virtual currency within Roblox (see **Error! Reference source not found.**24 below) – “Robux” – adds immediate mathematical concepts that can be explored and exploited for learning. Whilst not essential to play, Robux can be used to encourage play as you can do more things and undertake more activities with currency than you could otherwise (see below for the game Adopt Me! which uses Robux to buy pets).
- Addition, subtraction, division, multiplication via the creation of Mega Neon Pets in Adopt Me!,[117] a Roblox game where you make and trade pets. For example, to make a Mega Neon, kids need to grow four fully grown Neons, and to make one Neon you need to grow four of the same pets. That is, to get one Mega Neon, you need to grow 16

[113] https://cybercrew.uk/blog/how-many-people-play-roblox/#:~:text=Roblox%20has%2047.3%20million%20active%20daily%20users,-If%20you%20wonder&text=In%20comparison%2C%20in%20the%20second,million%20active%20daily%20users%20worldwide last accessed 13 September 2022.

[114] https://activeplayer.io/roblox/#:~:text=How%20Many%20People%20Play%20Roblox,on%20increasing%20month%20by%20month last accessed 13 September 2022.

[115] https://blog.roblox.com/2021/11/next-chapter-of-teaching-and-learning-on-roblox/ last accessed 13 September 2022.

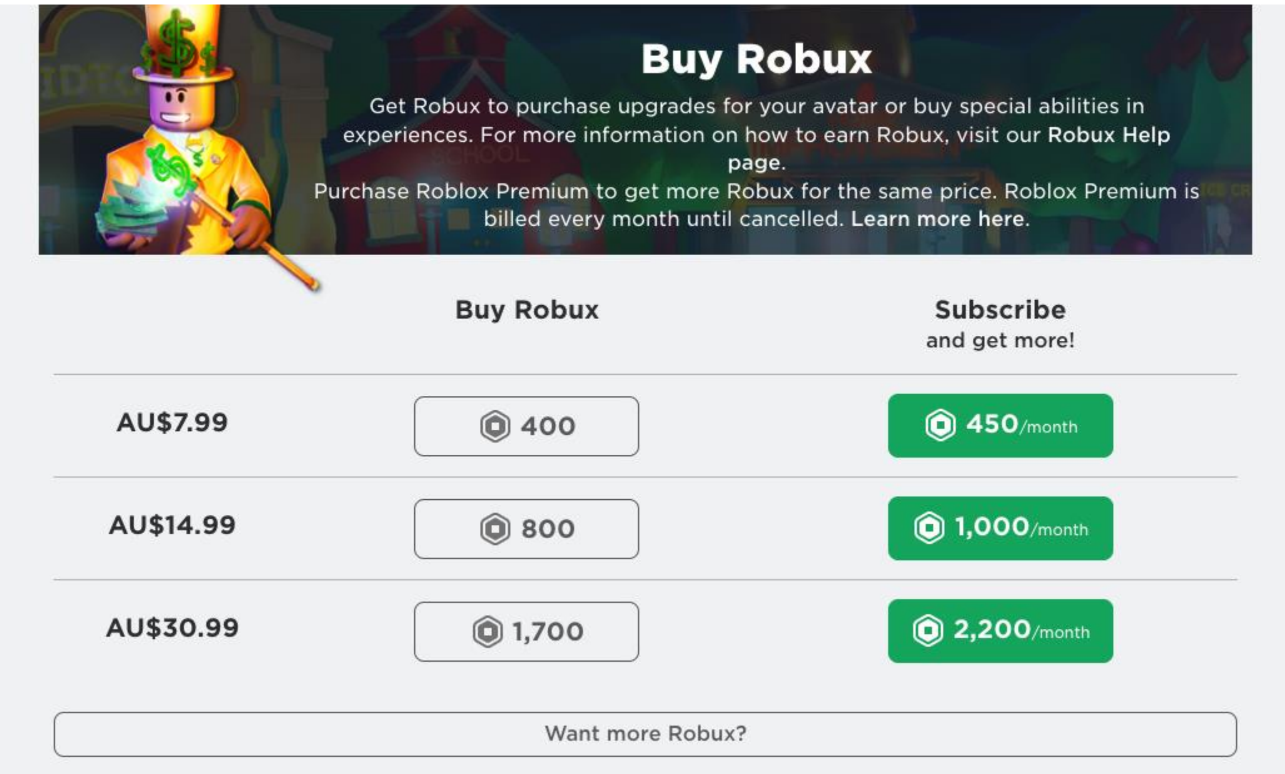
[116] https://www.esafety.gov.au/key-issues/esafety-guide/roblox last accessed 13 September 2022.

[117] https://primarylearning.com.au/2020/07/13/building-houses-and-buying-pets-the-maths-of-roblox/ last accessed 13 September 2022.

pets. Adopt Me! is a "freemium" product, allowing free play where users can build up Robux by e.g. logging on every day, or by purchasing Robux.

- Spatial reasoning, perspective, scale, direction, orientation, two- and three-dimensional space, floor map interpreting, position, length and area via Bloxburg. This game is not unlike Minecraft in allowing players to explore within a virtual environment where they can build and design their own house, own vehicles, hang out with friends, work, roleplay or explore the city of Bloxburg.[57,118] There are even blogs on Bloxburg house ideas and models. Bloxburg must be purchased for 25 Robux.
- Using obstacle courses ("obbies") to learn maths operations through embedding maths problems in a player journey,[119] and see Figure 27 below.

Figure 24: Virtual currency in the Roblox platform.



Alternative text: Figure 24 provides an example of the 'Roblox' user interface. The text at the top of the screen encourages users to 'buy Robux'. The bottom of the screen lists the different values and prices for 'Robux'. Users receive more 'Robux' per purchase if they subscribe.

118 https://faindx.com/game-update/bloxburg-house-ideas/ last accessed 13 September 2022.

119 https://www.youtube.com/watch?v=KxLnqF7tH1M last accessed 13 September 2022.

Figure 25: Example Roblox games using maths concepts in the game Adopt Me!

Alternative text: Figure 25 provides an example of 'Adopt me!' game interface.

Figure 26: Example Roblox games using maths concepts in the game Bloxburg

Alternative text: Figure 26 provides an example of the 'Bloxburg' user interface demonstrating the game's visual 3D design.

In addition to embedded maths learning, there are maths specific "games" built within Roblox, such as Brainika.

Figure 27: Example of Roblox "obbie" game Brainika for teaching maths at kindergarten, including a particular focus on children with ADHD.[120]

Alternative text: Figure 27 provides an example of the 'Brainika' user interface demonstrating the game's bright, attractive colours.

120 https://brainika.co/ last accessed 13 September 2022.

10.5 Target groups

There is evidence that all groups of students can benefit from visual and gamified ways of engaging with maths concepts.

10.6 Level of use

Between them, Minecraft and Roblox are two of the most highly played and popular games for Australian children.

One Australian study showed that more than 65% of children played Minecraft, with the highest incidence for children aged 9 to 10.[121] The study did show some gender differences by age, with girls playing less Minecraft than boys across all age groups.

At a state or school level, the extent of use of these platforms is varied and difficult to judge.

10.7 Cost

Access to gamified platforms ranges from free (in the case of some Roblox games) to subscription costs.

As an example, Minecraft: Education Edition negotiates access to organisations as part of licensing Microsoft Office M365 and other Microsoft products. Bulk licences can be negotiated as part of these agreements, with a standard organisational user licence at USD$5 per user per year.

10.8 Impact

There is mounting evidence that using games in learning environments can have a number of benefits. In particular, it seems clear that these platforms are effective for teaching specific concepts within maths and to develop and ensure a complete conceptual understanding of terms and functions – e.g., graphing, algebra, geometry.

10.8.1 Gamification can aid in cognitive development.

Studies demonstrate that using games or gamification increases the activity of regions of the brain responsible for development.[122] Games that are specifically developed for this purpose are often called "brain games" and include things like Wordle, Sudoku, Lumosity, crosswords, memory and logic puzzles. These games can improve the rate in which the brain processes and maintains information.

[121] Mavoa, J., Carter, M. and Gibbs, M. (2018) Children and Minecraft: a survey of children's digital play. New Media and Society. Vol. 20(9) 3283 –3303. Available at marcuscarter.com/wp-content/uploads/2020/04/1461444817745320.pdf last accessed 13 September 2022.

[122] Doraiswamy, P. M., Agronin, M. (2009). Brain games: do they really work? Scientific American. Available at https://www.scientificamerican.com/article/brain-games-do-they-really/ last accessed 7 September 2022.

10.8.2 Gamification increases the level of engagement, collaboration and learning in classrooms.

One recent review suggests that embedding gamification into hybrid learning environments can benefit students in several ways.[32] The main goal is often to increase individual student engagement. Gamification helps to achieve this goal in the following ways:

- Increasing confidence, interest and desire to learn
- Increasing knowledge retention
- Optimising the learning experience
- Introducing new and more varied types of learning material
- Influencing positive behaviours
- Increasing collaboration and socialisation around maths to spur a sense of community

Many studies have demonstrated that games do in fact deliver these benefits. For example, one study in a New Zealand cohort showed a gamified version of software (Desmos) was more effective in enhancing children's learning and they found it more engaging than the non-gamified alternative.[123] Studies of the Minecraft platform in the US and in Queensland focusing on Minecraft: Education Edition demonstrated students felt significantly more confident at maths and were much more interested in maths learning into the future using gamified tools.[124]

Nevertheless, there is some complex and sometimes contradictory evidence, in large part due to the broad impacts of games which stimulate many types of learning and behaviours. It seems clear that the type of game mechanics used can have varying impacts on different cohorts, for example girls may respond less well to ranking mechanics.[125] More research and evidence on where and how gamification mechanisms can be used in the teaching and learning of maths would be beneficial to Australian schools.

One particular advantage over other methods is that interacting visually and using sliders or practical modulators to play with variables enables learners to delve under answers to really understand the workings of things like volume, equations, graphs.

10.9 Success factors

There are factors that affect model success such as:

- Device access
- Broadband access, though many games allow for offline play once downloaded

[123] Nand, K., Baghaei, N., Casey, J. *et al.* (2019). Engaging children with educational content via Gamification. *Smart Learn. Environ.* **6**, 6 https://doi.org/10.1186/s40561-019-0085-2 Available at https://slejournal.springeropen.com/articles/10.1186/s40561-019-0085-2#citeas last accessed 7 September 2022.

[124] Dezuanni, Michael and Macri, Jo (2020) Minecraft: Education Edition for Educational Impact. A Research Report developed for Microsoft by Queensland University of Technology's Digital Media Research Centre. Available at https://research.qut.edu.au/dmrc/projects/mee-minecraft-for-educational-impact/, last accessed 13 September 2022.

[125] Smiderle, R., Rigo, S.J., Marques, L.B. *et al.* (2020) The impact of gamification on students' learning, engagement and behavior based on their personality traits. *Smart Learn. Environ*. **7**, 3. https://doi.org/10.1186/s40561-019-0098-x. Available at https://slejournal.springeropen.com/articles/10.1186/s40561-019-0098-x#citeas last accessed 7 September 2022.

- Alignment to curriculum
- Context is relevant to learners – particularly in relation to examples and data sets
- Confident teachers

10.10 Caution factors

There are factors that teachers and schools should be cautious about in considering whether to use this model

- eSafety factors associated with online, multi-player platforms. These can include:
  - anonymous communication
  - cyber bullying
  - sexually explicit content
- Aggressive advertising content in 'freemium' apps, which are free for basic access but strongly push for users for pay for a premium version of the app.
- Too much focus on games rather than the maths. In particular, there are concerns that games can skim over concepts to focus on process or getting the right answer, rather than ensuring an underlying understanding of concepts. To counter this however, some of these interactive and visual platforms are uniquely placed to enable students to dive into rich detail and play with e.g., numerators, volumes, variables, graphs, etc.
- Parent perception that engaging or gamified platforms are used as "babysitting" approaches for students, instead of to enrich in-class teaching.

10.11 Environmental pre-requisites

There are pre-requisites required to use the model including:

- Device access
- Reliable Broadband access, though many games or platforms are available offline following download
- Teachers having an appropriate level of understanding of online pedagogy and use for learning
- An appropriate and effective eSafety overlay for programs with external collaboration channels
- Effective communications regarding the application and evidence base for interactive platforms in maths teaching and learning

10.12 Implications and Opportunities for Australian Government

The Australian Government may consider opportunities to support this model via:

- Supporting more studies to develop the Australian evidence base on the impact on maths achievement for students using Desmos, Minecraft and Roblox to support maths teaching and learning across specific concepts within the curriculum.
- Providing more specific guidance for teachers (and parents) on 'parental' controls and eSafety, potentially via the eSafety Commissioner, around the use of online and multi-player platforms such as Minecraft and Roblox.

11 Deep Dive 7: Cohort-specific culturally relevant content and lesson plans

11.1 Model summary

Digital teaching tools that are designed to use culturally relevant pedagogies to engage and improve student outcomes in maths for culturally and linguistically diverse students.

11.2 Which challenges does the model address?

This model helps to address the differentiation challenge facing maths teachers:

- Students from disadvantaged contexts and/or whose second language is English face particularly acute challenges in succeeding in school mathematics.[126] This gap is well documented for Indigenous students in particular, as evidenced in the "Closing the Gap" report.[127]
- There is also evidence that students in this cohort who do perform well in maths are more likely to fall out of STEM pathways as they progress with their schooling.[128]
- Evidence shows that effective learning and retention in STEM pathways is directly impacted by the cultural context and background of students, and how much this is incorporated into teaching and learning.[129]
    - For example, in the case of Indigenous students, we heard that a more hands-on, relationship-based approach incorporating story-telling and relatable cultural problems can be more effective than standard approaches to teaching maths.
- For culturally and linguistically diverse (CALD) cohorts, approaches incorporating differentiated learning and culturally relevant maths content can be digitised to promote access and reduce the cost of distribution.

11.3 How does the model work?

This model involves the use of digital technology to provide culturally relevant lessons for students from backgrounds who typically report lower maths outcomes than their peers. Whilst we only found one example currently in use in Australia, Solid Pathways, we heard strong evidence that this is a promising model for lifting maths outcomes for disadvantaged groups.

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[126] Miller and Warren, Exploring ESL students' understanding of mathematics in the early years: factors that make a difference, Mathematics Education Research Journal, 2014. https://doi.org/10.1007/s13394-014-0121-z

[127] Australian Government, Closing the Gap report 2020-literacy and numeracy, 2020.

[128] MCEETYA Taskforce on Indigenous Education, Achieving Educational Equality for Australia's Aboriginal and Torres Strait Islander Peoples, 2000.

[129] McMillan et al., STEM Pathways: The impact of equity, motivation and prior achievement, 2021.

To date these groups, particularly Indigenous students, have been under-served by digital technologies. Experts we consulted with believe this is due to a number of pre-conditions not being met for effective use of digital learning, notably:

- Poor or unreliable wi-fi and/or data bandwidth
- Access to devices, particularly 1:1 student to device ratio that can enable online learning or engagement
- Lack or lag in digital literacy.

These pre-conditions are typically not met in schools with a high concentration of Indigenous students, including some rural, remote and regional schools. We caution that the Solid Pathways example should be considered in the context of significant deficits in digital literacy and broadband access for remote communities.

11.3.1 Solid Pathways

Solid Pathways is a critical and creative thinking program for high achieving Indigenous students operated by the Queensland Department of Education. It is an intervention strategy based on strong evidence, which has highlighted that Indigenous students identified as being high achievers at some stage of their schooling do not sustain this throughout their schooling and beyond.

Solid Pathways is available for students:

- in Years 4, 5 or 6
- that attend a Queensland State School
- who identify as Aboriginal and/or Torres Strait Islander
- that meet entry level criteria of achieving in the top two bands of NAPLAN in reading and/or numeracy

The program engages with students using Traditional Ecological Knowledge in teaching STEM. It offers 4 course rounds throughout the year aligned to school terms. Each course consists of 9 to 10 lessons a week with students in a virtual class via the iSee platform. In addition to the lessons, STEM professionals are brought in to be virtual guest speakers explaining scientific inquiry or for a Q&A session. The intention is that STEM professionals are role models to inspire and encourage students to reach their full potential.

Solid Pathways program staff state that their outcomes for students include:

- Developing high levels of STEM literacy
- Having a better understanding of and confidence in pursuing STEM learning
- Having higher aspirations for STEM careers
- Having greater confidence in cultural identity
- After engaging with Solid pathways, 71% of students are achieving an A or B in maths

11.4 Examples of use

11.4.1 Whitfield State School - Cairns, Queensland

Solid Pathways is run at Whitfield State School Queensland with 10 to 13 students. Students range from Years 4 to 6 and participate in Solid Pathways once a week. The Solid Pathways team run a class with these students via the iSee platform.

Figure 28: Example of iSee platform

Alternative text: Figure 28 provides an example of the 'iSee' user interface demonstrating the video link images of multiple players in a virtual room.

Solid Pathways teachers plan and deliver the lessons online. The school organises the technology and logistics behind getting students online. The teacher librarian at the school is the single driver for the Solid Pathways program, setting up the technology in the library for the students to log in.

Once students are in the iSee platform, they can connect with other students online and also with the teacher. We heard that the iSee platform is very reliable and students find it engaging as it is similar to a gaming platform. They have ICT support on site to troubleshoot if needed and receive support from the iSee platform.

Solid Pathways communicates with the school when additional equipment is required, such as mirrors or rulers, to ensure students have everything they need and aren't distracted during the class trying to source the right equipment.

If students miss Solid Pathways lessons, they do follow up lessons organised by the school. There is an attendance incentive with Solid Pathways as students understand that engaging with Solid Pathways may lead to a place at high achieving high schools such as Science Academy High Schools.

11.5 Target groups

This model can be targeted to any group, particularly those who historically are disadvantaged in maths outcomes, such as:

- Indigenous Australians
- Neurodiverse students

- Girls
- Students from culturally and linguistically diverse backgrounds

11.6 Level of use

We did not find evidence of widespread use of this model apart from the Solid Pathways program in regional and remote QLD.

Figure 29 - Solid Pathways level of use

Year	Student enrolments	Schools involved
2020	2,064	150
2021	2,424	165
2022 (as of Term 3)	2,398	162

11.7 Cost

The cost of implementing a cohort specific model will depend on design and reach of each initiative. Solid Pathways is supported by the Queensland Department of Education, and it comes at no cost to schools to implement. The Queensland Department of Education website reports that funding is provided at $3,000, per student, per calendar year.

11.8 Impact

Solid Pathways targets high achieving students. The theory of change underpinning the program design is that Indigenous students are more likely than the average student to disengage with maths, particularly in the transition from primary school to high school. The program aims to increase participation and achievement of Indigenous students in maths by delivering culturally relevant content designed to sustain their engagement.

It's 2021 program report states that:

- There was increased student engagement in STEM with between 74% to 89% retention of students in the program over the course of four school terms in 2021
- 71% of students who participated in two of more terms in 2021 achieved an A or B grade in maths for the year

11.9 Success factors

We heard the keys to the success of the Solid Pathways program have been:

- Access to culturally appropriate content which incorporates examples, context, places and people to which students can relate

- Buy-in from school staff and the wider school community
- 1-1 student to device ratio, as well as a reliable and secure internet connection
- Effective collaboration with staff on site at the school to allow the remote teacher to focus on the delivery and engagement rather than IT troubleshooting

Given the Solid Pathways sessions operate separately from the regular classes in the school, teachers at participating regional and remote schools we interviewed recommended that acknowledgement of those students involved in Solid Pathways be made at whole-of-school or year-level assemblies. This gives participating students a sense of pride and excitement about their participation in the program and works to maintain their engagement. It also facilitates recruitment of future participants.

11.10 Caution factors

Consultations with several maths experts suggest cohort-specific culturally relevant content and lesson plans can be a valuable way of engaging cohorts who typically can disengage from maths. Whilst we know these are important to consider, it is unclear how effective digital approaches are for CALD populations, especially those located in remote communities.

The Chair of the Aboriginal and Torres Strait Islander Mathematics Alliance (ATSIMA), Chris Matthews, reflected that for Indigenous education, differentiation alone is not enough. Given that traditional teaching methods and practices do not align with Indigenous students learning context, differentiation will only mean that "the same education that is already failing them [will be] delivered on different time scales." Matthews argued that there should be a consideration of the full Indigenous educational context for online learning. For example, how online resources can be tailored or developed for First Language speaking communities, and how they can be tailored for communities who are reviving their language.

Data provided in our consultations suggest that a number of pre-conditions are not being met for effective use of digital learning, notably:

- Poor or unreliable wi-fi and/or data bandwidth at the school
- Inconsistent access to devices, or high student-to-device ratios such as 3 or 4 to 1
- Limited digital literacy of students

For example, consultations related to the Learning+ program implemented in South Australia indicated that the program was unable to be deployed in digital format to a regional school (the Ernabella Anangu School). The school currently uses no digital teaching or learning due to the environmental and infrastructure prerequisites not being in place.

We caution that the replicability of the Solid Pathways model should be considered in the context of significant deficits in digital literacy and broadband access for remote communities.

In addition, the scope, design and target year levels for the Solid Pathways program has been refined quite substantially in the 9 years since the program was first launched. This suggests that any new program of its type will need patient, medium-long term funding and a preparedness to adjust the operating model in response to feedback on what is working and what is not.

11.11 Environment and infrastructure prerequisites

To roll out a model like Solid Pathways there are a number of hardware, software, and environmental requirements:

- **Hardware:** 1:1 student to device ratio, headset, microphone, and quality video camera
- **Software:** Access to iSee and Stile platforms. Strong internet connection at each school capable of facilitating video calls, students watching videos, and interacting with the online platforms simultaneously,
- **Environmental:** We heard from teachers that a dedicated room for students to complete the lessons in is essential. It's also important for there to be a teacher or education support staff member who is championing the project who can help get together the physical materials required for each lesson.

11.12 Implications and Opportunities for Australian Government

The Australian Government may consider opportunities to support this model via:

- Partnering with the Queensland Government to investigate the ongoing effectiveness of the Solid Pathways program through analysis of student maths learning trajectories after participating in the program. This is an important first step in investigating if the model should be expanded for use in other jurisdictions.
- Supporting the program operators to document the program model in a fashion that can allow other groups of maths educators serving CALD students to learn lessons from the Solid Pathways experience, which set them on solid foundations to implement their own versions of the program.

12 Deep Dive 8: Teacher recorded Worked Examples

12.1 Model summary

Teachers record short, 2-5 minute, videos of their handwritten completion of maths problems on screen with their own voice-over commentary. They distribute this recording to individual students or cohorts of students who have the same misconception or learning challenge.

12.2 Which challenges does the model address?

This model addresses two key challenges for maths teaching:

- Differentiation
- Teacher Capacity and Efficiency.

Unlike many subjects, maths involves handwritten tasks which stakeholders suggest are not easily completed using a keyboard. Solving many types of maths problems involves working through equations with symbols not found on a standard keyboard. In maths, students are typically marked both on the solution they obtain as well as the workings they present to demonstrate how they reached their answers. Whilst there are type settings available to write maths symbols electronically, often handwritten workings are the most efficient and effective for teachers to use when explaining workings and solutions. For this reason, for teachers to leverage the efficiency gains obtainable from the use of IT in the maths classroom, they require a means to digitally capture handwritten equations and workings.

12.3 How does the model work?

The tools required are:

- Tablet or laptop with stylus functionality (i.e., a touch screen with ability to capture handwritten equations digitally) and a microphone
- Screen and voice recording software, such as Screencastify or Loom
- A learning management system such as Google Classroom or Canvas to distribute teacher-recorded worked examples to students

Teachers interviewed for this project report that they use this model:

- To provide feedback to individual or groups of students who need assistance with specific questions they answered incorrectly on an assessment.
- When introducing a new topic to their class, they may record several videos outlining the approach to key types of problem to be covered in the unit. All students in the class may individually review the videos at their own pace and time of day/week.

- Where a student is struggling with a particular step or process in the solution methodology and needs a tailored explanation highlighting where and how they are going wrong. This can sometimes involve the teacher partially demonstrating how to get to the answer and leaving the remainder of the steps to the student to work through themselves.

As distinct from videos available on the internet of teachers completing maths problems from the US, UK and other schools across Australia, this model's advantage is that the voice and terminology of the videos are of the same maths teacher the student works with in the classroom each week. The teacher is a known person with a face-to-face relationship with the student, strengthening their connection and engagement with the video content. In their voiceover, the teacher can use humour, familiar examples, and refer back to the terms or contexts they covered in the classroom to strengthen the students' engagement and understanding. For the student, the ability to watch the videos on repeated occasions, to pause the video at key steps, and to choose the time of day/week they watch the video to align with when they are most ready to absorb the material, are all aspects of this model which serve to improve learning outcomes.

In addition, the matching of the teacher-recorded videos with the specific problem types being covered in the class means the student does not need to navigate and search to find the correct worked examples to review to address their concerns.

Schools and teachers report utilising learning management systems (LMS) such as Google Classroom and Canvas to distribute the videos to students and organise them within the units being taught to make it easy for students to find videos covered in the past when they are revising for summative assessments. These LMS are typically used to share content presented by the teacher in face-to-face teaching in the classroom, to distribute problem sets and homework tasks. They can also be used to coordinate the distribution of solutions, feedback, and marks on quizzes and tests. There is substantial time saving for teachers from the use of a LMS when multiple students have the same misconceptions or learning challenges and they can record and share a video of a worked example just once, rather than needing to repeat the same teaching on separate occasions.

In some schools, a bank of teacher-recorded worked examples is shared across classes at the same year level. So, rather than every teacher in every class recording the same (or similar) introductory videos for every topic, they may divide the syllabus up amongst colleagues and have each teacher record a share of the total videos required, reducing the duplication of teacher effort. This has an added benefit of supporting teachers who are new to the content being covered, who can benefit from observing how more experienced teachers complete worked examples.

12.4 Examples of use

12.4.1 Mount Waverley Secondary College

A public school in Melbourne's eastern suburbs, Mt Waverley is a co-educational college with around 1900 students. Its school wide LMS is Google Classroom. A range of maths teachers across years 7-12 use teacher recorded worked examples in their teaching using a hybrid laptop which comes with a stylus and the Screencastify software. Teachers share banks of their recordings with colleagues in the maths department via Google Classroom. They typically use this model in providing feedback on assessment tasks and use it across all ability levels and year levels. Interviewees report strong positive feedback from students on the personalisation of the video recordings, and how important it is to be able to pause and rewind teacher explanations of problem types they are struggling with.

12.4.2 Haileybury College

Haileybury is a co-educational independent school with 6 campuses in Victoria, the Northern Territory and China. It has built teacher-recorded worked examples into its standard toolkit for teachers teaching maths in years 4 through to 12. Teachers are all provided with hardware and software which supports the delivery of the model. The school operates a LMS via which it manages the provision of content to students, assessments, and feedback, reporting and communication to parents all on the same platform. The school has built a bank of videos of full lessons, teacher recorded worked examples of different categories of maths problems which are available for teachers to utilise in their classes as they see fit. It operates in a video room with studio quality lighting, and sound recording equipment to enhance the impact of the full lesson videos its teaching staff prepare. Typically, teacher recorded worked examples are recorded by teachers on their tablets in their offices on school campus or home when grading assessment tasks.

12.5 Target groups

Stakeholders report using this model in secondary school maths teaching across years 7-12. All students benefit from the model, but it is particularly valuable for students at the top or bottom of the ability-scale who might otherwise need to watch their teachers providing live worked examples in the classroom, at a level above or below their current ability level. Students with challenges with working memory can also benefit from the model because it provides the option to pause the video to absorb each part of the methodology before progressing to the next.

The model offers benefits to out of field teachers and teachers who are teaching a year level they have not taught before. For these teachers, being able to review videos from other teachers to brush up their content knowledge, to absorb pedagogical techniques that experienced teachers use, and to anticipate and prepare for commonly occurring student misconceptions is highly valuable.

12.6 Level of use

We have not been able to source data on the level of use of this model among maths teachers nationally. Anecdotal feedback suggests that the COVID remote schooling period in VIC and NSW was a driver for increased adoption of this model, although it was practiced by some teachers prior to this. Some teachers experimented for the first time during COVID with using their stylus to demonstrate worked examples to their students during live video conferences. After this, some teachers progressed to recording their worked examples for individual students or cohorts of students in response to requests for feedback or as an efficient method to share the same worked examples with multiple students or colleagues. Some teachers interviewed for the project regarded this model as an 'essential' part of best practice in contemporary maths teaching.

12.7 Cost

Tablets and laptops with touch screens and stylus functionality are available from a range of brands at a range of price points.

The cost of screen recording products such as Screencastify and Loom varies from $0 to $12 per user per month depending on the plan. Loom offers a free subscription for verified teachers. Verification involves a registration step from an email account which Loom then checks to confirm the application comes from an educational institution.

LMS products such as Google Classroom and Canvas offer free entry-level versions with basic functionality with more feature-rich versions requiring a license fee which is negotiated with schools, dioceses and education departments depending on user numbers, features required and term of contract. Pay per user models of licensing typically range between $3 - $10 per user, per month.

12.8 Impact

Differentiation - Teachers and schools interviewed report that this model is an important aid to differentiation in maths teaching. In the average classroom, rather than effectively wasting the time of students who have already mastered content which other cohorts in the class are still struggling with, the teacher can provide recordings which are tailored to the rate of progress for different cohorts in their class. Students can individually review the recordings which apply to their level of progress thereby allowing all cohorts to continue to learn and expand their abilities.

Teacher Capacity and Efficiency - This model provides a substantial benefit in improving maths teacher efficiency, according to stakeholders interviewed for this project. Once a teacher can confidently record their videos of worked examples, they can provide higher-quality, tailored feedback and instruction to more cohorts of students, more quickly than if they were relying on traditional face-to-face classroom time and annotation of assessment tasks. Schools also report substantial benefit for teachers who are teaching a year level for their first time or when they are teaching maths without a strong background in the field. Videos of worked examples from other teachers provide these teachers with strategies for explaining content and problem solving methodologies, and provide early warning of students' most common misconceptions or challenges.

12.9 Environment and infrastructure prerequisites

Provision of the hardware and software cited above as well as reasonable internet bandwidth are essential prerequisites. Both the Screencastify and Loom recording tools reviewed for this project store videos recorded by teachers online in the cloud and support a range of screen resolution settings which increases the reliability of the tool for teachers, schools and students with low-bandwidth internet connections. While one-to-one laptop or tablets for students is ideal for successful implementation of the model, it is not an essential requirement. Reports from some teachers at some schools indicate that some students view the videos on their phones.

If teachers are sharing videos to students without using a school provided LMS, which typically has compliant privacy and security settings built in, then they should be careful to make use of the privacy protection options available to users of the video sharing software product they are using. There is a risk if these options are not used that videos could be accessed by audiences others than the students they were intended for. Training of teachers in how to effectively use the model is optimal, although most of the teachers we spoke to regarding the model were self-taught. The extent of teachers' confidence and experience with technology will drive the extent to which training is essential. Training could easily occur via a peer-to-peer approach whereby a maths teacher who has successfully used the model themselves runs a short workshop for their maths department colleagues demonstrating how the tool works, the most common applications and use-cases, and tips for maximising impact.

12.10 Success factors

For a school considering adopting this model, the first steps are to ensure the environment and infrastructure foundations in place (i.e. every teacher has the hardware and software) and that every teacher is confident enough with the functionality of these tools to be able to incorporate them into their day to day teaching practices. The basic content of a recorded video covers the same domain as a typical maths teacher covers in face-to-face contact with their students in the classroom. The difference with the model is delivering these worked examples and accompanying verbal explanations into a laptop or tablet, and then distributing it to relevant cohorts of students.

Several of the schools we interviewed created shared libraries of recorded worked examples for all teachers at a year level to review and use as they saw fit in their classes. This sharing practice saves time for teachers involved by reducing the video-creation load, and also provides a professional development opportunity as teachers learn from each others' practices and innovations in use of the model.

12.11 Caution factors

We heard that:

- Some teachers tend to fall into the trap of recording too lengthy videos, covering very complex problems or multiple problems in the same video. This approach leads to students disengaging and reducing the effectiveness of the model in supporting learning. Aiming for a length of 2-5 minutes per video is ideal.
- It is important to recognise that one of the keys to the power of this model is that it leverages the relationship between the teacher and the students and the ability for the teacher to personalise their commentary to match the students' needs. So, rather than reverting to creating generic videos useful for all students, it is preferable to the use the recording technology to provide a customised worked example for individual students or groups of students with a shared misconception. Peppering the video commentary with the same sorts of humour and relatability points that an experienced teacher would use in a face-to-face setting will help embed the learning for the students.
- It is important not to underestimate how important it is to create a safe, confidence-building training environment for using this model for teachers who have less well developed technology skills. This model does not require highly sophisticated knowledge of technology from teachers to implement successfully. However, when low-confidence teachers start out with the model they will benefit being given a chance to play around with the tools, make mistakes, ask questions and generally build their skills in an encouraging and supportive environment. Video recording – even for a small audience of students - can be somewhat anxiety-producing for some teachers. To

ensure all teachers successfully adopt the model and stick with it in their daily teaching practice, the provision of this type of training environment early on is critical.

12.12 Implications and Opportunities for Australian Government

The Department of Education may consider supporting the use of this model in maths teaching via initiatives such as:

- Investing in the creation of how-to-guides, videos and example libraries which can be made available to schools and systems nationally (as well as universities providing teaching qualifications).
- Commissioning the design and delivery of professional learning units on this model nationally. This could also involve investment in codifying the model with input from experts and practitioners in order to build standardised terminology for the different types of recordings which are appropriate for the different topics in the maths curriculum.

13 Conclusions

13.1 Assessment of the emerging landscape for use of digital technology in maths teaching

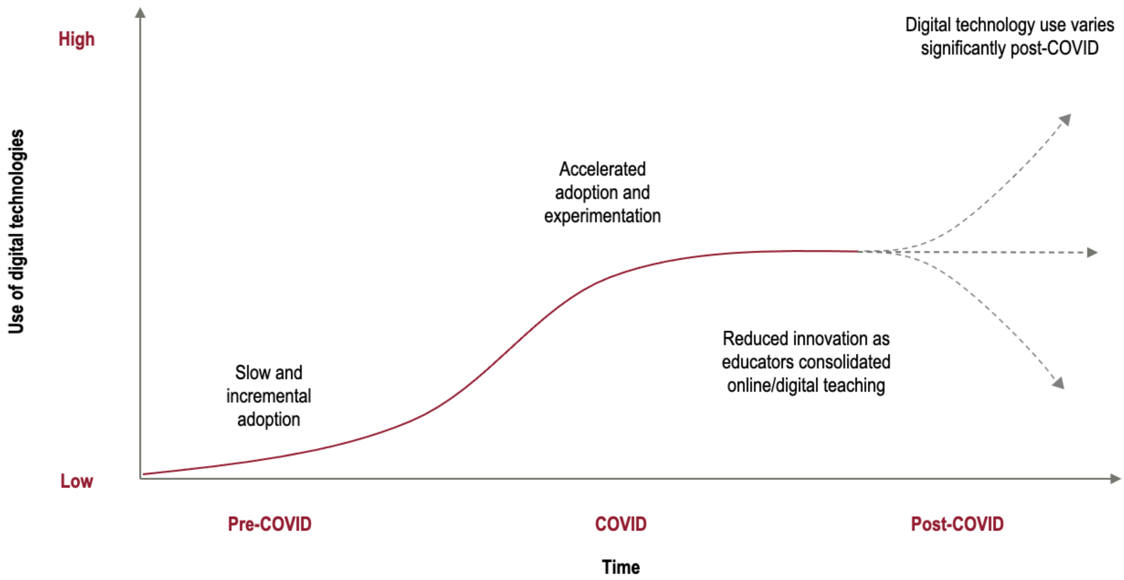
This section assesses the emerging landscape for the use of digital technologies in the teaching and learning of mathematics in Australia, drawing on the project's review of the academic literature, consultations with maths teachers, school leaders, subject matter experts, stakeholders from State and Territory Departments of Education and Catholic Dioceses, and vendors of maths teaching and learning technologies.

13.1.1 There have been three broad stages of digital technology adoption in maths teaching and learning in the past decade

Australia has seen three broad stages of technology adoption for the teaching and learning of mathematics in the last several years (summarised in Figure 30):

- **Before** the COVID crisis, there was slow and incremental adoption of digital technology broadly across the Australian education system.
- **During** the COVID crisis, there was accelerated adoption of – and experimentation with – digital technology, particularly in jurisdictions where schools closed on short notice.
- **After** the COVID crisis, many schools have slowed their rate of adoption and consolidated the innovation advances they achieved during COVID, but are now generally more positively disposed to using digital technology as a tool for enhancing teaching practice and improving students' maths performance. Digital technology use varies and diverges significantly post-COVID.

Figure 30: Three broad stages of digital technology adoption before, during and after the COVID crisis



13.1.2 Technology adoption and experimentation accelerated during the COVID crisis

Before the COVID pandemic, many schools used face-to-face teaching and learning with limited digital technology. Some maths teachers preferred using a 'chalk and talk' method of teaching with technology being used as a one-off activity, rather than being embedded into teacher practice.

The onset of the pandemic and its associated school closures was an external shock that triggered a significant and necessary acceleration in digital technology adoption for maths teaching and learning:

- Most schools pivoted quickly to **more basic digital technologies** that enabled immediate remote learning, such as digital take home packs or video conferencing. Teachers using video conferencing technology would often deliver learning live, consistent with existing student timetables. Some teachers pre-recorded videos for asynchronous learning.
- Some schools went further and adopted other **more innovative technologies** that improved the online experience, such as digital classroom platforms and adaptive software. For example, teachers used digital classrooms like Teacher Dashboard 365 and Google Classroom to provide learning content.

1.1.1 Innovation has slowed as teachers consolidate post-COVID

The post-COVID period has allowed teachers to review their teaching styles and assess their students' progress over this tumultuous phase. The rate of innovation has slowed as schools return to pre-COVID teaching approaches.

We heard that maths teachers have two main priorities post-COVID:

- **Supporting students** who had fallen behind – or were perceived to have fallen behind – during remote learning periods, with a particular focus on student cohorts who may have faced significant barriers to learning including challenging home environments and poor internet and device access.

- **Coping with burnout** from the intense COVID period, which had required many teachers to significantly change their teaching delivery and engagement with students, including through the use of unfamiliar digital technologies.

These priorities mean that many teachers have not had time to further explore digital technologies that came to prominence during COVID. Teachers have kept using some of the digital technologies that worked for them such as digital classroom platforms. Other approaches, such as video conferencing, were replaced with a return to face-to-face teaching.

Despite this, across Australia, more teachers now have experience using digital technologies in teaching. We heard from education system stakeholders that this has resulted in:

- **Greater awareness** of different types of digital technologies and their potential to augment teaching and learning in positive ways; and
- **Greater willingness** to adopt digital technologies in the future where there is a clear link to improved teaching practice and student performance.

13.1.3 There is a lot of variation in the practice of maths teachers

It is hard to generalise about how schools use digital technology for the teaching and learning of maths. Digital technology use varied in schools before COVID as individual teachers made their own decisions about digital technology adoption. For example, dandolo was commissioned by a state education department to review the use of department provided notebooks by teachers and principals. The evaluation found the use of digital devices and software by teachers varied dramatically between individual teachers within schools. The use of technology among teachers can be mapped onto a bell curve, ranging from early adopters of technology to laggards and non-adopters.

Variation in teacher adoption of technology in the classroom is influenced by:

- **Teacher confidence** in their technological capability and ability to use digital technologies effectively and efficiently in practice.
- Related to the above point, levels of **training and IT support** for teachers, which varies dramatically between schools and can also be impacted heavily by school budgets.
- **Teacher attitudes** towards digital technology, in particular their views on whether digital technology positively augments teacher practice rather than disrupting their practice and student engagement.

There are also school level factors. The extent of **student and teacher access to devices** in the classroom and at home is significant. For example, some schools chose to provide devices to all students or mandate that parents must buy devices for their children, whereas other schools had a limited number of devices that were shared between students.

13.1.4 The impact of COVID on technology use depended on school and teacher attitudes and departmental responses.

COVID caused significant shocks to the Australian education system and how schools operated. School responses to COVID varied based on three key factors:

Level of remote learning periods

The duration of school closures varied significantly across different jurisdictions. Victoria and New South Wales experienced significantly longer and more frequent lockdowns than other states, leading to more prolonged school closures and home-based learning. Even at the start of the pandemic the effects were uneven, with the discrepancy increasing over time. For instance, between March and August 2020 some Australian states had partial school closures of 17 weeks whereas Tasmania had only 6 to 8 weeks (for primary and high schools respectively).[130]

The duration and intensity of COVID lockdowns and associated school closures differed substantially across jurisdictions. This heavily influenced the degree to which teaching changed and whether individual schools increased their use of digital technologies for the teaching and learning of maths:

- Jurisdictions and regions that experienced **greater school closures** – such as Victoria – tended to see a much greater increase in their use of digital technologies. For example, many Victorian schools increased their use of digital classrooms to facilitate everyday classroom maths activities and student collaboration.
- Jurisdictions and regions that experience **fewer school closures** – such as Western Australia – were less likely to increase their use of digital technology. These jurisdictions were more likely to rely on physical 'take home' maths packs or technologically basic solutions such as maths worksheets on a USB drive.

Differing attitudes regarding remote learning

Consistent with the discussion above on the pre-existing influence of teacher confidence and attitudes on adoption of digital technology, we heard that there were two schools of thought among maths teachers on the role of digital technology during school closures:

- Some maths teachers believed that the use of digital learning was merely a **'holding pattern' for regular schooling** and did not invest significant time and effort in technology adoption. For example, they were more likely to use more basic technology to provide existing maths worksheets in digital form.
- Others viewed remote digital learning as a **substitute for regular schooling** and invested more time and effort in medium to long-term technology adoption. For example, they set up digital classrooms and integrated specific maths software platforms into their teaching approaches.

Departmental responses

Individual jurisdiction education departments and agencies also adopted their own responses to the COVID crisis that shaped school and teacher behaviour in relation to digital technology use. For example:

- The **WA education department** helped government schools to supply physical 'take home' packs that contained printed worksheets.

[130] Wojtek Tomaszewski et al, Uneven Impact of COIVD-19 on the attendance rates of secondary school students from different socio-economic background in Austraia: A quasi-experimental analysis of administrative data, 2022.

- The **NSW and Victorian education departments** provided laptops and internet dongles for students, to ensure sufficient device and internet access for students learning remotely from home, particularly those in remote areas and from low socio-economic backgrounds.
- The **SA education department** engaged specialist maths teachers to prepare PowerPoint presentations on maths units with accompanying voiceovers which were then distributed to teachers, parents and students for use.

1.1.2 What we are seeing now

It is still hard to generalise about digital technology use in schools post-COVID. The same variables that were important influences on digital technology adoption prior to and during COVID remain pertinent. However, additional variables have emerged to shape digital technology use, such as:

- **Individual teacher decisions:** Teachers typically have substantial discretion regarding whether they continue using existing digital technologies or adopt new technologies in their classroom.
- **School leader decisions:** Schools can provide support and funding for digital technologies. This depends on the school leadership's attitude towards digital technologies. The cost, profile of student cohort, appetite from the parent and carer community, and the ease of implementation all affect these attitudes.
- **Jurisdiction decisions:** Schools' level of independence to decide on digital technology adoption varies across jurisdictions and sectors. Some jurisdictions allowed government schools greater independence to choose what mix of digital technologies they use. For example, Victorian schools have independence to choose how they teach. Other jurisdictions have provided government schools with access to certain digital technologies. For example, the NSW education department provides teachers with software to observe student maths progress and create differentiated lessons.
- **Student / parent decisions:** Students and parents in some cases are making decisions about whether they learn at school or from home, or a blended combination. This places expectations on schools and teachers for how they deliver learning and the level of technology use they need to sustain an ongoing learning model.

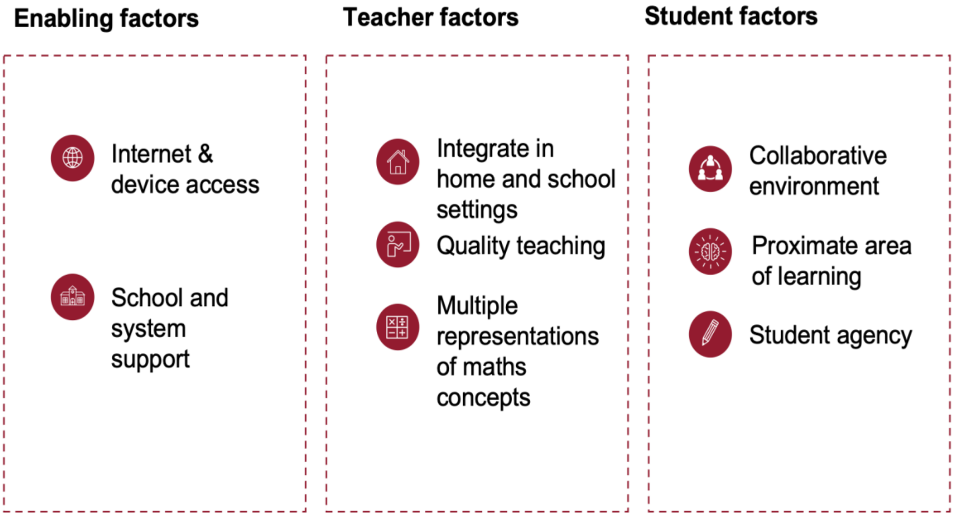
13.2 Key considerations for schools in adopting technology for maths teaching and learning

Below is a summary of the key findings from the literature review and deep dive analyses that should be considered by schools when deploying digital technology tools for maths teaching and learning.

As a general observation, no one digital technology suits all teaching and learning contexts:

- Students, teachers and schools have different needs that call for different uses of digital technology. There is **no 'one size fits all' option**.
- The Australian education system benefits from having a **broad 'ecosystem'** of digital technologies that empower education actors to choose the technology that best serves their needs and contexts.

Figure 31: Key factors for success



Alternative text: Figure 31 presents the three types of factors that support successful adoption of digital tools for maths teaching and learning. The first category is 'enabling factors'. Within 'enabling factors' is internet and device access, and school and system support. The second category is 'teacher factors'. Within 'teacher factors' is integration in home and school settings, quality teaching, and multiple representations of maths concepts. The final category is 'student factors'. Within 'student factors' is collaborative environment, proximate area of learning, and student agency.

13.2.1 Enabling factors

When implementing digital technologies in schools, it is important to consider the following enabling factors. Both the literature review and deep dive consultations stressed the importance of these enabling factors being in place, before a technology is rolled out, to ensure success and avoid potential negative outcomes.

Environmental pre-requisites

There are several digital technology considerations to be considered when rolling out digital technology in a school. If these are not in place, there is a risk of student disengagement, and potentially even worsening the digital divide:

- **An internet connection and reliable internet speeds** that are sufficient to use a variety of digital technologies.
- **An appropriate device** that enables the use of – for example – different software platforms. This may include a laptop or tablet, depending on the level of schooling.
- **Reliable and effective IT support** that is available to teachers and students throughout the school day to troubleshoot and problem solve any issues that may arise during a lesson. Without this, if a problem was to arise it may disrupt an entire lesson.
- **Adequate student to device ratio** is available, the ratio needed will depend on the model that is being rolled out.
- **Cyber security** must be considered for each model. Cyber security is of increasing interest and importance for users, particularly for the models which include videoing students, and storing personal data.

It is important to consider these factors at both the school and home environments. Many models are designed for students to access as a homework tool. However, we know that many families share devices between multiple family members, or do not have reliable internet connectivity at home. If a model is rolled out without considering students home environments, there is a risk of intensifying the digital divide.

School and system support

To enable success, there must be a high level of school and system support in place for the model to ensure it is effective and used to its full potential. The following principles are important contributors of success:

- **Deliberate and planned roll out of the technology to be implemented into the classroom**. We heard that having a 'champion' of the model in the school is often key to the success of the model. Meaning there is someone who is driving the roll out, is confident in using the model and can teach others, and who can build teacher / student / family buy-in to the technology so there is a positive attitude towards it.
- **A reflection on why a tool is being embraced, before embracing it.** School leadership and maths teachers should be cautious in their adoption of digital tools and first consider the precise contribution these resources are intended to make in strengthening teaching capability and practice and/or to students' learning. This will ensure the technology is being used for the right reasons, and to its fullest potential.
- **School leadership and school processes supporting teachers to use the model effectively**. This includes allowing teachers time to attend training for the technology, paying for necessary equipment / memberships if necessary, providing spaces in the school where the lessons can take place if needed (e.g., for Solid Pathways this is essential).

13.2.2 Teacher factors

Use of the technology in the classroom

- The use of digital technologies must be **coherent and minimise the cognitive load** for teachers and students. This can be done by ensuring there is a predictable pattern of use for both students and parents, and clearly aligning the use of technology with the **Australian Curriculum.**
- The model needs to be **integrated deliberately into lessons**, ensuring it is enhancing teaching, not substituting for it.
- **Multiple representations of maths concepts** should be presented through the use of digital technologies to promote student learning and conceptual understanding.

Teacher professional development

- **Quality teaching is essential for the effective use of digital technologies.** This includes teachers being confident in both their capability teaching the maths concepts, as well as being confident in using the technology. Without this the teaching will not be effective and student performance may not improve. Therefore, professional development may be necessary to improve teacher capability and confidence in maths before rolling out a digital technology.

13.2.3 Student factors

Student characteristics

- Students must be **motivated** to use the technology. When using their own device, there is a higher risk of students getting disengaged and off-task. It's important to build buy-in amongst students so they see the value in using it and are motivated. Teachers we spoke to reflected that they find it useful to communicate why, and for how long, students will be using a model in the class to set expectations and ensure they remain engaged.
- It is important to recognise that **digital literacy is not universal amongst students**. Schools and teachers must consider the digital literacy of all students before rolling out a model.

Students' interaction with the digital technology

- **Students can use digital technologies together in a collaborative environment.** Whilst not suited for all models, our consultations suggest students are the most engaged with digital technologies when they are interacting and collaborating with their peers.
- **Digital technologies should support differentiation** in a classroom. The technologies should support both 'stretch opportunities' for high achieving students, and more support and a slower pace for low achieving students.
- **Student agency is important for secondary school students.** Principal 6 of the literature review highlighted that student agency is critical to the effective use of digital technologies, particularly where a student is expected to self-pace their learning or explore maths concepts and problems in digital environments. Allowing students agency to control their own learning allows them to learn at their own pace and have ownership over their learning.
- **Student-facing digital technologies appear to be better suited to secondary school students.** Digital technologies have the potential to benefit students at all levels of schooling. However, student-facing tools have more potential to benefit students at the secondary level than the primary level due to higher digital literacy levels, ability to work independently, and the technologies allow for different ways of learning advanced concepts that are within the secondary curriculum.
- Early primary teaching relies on the use of **physical manipulatives**, which can be difficult to translate into a digital environment suitable for young children (noting there are some software platforms that provide virtual manipulatives that are suitable for primary, as referenced in the Department of Education's (soon to be released) F-2 Maths MOOCs).[131]

13.3 Key findings and implications

13.3.1 Reversing Australian students' declining performance in maths will require tackling three key challenges for maths teaching.

We know that maths is critical for education outcomes, as well as broader life outcomes including employment.[132] But Australian student performance in mathematics has been declining in real terms since 2003, according to PISA test

[131] https://www.mathematicshub.edu.au

[132] Productivity Commission, 'Literacy and Numeracy Skills and Labour Market Outcomes in Australia', 2014; OECD, 'Skills Matter: Additional Results from the Survey of Adult Skills', 2019.

results. The average 15-year-old student is more than one full year behind in mathematics compared to their 2003 equivalent.[133]

Australian student performance in maths is also declining relative to other OECD countries. In the most recent round of testing in 2018, Australia fell below the OECD average for the first time. Nearly half of all Australian students did not meet the OECD's minimum standard in mathematics.[134]

Underperformance in mathematics is worse for students from certain demographic cohorts. Strengthening mathematical performance is therefore important for equity, as well as overall education excellence. According to 2018 PISA results, for example, students from the lowest socio-economic quartile were about three years behind students in the highest socio-economic quartile in maths.[135]

While the drivers of this declining performance are complex, our fieldwork and the MGSE literature review identified three key challenges for improving maths teaching:

1. Teacher Capability and Confidence
2. Differentiation
3. Teacher Capacity and Efficiency

13.3.2 Digital tools can be employed to address the capability and confidence of maths teachers via models such as remote delivery, time-shifted observation and teacher-recorded worked examples

We know that:

- Teacher quality is widely regarded as the most important in-school driver of student performance in maths.[136]
- The highest-performing education systems in the world in maths – such as Singapore and subsystems in China – put large emphasis on teacher education, professional development, and career progression. Singapore in particular fund up to 100 hours of professional development per year for each teacher. This emphasis on capability building is their primary means for improving teacher quality and therefore student performance.[137]

We also know that there are specific workforce challenges relating to maths that digital technology can potentially help to address:[138]

- There is a shortage of high-quality maths teachers in secondary schools across many state and territory education systems. As a result, many secondary teachers are teaching maths 'out-of-field', without the necessary knowledge, skills, and experience.

[133] OECD, "Country Note: Australia – Programme for International Student Assessment", 2018.

[134] Ibid.

[135] Ibid.

[136] Dunn, Gottlicher-Hill & Stephens, Melbourne Graduate School of Education, The University of Melbourne, Research into best practice models for the online teaching of mathematics, 2022.

[137] Ibid.

[138] Weldon, Australian Council for Educational Research, The teacher workforce in Australia: Supply, demand and data issues, 2015.

- There is also a lack of experienced maths teachers to coach or mentor early career maths teachers, which is one of the most effective forms of professional learning.
- Primary school teachers are not required to specialise in maths and they tend to be less confident teaching maths compared to other subjects.

In circumstances where it is difficult to improve teacher capability, digital technology can enable student access to alternate teachers with maths expertise. This is particularly important given the workforce challenges described above and the fact that most secondary students will have a maths teacher who is teaching maths out-of-field.

Prior to COVID, digital technology primarily enabled student access to maths specialists through online video libraries such as Khan Academy. Online video libraries – which are often free of charge – enable any student to access videos of maths specialists delivering lessons or worked examples across a variety of maths subjects. We heard from maths experts that these online video libraries are often a good resource for revision as a supplement to mainstream maths classes, but are not a substitute for direct learning with a teacher who understands their learning context.

We have outlined the most promising applications of digital tools to address **Teacher Capability and Confidence** in Figure 32.

Figure 32: Application of digital tools to address Teacher Capability and Confidence and description of impact

Application of digital tools	Description of impact
Lesson plan libraries for teachers who are inexperienced or have low confidence teachers of maths.	Cloud-based libraries of quality-assured lesson plans, aligned to the Australian curriculum and accompanied by streamed videos of lessons delivered in a classroom by a specialist maths teacher appear to have high potential to enhance teaching capability and confidence, at scale. These resources both serve to bridge teachers' knowledge gaps on key maths topics and guide these teachers towards evidence-based pedagogical practice.
Remote delivery from specialist secondary maths teachers.	Many regional and remote schools lack suitably experienced maths teachers capable of delivering advanced maths, particularly at Years 11-12, as they draw on much smaller population pools than their peers in major metropolitan centres. Several programs we reviewed have strategies to manage the constraints of remote teaching to support sustained student engagement and contextual knowledge of students and their families.
Using digital tools to make recordings of one's teaching to share with remote or time shifted coaches or peers.	Observation of teaching, reflection, feedback and coaching has a strong evidence base for contributing to improved teacher capability in maths,

	and many other subjects.[139] We heard strong endorsement of the value of being able to overcome the logistical difficulties associated with real-time observation. We also heard digital tools have enhanced the quality of reflection, feedback and coaching through classroom video recording products and secure sharing and viewing software.
Using task specific gamified tools that enable teachers and students to explore concepts together.	There is an evidence base[140] and demonstration of use in Australian schools for task specific digital tools to explore concepts such as graphing, equations, geometry, volume, ratios etc. We heard endorsement of the utility of gamified or interactive play-based environments to aid teaching and learning.

13.3.3 Differentiation in maths can be substantially easier with well-supported adoption of digital technologies

Through Growth to Achievement: Report of the Review to Achieve Educational Excellence in Australian Schools in 2018 highlighted that Australia can improve student achievement – including in maths – by tailoring learning to the needs of individual students.

Teachers are often faced with a significant differential between the lowest and highest levels of achievement in their own class (up to several years of learning), which can be challenging to address through conventional face-to-face teaching due to the time required with each individual student:[141]

- **Low achieving** students risk 'falling behind' the rest of the class, which requires significant remedial attention from the teacher.
- **High achieving** students risk stagnating if learning is pitched to the 'middle of the pack' or teacher time is consumed by low achieving students.

Digital technologies can support teachers to better differentiate learning for students at different levels of achievement. In particular, various categories of adaptive software offer more sophisticated differentiation for students than what many teachers may be able to provide in an average Australian classroom.

Differentiation is particularly important for specific student cohorts who are at greater risk of falling behind in maths performance, including:

- **Girls:** There is a gender gap, with female students scoring lower than male students on average, and a lower proportion of high-performing female students than male students.[142]

[139] Thomas J Kane et al., The Best Foot Forward Project: Substituting Teacher-Collected Video for In-Person Classroom Observations, 2015.
[140] Puhl, L. The effect of using Desmos in high school algebra when teaching the slope of a line, 2019
[141] Australian Council for Educational Research, Within and Between School Variation in Achievement on the PISA in Australia, 2022.
[142] Grattan Institute, The maths puzzle we need to solve: our girls trail the boys, 2022.

- **Rural, regional and remote students:** Students in rural, regional and remote schools were one-and-a-half years behind students in metropolitan schools on average, with only 34% achieving the OECD's minimum standard.[143]
- **Indigenous students:** The mathematical literacy of Indigenous students was around two-and-a-half years behind that of non-Indigenous students.[144]
- **Low SES students**: Students from the lowest socio-economic quartile were about three years behind students in the highest socio-economic quartile.[145]

The most promising applications of digital tools to support **Differentiation** that we found are outlined in Figure 33.

Figure 33: Application of digital tools to support Differentiation and description of impact

Application of digital tools	Description of impact
Teacher recorded worked examples for individual students and/or cohorts in a class with a specific misconception or learning challenge	This is a particularly valuable new tool in maths teachers' digital toolkit. By its nature, maths requires progressively working out problems using equations, traditionally on a whiteboard or paper. Use of this approach involves teachers recording their workings with voiceover for students to review, often as a demonstration of the steps involved or to highlight a misconception evident in the student's response to an assessment task. This allows precise differentiation by learning style, rate of progress, pattern of mistakes or extension need.
Analytics tools and adaptive assessment tasks in fully featured teaching and learning platforms	These platforms (such as Maths Pathways, Mathspace, Education Perfect and Edrolo) contain diagnostic assessment tasks and student cohort analytic dashboards which enable teachers to understand the spread of the mastery present across different groups in their maths class. This makes monitoring changes in ability over time simpler and enable teachers to better match content and resources to student's specific rate of learning.
Online tutoring programs for diverse groups of low or high achieving students	While resource intensive, there is evidence supporting the efficacy of tutoring programs delivered exclusively via video conferencing tools and maths specific learning platforms to these cohorts. The South Australian Department of Education's Learning+ in South Australia has a strong track record of supporting maths students who fell behind during COVID disruptions.

[143] Education Council, Optimising STEM Industry-School Partnerships: inspiring Australia's next generation, 2018.
[144] Ibid.
[145] Andrew McConney and Laura Perry, Socioeconomic status, self-efficacy, and mathematics achievement in Australia: A secondary analysis, 2010.

Maths and science extension programs for Indigenous primary school students in rural, regional and remote communities	The Queensland Department of Education's Solid Pathways program has attracted strong participation with its combination of Indigenous cultural knowledge, the iSee virtual classroom, and specialist maths and science teachers for Years 4 - 6. Solid Pathways has consistently demonstrated positive results for participating students from across remote QLD, including: • Increased proficiency in STEM skills • Better understanding of and confidence pursuing STEM learning • High aspirations for a STEM career • Greater confidence in cultural identity

13.3.4 Appropriate application of digital tools can save teachers valuable time each week on preparation and assessment related tasks

Digital technologies can improve maths teachers' capacity by helping them to complete tasks more efficiently, allowing them to reallocate this time to higher value activities that are more likely to contribute to improved student performance. It can also reduce the overall burden on maths teachers, decreasing burnout and enabling them to operate at full capacity, more often.

Teachers in general are notoriously time poor:[146]

- Over 90% of teachers struggle to find time to effectively prepare for classroom teaching.
- Teacher workload has also expanded significantly in recent years. Education systems are placing increased expectations on the role of teachers, such as increased responsiveness to parents, supporting student wellbeing and greater emphasis on the importance of differentiated learning.

Throughout our interviews, we received consistent feedback that time pressures intensified during the COVID pandemic, in addition to the usual demands such as after-hours marking. During school closures, for example, teachers had to:

- Prepare or recalibrate lessons in a format appropriate for remote learning.
- Manage an increased administrative burden caused by switching to remote learning, such as managing subscriptions or migrating content to digital systems.
- Undertake remote classroom management to ensure that students were sufficiently engaged in learning, which involved a much greater call on teacher time than in a face-to-face classroom setting.

We acknowledge that there are technologies that support the administrative operation of schools and classrooms and that these may also improve teacher capacity, but we have focussed on technologies that have a closer connection to maths teaching and learning.

[146] Grattan Institute, Making Time for Great Teaching: How Better Government Policy Can Help, 30 January 2022.

The most promising applications of digital tools to address **Teacher Capacity and Efficiency** are outlined in Figure 34.

Figure 34: Application of digital tools to address Teacher Capacity and Efficiency and description of impact

Application of digital tools	Description of impact
Leveraging fully featured teaching and learning platforms to save time on teaching resource and assessment task searching and assigning	These platforms are in widespread use, especially in high resource independent and public secondary schools, and can save substantial preparation and student progress tracking time with their banks of problem sets and auto-marking functionality. They also appear to increase the visibility of students' progress or plateauing to the maths teacher, enabling more timely intervention.
Using teacher recorded worked examples to reduce duplication of feedback	The ability to provide 2 - 5-minute video recordings to students with similar challenges on the same topics allows teachers to avoid duplicating their effort and also helps reduce the amount of time that students need to listen to feedback not relevant to their specific learning needs.
Lesson plan libraries for teachers who are inexperienced or low confidence teachers of maths	These resources reduce time teachers spent searching, collating and curriculum aligning lesson content. This allows teachers to allocate greater time for preparation, enhancing the quality and consistency of their lesson delivery, and to devising strategies tailored to cohorts of students with different learning needs.

14 Opportunities for the Australian Government

This section considers opportunities for future policy work and possible investment by the Australian Government. The opportunities we identify here are based on:

- Our analysis of success factors and cautions for digital technology use in mathematics teaching,
- The specific opportunities we have identified as most having the greatest potential to address the three major challenges in mathematics education, *and*
- The unique role and capabilities of the Australian Government.

14.1 We're building on our earlier thinking about the best roles for the Australian Government to play

In prior work evaluating education initiatives delivered under the National Innovation and Science Agenda (NISA) we noted that there are a range of different roles that the Australian Government can play, and considered their relative merit. Some of that analysis relied on the context of NISA / STEM education specifically but much of it remains instructive for this project. Our conclusion was that key roles for the Australian Government are as:

- A coordinator and linker
- An evaluator and assessor
- A capability builder

Figure 35: Potential roles for the Australian Government

Potential role	What does it mean?	Example
Co-ordinator and linker	Acting as the coordinator between different parties (e.g. schools and industry partners, or states and territories) to: • Improve STEM networks in education. This will allow more parties to collaborate on new ideas and approaches, • Inform the sector of existing initiatives. This helps avoid 'reinventing the wheel' with new initiatives.	• Raising awareness of existing initiatives e.g. through mechanisms such as the Digital Technologies Hub • Linking organisations who are thinking of doing similar activities (e.g. two states who want to set up an engineering academy) • Bringing together and building consensus between different stakeholders

Evaluator and assessor	Evaluating and assessing initiatives to: • Better understand impact and opportunities for future improvement • Share lessons learned with the sector • Build an evidence-base about what success looks like to inform future policy decisions.	• Evaluating, or funding the evaluation of, individual or packages of initiatives • Facilitating evaluation activities (e.g. by developing or promoting resources to help others run evaluations)
Capability builder	Focusing on building system capability to: • Support schools, school leadership and teachers to provide high-quality STEM education • Ensure the system maintains relevance and remains up-to-date with evolving leading practice	• Professional development or online resources for schools on new STEM strategies or best-practice evidence

When considering what role to take, the Australian Government should consider the criteria outlined in Figure 36.

Figure 36: Criteria for considering roles

Criteria	Why does this add value?
Does the role fill a gap?	It doesn't make sense to duplicate existing services. For example, there is limited value in expending time and resources in implementing an initiative that others are already doing. Rather, it is better to focus attention on perceived or real gaps in existing service delivery / approaches.
Does the role align with government policy?	It's important that any role aligns with existing government policy. For example, does it align with Government objectives or areas of focus?
Is the government well-equipped to deliver this role?	It's important to consider whether: • Government has the right capabilities and resources to deliver the role. For example, considering internal evaluation capability • Government is best-placed to deliver. For example, does it disincentivise states and territories? Is it someone else's role?

Does the role deliver value for money?	Where the role entails funding or resourcing, it's important to consider: • Potential ROI and impact • Whether there is a more effective or efficient approach • Others are better placed to deliver

14.2 Opportunities for impact

We've considered how these roles might best be leveraged in the context of the use of digital technologies in maths education. We've also considered the potential for Australian Government to:

- Demonstrate leadership and facilitate national consistency
- Realise economies of scale
- Consider the interface between education policy and other areas of Australian Government interest, including infrastructure.[147]

Similarly, there are other areas that we consider as less of a natural fit with the Australian Government's role, for example:

- Direct resourcing of mathematics teaching (for example funding or organising remote delivery teachers) as teacher recruitment is under State and Territory Governments' jurisdiction
- Endorsement of commercial products.

Within this context we've identified five thematic opportunities that we think are especially prospective for Australian Government action.

The first three opportunities relate to supporting teachers and schools to access high quality digital teaching and learning resources. These three opportunities capitalise on all three roles. The fourth and fifth opportunities focus on the enabling factors we have identified above for effective technology use (See Figure 1 **Error! Reference source not found.**). These opportunities emphasise the role of capability builder.

14.3 Opportunity 1: Quality assurance of digital maths tools to reduce burden and connect teachers to high quality resources.

There is a wide range of maths teaching and learning resources available and in use in Australian schools. We heard many categories of software had the potential to address the three key challenges for maths teaching highlighted in this report. However, there are also lower-quality, non-curriculum aligned products in use with questionable contribution to improving student outcomes. There's also no common language to define different kinds of resources. Terms like 'lesson

[147] Australian Government, Australia's Digital Economy, 2022; Australian Government Department of Industry, Science and Resources, National Innovation and Science Agenda report, 2015.

plan' or 'classroom resource' provide a wide range of different levels of detail. Some decisions also require decision making at different organisational levels. For example, learning management systems are often chosen at the school level, rather than at the teacher level.

Decisions about the use of specific classroom resources is often even further devolved to individual teachers. At worst, teachers that are lacking in confidence about teaching mathematics may not be able to easily identify which products are greater and lesser quality. At best, even highly discerning teachers need to invest time in finding and sorting through resources. This presents a significant 'search cost' when teachers' capacity is already stretched.

There are a range of ways that Australian Government may assist in creating easier pathways for teachers to find the highest quality resources. These include:

- Developing and publishing standards which resources should meet (e.g., explicit alignment to the Australian Curriculum, provision of 'rich' classroom tasks that support diversified teaching).
- Incorporating common definitions in these standards that define, for example, what a 'lesson plan' is.
- Setting up mechanisms to either quality assure resources or allow third party providers to demonstrate compliance.
- Collating materials / providing 'one-stop shop' or portal style access to resources that meet quality assurance standards.

We acknowledge that the current Mathematics MOOCs and Hub initiative (formally 'Online teaching and learning resources for mathematics'), which dandolo is evaluating, is intended to respond to this opportunity.

14.4 Opportunity 2: Addressing the teacher capability and confidence challenge in schools, particularly primary schools, by investing in Australian maths lesson plan libraries

Teachers need to utilise resources other than just textbooks to structure and support their lessons, a gap which can readily be filled by quality digital resources. However, we heard from teachers that suitable resources are less easily available in primary than secondary schools. Experts consulted for the project indicate a partial market failure for provision of maths teaching resources and tools at the primary school level. Primary schools typically have a smaller budget for such tools and there is a fragmented market across jurisdictions and systems. This has meant it is a less attractive segment for commercial providers than secondary schools.

Non-profit libraries of quality assured maths lesson plans offer a promising means of addressing this market failure. We heard these lesson plans provide out of field or inexperienced teachers with explicit direction on the approach and content needed to teach each maths topic, saving a substantial amount of preparation time and lifting the quality of their teaching. The accompanying videos of experienced teachers live teaching each lesson plan to a class were highly valued as a resource to help teachers to prepare and deliver high quality maths lessons.

Cloud hosting technology and the wide availability of easy-to-use tools to record and stream videos of lessons means this is a relatively low cost model to implement. However, there is potentially a role for the Australian Government in:

- Ensuring the Australian Curriculum at all year levels is comprehensively covered by lesson plan and lesson video libraries, with particular attention to primary school levels
- Ensuring ongoing quality assurance and improvement of these resources occurs
- Helping to promote the availability and appropriate role of the libraries to the target audience of out of field and inexperienced teachers of maths.

Importantly this opportunity is distinct from the first opportunity described above because it involves directly commissioning the *production* of resources, rather than quality assurance and / or collation alone. The Australian Government has already commenced work in this space as part of the Maths MOOCs and Maths Hub project, with the production of explicit teaching modules targeted at the primary level and other new resources being developed for the Maths Hub to address identified gaps.

There are good reasons for this to be an Australian Government role:

- There are indications of a market failure, from teachers and stakeholders we spoke to, and gaps in provision at a national level. Some larger jurisdictions may be able to address this market failure for their schools, but this is less likely in smaller jurisdictions, Catholic and Independent schools.
- There are not-for-profit organisations that have ambitions to create this content (notably Ochre), but are struggling to find resources to achieve this, demonstrating the challenge of national coordination. A competitive call for proposals from Australian Government would be likely to stimulate interest from other organisations too, supporting a value for money response.

14.5 Opportunity 3: Building the evidence base to support better decision-making around technology use and assessment

We heard from teachers and system level stakeholders that many, if not most, decisions about use of digital technologies for maths are made by individual teachers or schools. Examples include:

- Decisions about software licenses, e.g. for fully featured teaching and learning platforms
- Navigating parent, student and teacher expectations about screen time and device usage
- Whether and how to incorporate new technology that might challenge community expectations, such as gamification or products incorporating aspects of AI
- Decisions about investment in hardware for students and teachers

This decision making can be challenging for schools and teachers:

- Who may be time poor
- Who have fixed budgets to spend and need to maximise value for money
- When information about the usefulness of tools tends to be provided by private companies who are trying to encourage uptake

We suggest a potential role for the Australian Government to help build, and make user friendly, the evidence base that schools and / or teachers can use to inform their decisions. Examples may include:

- Commissioning independent evaluations of specific tools, or sets of tools, to assess their impact on student outcomes.
- Publishing or commissioning thought leadership that unpacks and advises on questions that schools and teachers may be facing. A discussion of the use cases, benefits and limitations of gamification is a good example.
- Periodically commissioning research (not dissimilar to this project) to identify and share promising practice and / or pitfalls that schools have faced.

14.6 Opportunity 4: Investing in professional learning for teachers to embrace and effectively use digital tools in teaching of maths

We heard from system level stakeholders that providing more students with access to high quality maths teaching remains the key to tackling the decline in student performance in numeracy and mathematics.

A range of the digital tools profiled in this report can help to improve teacher capability and confidence, to strengthen differentiation in maths classes, and to increase teacher capacity and efficiency.

To leverage these tools in their maths teaching, teachers need to build on their foundational teaching skills and strengthen their digital skills in areas including:

- Teacher recorded worked examples – how to provide targeted, personalised feedback and worked examples that students can access when and where it best suits them to help them build their maths confidence and skills.
- Leveraging the ability of fully featured teaching and learning platforms to assess the level of prior knowledge of different student cohorts, their rate of progress and tailor their teaching to these different cohorts accordingly.
- Effective incorporation of digital tools which offer maths exploration, investigation and simulation environments into lessons.

Support from the Australian Government to strengthen teacher digital literacy and embed these types of digital teaching skills into teaching degree programs and professional learning course offerings is worthy of consideration.

14.7 Opportunity 5: Influencing national broadband policy to support more enterprise-grade broadband connections in schools in regional and remote areas

Two of the three key challenges for maths teaching were most acutely felt in regional and remote schools:

- Teacher Capability and Confidence – There are shortages of maths teachers across Australia, but this is especially true in smaller schools in regional and remote areas which draw from a smaller pool of commutable municipalities for their workforce.[148]
- Differentiation – Smaller schools in regional and remote areas with enrolments of 300 or less often have students from multiple year levels in the same classroom providing an even larger differentiation challenge for teachers than is present in an average single year level classroom in a metro area.

Several best practice models for maths teaching analysed in this report offer important contributions to addressing these two challenges but, for effective implementation, schools need enterprise-grade broadband connections and reliable campus-wide networks which we heard from teachers and system level stakeholders is often lacking in regional and remote areas:

- Model: Remote Learning Delivery – For students accessing specialist maths classes delivered by teachers at remote locations, reliable highspeed broadband at their school is an essential requirement. We heard from teachers and system level stakeholders that the lack of this connectivity limited or prevented a range of schools in regional and remote areas from effectively accessing remotely delivered classes.
- Model: Teacher Recorded Worked Examples – The impact of this model hinges on teachers being able to record and upload videos, and for students to stream, pause and rewind them to support their learning.
- Model: Digital Observation and Coaching – This model allows an out of field or inexperienced teacher to access valuable coaching from a maths specialist at a remote location. This model hinges on the teachers being able to record and upload videos and for coaches to stream, pause and rewind them to support their coaching.
- Model: Fully featured Teaching and Learning Platforms – These cloud-based platforms are now fully entrenched in the 'standard' resource suite at some of the highest resource secondary schools in major cities and receive strong endorsement from many highly capable maths teachers. However, as a cloud-based software product, they require that all students have high speed broadband in their maths classrooms for successful implementation.

Stakeholders we spoke to in less urbanised locations emphasised their frustration at not being able to access the level of connectivity they need to effectively use technologies and what they saw as the limited funding and / or influence that jurisdictions have to address this. This frustration was the single biggest barrier for stakeholders we spoke with.

We acknowledge that broadband policy is not the responsibility of the Australian Government Department of Education, nor any of the agencies in the national education architecture. However, we also note that broadband infrastructure continues to be an area of Australian Government interest and activity and we would encourage implications for schools to be part of that conversation.

[148] Australian Education Union, State of our Schools, 2020.

14.8 These opportunities may be able to be generalised to teaching more broadly, but not without caution

Our project focussed on the use of digital technologies for teaching maths. In our research we have necessarily also touched on issues that extend to technology use in schools more generally. In this sense, many of the opportunities we have identified may be able to be applied outside of mathematics. For example, the argument that there may be a role for Australian Government in curating and quality assuring classroom resources probably applies for literacy just as much as numeracy, and the argument that poor connectivity in regional and remote schools inhibits uptake of digital tools certainly does.

In this sense we hope that our work may contribute to wider thinking about the role of the Australian Government in supporting the use of technology in education. However, we also note that there are specific opportunities that apply in specific contexts. For example, we identified indications of specific market failures for primary school mathematics teaching resources. This pattern may or may not be replicated for other subject areas.

14.9 Specific opportunities arising with regard to the eight models for which we completed deep dive analysis in the report

There are also opportunities for the Australian Government associated with each of the eight deep dives into specific technologies contained in this report in the sections above, these are outlined in Figure 37.

Figure 37: Australian Government Opportunities for Impact in each maths teaching and learning model

Model	Australian Government Opportunities
Maths lesson plans	• Ensuring the full Australian Curriculum is comprehensively covered by lesson plan and lesson video libraries, • Ensuring ongoing quality assurance and improvement of these resources occurs, and • Helping to promote the availability and appropriate role of the libraries to the target audience of out-of-field and inexperienced teachers of maths.
Digital observation and remote coaching	• Preparing and publishing implementation guides for a video recording and remote coaching program for maths teachers in an Australian context.
Remote learning delivery	• Teacher qualifications – Additional skills are needed by maths teachers to effectively deliver teaching remotely. There may be a role for the Australian Government in supporting the codifying of a set of standards for best practice in this area providing structure for professional learning in this domain.

	• Building maths participation and skills attainment in remote and regional communities – This model may represent a cost-effective and relatively quick to implement solution to the teacher workforce shortages plaguing schools nationally and particularly in regional, rural and remote Australia. We note that there are in-field teacher shortages in metro areas, however, the issue is most acute in rural, region and remote setting. This model allows rural, regional and remote schools to tap into the greater number of specialist teachers located in larger cities. • Software quality assurance– There are many high-quality software products available in the market for use in remote delivery of maths teaching under this model. There are also products of lesser or uneven quality. There may be a role for the Australian Government to commission work to quality assure software products in maths teaching and learning to assist schools in their decision making about resources in this area.
Online tutoring	• Working with the South Australian Department of Education to scale up the Learning+ Number interview and/or diagnostics for broader use in schools to support maths teaching and learning.
Fully featured teaching and learning platforms	• Lessening the burden of identifying the highest quality digital maths teaching tools for schools via commissioning research on quality assurance and collation. For example: o Developing and publishing standards which resources should meet (e.g., explicit alignment to the Australian Curriculum, provision of 'rich' classroom tasks that support diversified teaching). o Incorporating common definitions in these standards that define, for example, what a 'lesson plan' is. o Setting up mechanisms to either quality assure resources or allow third party providers to demonstrate compliance. • Initiatives that support teachers to develop the skills needed to effectively utilise these platforms in maths teaching. This may involve both the role of digital maths teaching skills in teaching degree programs and professional learning course offerings.
Digital exploration, investigation & game environments	• Supporting more studies to develop the Australian evidence base on the impact on maths achievement for students using Desmos, Minecraft and Roblox to

	support maths teaching and learning across specific concepts within the curriculum. • Providing more specific guidance for teachers (and parents) on 'parental' controls and eSafety, potentially via the eSafety Commissioner, around the use of online and multi-player platforms such as Minecraft and Roblox.
Cohort-specific culturally relevant content and lesson plans	• Partnering with the Queensland government to Investigate the ongoing effectiveness of the Solid Pathways program through analysis of student maths learning trajectories after participating in the program. This is an important first step in investigating if the model should be expanded for use in other jurisdictions. • Supporting the program operators to document the program model in a fashion that can allow other groups of maths educators serving CALD students to learn lessons from the Solid Pathways experience which set them on solid foundations to implement their own versions of the program.
Teacher-recorded worked examples	• Investing in the creation of how-to-guides, videos and example libraries which can be made available to schools and systems nationally (as well as universities providing teaching qualifications). • Commissioning the design and delivery of professional learning units on this model nationally. This could also involve investment in codifying the model with input from experts and practitioners in order to build standardised terminology for the different types of recordings which are appropriate for the different topics in the maths curriculum.

Appendix 1 - Literature review references

Alexander, R. (2006). *Towards dialogic teaching: Rethinking classroom talk.* Dialogos.

Antonini, S., Baccaglini-Frank, A., & Lisarelli, G. (2019). From Experiences in a Dynamic Environment to Written Narratives on Functions. *Digital Experiences in Mathematics Education, 6*(1), 1–29. https://doi.org/10.1007/s40751-019-00054-3

Bingham, T., & Conner, M. (2010). *The NEW Social Learning: a Guide to Transforming Organizations Through Social Media.* Astd Usa.

Brown, N., te Riele, K., Shelley, B., & Woodroffe, J. (2020). *Learning at home during COVID-19: Effects on vulnerable young Australians.* https://www.utas.edu.au/__data/assets/pdf_file/0008/1324268/Learning-at-home-during-COVID-19-updated.pdf

Butler, G., Deaton, S., Hodgkinson, J., Holmes, E. & Marshall, S. (2005). *Quick but not Dirty: Rapid Evidence Assessments as a Decision Support Tool in Social Policy.* http://www.gsr.gov.uk/downloads/new_research/archive//quick_not_dirty05.pdf

Collins, A., & Halverson, R. (2010). The second educational revolution: rethinking education in the age of technology. *Journal of Computer Assisted Learning, 26*(1), 18–27. https://doi.org/10.1111/j.1365-2729.2009.00339.x

Cramer, M. (2020, September 25). *Sorry, kids. Snow days are probably over.* The New York Times. https://www.nytimes.com/2020/09/25/us/snow-days-online-school.html

Denker, K. J., Manning, J., Heuett, K. B., & Summers, M. E. (2018). Twitter in the classroom: Modeling online communication attitudes and student motivations to connect. *Computers in Human Behavior, 79*, 1–8. https://doi.org/10.1016/j.chb.2017.09.037

Doerr, H. M., & Lerman, S. (2010). Teachers learning from their teaching: The case of communicative practices. In *Learning Through Teaching Mathematics* (pp. 247–262). Springer.

Dunn, R., & Hattie, J. (2021). *Developing Teaching Expertise: A Guide to Adaptive Professional Learning Design*. Corwin Press.

Dunning, D. (2011). The Dunning–Kruger effect: On being ignorant of one's own ignorance. In M. P. Zanna (Ed). *Advances in experimental social psychology. Volume 44*. Academic Press/Elsevier.

Fairweather, J. (2008). *Linking Evidence and Promising Practices in Science, Technology, Engineering, and Mathematics (STEM) Undergraduate Education: A Status Report.* Washington, DC: National Research Council.

Fendick, F. (1990). *The correlation between teacher clarity of communication and student achievement gain: A meta-analysis* [Doctoral dissertation, University of Florida]. https://ufdc.ufl.edu/AA00032787

Fennema, E., & Romberg, T. A. (Eds.). (1999). *Mathematics classrooms that promote understanding*. Routledge.

Goldhaber, D., Kane, T.J., McEachin, A., Morton, E., Patterson, T., and Staiger, D. O. (2022). *The consequences of remote and hybrid instruction during the pandemic.* https://cepr.harvard.edu/files/cepr/files/5-4.pdf?m=1651690491

Gore, J., Fray, L., Miller, A., Harris, J., & Taggart, W. (2021). The impact of COVID-19 on student learning in New South Wales primary schools: an empirical study. *The Australian Educational Researcher, 48*(4), 605-637. https://doi.org/10.1007/s13384-021-00436-w

Government Social Research. (2008). *REA Toolkit: Rapid Evidence Assessment Toolkit Index.* http://www.gsr.gov.uk/professional_guidance/rea_toolkit/

Grant, M. J., & Booth, A. (2009). A typology of reviews: an analysis of 14 review types and associated methodologies. *Health Information & Libraries Journal, 26*(2), 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x

Hand, S. W. (2016). *Uncovering and predicting teacher stages of concern in phased 1:1 iPad device implementations* (Publication No. 10253468) [Doctoral dissertation, Regent University]. ProQuest Dissertations & Theses Global.

Harper, B. (2018). Technology and Teacher–Student Interactions: A Review of Empirical Research. *Journal of Research on Technology in Education, 50(*3), 214–225. https://doi.org/10.1080/15391523.2018.1450690

Hattie, J. (2009). The black box of tertiary assessment: An impending revolution. *Tertiary assessment & higher education student outcomes: Policy, practice & research*, *259*, 275.

Hennink, M., Hutter, I., & Bailey, A. (2010). *Qualitative research methods.* Sage.

Hill, J. C. (2022). *A case study of the introduction of iPads at an Australian K–12 school.* Monash University. https://doi.org/10.26180/19364999.v1

Hollebrands, K., & Okumuş, S. (2018). Secondary mathematics teachers' instrumental integration in technology-rich geometry classrooms. *The Journal of Mathematical Behavior, 49,* 82–94. https://doi.org/10.1016/j.jmathb.2017.10.003

Hwang, G., Chang, S., Song, Y., & Hsieh, M. (2020). Powering up flipped learning: An online learning environment with a concept map-guided problem-posing strategy. *Journal of Computer Assisted Learning, 37*(2), 429–445. https://doi.org/10.1111/jcal.12499

Institute for Social Science Research [ISSR]. (2020). *Learning through COVID-19: Maximising educational outcomes for Australia's children and young people experiencing disadvantage.* https://issr.uq.edu.au/Learning-through-COVID–19

Jonassen, D. H. (1999). Constructivist learning environments on the web: engaging students in meaningful learning. In t*he educational technology conference and exhibition, Singapore.* *http://www.moe.edu.sg/iteducation/edtech/papers/d1.pdf*.

Kilpatrick, J., Swafford, J., & Findell, B. (2001). *Adding it up: helping children learn mathematics.* National Academy Press.

Koehler, M. J., & Mishra, P. (2005). What happens when teachers design educational technology? The development of technological pedagogical content knowledge. *Journal of Educational Computing Research, 32*(2), 131–152. https://doi.org/10.2190/0ew7-01wb-bkhl-qdyv

Laursen, S. L., Hassi, M. L., Kogan, M., & Weston, T. J. (2014). Benefits for women and men of inquiry-based learning in college mathematics: A multi-institution study. *Journal for Research in Mathematics Education*, *45*(4), 406-418. https://doi.org/10.5951/jresematheduc.45.4.0406

Li, F., Jin, T., Edirisingha, P., & Zhang, X. (2021). School-Aged Students' Sustainable Online Learning Engagement during COVID-19: Community of Inquiry in a Chinese Secondary Education Context. *Sustainability, 13*(18), 10147. https://doi.org/10.3390/su131810147

Martin A., Collie R., and Nagy R. (2021). Adaptability and High School Students' Online Learning During COVID-19: A Job Demands-Resources Perspective. Frontiers of. Psychology. 12:702163. https://doi: 10.3389/fpsyg.2021.702163.

Mayer, R. E. (2014). Incorporating motivation into multimedia learning. *Learning and Instruction, 29,* 171–173. https://doi.org/10.1016/j.learninstruc.2013.04.003

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.

Mukuka, A., Shumba, O., & Mulenga, H. M. (2021). Students' experiences with remote learning during the COVID-19 school closure: implications for mathematics education. Heliyon, 7(7), e07523-e07523.

National Center on Education and the Economy (2021). *Singapore*. https://ncee.org/country/singapore/

Paas, F., & Sweller, J. (2012). An evolutionary upgrade of cognitive load theory: Using the human motor system and collaboration to support the learning of complex cognitive tasks. *Educational Psychology Review, 24*(1), 27-45.

Perry, T., Lea, R., Jørgensen, C. R., Cordingley, P., Shapiro, K., & Youdell, D. (2021). *Cognitive science in the classroom.* Education Endowment Foundation (EEF). https://educationendowmentfoundation.org.uk/evidence

Puentedura, R. R. (2006). *Transformation, technology, and education.* Hippasus. http://hippasus.com/resources/tte/

Robotti, E., & Baccaglini-Frank, A. (2017). Using digital environments to address students' mathematical learning difficulties. In *Innovation and Technology Enhancing Mathematics Education* (pp. 77-106). Springer, Cham.

Sahni, S. D., Polanin, J. R., Zhang, Q., Michaelson, L. E., Caverly, S., Polese, M. L., & Yang, J. (2021). A What Works Clearinghouse Rapid Evidence Review of Distance Learning Programs. WWC 2021-005REV. What Works Clearinghouse.

Santi, G., & Baccaglini-Frank, A. (2015). Forms of generalization in students experiencing mathematical learning difficulties. PNA. *Revista de Investigación en Didáctica de la Matemática, 9*(3), 217-243.

Schleicher, A. (2022). *Lessons from the pandemic: Why digitalisation and inclusivity should be top priority for education* (OECD Webinar, 2022) OECD Education Webinars - See the data, hear the experts! (oecdedutoday.com)

Schleicher, A. (2020). *The impact of COVID-19 on education: Insights from education at a glance 2020.* https://www.oecd.org/education/the-impact-of-covid-19-on-education-insights-education-at-a-glance-2020

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher*, *15*(2), 4-14.

Sonnemann, J., & Goss, P. (2020). *COVID catch-up: Helping disadvantaged students close the equity gap*. Grattan Institute.

Stewart, I. (1989). *Does God play dice? The mathematics of chaos.* Blackwell.

Symons, D., & Dunn, R. (2019). Productive discussion as a foundation for primary mathematics. *Australian Primary Mathematics Classroom*, *24*(2), 21-25.

Torrington, J., & Bower, M. (2021). Teacher-created video instruction in the elementary classroom—Its impact on students and teachers. *Journal of Computer Assisted Learning, 37*(4), 1107-1126. https://doi.org/10.1111/jcal.12549

Tosh, K., Doan, S., Woo, A., & Henry, D. (2020). Digital Instructional Materials: What Are Teachers Using and What Barriers Exist? Data Note: Insights from the American Educator Panels. Research Report. RR-2575/17-BMGF/SFF/OFF. *RAND Corporation*.

Tzu-Chi, Y. (2020). Impacts of observational learning and self-regulated learning mechanisms on online learning performance: a case study on high school mathematics course. In *2020 IEEE 20th international conference on advanced learning technologies (ICALT)* (pp. 194-197). https://kodu.ut.ee/~roogsoo/icalt/pdfs/ICALT2020-4iCjwFBhzDv7BDGx7xnFnB/609000a194/609000a194.pdf

UNICEF (2021). *Children cannot afford another year of school disruption: Statement by UNICEF Executive Director Henrietta Fore.* https://www.unicef.org/press-releases/children-cannot-afford-another-year-school-disruption

Wetzel, A. P., De Arment, S. T., & Reed, E. (2015). Building teacher candidates' adaptive expertise: Engaging experienced teachers in prompting reflection. *Reflective Practice, 16*(4), 546-558. https://doi.org/10.1080/14623943.2015.1064380

Appendix 2 - Literature review search scope

Searches April 25 to 29, 2022 (all searches done with range 2020 to 2022) 196 articles in Zotero library				
Search	Database	Search terms	Results	Notes
1	Google Scholar	(math* OR numeracy) AND (“online learning” OR “remote learning” OR “distance education” OR “online school” OR “online courses” OR “online program” OR “online models” OR home based learning”)	17,100	First 10 pages of results checked – few were relevant
2	Google Scholar	(math* OR numeracy) AND (“online learning” OR “remote learning” OR “online school” OR “online courses” OR “online program” OR “online models”) AND (teach* OR instruction OR “teaching models” OR education OR pedagogy OR learning)	17,100	First 10 pages of results checked “distance education” and “home based learning” removed
3	ERIC	(math* OR numeracy) AND (“online learning” OR “remote learning” OR “distance education” OR “online school” OR “online courses” OR “online program” OR “online models” OR home based learning”) AND (teach* OR instruction OR “teaching models” OR education OR pedagogy OR learning) AND (“primary school” OR “elementary school” OR “high school” OR “middle school” OR “secondary school”) AND (“student outcomes” OR achievement)	76	All checked
3a	ERIC	(math* OR numeracy) AND (“online learning” OR “remote learning” OR “distance education” OR “online school” OR “online courses” OR “online program” OR “online models” OR home based learning”) AND (teach* OR instruction OR	1460	most not tech related (focus on pedagogy

		"teaching models" OR education OR pedagog* OR learn*) AND (primary OR secondary OR middle OR high OR elementary) N3 (school* OR teach* OR class* OR child* OR student* OR education)		and curriculum)
3b	ERIC	math* OR numeracy AND "online learning" OR "remote learning" OR "distance education" OR "online school" OR "online courses" OR "online program" OR "online models" OR "home based learning" AND teach* OR instruction OR "teaching models" OR education OR pedagog* OR learn* AND "primary school" OR "elementary school" OR "high school" OR "middle school" OR "secondary school" AND "student outcomes" OR achievement OR performance OR GPA OR "grade point average"	78	more relevant results than above but many already located- all checked
4	ProQuest	(math* OR numeracy) AND ("online learning" OR "remote learning" OR "distance education" OR "online school" OR "online courses" OR "online program" OR "online models" OR "home based learning") AND (teach* OR instruction OR "teaching models" OR education OR pedagogy OR learning) AND ("primary school" OR "elementary school" OR "high school" OR "middle school" OR "secondary school") AND ("student outcomes" OR achievement)	(14,590 total) Peer reviewed (1,386) and full text (1,194)	Results 1-40 checked so far and 25 collected 27/4/22
4	ProQuest	math* OR numeracy AND	(6093 total) Peer reviewed	

		"online learning" OR "remote learning" OR "distance education" OR "online school" OR "online courses" OR "online program" OR "online models" OR "home based learning" AND teach* OR instruction OR "teaching models" OR education OR pedagog* OR learn* AND "primary school" OR "elementary school" OR "high school" OR "middle school" OR "secondary school" AND "student outcomes" OR achievement OR performance OR GPA OR "grade point average"	and full text (533)	
6	EBSCOhost	(math* OR numeracy) AND ("online learning" OR "remote learning" OR "distance education" OR "online school" OR "online courses" OR "online program" OR "online models" OR "home based learning") AND (teach* OR instruction OR "teaching models" OR education OR pedagogy OR learning) AND ("primary school" OR "elementary school" OR "high school" OR "middle school" OR "secondary school") AND ("student outcomes" OR achievement)	6 results – none useful	
6	EBSCOhost	(math* OR numeracy) AND ("online learning" OR "remote learning" OR "online school" OR "online courses" OR "online program" OR "online models") AND (teach* OR instruction OR "teaching models" OR education OR pedagogy OR learning)	0	
6	EBSCOhost	math* OR numeracy AND	(42 using below search terms) (37	all relevant results collected

		“online learning” OR “remote learning” OR “distance education” OR “online school” OR “online courses” OR “online program” OR “online models” OR “home based learning” AND teach* OR instruction OR “teaching models” OR education OR pedagog* OR learn* AND “primary school” OR “elementary school” OR “high school” OR “middle school” OR “secondary school” AND “student outcomes” OR achievement OR performance OR GPA OR “grade point average”	peer reviewed)	
7	Web of Science	math* OR numeracy AND “online learning” OR “remote learning” OR “distance education” OR “online school” OR “online courses” OR “online program” OR “online models” OR “home based learning” AND teach* OR instruction OR “teaching models” OR education OR pedagog* OR learn* AND “primary school” OR “elementary school” OR “high school” OR “middle school” OR “secondary school” AND “student outcomes” OR achievement OR performance OR GPA OR “grade point average”	18	Mostly repeated results from above
8	Scopus	math* OR numeracy AND	24	Mostly repeated

		"online learning" OR "remote learning" OR "distance education" OR "online school" OR "online courses" OR "online program" OR "online models" OR "home based learning" AND teach* OR instruction OR "teaching models" OR education OR pedagog* OR learn* AND "primary school" OR "elementary school" OR "high school" OR "middle school" OR "secondary school" AND "student outcomes" OR achievement OR performance OR GPA OR "grade point average"		results from above
9	A+ Education	(math* OR numeracy) AND ("online learning" OR "remote learning" OR "distance education" OR "online school" OR "online courses" OR "online program" OR "online models" OR "home based learning") AND (teach* OR instruction OR "teaching models" OR education OR pedagogy OR learning) AND ("primary school" OR "elementary school" OR "high school" OR "middle school" OR "secondary school") AND ("student outcomes" OR achievement)	0	
9	A+ Education	math* OR numeracy AND "online learning" OR "remote learning" OR "distance education" OR "online school" OR "online courses" OR "online program" OR "online models" OR "home based learning" AND teach* OR instruction OR "teaching models" OR education OR pedagog* OR learn* AND		

		"primary school" OR "elementary school" OR "high school" OR "middle school" OR "secondary school" AND "student outcomes" OR achievement OR performance OR GPA OR "grade point average"		
9	A+ Education	math* OR numeracy AND "online learning" OR "remote learning" OR "distance education"	7	

Appendix 3 - Members of the Project's Expert Panel

Name	Position	Organisation
Wee Tiong Seah	Professor in Education (Mathematics Education)	Melbourne Graduate School of Education, The University of Melbourne
Ryan Dunn	Senior Lecturer	Melbourne Graduate School of Education, The University of Melbourne
Tim Marchant	Director	Australian Mathematical Sciences Institute
Allan Dougan	CEO	Australian Association of Mathematics Teachers
Danielle Toon	Director at Evidence for Learning	Social Ventures Australia
Bruce Armstrong	Former Deputy Secretary	Department of Education and Training Victoria
Summer Howarth	CEO	Eventful Learning Co
Chris Matthews	Chair	Aboriginal and Torres Strait Islander Mathematics Alliance