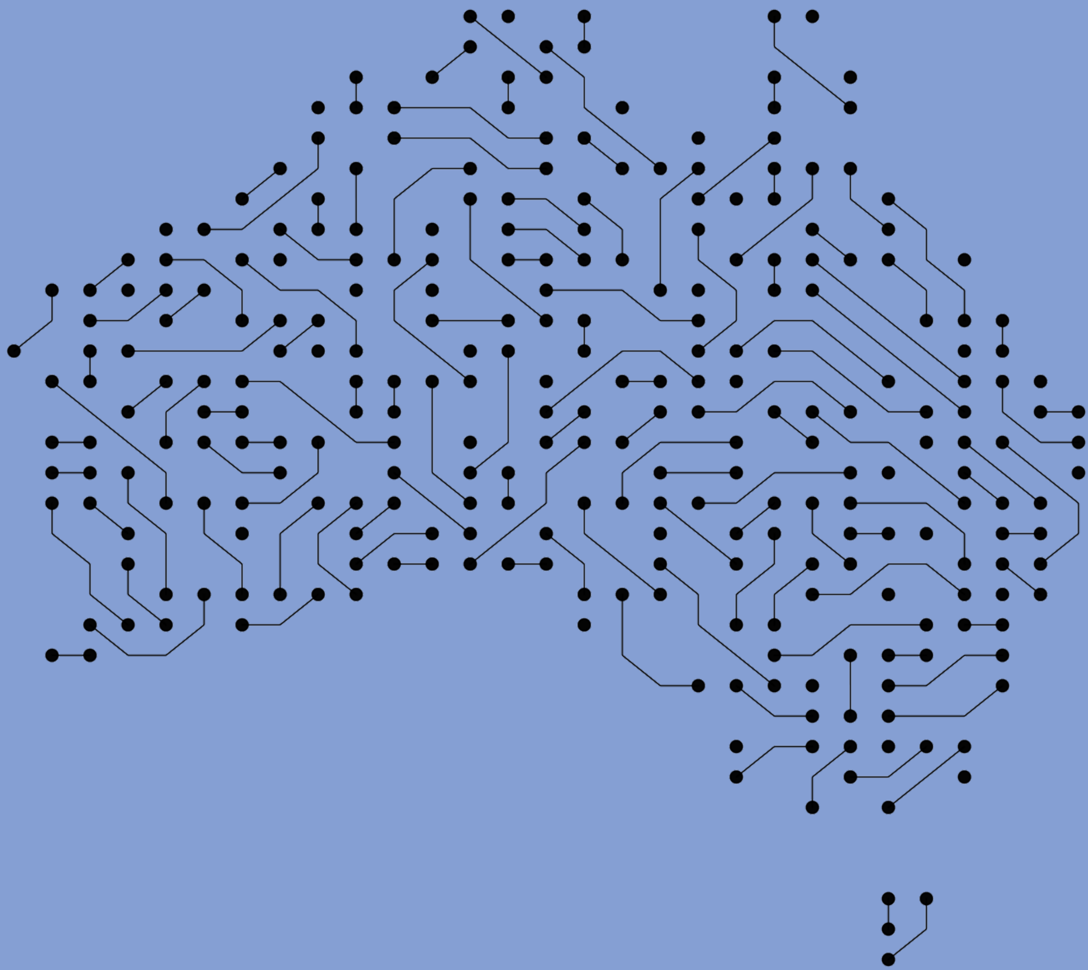

Shaping AI and edtech to tackle Australia's learning divide

December 2022

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Examples and case studies presented in this report are not intended as endorsements.

We all acknowledge the Traditional owners of country throughout Australia and pay our respects to Elders past and present.

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Executive Summary

The purpose of this report

The global market for artificial intelligence (AI) and machine learning applications is booming, creating opportunities for change in every aspect of our lives – including education. More than 1 billion students globally have been forecast as consumers of education technology (known as '**edtech**'), and 43 billion dollars in venture capital is projected to flow to digital instruction tools by 2025 (HolonIQ 2020, 2022).

There are many potential benefits to embracing these technologies and the positive evidence is building, but the use of AI-enabled learning tools in educational settings also raises thorny quality and ethical questions. In an ever-changing field, claims about the effectiveness of particular AI educational products are accepted largely without scrutiny, and the pace of technological development often outstrips standards and regulation. This can leave educators, policymakers and the public feeling overwhelmed – and paralysed by indecision. These technologies need to be carefully researched, monitored and guided to maximise educational benefit and minimise risks.

In the midst of this uncertainty – and the widening gap between Australia's most and least advantaged learners -- the question this report seeks to answer is **whether high-quality edtech can, in the right environment, be used to improve outcomes for disadvantaged students**.

The answer is yes – but only if this edtech is well-designed, **well-used and well-governed**.

There are creative, workable solutions to the conundrum of how to use AI applications safely and effectively in schools to make a difference, and there's a growing body of research that reveals an improving track record for high-quality edtech in school settings both in Australia and overseas.

These new technologies are not – as some proponents might claim – a magic bullet that can fully solve the wicked problem of education disadvantage. They are simply tools that can be used as one measure among many to help close the education gap. Yet they are powerful tools that can have measurably positive or negative impacts, depending on how they're designed and used. They cannot simply be rolled out indiscriminately without the right governance structures in place to ensure accountability and quality control.

What this means in practice and policy is covered in **ten recommendations** that are designed to empower governments and education stakeholders in Australia to take practical steps towards establishing a fair but vigilantly assessed process through which high-quality AI-enabled tools with proven benefits can be harnessed to support disadvantaged students.

These recommendations give educators, governments, industry, social benefit and philanthropic organisations the information they need to make meaningful decisions to lay this groundwork and create appropriate incentives – and checks and balances – for the sensible, sustainable and equitable use of edtech applications now and into the future.

Closing the education learning gap

There is a documented **learning chasm** in Australia: disadvantaged Year 3 students in Australian 2021 NAPLAN results were two years and five months behind students with advantaged backgrounds, a gap that widened to more than five years by Year 9 (Hunter & Emslie 2021). The COVID-19 pandemic further entrenched this inequality in education, especially for vulnerable students who lacked sufficient learning support (CIRES & Mitchell Institute 2020, Goss & Sonneman 2020).

Australia's digital divide further penalises disadvantaged students, who lose out on learning opportunities afforded by better off schools and families especially as post-pandemic education shifts to greater use of digital tools. Disadvantaged students were 40 times more likely to lack a computer than their better-off peers during the pandemic (Shergold, Broadbent, Marshall & Varghese 2022). **Now, access to high quality learning support applications is set to become the next frontier of the digital divide.**

The good news is that there is extensive evidence that effective teaching and learning strategies make a significant difference in overcoming disadvantage. **Previous research has highlighted the key factors that have been found to lift educational outcomes in disadvantaged settings**, including:

- Strengthening and supporting school leadership;
- Creating a supportive school learning climate;
- Attracting and retaining quality teachers;
- Encouraging effective classroom learning strategies;
- Building better links between schools and families.

It's crucial that any edtech used in Australia is closely aligned with these factors, so that these new tools can potentially improve and extend quality learning practices for disadvantaged students.

Edtech categories

One of the biggest challenges within Australia's education system is how to support educators in providing targeted, effective and compelling instruction, particularly to disadvantaged, complex-need students. Edtech – if designed, used and monitored properly – can be a useful element in addressing education disadvantage.

The **three categories of advanced edtech with the most promise and supporting evidence for reducing education disadvantage** are:

- **Student-oriented technology** (such as adaptive and personalised learning tools and intelligent tutoring systems);
- **Teacher-oriented technology** (such as teaching support platforms and curriculum tools to deliver 'proven in practice' resources to teachers for lesson planning; diagnostic tools for early detection and remediation of additional needs; and adaptive assessment systems that respond to individual student learning);
- **System-oriented technology** (such as early warning diagnostic systems informed by machine learning to identify and direct support to students at risk of disengagement; and applications that generate insights and analyse trends to improve program and policy design).

The evidence for positive learning outcomes using edtech

A growing body of evidence shows that high-quality edtech, when used in the right environment, can improve outcomes for disadvantaged students. As education disadvantage remains stubbornly entrenched, we need to marshal every possible resource. Edtech represents an opportunity to use innovative technologies for social good – not as a replacement for other established and effective teaching and learning strategies, but as a targeted aid.

There are several **real-world applications of edtech that have resulted in statistically significant improvements for disadvantaged students**. While this is promising, much more research of this nature is needed to better inform the design and implementation of this kind of edtech before it is widely distributed into Australian classrooms.

This report identifies **model practice in the independent evaluation of edtech initiatives based on their quality and impact**, such as the non-profit *Evidence for ESSA and EdReports* (which help U.S. school districts identify high-quality teaching resources, including digital learning and smart curriculum tools). These are funded by both government and major philanthropy organisations.

The caveat is that **only edtech that is properly designed, used and regulated can have a demonstrably positive impact** on learning outcomes for disadvantaged students. This has clear implications for action within every part of the education ecosystem in Australia:

- **Educators** and schools can help to shape and inform best practice design of edtech for the public good; provide feedback about which tools work best for different purposes and how to limit overuse of these tools in the classroom; and ensure they support teacher-led instruction with professional development in the integration and use of these tools;
- **Policymakers** can develop better governance and clear rules and standards for edtech products; require transparent proof of evidence-based pedagogical design underpinning edtech; and firmly regulate the use and collection of any data from children and young people;
- **The philanthropic sector** can help catalyse Australian commitment to world-leading, high-quality edtech that lifts learning outcomes and tackles disadvantage; direct funding towards initiatives that independently assess and compare edtech applications according to their impact on education disadvantage; and work on related initiatives to reduce the digital divide that threatens access to learning resources;
- **Academics and researchers** can generate in-depth, quality research to test assumptions and evidence about the impact of edtech and closely track real-world case studies.

What else needs to be in place for edtech to help disadvantaged students

Not all edtech is created equal. As with any technology, educational AI applications can be useful, or not, and a major responsibility of policymakers and social purpose organisations is to establish the governance and assessment systems that can help educators figure out what works – and what doesn't.

Australia currently lags behind other countries (like Singapore, the UK and the U.S.) in several key factors that affect the quality of edtech offerings:

- developing edtech locally and linking it to national learning goals;
- evaluating its effectiveness;
- understanding what factors really matter for teachers when using it;
- directing it towards high-priority and disadvantaged students;
- making sure it's accessible to all, safe and ethical.

There are **three key conditions** that must be met for optimum impact of edtech in reducing disadvantage:

- the **quality** of the tools;
- their **effective use and integration** into teacher-led instruction;
- the **network of policies, institutions and incentives** that shape the fast-growing edtech market

Recommendations

This report outlines **ten recommendations** (within four themes) to ensure any edtech that is proposed for use within Australian educational settings meets the expectations of national education priorities, helps to close the learning and digital divide, and is assessed for its proven ability to lift outcomes for all students, especially those with complex needs.

Partnership for positive change

Establish the Australian Forum on Quality Digital Education to help shape the strategic agenda for using technology to target educational disadvantage and boost student outcomes and wellbeing. The Forum would create a network of Australian leaders across education, industry, social purpose and philanthropic organisations, government and researchers, and provide an independent source of ideas and solutions to help develop and deliver safe, effective edtech that can reduce education disadvantage ***[Philanthropy, Government]***

Best practice use

- **Work with schools to test, develop and showcase best practice integration of teaching and learning technology tools** for disadvantaged and special needs students, building a network of peer-based support **[Philanthropy, Government]**
- **Provide extra resources to disadvantaged schools to access high quality edtech** learning tools, with linked implementation support and professional development, alongside investment to secure equitable access to essential technological infrastructure **[Government, Philanthropy]**

- **Commission the Australian Education Research Organisation (AERO) to provide expertise and advice** on what works best when using edtech to support teachers and improve student outcomes **[Government]**

Quality and impact

- **Include evidence standards for education interventions**, including edtech, in the next quadrennial national school funding agreement, along the lines of the U.S. *Every Student Succeeds Act* (ESSA) federal funding guidelines ***[Government]***
- **Accelerate high quality, independent research and evaluation** of teaching and learning tools to investigate:
    - Impact on learning progress for students facing educational disadvantage;
    - Features that amplify positive outcomes, including implementation factors ***[Government, Philanthropy]***
- **Catalyse a world-leading Australian social benefit edtech sector** by investing in promising systems that meet high standards for evidence, efficacy, ethics and equity. Novel forms of capital should be considered, such as impact investing, social enterprises, leveraging or partnering with venture capital funds, as well as direct public or philanthropic funding ***[Government, Philanthropy, Industry]***

Governance and information

- **Create an accessible repository of trustworthy information** on the quality and safety of available edtech tools so that schools, education systems and parents can make more informed choices ***[Philanthropy, Government]***
- **Develop education-specific standards** covering product design, data use, and life cycle governance and accountability to guide purchasing decisions and assist industry access to the sector ***[Government, Industry]***
- **Build public-private partnerships to safely share data** for better traction on solving education challenges, and to apply advanced data techniques to help optimise outcomes for students at risk ***[Government, Philanthropy, Industry]***

Introduction

In 2018, the deputy principal of a disadvantaged Western Sydney primary school was concerned that despite great effort by teachers, some of his young students weren't making enough progress with their literacy skills, and he knew this would cause long-term detriment to their learning.

The school had already tried various interventions, which worked for many but not all students. Then they heard about an adaptive learning technology platform that could integrate personalised student skill-building into a teacher's classroom program, provide supplementary learning resources, and deliver timely, detailed data on each student and class-wide progress. They decided to give it a shot.

The school saw literacy achievement improve in one year, especially for Year 5 students. Where once the school's Year 5 results were below those of schools with students of similar backgrounds, by 2019 they were outpacing their peers. Teachers later also noticed how quickly students rebounded when they returned to classrooms and to using the tool after COVID-forced learning disruptions.

Given the troubling, deep-seated learning gap between most and least advantaged students in Australia, there is promise and potential for teachers and learners to use high-quality education technology (known as 'edtech') as another tool in tackling education disadvantage. While there is an emerging body of evidence tracking the improved effectiveness and impact of these tools, there is also a proven need for clear, established governance frameworks to be in place before edtech becomes widespread in Australian schools.

The opportunity

There is a learning chasm in Australia: disadvantaged Year 3 students in Australian 2021 NAPLAN results were two years and five months behind students with advantaged backgrounds, a gap that widened to more than five years by Year 9 (Hunter & Emslie 2021). The COVID-19 pandemic dealt a further blow, especially for vulnerable students who lacked the learning support available to others (CIRES & Mitchell Institute 2020, Goss & Sonneman 2020).

Artificial intelligence (AI), machine learning and related emerging trends in digital and data capability are sending shockwaves of disruption and innovation across every aspect of modern life – including education. Yet the benefits and risks of using these new and increasingly powerful technologies in educational settings have remained unclear.

Meanwhile, the market reach of AI-enabled technologies is growing rapidly. Australia's Artificial Intelligence Roadmap estimates the global value of commercial AI-based innovation will top AU$22 trillion by 2030 (Hajkowicz et al. 2019). There are inspiring but limited examples of 'tech for good,' and current investment in technology with social purpose is low. Public and social sector use of AI-driven technology is largely contained to back office administrative functions, transactional or allocative services for the general population, and some data analysis. Very little is deployed to improve services for disadvantaged citizens who have the most complex needs that could be served by adaptive technology's strengths.

The health sector offers a useful glimpse of the social purpose possibilities of AI. It has adopted advanced technology for patient-oriented, health-enhancing applications faster and more widely than education.

This openness in the health sector to using AI-enabled tools is in part due to the normative structures that underpin the sector as a whole. In health, rigorous research and experimentation is encouraged even when risks are high, and accompanying regulation ensures that any health interventions (including the use of medical technologies) are properly tested and assessed for medical *and* ethical impacts. For health institutions and professionals, there's already an established framework in place that allows them to more confidently test, assess and safely use a new AI tool, whether for research or patient-based applications.

These technological developments raise an important question: How could we better direct this potent technology toward some of the most difficult challenges we face in helping individuals and communities overcome entrenched education disadvantage, especially when these challenges have proven stubbornly resistant to many existing policy and program approaches?

Advanced education technology

Edtech is a fast-growing wedge of the wider AI-driven technology ecosystem. It can serve multiple purposes, including teaching and administrative aids, data collection and analysis, and individualised student support, assessment and credentialling. The COVID-19 pandemic has sparked even greater interest in the use of edtech in schools in the wake of extended periods of distance and virtual learning.

By one global estimate, more than one billion students are potential edtech consumers. Entrepreneurs are drawn to the $300-plus billion worldwide opportunity and investors anticipate high returns. Some $43 billion in venture capital is projected to flow to digital instruction tools by 2025, up from $16 billion only three years ago. Over half the capital injection since 2010 has come from China, another 33% from the U.S., and 10% from Europe and India. Australian investment is minimal in this context (HolonIQ 2020, 2022).

Adaptive, advanced edtech applications – when developed and used in the right environment – could help to enhance education, especially for vulnerable students who might fall through the cracks. These tools can be useful to teachers in gathering more precise data for diagnosis and analysis of learning progress and providing proven resources, while other edtech products offer students personalised learning and support, and engaging ways to learn. This suite of technologies could help solve one of Australian education's great challenges: how to create targeted and compelling instruction for all students (and particularly disadvantaged, complex-need students) within the large-scale, universal schooling system.

There is an urgent need for an Australia-wide governance and regulatory framework so that education stakeholders can make informed, safe, effective and equitable decisions about the use of edtech, backed up by in-depth, quality research.

Consider the following examples of edtech:

- Learning tools that can adapt to a student's level of understanding, interests, and instructional needs as they travel on a trajectory towards mastery of complex and higher order knowledge and skills;
- Tools that help a teacher design and deliver classroom learning, incorporating high-quality, evidence-backed resources and instructional approaches to save time, improve

consistency, and provide fine-grained student insights for greater professional agency;

- Assessment systems that operate with a light touch (in the background and in real time) to provide formative, knowledge-building feedback to the student and teacher (and reduce reliance on high stakes, summative tests);
- Adaptive tutoring to extend learning opportunities outside the classroom;
- Systems for early and precise diagnosis of special needs, with direct access to support and remedial resources;
- Early warning systems that identify students at risk of disengaging and connect to productive interventions.

All of these kinds of edtech are potentially available to Australian schools but penetrate classrooms largely through marketing campaigns and without rigorous evaluation or understanding of how best to use them. Only some focus explicitly on disadvantaged students and their complex education needs. Too few are shaped by and for teachers, with evidence of effectiveness. Too many require high level technology access and support, or extra investment in teacher training. Most are privately developed, without public guidelines or clear rules, originate and retain control outside of Australia, and can capture and convert data into financial assets without knowledge or constraint.

Australian students deserve the highest quality edtech, proven to deliver learning progress, aligned to our curriculum standards and meets or exceeds expectations for both learning outcomes and equity. We must guard against bias or discrimination that is baked into the technologies themselves and could unintentionally *entrench* education disadvantage. This means that the public education sector (and Australian schooling generally) needs to take the lead in designing and shaping these technologies. The worst outcome would be for Australian educators simply to become passive ‘takers’ of what’s on offer, which could jeopardise Australian values, social cohesion and student protections if some edtech platforms show the same disregard for personal privacy and the ethics of data capture as other digital domains have in recent years.

The use of technology in the Australian public sector

Australian governments currently use technology primarily for back-office systems to support both centralised and front-line functions (such as records creation and access, data collection and analysis, resource or service allocation, and consumer payments or receipts). Within service delivery, public sector technology typically supports consumer-based, bulk or routine transactional services, like issuing drivers’ licences or facilitating tax payments.

The social purpose sectors of government, including education, have been slow to use technology for direct user benefit. Certainly, there has been significant investment in IT infrastructure and hardware like Wi-Fi, computers, electronic whiteboards, tablets and so forth. Yet these are necessary baseline investments, and education sector evidence shows they are not well-correlated with higher student achievement on their own.

The public sector in Australia also generally has quite limited knowledge of AI-enabled technologies and leaves technology decisions to dedicated branches of the bureaucracy – the ‘IT department’ – risking further distance from policy decisions, service delivery or oversight. Government-wide procurement criteria strongly shape these technology decisions, valuing price and efficiency, which may not always align well with the intended public purpose or the needs of its most disadvantaged beneficiaries (with potentially higher costs and lower financial returns). Procurement scrutiny of proposed technologies also overwhelmingly happens pre-purchase, whereas the real benefits or failures of that technology may only emerge once in operation.

These factors present a particular risk when it comes to AI, which powers highly bespoke technologies. The power for positive impact that is possible with AI must be very closely and specifically designed and monitored to avoid the unintended negative consequences that can arise once it's in use. While one of the advantages to machine learning is its capacity to autonomously find connections or new angles to solve complex problems, it cannot be left to operate within a 'set and forget' paradigm. The further AI moves from human control, the greater the risk of unintentional but devastating impacts. This has already been the case for many commercially-developed AI applications, including some in the public sector (such as racially-biased sentencing applications used in some overseas courts, or the Australian Government's disastrous automated welfare debt recovery system, dubbed 'Robodebt' and now terminated and subject to Royal Commission inquiry).

Governments and the public sector are thus understandably cautious about the risks posed by AI-enabled technologies, but this institutional uncertainty means that genuine opportunities for tech-driven innovation within the sector are sometimes overlooked.

Bending the curve towards positive impact

There is a growing body of reliable evidence to show that high-quality edtech (especially adaptive learning tools, smart teaching support platforms, and data-driven early risk identification systems) can have a statistically significant positive impact on learning outcomes. Even more promising are the findings that – in certain circumstances – these tools can be of extra benefit to disadvantaged or special needs students.

Yet all edtech tools are not created equal. There are three key factors that determine whether any given edtech tool can be useful in a classroom setting:

- the quality of the tools;
- their effective use and integration into teacher-led instruction;
- the network of policies, institutions and incentives that shape and govern the wider edtech market.

Australia lags behind global leaders in developing education technology, evaluating its effectiveness, understanding what factors really matter for teachers when using it, directing it towards the highest-priority students, and ensuring it is safe, ethical and appropriate. Singapore, the UK, the United States and other nations have all taken important steps to boost the quality of edtech on offer within their schooling systems, and to link it to their own national learning goals.

The underpinning digital divide further drives education inequality as disadvantaged students and schools can struggle to access even basic digital learning opportunities. Well-off students were vastly more likely to have a computer for remote schooling during the pandemic than disadvantaged students

(Shergold, Broadbent, Marshall & Varghese 2022). Access to top quality learning support tools now is poised to become the next frontier of this digital divide.

All stakeholders in the Australian education ecosystem can play an important role in catching up to these other countries. Government will be key, alongside philanthropy, researchers, educators and social purpose organisations. Philanthropic and non-government institutions can make an especially significant contribution by catalysing reform within the Australian edtech sector and incentivising providers to design and roll out tools that improve learning outcomes for disadvantaged students. This is why some of the world's largest charitable organisations (such as the Bill & Melinda Gates Foundation) are increasing their investment in this space.

This report outlines ten recommendations that can shift the curve of edtech towards better outcomes in education. This doesn't mean choosing winners, but it does mean designing the right incentives for equitable and effective edtech through a combination of public policy interventions, social capital investments and robust governance, including:

- Building the ecosystem of technology providers, social benefit organisations, schools, teachers, experts and governments committed to ensuring Australia's edtech is designed to tackle entrenched learning gaps while operating safely and fairly;
- Learning much more about 'what works' when using edtech, especially in disadvantaged schools, and supporting teachers to incorporate these practices in their classrooms;
- Investing in the best quality edtech products that are designed by and for teachers, backed by learning science, and bolstered by robust ethical and data protections;
- Creating public standards and requirements to reliably evaluate edtech products and boost school, teacher and parent agency and confidence in choosing from a range of options.

Right now, schools are largely flying blind while the education technology market booms. If technological innovation pushes further away from public and social purpose and toward private return, it becomes more pressing and salient to invest and innovate to deliver wider social benefit, to solve enduring social and economic challenges, and to broaden the aims of the education technology sector to fully tackle education disadvantage. This shouldn't be a question of 'if' but 'how'.

The stakes are high. These tools could be used to serve Australia's most vulnerable students, but without the right kind of public policy interventions, they will be harnessed to give an even bigger advantage to wealthier schools and students, which could further widen the learning chasm.

Chapter 1: What works in education to overcome disadvantage

There is substantial research that has examined the social and economic factors that drive education disadvantage, with parental education (and its associated impact on home literacy and learning environment) among the most powerful contributors (Shonkoff & Phillips 2000). This can set the stage for enduring disadvantage well before a child enters school and across their learning path. Worse, learning gaps can widen over time (Closing the Gap 2020).

Strong literacy and numeracy capabilities are essential and provide the platform for further learning and mastery of more complex knowledge. Yet today there exists a basic skills achievement chasm in Australia. Even in a high-performing state like Victoria, disadvantaged Year 3 students are 17 months behind more advantaged peers, and that gap *expands* so that by Year 9, they are four years and five months behind in reading and three years and six months behind in numeracy (Sonneman & Goss 2020). These gaps are replicated across Australia: Year 3 students whose parents hadn't completed high school were 29 months behind peers whose parents had a university degree, a divide that expanded to 64 months by Year 9 (Hunter & Emslie 2021).

Schools can struggle to overcome students' social and economic backgrounds if they lack the institutional capacity or support to effectively organise teaching and learning strategies for maximum positive impact. This creates a "double handicap" where schools not only fail to mitigate this external or demographic disadvantage, but can "amplify its negative effect" (OECD 2012, p. 107).

In schools with robust systems and quality teaching practices informed by the strongest pedagogical evidence, these 'starting gate' gaps can be narrowed or eliminated. It is encouraging that highly effective schools can be found in all education settings in Australia: in schools with predominantly disadvantaged or well-off students; in public or non-government sectors; and in a wide range of locations (Goss & Giles 2021).

While socio-economic factors powerfully influence student achievement, disadvantage clearly need not define a student's path, especially given the consensus in the research on what lifts student learning outcomes. The challenge is to make these practices easy to access, adopt and implement in all education settings; this is one area where technology may offer particular promise.

There is a vast body of evidence on the effectiveness of different teaching and learning approaches. Hattie's (2017) ranking of achievement effect sizes, for instance, examines 14,000 meta-analyses of 800,000 studies. Evidence is continually being refined, alongside new datasets and techniques.

What follows is a summary of factors demonstrated to lift outcomes in disadvantaged (and other) schools, and an analysis of where AI-enabled edtech could potentially be well-aligned in offering tools to extend quality learning practices. This draws on the Organisation for Economic Co-operation and Development (OECD)'s 2012 large-scale review of what works best in disadvantaged schooling and its 2021 Digital Education Outlook, with additional insights from recognised global education and AI researchers, as well as the Australian Education Research Organisation (AERO), Centre for Education Statistics and Evaluation (CESE), Grattan Institute, and the Education Endowment Foundation (EEF), among others.

Key factors for educational effectiveness

While it's broadly recognised that teaching quality is the chief ingredient for successful schools (Hattie 2009), there are many factors that define and support teaching quality at the classroom, school, and system level. No single element will deliver quality teaching, but a powerful combination of approaches is consistently found in the most effective schools and education systems.

For more than two decades, the OECD has refined its understanding of measures that will lift equity and outcomes for disadvantaged students and schools, and its major 2012 report identified the following five as essential:

- Strengthening and supporting school leadership
- Creating a supportive school learning climate
- Attracting and retaining quality teachers
- Encouraging effective classroom learning strategies
- Building better links between schools and families

School leadership

As with any complex organisation, school leaders frame the goals, culture and conditions for success. Schools with a culture of high expectations (for both students and staff) tend to deliver better results through effective organisational processes and support for teachers, including:

- Evaluating and developing teacher expertise and skill
- Setting clear whole-of-school goals, with regular monitoring and progress accountability
- Channelling resources towards the most effective practices
- Collaborating with other schools for improvement

Collective teacher efficacy (CTE) is central to school improvement. Hattie (2017) found that this has the largest impact on student attainment out of a total of 252 researched influences. One recent study found CTE explains as much as 50% of the 'between school' differences in maths and reading (Hoogsteen 2020).

CTE reflects a shared confidence in the ability of the school to make a real and positive difference to students' lives and education outcomes, regardless of their backgrounds (Hoogsteen 2020). Strategies to build collective efficacy include setting and monitoring aspirational goals, sharing specific examples of excellent teaching, encouraging collaboration and knowledge transfer, and celebrating success.

School learning climate and student engagement

A positive and well-ordered learning environment helps influence student behaviour and boosts student engagement and focus. This involves much more than disciplinary policies; it means positive relationships for students with their teachers and peers, a sense of being valued and connected to the school, and believing teachers have high expectations for their students and are committed to helping them achieve success. Students who feel connected and positive about their school tend to deploy more effective learning strategies and are more confident they will achieve their learning goals. This has positive knock-on effects: by one analysis, "having a well-calibrated motivation mindset is equivalent to vaulting into a higher socioeconomic status" (McKinsey 2018, para. 7).

High performing schools also use data as a tool to identify and properly support students who are at risk of becoming disengaged, falling behind or even dropping out. Early warning signs can include absenteeism, behavioural issues, and a decline in completing assignments or courses. Effective schools can then provide additional support and learning opportunities to these students and monitor their progress toward whole-of-school goals.

Additional learning time and support can help to get a student at risk of disengaging back on track both academically and in terms of feeling connected to the school. This works to prevent students from falling behind their peers, feeling isolated or adrift, and unable to access additional support outside of school. Tutoring – either one-to-one or in small groups – can be an effective tool to close learning gaps. The UK's Education Endowment Foundation, for instance, estimates an average of four months additional reading progress over a year of tutoring (EEF 2021).

Attract, develop and retain quality teachers

Teachers are the largest single school-based influence on student achievement, and investment in teacher support and development is crucial. Pre-service teacher education sets foundations and core capabilities, but ongoing professional development and a positive working environment are even more vital to boosting teachers' efficacy, expertise, sustained commitment and engagement.

Disadvantaged schools can struggle to attract and retain the most experienced and skilled teachers, leaving lower-performing students further disadvantaged. Higher concentrations of early career teachers can compound challenges in lifting student achievement (Darling-Hammond 2010).

Teaching is becoming increasingly complex and demanding, with multiple expectations and fast-changing policies not always aligned with core curriculum requirements. Gallop et al. (2021) found NSW teachers worked a weekly average of 55 hours, with time-consuming administrative tasks and a lack of curriculum planning time just some of the reasons for rising teacher frustration and burnout, and low rates of teacher retention. McKinsey (2020) found similar conditions in the United States, Canada, the UK and Singapore: teachers typically work a 50-hour week but spend less than half that time directly engaging with students.

Teachers report they often do not know where to find the best evidence of what works in the classroom or the high-quality support materials that would help them more effectively organise teaching and learning processes. This means they're often forced to search extensively for teaching resources, wasting time and risking using inconsistent and poorly evidenced interventions or materials (AERO 2021a).

Teachers also need to be supported in knowing whether they are being effective in delivering curriculum content, in measuring group and individual student progress against expected achievement, and in providing appropriate tasks and learning assets to drive the learning process for students with a range of abilities.

Effective teaching and learning strategies

High performing schools typically embrace high expectations for their students, which flow through to curriculum offerings, classroom teaching and learning strategies, and ultimately to student confidence, commitment and effort. Research shows that too many disadvantaged schools, even with the best of intentions, are unable to incorporate high expectations for their students, or lack awareness of how pedagogical evidence can be translated into specific practices in the classroom (OECD 2012).

Some of the most effective learning strategies include:

- Explicit and intentional instruction, where learning goals and the specific steps needed to achieve them are clearly communicated to students, and curriculum, teaching and assessment are integrated and aligned. Student inquiry-based learning also can be effective, for instance in science subjects, but as a smaller proportion of learning time (McKinsey 2017).
- Formative assessment – which allows teachers to monitor learning progress as learning occurs – supports effective, tailored feedback and, importantly, enables teaching adjustments. AERO (2021b) identifies four key elements:
    - Clear and well-communicated learning objectives
    - Detailed understanding of what students need to learn, including at the unit level, and the diverse starting points of each student
    - Frequent checking of student understanding or mastery
    - Timely, targeted and clear feedback aligned with the original learning objective and learning strategies to help students know where and how to focus their effort
- Effective use of data to guide and gauge differentiated, personalised learning for all students, set appropriate learning goals, and spot struggling students, especially in education settings where students have highly varied learning needs, backgrounds and skills. Data monitoring can help to refine learning strategies, lesson design and assessments, and provide valuable insights into learning progress and engagement.
- Development of metacognitive skills or, put simply, a student's self-awareness of what they need to know, how to get there and whether they have mastered it. Effective metacognitive techniques can be developed and encouraged – such as organising one's learning time and tasks, setting goals, reflecting on progress, putting effort into work, and seeking help where needed (Hattie 2017). These skills also correlate with positive behaviours like motivation, persistence, confidence and engagement (OECD 2012) and lead to higher achievement and other positive outcomes.
- Teacher self-evaluation and collaboration with peers helps educators adapt lesson structures,

tasks and pacing, and improves decision-making.

Stronger connections between schools, families and communities

Disadvantaged students don’t always benefit from the same parental learning engagement enjoyed by many of their better-off peers. This can be due to social and economic challenges, carers’ own negative experiences and attitudes toward schooling and academic achievement, or less confidence or ability to help with curriculum content, among other reasons. High-achieving students in any education setting (disadvantaged as well as advantaged) will more often have parents actively involved with their learning (OECD 2012).

Disadvantaged schools can thus play a crucial role by encouraging and supporting parents and carers to become more engaged with their child’s learning. This in turn leads to stronger connections between schools and families, community leaders, employers, counsellors and others, as well as better access to other support services for students (OECD 2012).

Chapter 2: Advanced education technology

There is a relatively small but growing body of evidence that suggests quality education technology (edtech) tools can positively impact education outcomes, when well-designed, effectively deployed and firmly governed. Beyond technology that simply makes back-office administration or communication more efficient, advanced edtech leverages data and sophisticated software to personalise learning, connect teaching methods with evidence-backed approaches, and draw new insights for students, teachers, and educational systems.

The documented learning gains supported by such tools – in certain education environments – reflect edtech's growing sophistication, scale and scope (for instance, its tighter alignment with learning science, wider range of curriculum areas, stimulation of metacognitive skills, and data-analytic methods to measure and prompt motivation and engagement). Some of these types of technologies now sit above Hattie's "hinge point," where interventions deliver above-expected learning progress (2017).

Three types of edtech – student-oriented, teacher-oriented and school/system-oriented – have the potential to synchronise well with the factors known to lift the outcomes of disadvantaged students (as outlined in Chapter 1). Importantly, these tools are also concentrated in domains that rest on very strong evidence as being key contributors to better student outcomes, such as teaching quality (see Chapter 4 for further discussion).

The below taxonomy of edtech tools (based on principal user and design purpose) helps to delineate how and where they are deployed for impact, though some advanced edtech applications integrate functions that serve all three user categories. One of the advantages of AI-enabled edtech is its flexibility, adaptability and efficient application across diverse uses.

The three types of advanced edtech with the most promise – and supporting evidence – in terms of lifting education outcomes are:

- Student-oriented applications – Intelligent tutoring systems can create personalised learning paths for students that adapt as they progress and encourage them to reflect on their learning. Existing literature shows these systems can have a statistically significant positive impact on student outcomes, especially for lower-achieving students (see Chapter 3 for further discussion of the evidence).

- Teacher-oriented applications – 'Smart' curriculum tools use AI to bring evidence-based and 'proven in practice' resources directly to teachers for lesson planning. Beyond standard resource search engines, smart tools built on evidence-based pedagogy and teacher-focused support can provide faster and more targeted access to quality materials that connect to required learning content and to data-informed student insights. Specific purpose platforms can also focus on certain types of students, such as enabling early detection of special needs like dyslexia and dysgraphia.

  Adaptive assessment systems adjust questions to meet a student's level of understanding and capability, offering better insight into learning areas needing attention and, in some cases, linking to targeted remediation resources.

- **System-oriented applications** – AI-based modern data techniques (such as machine learning) can empower schools and systems to more accurately identify students at risk of disengagement and intervene in a timely and targeted way. These tools also provide useful insights about longitudinal and systemic trends for better policy and program design.

Other forms of advanced education technology are available – such as facial recognition, biometric devices and robots -- but they currently rely on more experimental methodologies, raise thornier ethical questions, and have weaker evidence of effectiveness in classroom settings. There also are many technology products aimed at reducing administrative burdens, which can help free up valuable time for teachers, but are not directly linked to supporting core teaching and learning processes.

Student-oriented technology

Teachers generally aim to tailor instruction to individual learners or small groups of students, but that can be challenging, especially given typical class sizes and the growing diversity and complexity of student needs and curriculum requirements. Intelligent tutoring systems can play an important role by harnessing data, proven pedagogical methods and cognitive science to deliver personalised learning and feedback systems.

Intelligent tutoring systems (ITS)

Tutoring is a proven tool to remediate or accelerate learning, especially when one-to-one. Lower-achieving students, those from disadvantaged backgrounds, or students with special needs particularly benefit from the extra, personalised instruction and more time on task (CESE 2015b). Tutoring also can provide motivational and emotional support that improves student achievement (Gaustad 1992).

Tutors gauge a student's level of understanding, then provide them with individualised exercises and feedback at each stage of a task. Intelligent tutoring systems mirror this process. Well-designed systems incorporate best-practice cognitive science, and include appropriate scaffolding, instruction and resources. More recently designed systems also frequently deploy AI for analytics and system design improvements.

Personalised learning progressions are the backbone of ITS, alongside aligned curriculum outcomes. These components have shaped the core design of intelligent tutoring technologies since they were first developed and researched in the 1970s (Ma et al. 2014).

Today, ITS vendors have a sizable and growing global user base. For instance, more than 25 million students use the United States-based adaptive maths platform *ALEKS* (McGraw Hill 2022), 64 million users are registered with India's *BYJU's Learning App* (Mishra 2021), and there are 400 million users of the apps created by Chinese AI education company Yuanfudao (Mascarenhas 2020).

Design and function

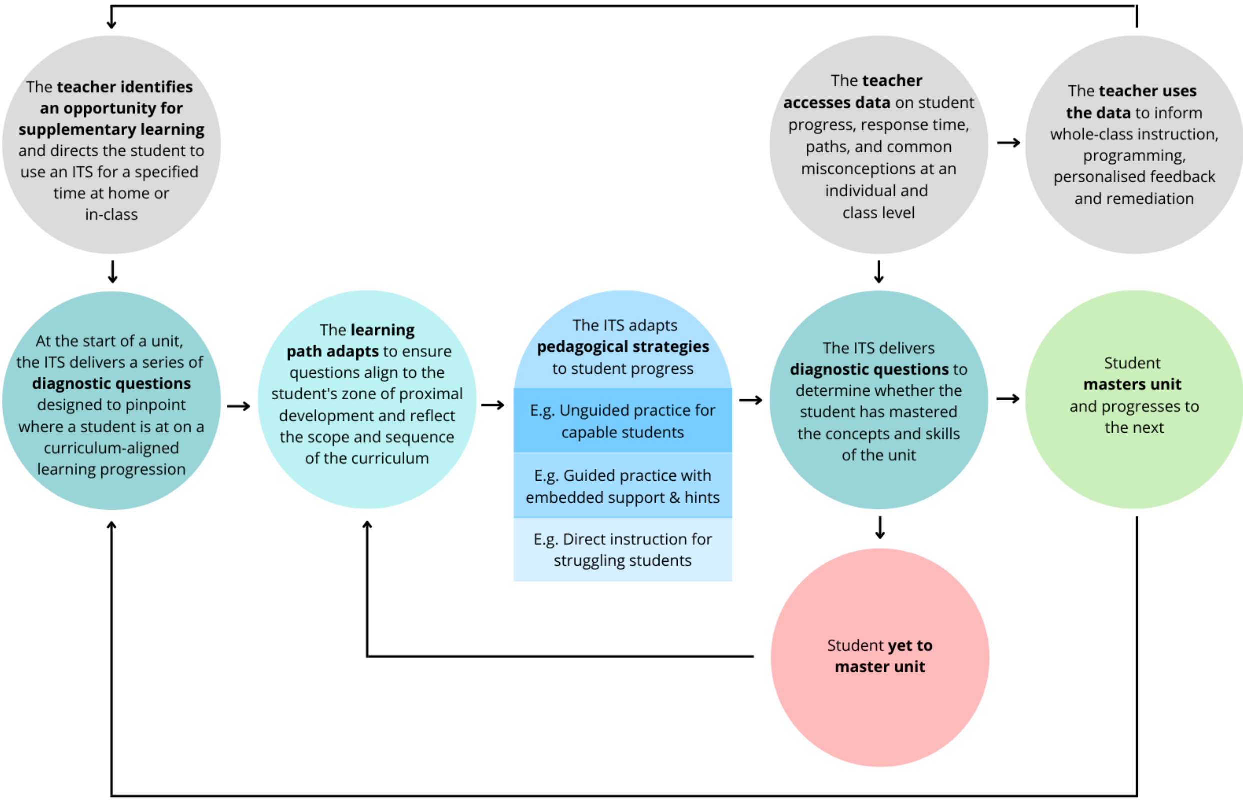
Intelligent tutoring systems are highly complex and rest on many inter-related design decisions across five key dimensions:

- *Curriculum content and skills* – A quality tutoring system incorporates the expected concepts, content and skills within a subject or learning domain (linked to curriculum structure). It reflects a logical sequencing of learning and content mastery (scaffolding), along with 'zones of proximal development,' which are the next steps a particular student can be expected to master with guidance. Curriculum-aligned formative and summative assessments are key components, with data generated at very specific levels.

- *Student capabilities* – ITS utilise data based on responses to questions, tasks or other assessments, as well as each student's engagement with the tool (such as time on task, pace of mastery, sustained absorption or 'flow,' distraction or disengagement) to identify a personalised learning path and adjust or branch as needed for additional instruction or challenge.
- *Pedagogical design and assumptions* – Evidence-based pedagogical design is central to ITS impact: the most effective ways to deliver instruction, materials and tasks to build engagement, motivation and mastery. High-quality ITS draw on cognitive science and other evidence-backed teaching approaches, as well as evidence of the most effective pedagogy in specific content areas such as maths or reading. The depth of evidence will shape key features, including:
    - Mastery learning (students move to the next exercise or topic when they demonstrate understanding of the content or skills)
    - Self-pacing (instructional content and exercises adapt to the student's knowledge)
    - Spacing and retrieval (exercises over multiple sessions to reveal embedded understanding)
    - Timely feedback (immediate, explicit and actionable feedback based on response accuracy and quality)
- *Student interface* – An ITS with a simple and intuitive interface with minimal distractions reduces cognitive load, allowing students to focus on the task at hand. Accessibility features ensure that students with a range of abilities can use the same system.
- *Teacher dashboard* – These systems can provide important data-informed insights for teachers at a granular level (for instance, by student, task, skill, curriculum unit, and so forth) and at classroom level (where groups of students may share common misconceptions or challenges needing extra instruction). Importantly, a teacher-oriented interface should allow teachers to assign tasks and tailor data analyses with intuitive data displays.

Figure 1 below provides a schematic representation of a typical ITS.

Figure 1: High-level schematic representation of a typical intelligent tutoring system



Examples of ITS and effective teaching strategies

Specific ITS features align with factors recognised to lift outcomes in disadvantaged schools, as outlined in Table 1 below.

Table 1: Alignment between ITS features and effective teaching strategies

Strategy	Explanation	Example
Personalisation and differentiation	➔ ITS analyse data to understand student capabilities ➔ Skill levels are matched with the most appropriate challenge and instruction to optimise learning growth	*Imagine Language & Literacy* uses ongoing predictive and evaluative checkpoints to ensure students are working in their zone of proximal development.
Explicit and intentional instruction	➔ Quality ITS clearly explain the learning goals of each task and link to curriculum outcomes ➔ ITS can directly instruct students with learning materials, explanatory videos or worked examples when students are struggling with specific skills or concepts	The adaptive reading program *Lexia Core5* explicitly identifies when a student has difficulty with a particular skill, provides specific instruction, and further scaffolds the remaining steps of the task. If a student needs this explicit instruction more than twice during a task the teacher is offered a sample lesson to assist the student offline.
Formative assessment	➔ ITS dashboards present data on student progress, helping teachers to pinpoint where they provide feedback or guidance ➔ Consistent evidence shows that dashboards help teachers to improve feedback practises and learning outcomes (OECD 2021)	Early years adaptive reading program *Amira* provides students with immediate feedback via an avatar. Amira's diagnostic report also suggests teacher resources to target student needs, such as lessons on specific phonemes.

Metacognitive strategies	➔ Quality ITS deliver progress data directly to the student. This metacognitive scaffold can help students stay interested and engaged (Arroyo et al. 2014), reflect on their learning, and set goals.	Carnegie Learning's *MATHia* utilises pop-up windows that enable students to see their progress towards mastery of multiple skills within a task.
High expectations	➔ ITS meet every student at their level and aim to develop mastery notwithstanding grade level or socioeconomic background	Designed by maths educators, *Maths Pathway's* 'Rich Learning' tasks aim to develop critical thinking and reasoning skills through problem-solving, in addition to core maths skills.
Additional learning time	➔ Teachers can assign homework tasks ➔ Students can use ITS to continue their learning (within or outside the classroom) while remaining under the supervision of their teacher who can observe data on usage, engagement and progress	*Mathspace* allows teachers to set tasks or question sets for homework. Students can also access adaptive learning tasks from home.

Sources: Imagine Learning 2022, Lexia Learning 2022, Amira Learning 2021, Carnegie Learning 2022, Sundar & Schenke n.d, Mathspace 2022

Note: The products included as examples are not intended as endorsements nor to draw conclusions about their effectiveness in Australian contexts.

Teacher-oriented technology

As already discussed in Chapter 1, the most influential in-school factor driving student progress is teaching quality. Advanced edtech tools designed to amplify teaching quality and expertise and reduce time-consuming tasks thus hold significant promise in terms of improving education outcomes.

Expectations for teachers are rising despite their already heavy workload by global standards (and compared to other Australian professions). There is an ever-growing burden of administrative tasks (like data gathering and reporting), as well as constant change and expansion to curriculum offerings and required outcomes. Meanwhile, there is increasing complexity and diversity of student needs and skills.

A recent Grattan Institute survey of 5,442 Australian teachers and school leaders found that more than 90% of teachers do not have enough time to prepare effectively for classroom teaching, and 86% "always or frequently" do not get enough time to do high-quality lesson planning (Hunter, Sonneman & Joiner 2022).

Smart teaching support tools

Advanced edtech tools can help to customise support for teachers in key aspects of teaching and learning, such as assessment design, feedback, reporting, lesson planning and accessing quality curriculum-based materials. Smart curricula and intelligent assessment tools also provide data from student activities and assessments to give teachers additional insight into student learning progress, and enable more effective teaching. Machine learning techniques can bolster accuracy, consistency, customisation and feedback loops, providing substantially more content and flexibility than simpler learning resource search engines.

The starting point for these systems is usually the curriculum itself, because this provides the structure for learning and, when "academically rigorous and knowledge-rich," strongly influences student outcomes. Australian states and territories do provide curriculum support materials, but teachers typically need to supplement these. This involves many hours of work to find, collect and incorporate high-quality resources and to make sure they align with mandatory learning outcomes. Few jurisdictions offer comprehensive packages of support for schools to work with, such as examples of lesson plans and student work (Steiner, Magee & Jensen 2019, p. 6).

When teachers lack access to high-quality instructional materials, they tend to turn to varying quality internet resources. Grattan Institute found Australian teachers use "difficult to quality assure" social media sites at least once every two weeks to find resources, including 64% turning to YouTube, 49% to Teachers Pay Teachers, 19% to Pinterest and 12% to Instagram (Hunter, Haywood & Parkinson 2022, p. 31).

Disadvantaged schools in Australia face even greater challenges. Around 20% of students in low SES schools are hindered by the lack of high-quality textbooks and instructional material, compared to only 1% of students in high SES schools (Cobbold 2020). Likewise, teachers in disadvantaged schools reported searching for material online at higher rates than teachers overall in a US-based RAND study (Opfer, Kaufman & Thompson 2016).

Design and function

A typical smart teaching support tool will include:

- A library of customisable lesson plans, teaching suggestions, differentiated activities for students at varying proficiency levels, and opportunities for student reflection or deeper analysis
- Assessments including formative and summative tests, quizzes, worksheets and other materials
- Teacher data dashboards with quality presentations of student data in customisable formats that can be sorted by individual, classroom, task or curriculum outcome
- Some tools also link to and include suggested materials for targeted remedial or extension activities.

Examples of smart teaching support tools that incorporate effective teaching strategies

Smart teaching support tools can facilitate the use of strategies known to lift disadvantaged school and student outcomes, as outlined in Table 2 below.

Table 2: Alignment between smart curricula tool features and effective teaching strategies

Strategy	Explanation	Example
Explicit and intentional instruction	➔ Quality lesson plans embed direct communication of learning goals, content and exercises	*Inquisitive* lesson plans clearly state the learning intentions of each lesson and provide teaching notes to help students meet those goals. Teachers are also supported to demonstrate solutions to class tasks.
Differentiation/ personalisation	➔ Lesson plans provide instructional strategies and activities for various levels within a class	*Inquisitive* characterises suggested activities as 'core, deeper learning, or challenging,' which allows teachers to scaffold and differentiate activities based on student capabilities. *Symphony*, offered by High Resolves, provides access to varied interactive group courses centred on building global citizenship capabilities. Teachers can assign courses, and access student data, while courses are student-led to promote agency and personalisation,
Formative assessment	➔ Data from informal quizzes, online activities and worksheets is analysed and reported to the teacher ➔ Teachers can use this information to adapt their feedback or teaching practice	*Education Perfect* provides in-built quizzes and other assessments to gauge students' understanding of lesson material. Dashboards deliver data not only on whether a question is answered correctly, but also on attempts taken, response time, and which questions have been particularly challenging for the student or class. Suggested learning tasks for teachers to use in areas needing further development help teachers target their focus.

Metacognitive strategies	➔ Activities designed to encourage students to reflect on their goals, progress and approach to mastering content	*Stile* lessons embed metacognitive routines designed to help students reflect on what they have learnt or to identify further questions. This aims to promote a deeper understanding of the content and to identify areas for further learning.
High expectations	➔ Teaching strategies embedded into lesson plans reflect high expectations for teaching and learning in any context	*Edrolo* provides teachers with high-quality print and digital resources to help raise student achievement in end of schooling state-wide exams. Designed based on cognitive load theory and other proven learning methodologies, *Edrolo* both provides teachers and students with exam-style questions and helps students learn the theory and higher order thinking behind Year 12 (or end-of-schooling) standards-based state-wide exams.

Sources: Inquisitive n.d., Education Perfect 2022, Hood 2021, Edrolo 2022, High Resolves n.d.

Note: The products included as examples are not intended as endorsements nor to draw conclusions about their effectiveness in Australian contexts.

Box 1: EdReports – Independent evaluation of curriculum resources

The non-profit organisation *EdReports* was launched in 2015 to help school districts in the United States identify high-quality instructional resources. Digital resources and smart curricula tools were assessed and added more recently, in the wake of COVID-19 pandemic-forced remote learning.

Teams of expert educators review instructional materials for alignment with curriculum standards in Maths, English Language Arts (ELA) and Science. ELA resources, for instance, are assessed on the quality and complexity of texts and how well materials construct knowledge.

EdReports evaluators also rate the utility of resources against criteria such as the degree to which programs support teacher planning and programming; the quality of assessment methods and support for teachers in collecting, interpreting and using student progress data; and ease of integration and professional support.

EdReports is funded by The Bill & Melinda Gates Foundation, Carnegie Corporation of New York, and other philanthropic foundations.

Source: EdReports 2022

Adaptive assessment

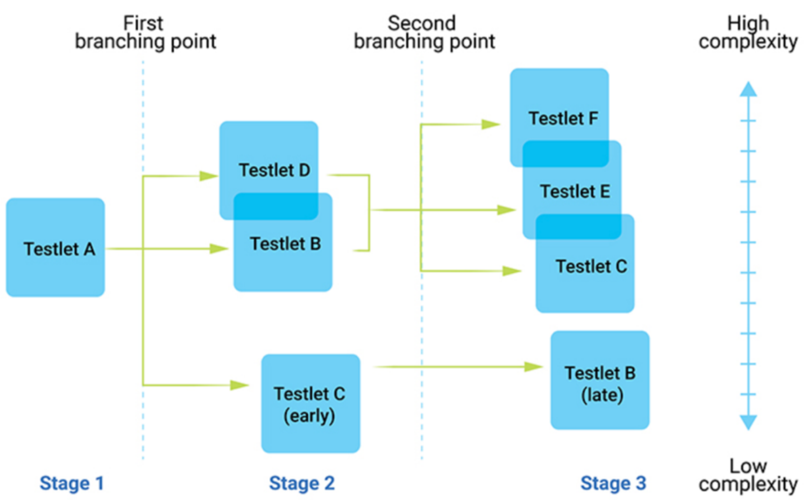
Adaptive assessment directs students to tougher or easier questions based on how they are travelling along the test's pathway, using automated algorithms. This has specific advantages: more efficient testing with a smaller number of questions necessary to pinpoint student achievement levels; more precise and quickly available data on student needs; capacity to test a broader range of curriculum content; and more secure testing as students receive different questions. Keeping students engaged and motivated to complete the test is another advantage, particularly for lower achieving pupils (CESE 2015a, NAP 2016).

These assets are especially useful where the spread of student achievement is wide, as it is in Australia. Students at the top of a class can be as much as five to six years ahead of those at the bottom, according to Geoff Masters (2021), head of the Australian Council for Education Research (ACER). Traditional tests simply cannot capture as much insight into those students outside of an expected range; in turn, this undermines targeted instruction.

In 2022, NAPLAN moved to adaptive assessment for reading, numeracy and language conventions. This is in keeping with many large-scale global assessments such as the TOEFL (Test of English as a Foreign Language) and the GRE (Graduate Record Examinations), and there are other examples of adaptive testing becoming the norm in the United States (Martin & Lazendic 2018).

Figure 2 below outlines how adaptive assessments adjust or 'branch' questions, typically grouped into 'testlets,' based on a student's responses.

***Figure 2**: NAPLAN online reading and numeracy test design*



Source: NAP 2016

Learning platforms also can embed 'micro' adaptive assessments to help teachers access student progress across a wider range of skills than typically assessed in standardised tests. For example, High Resolves, an organisation that focusses on building students' global citizenship engagement skills, has started to incorporate micro assessments in student-led group coursework offered through its learning platform *Symphony* (High Resolves 2020).

Examples of adaptive assessment and effective teaching strategies

Tailoring assessment to student performance aligns with key effective teaching strategies, as illustrated in Table 3 below.

Table 3: Alignment between adaptive assessment features and effective teaching strategies

Strategy	Explanation	Example
Differentiation/ personalisation	➔ Tests are personalised to a student's capabilities ➔ Connected teaching resources and professional development help connect the data to differentiated approaches	ACER's *Progressive Achievement Test (PAT)* suite of resources include: • adaptive assessments that analyse student performance on a 'testlet' to determine the difficulty of the student's next task/test • data analysis for teachers and schools • teaching resources linked to areas where students need assistance • professional development
Formative assessment	➔ Adaptive assessment provides specific information on student skills and knowledge beyond grade levels ➔ Teachers use detailed data and resource recommendations to inform feedback and instruction	*i-Ready Diagnostic* provides teachers with suggested lessons or resources, called 'Tools for Instruction,' to remediate specific skill gaps identified by the adaptive assessment platform.

Sources: ACER 2022, Curriculum Associates 2022

Note: The products included as examples are not intended as endorsements nor to draw conclusions about their effectiveness in Australian contexts.

Assessment for special needs

AI-enabled tools can assist in the detection and remediation of learning difficulties like dyslexia and dysgraphia. Families in Australia often wait six to twelve months to obtain a diagnosis, which can involve several cognitive and psychometric assessments and cost up to $2,000 (Fitzsimons 2021). Early detection can boost the success of remedial interventions (OECD 2021).

Machine learning-augmented tools that use brief, accessible digital screening can help experts identify specific writing or reading dynamics that negatively affect some children's literacy progress (and often their confidence).

Australian company Dystech, for instance, trains their machine learning algorithm on voice recordings of readers of all abilities and claims they can identify the likelihood of dyslexia with 90% accuracy (Dystech 2022). The *Dynamilis* application uses a similar process to detect dysgraphia and to assist children in improving their writing (see Box 3).

Diagnostic technology can have specific benefits:

- *Speed and cost* – These tools can help teachers and parents to recognise early signs of a learning difficulty and enable children to access specialist assistance earlier. The design for remote use via common tablets especially benefits children in areas where access to specialists is limited. Dystech's initial screening test takes five minutes online and costs around $20 (2022).
- *Specificity* – Apps can generate detailed reports on a range of specific writing and reading metrics (such as word reading fluency and accuracy, phonemic awareness, or syllabication) and can assess student progress over time.
- *Remediation* – Certain diagnostic tools can also assign remediation tasks targeted to the individual child's needs.

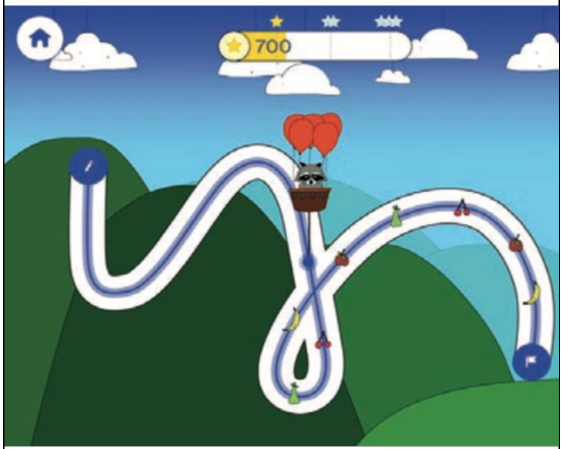
Box 2: *Dynamilis* – Diagnosing dysgraphia and delivering insights for remediation

Dysgraphia refers to difficulties with handwriting: distorted writing, malformed letters, or words written backwards or out of order. Diagnosis typically relies on an expensive and time-consuming process using experts and standardised tests involving copying text passages.

The *Dynamilis* application uses a machine learning algorithm to detect dysgraphia on a commercially available tablet within 30 seconds, with 96% accuracy (Asselborn et al. 2018). The algorithm examines 53 features of writing that distinguish children with dysgraphia, and works not only at the output level (completed writing) but also identifies specific features that emerge during the act of writing.

Features such as pen tilt, amount of pressure, speed and speed changes provide a finely grained analysis of how a student is struggling to write, rather than simply diagnosing whether or not a child is dysgraphic. Therapists can thus create a specific remediation program for the child based on these results. Teachers can also use the tool to create individual sequences of learning activities to target a student's needs (Figure 3).

Figure 3: Screenshot of a Dynamilis app



intervention activity

Note: Children use the stylus to practise letter tracing skills by moving the raccoon from start to finish, and receive rewards for precise tracing along the way.

Sources: OECD 2021, Dynamilis n.d.

School- and system-oriented technology

Advanced technology applications can use modern data techniques like machine learning to reveal new insights into teaching and learning, especially at the system level (where there are large data sets available for analysis). This helps to shape policy and investment, create targeted interventions, and establish school-based early warning systems to spot and support students at risk of disengaging or dropping out.

Early warning systems

Disengagement is a persistent challenge particularly within high school education. Around one in five Australian students will not graduate from high school with a leaving certificate (AIHW 2021). Students who drop out are less likely to find a job and more likely to experience ongoing employment challenges or to be involved in criminal activity (OECD 2021), among other demonstrated and far-reaching negative consequences.

Schools hold important data that can be used to predict, monitor and prevent these outcomes (Aguiar et al. 2015). Early warning systems (EWS) can collate and analyse this data to enable faster, better-informed interventions. Some EWS also incorporate data from a student's experience outside schooling to give a more complete picture of student well-being and risk factors.

The rollout of EWS has accelerated in the past decade, particularly in the United States. A U.S. Department of Education survey found that slightly over half of American public high schools had implemented an EWS (Policy and Program Studies Service 2016). These systems are even more prevalent in higher education: 90% of four-year higher education institutions in the United States had an EWS in place in 2014 (Hanover Research 2014).

Design and function

Historically, most early warning systems used simple statistical models that measured one or two key measures (such as course completion, grades or absences) deemed important to identify disengagement (Murphy 2019). These 'static' or 'threshold' systems typically analyse data from Year 8 or 9 to flag when a student reaches a certain risk threshold (Boyd 2017).

Machine learning techniques enable a much richer and more accurate picture of risk factors. These systems customarily feature:

- *Data collection and business intelligence services* – Quality EWS collect data directly from a school or group of schools, including enrolment demographic information, assessment results, records of disciplinary events, library activity, attendance, participation in extracurricular activities, and well-being surveys, among other sources.

- *Machine learning data analysis models* – EWS systems are typically trained on the data of prior cohorts to analyse why past students have left school. With this information, the system identifies key local indicators and applies weights according to their relevance. Data on the current cohort of students is then fed into the model.
- *Data dashboards* – The EWS communicates findings and data to a variety of possible users, identifying which students are at risk and which factors contribute to the particular risk appraisal.
- *Resources and recommendations for remediation* – Some EWS can recommend specific actions and provide resources to connect intervention with available data.

Early warning systems and effective teaching strategies

Common EWS features can align with student engagement strategies that have been proven to be effective, as well as positive school culture and climate initiatives, as described in Table 4 below. Of course, interventions need to be connected to identification for optimum impact.

Table 4: Alignment between early warning system features, effective teaching strategies, and school climate and culture

Strategy	Explanation	Example
Early intervention	➔ Early warning systems provide data to teachers and school leaders to identify students heading off-track and enable targeted intervention strategies earlier	*SEAtS software's* case management and early warning system identifies at-risk students and notifies administrators and teachers via email.
Data-driven teaching and learning	➔ Data from various sources within schools are analysed and visualised, allowing teachers and school leaders to understand factors leading to dropout and make informed decisions	*Brightbytes* partners with the American Institutes for Research to develop and validate indicators that predict student progress towards high school completion and readiness for university.

Sources: SEAtS software 2022, AIR 2018

Note: The products included as examples are not intended as endorsements nor to draw conclusions about their effectiveness in Australian contexts.

Box 3: Early warning in the Pittsburgh Public Schools network (PPS)

In the United States, the Pittsburgh Public Schools network (PPS), the Propel Schools charter network, and the Allegheny County Department of Human Services collaborated with a local research laboratory to better predict near-term academic risk factors. The machine learning model incorporated school data and out-of-school data, such as trends in child welfare and other human services, justice and subsidised public benefits.

While out-of-school data made only a slight difference to the statistical accuracy of the warning system, it nonetheless was useful in giving educators and human services support workers better insight into the underlying challenges facing students:

- PPS high school students who started an out-of-home placement were 45 percentage points more likely to be chronically absent in the next quarter than students who did not;
- Active juvenile justice cases and emergency shelter stays of seven days or more had strong relationships with academic problems in the following months.

These insights helped PPS promote collaboration between educators and human services agencies to better support students.

Source: Bruch et al. 2020

Machine learning insights beyond early warning systems

Machine learning systems can drive data-informed policy and channel investment to support more effective teaching and learning approaches. While some of these data-driven insights may confirm previous assumptions and findings, they can provide more fine-grained and actionable insights into factors that schools and systems can control.

The NSW Department of Education's 'Pathways for the Future' pilot used machine learning to examine de-identified NSW demographic, education and employment data from over 3.5 million young adults aged 15-24, collected from 1996 to 2016 (NSW Department of Education 2022). The model tracked student career pathways and their impact on employment outcomes and wages, providing some clearer insight into potential school-level action: subjects chosen in Years 11 and 12, and academic achievement in Year 10, could predict the likelihood of gaining better employment and earnings at age 24.

The Gradient Institute partnered with the ACT Education Directorate to investigate well-being factors linked to academic performance and found that self-reported levels of depression had a large, negative effect on NAPLAN results. This gave the Directorate new ideas for policy and remediation pathways (Cardenas et al. 2022).

Box 4: *Pivot Professional Learning* – Survey data for teacher feedback and targeted interventions

Some 75,000 classrooms in over 900 schools in Australia use *Pivot Professional Learning (Pivot)* surveys to gather actionable insights into teaching effectiveness, student well-being and school leadership.

The *Student Perception Survey on Teaching Effectiveness* helps teachers identify areas for growth and ways to improve student learning and engagement. Teachers receive the results from the short survey completed by their students along with resources aligned with the AITSL Australian Professional Standards for Teachers. *Pivot's* own evaluations indicate that three quarters of teachers make changes to their teaching practice after using Pivot.

Pivot has also introduced a *Student Wellbeing for Learning Tool* to help teachers and school leaders measure, track and support student well-being. Nearly 20,000 students took part in the 2021 pilot, which asked students about their general well-being, resilience, safety, belonging and protective behaviours in one-minute weekly check-ins.

With this large bank of survey data, and using machine learning analytical techniques, *Pivot* has developed a longitudinal, de-identified database to help schools and systems uncover and learn from broader insights.

Sources: Pivot Professional Learning n.d., Flack et al. 2022, Flack et al. 2020

Other AI-enabled technologies

There are several other types of AI-enabled technologies being used (or proposed for use) in Australian education sectors, whether early childhood, primary and secondary schooling, or tertiary education. These have varying utility (at least as currently configured), can be costly, and raise complicated ethical and legal concerns. Research on impact and implementation is also relatively limited. Despite these drawbacks, commercial investment is increasing across these applications.

Augmented/virtual reality

Within the edtech space, augmented reality (AR) applications overlay information or virtual objects on top of the natural world, and virtual reality (VR) replaces the learning environment with computer-generated objects or alternative worlds (Southgate et al. 2019). These immersive technologies can enable learning in situations unfeasible or impractical in real life: students can, for instance, go on expeditions to Mars, travel like a virus in the body, or look through the eyes of others.

These tools have been found to positively impact learning outcomes when simulating science experiments (D'angelo et al. 2014). For assessment purposes, AR/VR can potentially test a range of skills such as critical thinking, communication, collaboration and creativity (Vincent-Lancrin et al. 2019, OECD 2021).

However, quality headsets and software are expensive, and sharing AR/VR content can raise privacy and intellectual property concerns, especially when video frames capture non-consenting students or location information (Southgate et al. 2019).

Robotics

Social robots (typically powered by adaptive learning technology) have been used in some education settings to assist with instruction in reading, writing (Zhexenova et al. 2020) and second languages (Alemi, Meghdari & Ghazisaedy 2014). They have also been deployed to develop social skills in children with Autism Spectrum Disorders (Robins et al. 2004, Scassellati 2007).

Some research suggests that social robots that provide tutoring services can support improved student outcomes (Belpaeme et al. 2018). The physical and social presence of a robot – compared to its depiction on a screen – can also encourage behaviours in students that are conducive to learning. Social robots can be more persuasive, receive more attention, and provide more positive experiences for students than a virtual agent on a screen (Bainbridge et al. 2011, Li 2015).

Social robots are increasingly being used in non-educational settings, such as health and aged care, with slow but steady growth predicted (Savage 2022). Commercial investment in this space is increasing: Toyota, for instance, has a Partner Robot division and has developed a Human Support Robot, and there are many assistive robots already available in Australia (Smith 2019). Significant legal and ethical issues, however, have yet to be resolved (Corby & Jennings 2022).

Facial recognition and biometric data

Applications that leverage facial recognition technologies and other biometric data (for instance, student facial expressions or body movements) are being marketed to schools as potential time savers and tools to gain better insights into student behaviours and well-being. Some examples include:

- Melbourne start-up Looplearn offers a facial recognition automated attendance system (Cook 2019);
- Swedish-designed Lexplore uses eye-tracking technology to analyse and assess the process of silent reading (OECD 2021);
- Shanghai's Luwan No 1 Central Primary School integrated facial and voice technologies to measure social-emotional aspects of learning, such as engagement and affective states. Similarly, the Jinhua Xiaoshun Primary School in Zhejiang Province trialled the FocusEDU headband which analyses brain signals to measure attention and focus (OECD 2021).

These technologies have not been widely accepted or used, however, largely for technical and ethical reasons. Following a trial by Looplearn in Melbourne, the Victorian Department of Education banned the use of facial recognition technologies unless formally approved by education authorities (Cook 2019). Similarly, local Chinese authorities suspended the trial of the FocusEDU headband in 2019 due to privacy concerns (Standaert 2022, Wang, Hong & Tai 2019).

Smart classrooms

Like a 'connected home' that integrates lights, appliances and security, a 'smart classroom' connects data across devices (such as tablets and cameras) and learning software applications to provide consolidated insights in a single dashboard for teachers. The aim is to help teachers easily and quickly identify when learners are struggling, stalled or disengaged, and to support teaching adjustments (OECD 2021). Smart classrooms, however, have been slow to emerge from the research phase, and their future success or failure will depend heavily on the quality of the supporting infrastructure and policy frameworks.

Chapter 3: The evidence

Research and evaluation of education technology has become more robust and insightful over the past decade or so, with increasingly positive learning impacts being documented as the tools develop and implementation factors are better understood. These advanced edtech systems have greater capability to target key points of confirmed leverage in lifting education quality. This sets them apart from general technology in use in classrooms, like digital whiteboards or computers, which have been shown to have muted effect on outcomes and achievement, especially if overused.

Some education experts once sceptical about edtech now believe these types of advanced tools with proven positive impacts can become part of a suite of strategies to lift attainment (Slavin 2019). Nonetheless, there is much room for improvement in the extent and quality of research on advanced edtech, and in the effectiveness of the tools themselves (see Chapter 4 for further discussion). Existing evidence can be uneven, especially when it comes to understanding factors unique to disadvantaged students.

Evidence: Student-oriented technology

Intelligent tutoring systems

Tutoring, when done well, can be a game changer for disadvantaged students. Whether in person or online, studies show substantial learning gains from one-to-one tutoring with personalised instruction, extra time to master content and timely feedback. Students say they would like more such support, though costs can be substantial; this typically limits the amount of tutoring they can access. A UK survey of 123 studies, for example, found tutoring gave students an average learning boost of an extra five months (EEF 2021). The NSW Centre for Education Statistics and Evaluation (CESE), after surveying maths tutoring for disadvantaged students, concluded it has "significant positive effects" with "marked improvement" in student success (CESE 2015b, pp. 2, 5).

Investigations of intelligent tutoring systems (ITS) with capabilities akin to traditional tutoring – adaptive branching, quick feedback and tailored instruction – show they too can have a substantial impact on student outcomes, especially for lower-achieving students, and can be more effective than a large range of other education interventions. A sample of the research findings includes:

- A recent synthesis by Escueta et al. (2020) finds adaptive learning systems offer "enormous promise," with two-thirds of the high-quality research studies they examined demonstrating substantial and statistically significant effects.
- An oft-cited meta-review by Kulik & Fletcher (2016) reports a mean effect size of 0.62 from their analysis of 50 controlled experimental or quasi-experimental evaluations of ITS in elementary, secondary and tertiary institutions. This is an effect size considered moderate to large in social sciences (Cohen 1988), and well above many other traditional education interventions.
- Hattie (2017) attributes an overall effect size of 0.48 to ITS, and 0.57 for technology supporting students with disability, in a ranking of meta-analyses across 252 teaching and

learning approaches. These two types of advanced edtech sit above the defined average effect size or "hinge point," where interventions deliver greater positive impact.

- Ma et al. (2014) found a mean effect size of 0.43, analysing 73 studies of ITS with a total of 14,321 participants in K-12 and post-secondary education across all subject domains.
- A systematic review of the effect of ITS among university students found a smaller but still statistically significant mean effect size of 0.35 (Steenbergen-Hu & Cooper 2014).

The *What Works Clearinghouse (WWC)*, an initiative of the U.S. Education Department's Institute of Education Sciences (IES), gathers scientific evidence on education approaches, including edtech. The *Evidence for ESSA* website (see Box 5) evaluates edtech learning applications against the United States federal evidence standards contained in the *Every Student Succeeds Act* (*ESSA*).

Both of these initiatives have investigated adaptive learning systems and other advanced edtech tools. Several popular literacy and mathematics ITS in their evidence catalogues have been shown to deliver significant positive effects on student learning gains (though many other edtech products do not meet their evidence standards or have not been evaluated).

Evidence for ESSA (2022) rates eight ITS as having 'strong' evidence support, with higher effect sizes particularly for reading software such as *Amira* (+0.64), *Lexia* (+0.36), and *Intelligent Tutoring for the Structure Strategy Reading* (+0.18). Some effect sizes are smaller, for instance *Dreambox Learning* Maths preK-2 (+0.11).

Box 5: *Evidence for ESSA* – Trustworthy insights on evidence

Evidence for ESSA launched in the United States in 2017 to provide the most recent and reliable information on educational programs meeting evidence standards. Under U.S. federal school funding (the *Every Student Succeeds Act*, or ESSA), states are expected to ensure education initiatives address a four-tier hierarchy of evidence (see Figure 4).

Established by respected education researcher Robert Slavin at Johns Hopkins University, the *Evidence for ESSA* website reports effect sizes for interventions across reading, maths, socio-emotional learning and other domains, including impact assessments for learning technology.

Learning technology applications currently comprise a quarter of all reading and maths programs assessed as 'strong.' A 'strong' intervention must be supported by at least one randomised control study with statistically significant positive effect, and have no studies showing significant negative effects.

Figure 4: ESSA Tiers of Evidence

	TIER 1 Strong Evidence	TIER 2 Moderate Evidence	TIER 3 Promising Evidence	TIER 4 Demonstrates a Rationale
Study Design	Well-designed and implemented experimental study, meets WWC standards without reservations	Well-designed and implemented quasi-experimental study, meets WWC standards with reservations	Well-designed and implemented correlational study, statistically controls for selection bias[a]	Well-defined logic model based on rigorous research
Results of the Study	Statistically significant positive effect on a relevant outcome	Statistically significant positive effect on a relevant outcome	Statistically significant positive effect on a relevant outcome	An effort to study the effects of the intervention is planned or currently under way
Findings From Related Studies	No strong negative findings from experimental or quasi-experimental studies	No strong negative findings from experimental or quasi-experimental studies	No strong negative findings from experimental or quasi-experimental studies	N/A
Sample Size & Setting	At least 350 participants, conducted in more than one district or school	At least 350 participants, conducted in more than one district or school	N/A	N/A

Source: Regional Educational Laboratory at American Institutes for Research 2019

The Annie E. Casey Foundation was an inaugural funder of *Evidence for ESSA*, and The Bill & Melinda Gates Foundation supported expansion of the website.

Source: Evidence for ESSA 2022, Evidence for ESSA n.d.

Greater positive impact for struggling students

ITS can particularly help students at risk of falling behind in a large classroom of peers with wide-ranging abilities. Gerard et al. (2015) found students with low prior knowledge benefited more from automated adaptive learning systems than higher-achieving students. Similarly, a Cheung & Slavin (2012) review of advanced edtech learning aids identified ITS as having the largest positive effect on outcomes for low-performing students.

Several studies certified as 'strong' by the *Evidence for ESSA* website also show a more pronounced impact of ITS for students who are struggling academically. A Chicago-based evaluation of Kindergarten to Year 5 students needing remedial literacy instruction showed they were twice as likely than the control group to be proficient readers after using *Lexia® Core5®* for an average of 60 minutes per week across a school year (Hurwitz & Vanacore 2020). Similarly, Mostow et al. (2011) found early primary students with reading difficulties scored significantly higher on a standardised assessment after using *Amira* for 20-25 minutes per day for seven months.

Mindspark, an ITS developed in India, has had sizable effects on Hindi Language and Maths achievement for students from impoverished backgrounds who participated in a randomised control study. At the start of the study, the average Year 6 student was two and a half year levels below standard; the average Year 9 student was four and a half year levels behind. After using the adaptive program daily for four and a half months at after-school study centres, students had significantly improved test scores, with relatively greater learning gains observed for academically weaker students (Muralidharan, Singh & Ganimian 2017).

Overall, however, not enough edtech research has focused specifically on disadvantaged students, and it should be noted that some studies of edtech impacts show learning progress in general, but no greater or lesser gain for lower-achieving students.

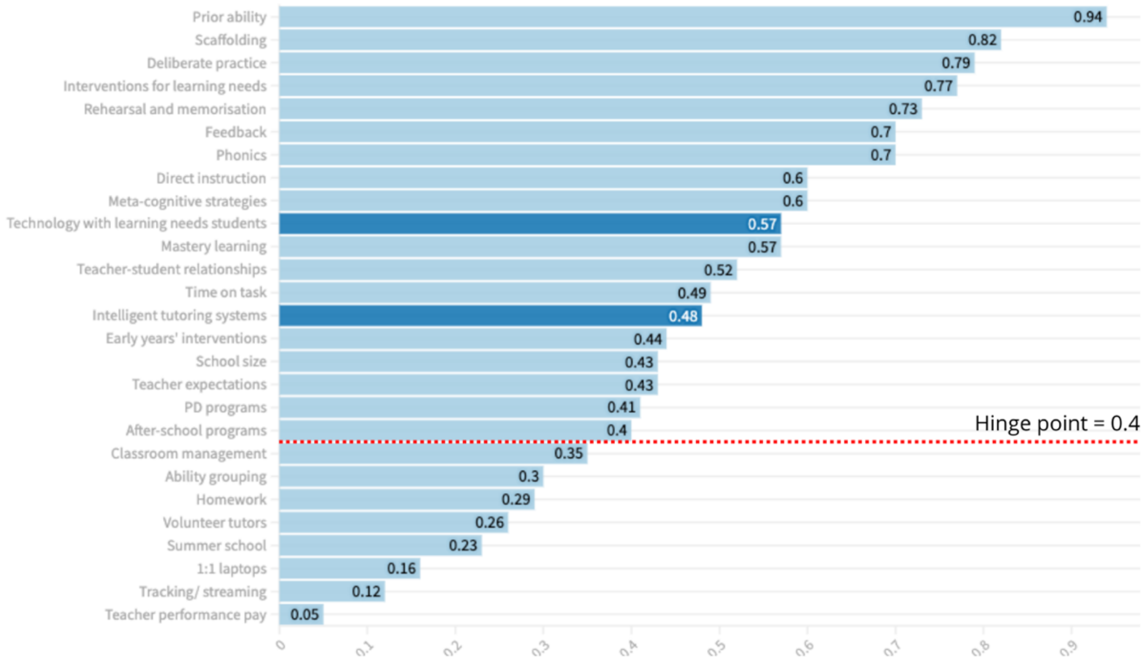
This gap in the research suggests avenues for future studies, which could ask useful questions with regard to the outcomes for disadvantaged students in particular. What types of tools work best? Are there special design dimensions that should be incorporated into the technologies to best serve and protect vulnerable students? Are there implementation approaches that make a difference for disadvantaged or special needs students?

Adaptive learning systems can be more effective than other education interventions

Two of the largest meta-analyses of adaptive learning tools found they had greater impact on learning progress than some other widely used teaching and learning strategies, such as textbooks or workbooks (Ma et al 2014), self-directed exercises, homework or lab work (Steenbergen-Hu & Cooper 2014).

Hattie's ranking of 252 education interventions places intelligent tutoring systems and technology for students with special needs above expected learning progress (2017). Figure 5 below compares a range of common education practices in the Hattie hierarchy, including education technology.

Figure 5: ITS and technology for students with learning needs have higher than average effect sizes (selected elements from Hattie 2017)



Source: Hattie 2017

Evidence: Teacher-oriented technology

Smart curriculum tools

Teaching expertise and an excellent curriculum drive positive learning outcomes. A curriculum provides structure and consistency by articulating expected outcomes, content, scope and sequence, but teachers bring curriculum-based learning to life through good planning, programming and pedagogy.

Being able to access and use high-quality curriculum support materials makes a significant difference to teaching outcomes. Research from Johns Hopkins University and Learning First suggests that using high-quality textbooks lifts student achievement even more than other interventions like increased years of preschooling, or smaller class sizes (Steiner, Magee & Jensen 2018, 2019). Likewise, an evaluation of well-structured and coherent maths resources aligned with curriculum standards demonstrated they had a positive impact on student exam results (Kane et al. 2016).

A 2018 study of middle school teachers in the United States found that making available high-quality, scaffolded lesson plans – embedding evidence-based pedagogy and resources to support implementation – lifted student maths achievement. Test scores rose particularly for students in classes with teachers who previously had struggled to achieve better student outcomes (Jackson & Makarin 2018).

Smart curricula tools can thus provide important support for teachers by making it easy for them to access quality resources, potential lessons, tasks and assessments, and data-based insights into student progress. Evaluations of smart curricula tools are beginning to document positive effects, especially in classrooms with low SES and struggling students. Research shows these tools are more effective when they are intentionally designed with a ‘teacher first' approach and integrate digital and non-digital instruction (Cheung & Slavin 2012).

Abracadabra (ABRA) is an online literacy toolkit that combines lesson plans and activities on phonics, fluency and reading comprehension. In a randomised control study (RCT) involving students in English schools, those using *ABRA* made two to three months’ greater progress in literacy compared to children who received standard instruction (EEF 2015). *Read 180* is a program designed in the United States specifically for struggling readers two or more years behind their grade level. It combines teacher materials for whole-group instruction and an online adaptive learning platform. Seven studies of the use of this program have showed it produced mostly positive outcomes (Evidence for ESSA 2022).

A randomised control study across three high-poverty rural American elementary schools found that students in classrooms where teachers used a smart teaching support tool (containing instructional material and learning resources) scored significantly higher on a standardised reading assessment than those in business-as-usual classrooms (Ho & Mathias 2019). Another RCT involving 43 schools in Maine in the United States found that *ASSISTments* – an open-source, online homework tool that provides teachers with a bank of student tasks and student progress data, and gives students direct feedback on their responses, delivered better student test scores on a standardised maths test (Roschelle et al. 2016; Evidence for ESSA 2022).

Adaptive assessment

Some advanced digital teaching support tools also incorporate adaptive assessment capability. Teachers highly value formative assessment for the insight it affords into a student's mastery of skills and content, and the foundation it provides for reflection on teaching practice and learning design.

When that formative assessment is also adaptive – incorporating modern data techniques and automated approaches – the information it gathers becomes especially powerful. Adaptive assessment offers more precise insight into student achievement than standard testing formats, and can have positive motivational effect for test-takers when branching into easier or harder questions based on student responses. Higher motivation correlates with better test scores (Cowell 2013, Wise 2015).

In 2022, NAPLAN tests in Australia shifted to adaptive testing for these reasons. A recent analysis of NAPLAN numeracy tests of Australian students in Years 3, 5, 7 and 9 found that adaptive testing yielded a statistically significant improvement in measurement precision over traditional tests, with an effect size of 0.56 (Martin & Lazendic 2018).

Importantly, this measurement accuracy is especially strong for students whose results lie outside the expected normal distribution. Evaluating the Australian Curriculum, Assessment and Reporting Authority (ACARA)'s 'tailored test design' for NAPLAN Year 5 reading, ACER found improved measurement across all student capabilities, with this improvement even more pronounced at the low and high ends of the ability distribution (ACER 2013, ACARA 2014).

Students have been found to engage better with adaptive assessment, which means richer insights into specific skill gaps. Martin & Lazendic's (2018) study of students taking adaptive NAPLAN tests found a higher level of motivation and engagement for Year 9 students than other test-takers, which is especially encouraging for an age group typically less motivated and engaged, and at greater risk of academic downturn (Martin 2007).

Educationally disadvantaged students also tend to have a more positive experience with testing better tailored to their capabilities. Interview and observation data from a study on proposed numeracy tests conducted in a collaboration between Charles Sturt University and ACARA found these students remained engaged throughout the full test, and most students exited the test feeling positive, and with a sense of achievement (Lowrie & Logan 2013, ACARA 2014).

Teacher confidence

Not every smart curriculum tool (or adaptive assessment) will work equally well. Utility and impact can vary considerably, and each tool's design quality will determine whether and how teachers decide to use it.

For example, one of the oldest and most-studied systems, a suite of products offered through Carnegie Learning, has had mixed impact evaluations. Originally developed by experts at Carnegie Mellon University, and used and monitored for some two decades, *Carnegie Maths Solution (*previously called *Cognitive Tutor Algebra I*) provides lesson plans, textbooks, teacher training, and access to an intelligent tutoring system (*MathIA)*.

A *What Works Clearinghouse* (2013) review of the *Carnegie Maths Solution* program found that 6 of 27 reports between 2001 and 2010 met the criteria for their analysis, and the average effect across those studies was minimal. However, a 2014 study of the same program across seven U.S. states with 13,000-plus students showed significant student learning improvement, especially in the second year of use, when teachers were more familiar with the system (Pane et al. 2014).

While much advanced education technology research to date has used experimental conditions to measure impact, future research needs to focus on which practical use and context factors influence whether an edtech application has a positive impact in the classroom. Is the tool alone enough to make a difference, or is the effective, skilled use of it by educators that is more important? As researchers Cheung & Slavin (2013b) note below, these two factors are inextricably linked:

> What determines the effectiveness of technology applications for struggling readers is the nature of the software, the role of the teacher, the nature and quality of professional development and follow-up, the amount of time devoted to the technology and nontechnology parts of each approach, how these activities are placed in students' days and weeks, what activities they replace, and much more. [No one should] still imagine that computers will make a difference if they merely arrive in a box, ready to plug in and play with minimal professional development…
>
> [Cheung & Slavin 2013b, p. 297]

The evidence for best practice implementation of advanced edtech is comparatively thin, unfortunately, though that is starting to change. Where once only 4 of 50 studies analysed by Kulik & Fletcher (2016) considered implementation variables, there is a slowly growing body of research that identifies the crucial contextual factors for the successful use of edtech. These include the following:

- **Intentional integration into teacher planning and programming** – These tools work best when part of teacher-led instructional design. Wijekumar et al.'s (2013) randomised control trial of a reading comprehension program found that when teachers used the digital tool consistently across six months, closely monitored the data generated on student learning, and provided timely feedback to students, student reading comprehension improved more than for students in classrooms where teachers inconsistently used the tool or its data.
- **Professional development** – Teachers need a thorough understanding of what these systems can do, and how they can best use them in their classroom programming (Luckin et al. 2016). Teacher professional development linked to edtech should include:
    - Understanding the capabilities of the tool – When teachers value the full range of a tool's capabilities, and are supported with professional development, they are more willing and motivated to use the systems (Liaw et al. 2007, Schieb & Karabenick 2011). A program of training sessions and just-in-time assistance, for example, contributed to the successful implementation of edtech and better student outcomes in the EEF study of ABRA (EEF 2016).
    - Interpreting data – Professional support in understanding and interpreting the granular data made available by these tools is particularly crucial. A 2018

OECD study found that less than 40% of European Union educators felt ready to use digital technologies in their teaching (European Commission 2020).

  - Knowing what works best – Koedinger & Anderson (1993) found that ITS improved student outcomes considerably when implemented by an experienced teacher who felt comfortable integrating the tool alongside direct student engagement. Interestingly, there was a negative impact on student test scores when teachers inexperienced with the ITS completed administrative tasks or other work while their students used the platform without proper guidance.

- **Keeping the use of these tools in proportion** – Avoiding overuse of edtech tools like ITS in the classroom (and at home) is important. Cheung & Slavin (2013a) found the use of advanced edtech had larger effects when used only between 30 to 75 minutes per week. Some ITS providers set recommended usage limits, which vary by age and capability (Daigle 2022, Lexia Learning 2021).

Evidence: School- and system-oriented technology

Machine learning early warning systems

Machine learning (ML) techniques have opened up new worlds of insight in health, environment, transport, and other domains. Increased computing power enables vast amounts of data, across multiple data sets, to be crunched faster and parsed more precisely than previous methodologies.

These tools can help drive more complex analysis and better policy and program interventions. Health and medical research routinely uses machine learning and offers many examples of its power (perhaps none more universally relevant than the development of effective COVID-19 vaccines). MIT Professor Regina Barzilay, who received the inaugural Squirrel AI US$1 million prize for 'positive for humanity' AI research in 2020, has used machine learning in research on everything from dead languages to antibiotics to breast cancer. She has said her own breast cancer could have been detected two to three years earlier if her ML-enabled detection model had been available at the time (Conner-Simons 2020).

In contrast with the health sector, education has been slow to embrace modern data techniques, whether for systemic policy-oriented analysis, or for targeted uses, such as the early detection of students at risk of falling behind or disengaging.

While the research on education 'early warning' systems (EWS) is still developing, EWS designed for education purposes and built with machine learning models are now achieving accuracy comparable to the best statistical models. ML-predictive accuracy has been shown to be, on average, above 80-90%

in studies examining substantial numbers of students across diverse contexts (OECD 2021).

Using ML techniques to process a sizeable data set of more than 72,000 Danish students' grades, missing assignments, school size, and community demographic information, a 2015 study found the probability of student dropout in the subsequent three months could be predicted with 93% accuracy (Sara et al. 2015). Machine learning techniques were also shown to be highly accurate in a U.S. study that analysed data from more than six million students across 32 states, in a model using over 70 predictive factors (Christie et al. 2019).

Effective use and governance

Much like other advanced edtech systems, however, the effectiveness of EWS in helping at-risk students stay engaged and out of jeopardy depends considerably on how they are used by educators. Accuracy may be improved but the consequent response is what determines whether students remain in jeopardy.

Education systems therefore need to invest both in ML data and analytical expertise and in identifying the best evidence-backed interventions to keep these students engaged and at school. Professional support and development for educators is essential to enhance user confidence and data proficiency. As an Australian education expert (and former teacher) stated in a recent appraisal:

> It seems like there is capability for this, but it depends on (a) whether the school has the right data and is able to integrate it seamlessly; (b) whether the school knows what to ask for so that teachers can get useful data insights; and (c) if teachers, students, parents, school leaders actually respond to the data and change their behaviours.

The existing research supports this call for more nuanced and human-centric understandings of how EWS work in practice. An American study randomly provided an EWS to 73 schools, for instance, with mixed outcomes: the schools recorded fewer chronic absences and course failures, but no effect on suspensions, low grade point averages, or student credit accrual (Faria et al. 2017). A different RCT in 41 U.S. high schools also saw decreased chronic absenteeism, but no significant change in student course failures or credits earned, even when a data specialist was made available to educators (Mac Iver et al. 2019).

Still, the data insights have been important, especially at system level where clearer patterns can emerge, and where additional resources can be delivered across schools. The Chicago school system's 'on-track' database, for example, has been important in helping identify risk patterns, target interventions and lift graduation rates from 52.4% in 1998 to 94% by 2019 (Allensworth et al. 2016, Issa 2019).

Using similar data techniques, but flipping the perspective to positive outcomes, Australia's CSIRO, with Paul Ramsay Foundation support, has initiated a major research initiative to ascertain factors that contribute to successful school completion for disadvantaged students (CSIRO 2022).

The emerging research (OECD 2021, Aguiar et. al. 2015) on machine learning-driven education tools has begun to identify some key factors that influence effectiveness in school settings:

- A strong and continuously-built longitudinal data set;
- Data derived from, or directly relevant to, the school or system's context;

- Actionable insights (such as student behaviours) are more useful than demographic factors that are more difficult for a school or system to change;
- Explainable and transparent systems, so that users understand how insights were derived
- Continuous monitoring for bias;
- Easily-accessed data displays.

Chapter 4: Making sure edtech helps disadvantaged students

As advanced edtech usage accelerates and the market expands, it's vital to make sure that only the best, most effective tools with a proven track record are used in schools, especially for students facing the toughest challenges and for teachers trying to close persistent learning gaps. Edtech is not a magic bullet that can solve this wicked problem of education disadvantage; but it is another tool to be added to the existing suite of interventions.

Useful analysis of advanced technology, as with any education intervention, starts with the substantial body of research into what works to lift student and school outcomes, as outlined in Chapter 1. Broadly, this evidence points to five key factors that make a difference:

- School leadership;
- School learning climate and engagement;
- Attracting, developing and retaining quality teachers;
- Effective teaching and learning strategies;
- Community connection.

The good news is that some forms of adaptive learning technologies align well with these factors, and certain applications (like intelligent tutoring systems) have quite strong synergies (see Figure 6). Across three categories of advanced edtech (student-, teacher-, and system-oriented tools), the closest alignments are found in technologies that:

- Support teachers in core areas like planning and organising instruction;
- Enhance personalisation of teaching and learning within curriculum standards and content;
- Amplify teacher expertise and agency through better insights into student engagement and learning progress, and provide opportunities for data-enhanced reflection and adaptation.

Figure 6: Alignment of advanced education technology with factors demonstrated to lift outcomes in disadvantaged schools

Conditions to enhance edtech effectiveness

The extent to which advanced learning technologies align with factors we know will boost outcomes helps explain why direct research into the impact of edtech tools also finds some promising positive impact on student outcomes. This evidence is particularly strong for adaptive student-oriented technology like intelligent tutoring systems, as outlined in Chapter 3. Recent work suggests the impact is strengthening: two-thirds of more recent and high-quality experimental investigations of adaptive learning systems show statistically significant impacts, with lower-ability students benefiting especially (Escueta et al. 2020).

Yet there is high variability in the evidence: certain edtech tools have significant positive impacts, while others show only marginal or insignificant gains. Three conditions strongly influence the efficacy of these tools:

- Quality;
- Effective and appropriate use;
- Strong governance and support structures for better decision-making.

Quality

Advanced edtech tools rely on many interdependent elements that can introduce significant risk without the right expertise, methodology and governance to ensure they are effective and safe to use in classrooms. Quality products typically take longer to develop, and require substantial investment, especially to avoid a 'set and forget' design approach and to explicitly address disadvantage.

Four ingredients are vital to ensure the quality of edtech products across their life cycle, and to prioritise learning gains for disadvantaged students:

1. Co-design with teachers, educational experts, and other users;
2. Evidence-backed pedagogy and learning science;
3. Research and evaluation of impact and implementation factors;
4. Data privacy and protection through regulation and ethical industry behaviour.

Ensuring **co-design** of these tools with teachers and educational experts is crucial, and this needs to be more substantial than the technology industry's typical user-testing. Embedding professional teaching expertise and curriculum knowledge in edtech design not only builds better products but increases user trust in the tools.

Despite growing consumer preference for safe, ethical and inclusive tools, product designers currently rate efficiency well above privacy or inclusion as priorities: in a recent survey, 56% of designers listed operational performance as a strategic priority in product design, compared to 38% for privacy and only 17% for inclusion (McKinsey 2022). There is clearly a need to incentivise the edtech industry to work with educators and other users in the design of these tools, and to design them with vulnerable and disadvantaged student needs in mind. Co-design with teachers, students, parents and vulnerable communities will offer expertise and a 'check and balance' to maximise benefit and minimise privacy, exclusion, discrimination or other risks.

Too few commercially available edtech tools reveal what, if any, **evidence-based pedagogical design** and learning science underpins the application. A high-level survey of some 200 products found only a quarter provided even limited information on the pedagogical evidence informing their design, and even fewer offered verified independent evaluations (see Appendix E). This disconnect worries Stanford University Education Dean and technology expert Daniel Schwartz, who has noted that "AI may make us more efficient at what is basically not very effective instruction" (Waikar 2021). The lack of transparency is deeply concerning: it undermines educator confidence and trust in the tools, risks wasted investment on ineffective applications, and potentially exposes students to sub-quality or even harmful technologies.

Advanced technology **research** is concentrated in the computer and data sciences, with little in-depth research into how these tools are applied and used in particular contexts and environments – which is exactly where the impact on social outcomes could be properly assessed. The education sector could learn from the example of applied research within the health and medical sectors, which more closely evaluates the application and use of high-impact technologies (such as in cancer detection and treatment). Health research also values quality experimental design, and the sector's evidence culture fosters tight regulation of medical devices both before and after they are made available for use; for instance, through Australia's Therapeutic Goods Administration (TGA 2022).

By contrast, there is less quantity and quality of research and evaluation of advanced edtech, and no firm regulation of these products. Many studies of edtech use are small-scale or of short duration and tend not to use robust scientific techniques (Cheung & Slavin 2013a).

Research of how edtech tools are implemented in the classroom, and which contextual factors are linked to their effectiveness, is vital to ensure adaptive learning technologies have a positive impact on disadvantaged and/or lower-ability students. The existing digital divide will soon begin to be felt not just in terms of access to devices and reliable internet, but in access to these advanced edtech learning tools. Productive questions for future research include: are results affected by the degree of integration into a teaching program or amount of teacher professional development? Is personalisation a key factor, or intensity of use? Are there different impacts across curriculum areas, student characteristics or school environments?

Unfortunately, the educational technology industry generally avoids investing in high-quality impact and implementation research (Sullivan 2022). What research is available rarely involves independent review, quality research design, large-scale impact assessment, or detailed exploration of implementation factors. There are few incentives for edtech companies to invest in this kind of research, and little accountability for companies that make unproven claims about the effectiveness of their heavily-marketed products.

Still, there are some encouraging signs that this state of affairs is beginning to change, especially when evidence of proven impact and pedagogical soundness of these tools has become a key criterion in purchasing decisions. This is starting to happen through federal school funding guidelines in the United States; where social purpose organisations have funded and launched initiatives to provide independent assessment of edtech products for schools and teachers; and where industry leaders have voluntarily invested in independent review.

The mostly hidden engine behind adaptive technology is data harvesting, which raises difficult questions of how this information is curated, used and protected, especially when it involves children. Current **data privacy regulation** both in Australia and internationally is inadequate, and does not include enough specific protections for children. This is concerning given the exploding usage of data-harvesting techniques and increased incidence of data security breaches: by one estimate, 72 million bits of personal data will be collected from a child by the time they turn thirteen (Duffy & Thorne 2022). Stronger enforcement of data protection regimes is essential, and requires specialised expertise within regulatory agencies to lift the covers on complex technology.

Technology developers should be required or incentivised to build effective data controls into applications across the product life cycle. What rules, practices and processes can encourage data protections to be prioritised? How can edtech companies assure schools and students that there is sufficient vigilance, from design all the way through downstream adaptations and operation?

Education systems and schools also need to be empowered to demand more transparency from the companies developing these edtech applications, so that they are fully aware of the opportunities and risks, and can use their purchasing power to shape the market to be safer and more equitable.

Effective and appropriate use

Improved learning outcomes depend on purposeful, structured use of these powerful edtech applications. Though they can be marketed to parents or schools as stand-alone, autonomous tools, the evidence suggests that clear parameters should define their use, and that teacher professional development is important.

Research on adaptive learning tools indicates optimum outcomes occur when they are:

- Integrated intentionally into school and teacher planning, programming, reflection and learner feedback;
- Backed by effective pedagogy for using technology;
- Anchored by a commitment to support rather than replace or undermine teacher-led instruction;
- Linked to a school or teacher's confidence in using student-level data;
- Limited to relatively short periods for each technology session or curriculum block.

Teacher professional development in using these tools in the classroom is a key factor in their success or failure. Product sales teams may offer training in the tool itself, but the positive impact of these tools is more closely aligned with teacher and school expertise in knowing when, how and with which students an application will be most beneficial.

To date, the education sector in Australia has not invested enough in broadening educator understanding of these technologies, their potential for lifting student achievement, and the conditions and skills required for greatest impact. As a result, schools and teachers have been left to figure this out on their own, which results in inconsistent use and can undermine teaching quality and outcomes.

Accessing best practice evidence for edtech should become part of routine support teachers seek for any education intervention. Despite 85% of Australian teachers wanting to use evidence-based methods in their teaching practice, a recent Monash University survey found that 35% of teachers do not know where to find relevant studies, and a third lack confidence in interpreting existing research (Rickinson et al. 2021).

The digital divide

For disadvantaged students, accessing advanced edtech learning tools is set to become the next frontier in the digital divide.

Many better-off schools and families have embraced edtech learning applications and have the resources to supplement and support those tools. Meanwhile, teachers from disadvantaged schools report in consultations that tight budgets push learning technology out of the kitbag, even when they know a learning tool has made a difference to their students (or to students in similar schools), and they would like to use it. These teachers also may lack the time or resources to access proper training in using the tools.

Social purpose organisations and philanthropic foundations have long been raising the alarm over the growing digital divide, especially during and in the wake of the COVID-19 pandemic and forced remote learning. The Smith Family, for example, found that some disadvantaged students and families actively using adaptive learning tools during the pandemic had a positive experience, but others experienced significant challenges. Critical factors included low levels of digital access and literacy, and less guidance from family members (often due to carers not having any available time due to work and other demands to help their children navigate these tools).

As the adaptive learning technology improves its impact on educational outcomes, and usage concentrates in more advantaged schools and households, disadvantaged students may fall even further behind.

Strong governance and support structures for better decision-making

Currently, the development of advanced edtech tools largely travels under the public radar, despite surging growth of the edtech market and the high stakes for whether these applications can successfully tackle learning gaps. Too little attention and resources are being directed towards ensuring good governance across the industry as a whole, which undermines effective decision-making by schools, teachers and parents, and means these tools are not necessarily being used for social benefit.

Governments have the most powerful tools to shape edtech but public sector processes tend to move slowly and often follow rather than lead in terms of innovation. Philanthropy, researchers, social purpose organisations and technology industry leaders therefore need to play a role in galvanising reform on this issue: through investment, governance structures, encouraging public input and discussion, and building a network of expertise on how these tools can be effective as well as equitable.

A strategic combination of policies, investment and institutional leadership can shape the future of the edtech ecosystem, and bend the curve of its development towards benefiting disadvantaged and special needs students. This requires active, purposeful intervention at points of greatest leverage – governance, investment, information-sharing and consensus-building.

Governance

It should be the responsibility of both the public and private sector to ensure that only top quality edtech is introduced into Australian schools, and to put in place strict data protections for all users, especially children. Within government, this means setting clear priorities for school funding, introducing quality assurance regulation, building AI governance expertise, and using smart procurement strategies to purchase only the most effective, ethical and equitable tools.

The edtech industry itself must also strengthen its governance muscle. Simple user-testing processes are no longer adequate. Tech developers will need inclusive, ethical design processes, audits and reviews throughout the life cycle of their products, and accountability for both intended and unintended impacts.

Philanthropy also can play an important role. The UK-based 5Rights Foundation (2021), for instance, has partnered with the Institute of Electrical and Electronics Engineers to create a child-centred software design standard for advanced learning technology. Other philanthropic organisations (such as the Jacobs Foundation) have sponsored development of a rating system to signal effectiveness and quality for advanced edtech tools. See Appendix B for further case studies of philanthropic actions and interventions in this space.

Investment

Venture capital funds have thus far been drawn to invest in edtech primarily for the promised lucrative financial returns. It's a bonus that these technologies, by operating within the education domain, can also hope for a social return. But there remains a clear gap in the market for advanced edtech that will specifically serve disadvantaged and other students with complex needs. This is why other countries are purposefully shaping the edtech market to have more of a social impact: the UK's innovation funding, for instance, sets aside resources for edtech tools that enhance access for special needs students.

Social sector capital can have significant influence as well. Internationally, philanthropies have begun investing in promising education technology that meets two core criteria: demonstrated learning impact, and targeted benefit for underserved, disadvantaged or vulnerable students. Novel forms of investment – such as impact investing and technology social enterprises – not only catalyse new tools for high-need students, but also build market share and capacity for advanced edtech products with an equity focus.

A large social investor, the non-profit Global Innovation Fund, has invested US$2 million into an adaptive learning application called *Mindspark*, which has lifted Maths, Language and Science achievement for some of India's poorest children (an impact that has been confirmed through randomised control trials and independent reviews). The Jacobs Foundation, which is one of the world's larger philanthropic organisations (with a US$7.6 billion endowment) and has a strong focus on education, strategically invests in edtech initiatives that prioritise closing the education disadvantage gap (see Appendix B for more details).

Better information

Education systems, schools, teachers and families are essentially flying blind at the moment when it comes to education technology: there is too little trustworthy information freely and publicly available to allow for accurate comparisons of the effectiveness of these tools.

There is an urgent need for large-scale, independent assessment of edtech tools, including information about pedagogical inputs, appropriate use, and ethical and data protections. This kind of information would increase the ability of education consumers to make better decisions, and could incentivise the edtech industry to improve product development and accountability.

Several governments overseas (most notably the United States and the UK) already fund these sorts of edtech intermediary institutions (see Appendix C for further details). Australia has AERO and Education Services Australia, but neither yet has the mandate to create accessible public resources, evidence, and advice on the quality and effective use of edtech tools. Expanding the remit of these organisations could offer Australia similar impact as found with the UK's influential, quasi-governmental organisations NESTA and EEF. NESTA, for instance, works directly with industry to design social benefit technology and helps edtech users understand advanced systems. Its sister agency, EEF, researches and ranks effectiveness of teaching and learning interventions, including adaptive learning systems.

Independent bodies are emerging globally as well, and can often move faster to keep pace with technological developments. While the U.S. government-funded *What Works Clearinghouse* could only focus in a limited way on evaluating education technology, the Annie E. Casey Foundation stepped in with seed funding for the independent Johns Hopkins University-based *Evidence for ESSA*, a searchable website backed by rigorous assessment of the evidence supporting education interventions, including edtech tools (see Box 5).

The Bill & Melinda Gates Foundation, Carnegie Foundation, Chan Zuckerberg Foundation and others support independent, not-for-profit initiatives that drive capacity-building: for instance, commissioning and sharing high-quality research, working with groups of schools to understand edtech impacts, and expanding teacher professional development to include best practice in the integration of edtech in the classroom. These provide important models for change but are not a substitute for Australian-based initiatives connected to Australian schooling and education priorities.

Another possible public-private intervention is the establishment of safe data partnerships between edtech providers and public education systems, to maximise insights and better tailor interventions to disadvantaged learners and schools. NAPLAN and other standardised assessments do not offer the same degree of insight as those gained through these new adaptive tools. Collaboration through formal data partnerships could ensure that data collection is used for social good, is subject to high ethical standards, enables education breakthroughs, and constrains monetisation of student and teacher information.

Consensus-building

To bend the trajectory of advanced edtech teaching and learning tools toward greater social purpose, diverse education stakeholders need to work together. While clearer overall governance and education sector purchasing power will be important factors, so too will forming a consensus on the sustainable, safe and equitable future of education technology, involving:

- Schools, teachers and students – who should be at the heart of any strategy to improve education technology;
- Industry – where some edtech entrepreneurs have shown a commitment to equity and are alarmed at the growing gap in learning outcomes;
- Social charities and support organisations – who work closely with students and their families and see the digital divide's impact outside the school gates;

- Government – which brings the necessary policy expertise and resources;
- Philanthropy – as a catalyst for innovation and impact related to social good.

Chapter 5: Recommendations

Advanced education technology offers promising possibilities to help close Australia's widening learning gap. Yet the fast-growing edtech market currently operates with little public governance or oversight, and this creates considerable risks and challenges. Leadership from government, philanthropy and industry can bend the curve of Australian education technology towards applications that have social purpose, and set a new global standard for edtech excellence and impact.

Ten actions are recommended to make sure that education technology in Australia meets the aims and expectations of national education priorities, tackles the learning and digital divides, and lifts education outcomes for all students, especially those with complex needs.

These recommendations will require collaboration across all sectors to succeed. Suggested responsibility for which sector takes the lead is indicated at the end of each recommendation.

Partnership for positive change

- **Establish the Australian Forum on Quality Digital Education** to help shape the strategic agenda for using technology to target educational disadvantage and boost student outcomes and wellbeing. The Forum would create a network of Australian leaders across education, industry, social purpose and philanthropic organisations, government and research bodies, and provide an independent source of ideas and solutions to help develop and deliver safe, effective edtech that can reduce education disadvantage [*Philanthropy, Government*]

Best practice use

- **Work with schools to test, develop and showcase best practice integration of teaching and learning technology tools** for disadvantaged students and special needs students, building a network of peer-based support. [*Philanthropy, Government*]
- **Provide extra resources to disadvantaged schools to access high-quality edtech** learning tools, with guaranteed implementation support and teacher professional development, alongside investment to secure equitable access to essential technological infrastructure. [*Government, Philanthropy*]
- **Commission the Australian Education Research Organisation (AERO) to provide expertise and advice** on what works best when using education technology in classrooms, to support teachers and improve student outcomes. [*Government*]

Quality and impact

- **Include evidence standards for education interventions**, including education technology, in the next quadrennial national school funding agreement, along the lines of the U.S. *Every Student Succeeds Act* (ESSA) federal funding guidelines. [***Government***]
- **Accelerate high quality, independent research and evaluation** of teaching and learning tools to investigate:
  - Impact on learning progress for students facing educational disadvantage;
  - Features that amplify positive outcomes, including implementation factors. [*Government, Philanthropy*]
- **Catalyse a world-leading Australian social benefit edtech sector** by investing in promising systems that meet high standards for evidence, efficacy, ethics and equity. Novel forms of capital should be considered, such as impact investing, social enterprises, and leveraging or partnering with venture capital funds, as well as direct public or philanthropic funding. [*Government, Philanthropy, Industry*]

Governance and information

- **Create an accessible repository of trustworthy information** on the quality and safety of available edtech tools so that education systems, schools and parents can make more informed choices. [*Philanthropy, Government*]
- **Develop education-specific standards** covering product design, data use, and life cycle governance and accountability to guide purchasing decisions and to assist industry access to the sector. [*Government, Industry*]
- **Build public-private partnerships to safely share data** for better traction on solving education challenges, and to apply advanced data techniques to help optimise outcomes for students at risk. [*Government, Philanthropy, Industry*]

Appendix A: Three case studies

The following case studies provide insight to how three schools have integrated education technology learning tools.

Note: The products included as examples are not intended to suggest endorsement or conclusions about effectiveness in all Australian contexts.

NSW | Low SES primary school | Lexia® Core5® literacy platform

School Sector	Year range	ICSEA value	Language background other than English
Government	K-6	983 (38th percentile)	25%

Source: My School (ACARA 2022)

In 2018, a disadvantaged public primary school in the Greater Western Sydney Region began to use *Lexia® Core5® Reading (Core5)* to lift student literacy skills.

Technology

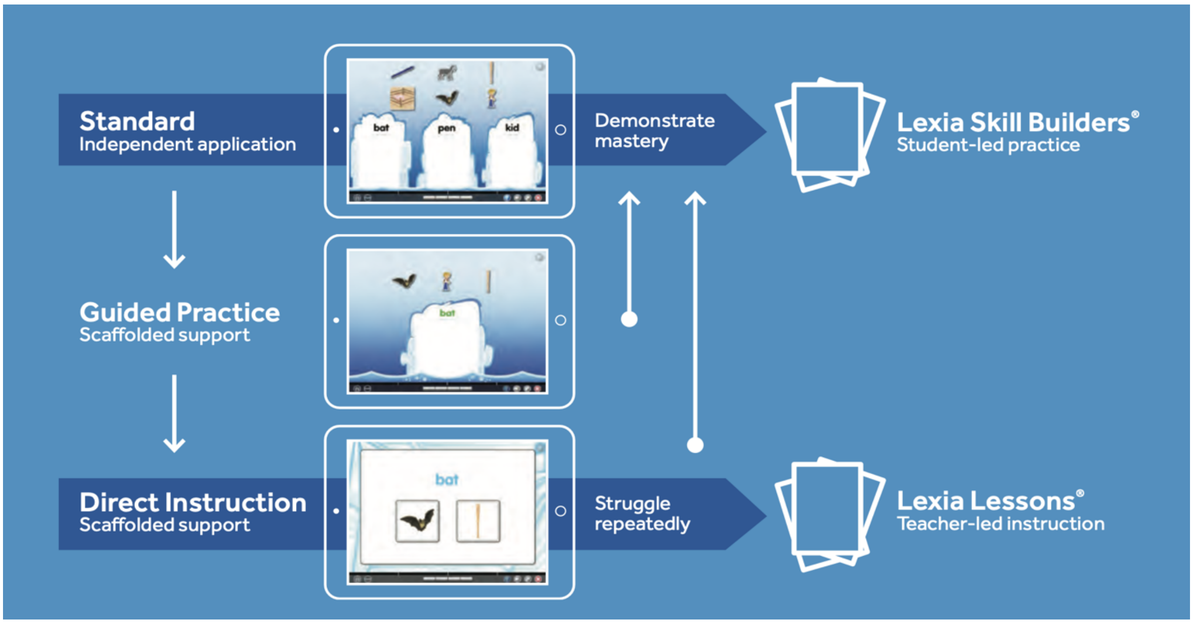
Core5 is an adaptive learning platform used by over 921,000 students across more than 10,000 schools in the United States, and by more than 20 countries worldwide, including Australia (Lexia Research 2020). Aimed at pre-K to Year 5 students, the platform aims to develop mastery of foundational literacy skills.

The content of *Core5* is aligned with the NSW and Australian national curricula. Its effectiveness has been tested through several randomised control trials that meet standards for 'strong' evidence (Evidence for ESSA 2022). One study found that – of students receiving learning support for reading disabilities – those using *Core5* were twice as likely as non-users to become proficient readers (Hurwitz & Vanacore 2020).

The platform identifies a student's capabilities and develops a personalised learning path that targets skill gaps as they emerge in six areas of reading instruction: phonological awareness, phonics, structural analysis, automaticity/fluency, vocabulary and comprehension. Students must master skills to advance to the next level. Branching helps struggling students achieve proficiency through guided or direct instruction (see Figure 7).

Teachers can observe data on student progress and engagement via the online program, and the platform recommends lesson plans and offline student worksheets to support teachers with specific resources to target learning gaps.

Figure 7: Branching on Lexia® Core5® Reading



Source: Lexia Learning 2022

Use

The Western Sydney public primary school adopted *Core5* to address serious literacy challenges and limited teaching resources. The deputy principal highlighted that many students needed specialised interventions in literacy, but learning support teachers could only feasibly assist those with the most intensive needs. *Core5* was used to provide personalised support and to help teachers identify and address literacy issues at risk of being missed.

This need became more pronounced in the aftermath of enforced COVID-19 pandemic lockdowns. The school found their youngest students had fared the worst during home-learning: 65% of the stage 1 cohort (Years 1-2) were underperforming once they returned to in-school instruction. *Core5* provided an opportunity for those students to catch up.

Core5 is formally integrated within the teaching program at the school. It is mandatory that every student in the school uses *Core5* for a minimum of 30 minutes per week. Teachers use *Core5* in their classrooms an average of two to three times per week, on school-provided iPads, to supplement whole class reading instruction, and spelling and reading group rotations.

Teachers refer to feedback data on the *Core5* platform to organise students into groups, which keeps those groups fluid and responsive to student needs. Students work independently on the platform, but the teacher works with the students performing below their grade level or others who need additional help.

Teachers make time to ensure that their students reflect on their learning progress (tracked in the application's dashboard), highlighting for each student their success in specific skills and areas needing further work. When the data shows a student's progress in a particular skill has reached a plateau, the teacher can provide a worksheet recommended by the program to test and extend that skill. Teachers can send these worksheets home with students so that parents can be involved.

Impact

The school's NAPLAN results have improved since introducing the adaptive learning tools as part of teacher-led literacy instruction, particularly for Year 5 students (see Figure 8). Even with the impact of COVID-19 pandemic disruptions to formal schooling, teachers report that the platform has helped students to catch up more quickly. A success story shared by an educator at the school is that one Year 6 student had slipped to a literacy level four years below their peers, but – working with the platform – had caught up to their cohort within a year.

The deputy principal has emphasised that the tool needs to be embedded in teachers' planning, programming and instruction for best impact. Teachers monitor use of the tool in class to prevent students from rushing through the program carelessly, and teacher encouragement boosts motivation. An important lesson from COVID-19 pandemic disruptions to schooling was how important teacher guidance is in using the tool for the best student outcomes.

Figure 8: (De-identified public school) NAPLAN results 2014-2021

Note: In 2020, NAPLAN testing did not take place due to the COVID-19 pandemic.

Source: MySchool 2022

VIC | Disadvantaged regional secondary school | Maths Pathway

School Sector	Year range	ICSEA value	Language background other than English
Government	7-12	966 (30th percentile)	3%

Source: My School (ACARA 2022)

A low-SES regional Victorian high school integrated *Maths Pathway* into their teaching program to better differentiate learning for all students. Previously, the school had created three levels of maths proficiency per year group. The head Maths teacher found that this three-tier approach had worked for most students, but failed to meet the needs of students at the very top and bottom of each cohort. Based on the experience of a nearby school whose student results improved with *Maths Pathway*, the school decided to deploy the program in 2020.

Technology

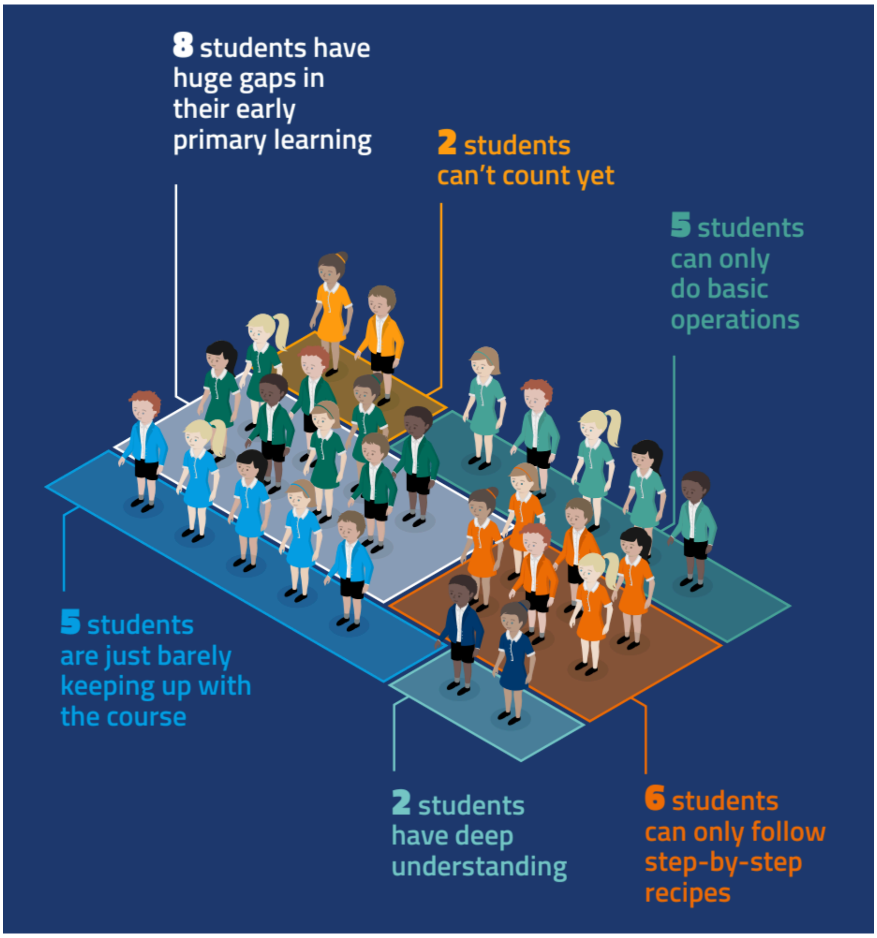
Maths Pathway is an adaptive learning tool and smart curricula system for Years K-10. It is used by over 300 schools and 3,774 teachers in Australia. The platform is aligned with the Australian national curriculum and all state curricula (Maths Pathway 2022).

The Years 5-10 platform combines teacher-led instruction and support with student-led personalised learning to make differentiation achievable for teachers in classrooms where students are at varying levels (see Figure 9).

A *Maths Pathway* classroom revolves around a two-week cycle. Students take a diagnostic test on the online platform, which forms an individualised learning path. This path adapts to their zone of proximal development, and provides fully worked solutions and instructional videos. Detailed data from fortnightly formative assessments gives teachers an opportunity to provide one-to-one feedback, address concerns, and set goals with students. The real-time data from assessments and personalised online learning helps teachers cluster students with similar needs, and to conduct small group remediation lessons. Lesson plans are provided, alongside resources for problem-solving tasks.

The K-4 *Maths Pathway* platform, 'Early Insights,' is tailored to younger students. The program supports different literacy levels and students with English as an additional language or dialect (EALD) backgrounds. Voice recognition features, for instance, allow students to participate despite literacy barriers.

Figure 9: The potential eight-year spread of a sample Year 7 class in Australia



Source: Maths Pathway Impact Report (Maths Pathway 2021)

Use

The Victorian high school uses *Maths Pathway* for Years 7, 8 and 9 students. Three out of five lessons a week involve *Maths Pathway*.

While students work individually, teachers conduct mini-lessons with smaller groups of students to address common learning gaps identified by the platform. Data 'flags' pop up when specific students are struggling with a task. The school has also arranged extra teaching support staff to join each class for one lesson per week.

Impact

The school performed a cross-analysis of the year groups using *Maths Pathway* in comparison with those who weren't using it, and found growth in learning outcomes was higher in the classrooms using *Maths Pathway*, including for students from low-SES backgrounds.

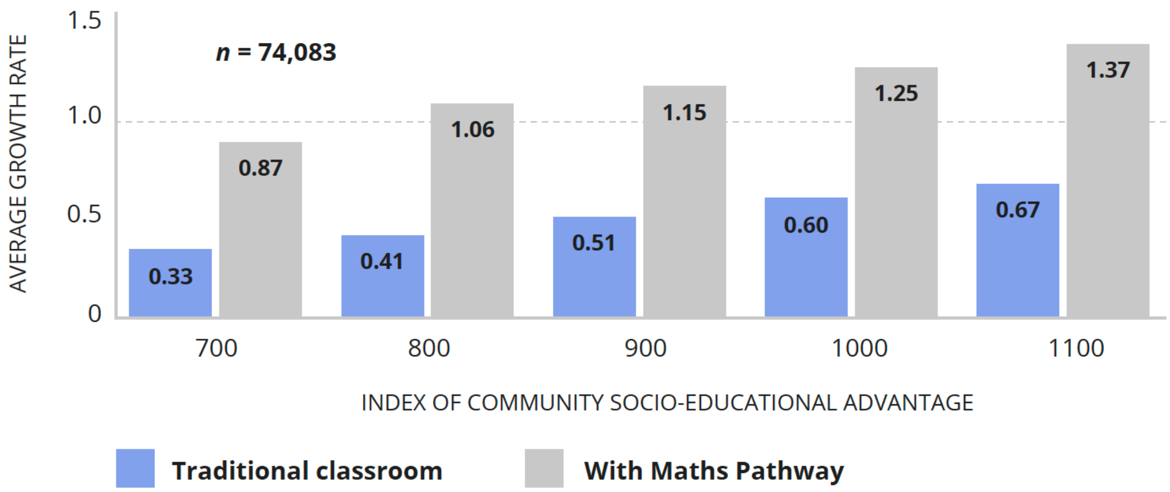
The head Maths teacher at the school has noted that the program had a considerable impact on students previously struggling to meet grade level expectations. In the past, students in Years 7 or 8 at the school were performing at a Year 2 level, and had become completely disengaged. Teachers observed these students subsequently gained in Maths. As *Maths Pathway* caters to students in Years

K-10, this meant that teachers could use the tool to take these struggling students right back to foundational maths concepts and build their confidence, with demonstrated positive outcomes.

The Maths department at the school has emphasised the importance of utilising the whole program, not just the individual pathway components. *Maths Pathway* lessons, mini-lessons, whole class written learning, games and one-to-one interventions helped students of varying abilities master modules and stay motivated.

Maths Pathways conducted its own impact analysis across schools, which indicated stronger average growth rates in those classrooms using their product (see Figure 10).

*Figure 10: **School improvement by ICSEA level – Maths Pathway impact report***



Source: Maths Pathway 2021

NSW | K-12 community school | Education Perfect

School Sector	Year range	ICSEA value	Language background other than English
Government	K-12	1026 (59th percentile)	19%

Source: My School (ACARA 2022)

Located in southern Sydney, this combined K-12 community school initially adopted the teacher-support tool *Education Perfect* for Biology, Chemistry and Physics instruction. After noticing positive impacts on learning outcomes in these subjects, teachers expanded its use to Maths, Spanish, PDHPE, and Technological and Applied Studies.

Technology

Education Perfect is a smart curriculum tool originally developed in New Zealand, and currently used by more than one million Years 5-12 students in 3,000-plus schools globally (Education Perfect 2022). It offers a library of some 35,000 customisable, curriculum outcome-linked lessons, quizzes and activities for English, Maths, Biology, Chemistry, Physics, History, Geography, Civics & Citizenship, Health and Physical Education, Technology, and Languages.

The program delivers data insights on how students are faring, including which questions have been particularly challenging, using indicators like attempts taken and response time, as well as correct answers. It can highlight which areas were consistently difficult across the whole class to facilitate further direct instruction and/or remediation tasks.

Education Perfect (2015) analysed data from the New Zealand Qualifications Authority's National Pilot Online Assessments Program in Maths, Science and French, and found a link between the extent to which a student had used the platform's learning materials and performance on national standardised tests.

Use

When this southern Sydney school implemented a bring your own device (BYOD) policy, head teachers investigated technology platforms that could ease teacher workload (for instance, by providing easy access to quality-assured lesson plans, activities and assessments), especially for teachers new to the school.

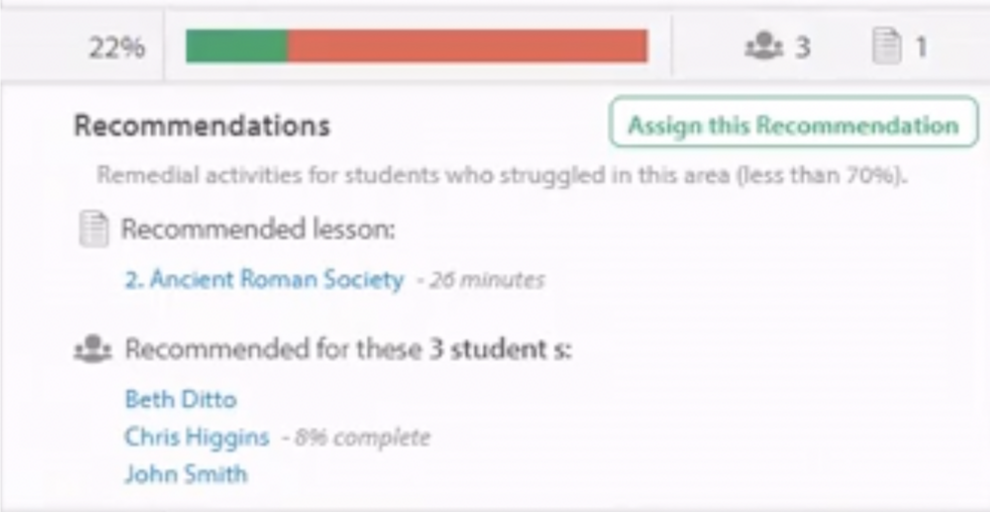
Education Perfect is used in Stage 3 (Years 5-6), and in early secondary school with Years 7-10. Two courses, Science and Spanish, incorporate *Education Perfect* for senior secondary classes. Teachers use suggested lessons for planning and programming, and typically deliver direct instruction at the start of a lesson. Then students are directed to complete activities on their personal devices in class as the teacher monitors and helps those in need. The data provides feedback to help target additional instruction (see Figure 11). The head teacher at the school has reported that this feedback helps educators reflect on their own teaching practice.

The platform provides banks of questions and possible assessments. Teachers at the school also customise and upload their own original assessments, so that students can do the assessments at home, which is how the school ensured students could undertake HSC trial exams during the pandemic. Due to the ease of the set-up and marking process, the school has also established assessments for Years 7-12 on *Education Perfect*.

Impact

The deputy principal has reported that *Education Perfect* has had a significant positive impact on teaching confidence and consistency, particularly with the shift to online learning during the pandemic. Once students had returned to in-school instruction post-lockdowns, *Education Perfect* allowed the school to deal more effectively with teacher absences and shortages, and the consequent need for casual teaching. *Education Perfect* has allowed casual teachers to adapt more quickly to the school's teaching priorities and classroom planning methods. Using data provided by the tool means casual teachers can ensure they are teaching at the right level based on student and class progress.

Figure 11: Education Perfect teacher interface, demonstrating how teachers can recommended remediation tasks for students (pseudonyms used)



Source: Education Perfect 2022

The platform also assists students with special needs or learning difficulties (such as dyslexia) by giving them access to oral and aural features, along with traditional text-based comprehension. The deputy principal of the school has reported that senior students with physical disabilities can turn on their device and log into *Education Perfect* with ease. These students have equal access to learning content, tasks and instantaneous feedback to support self-directed learning.

Teachers at the school have stressed the importance of professional development to get the most out of using the platform, and to best integrate it into their teaching practice. They have also noted other factors that can affect proper implementation, including technical issues (such as poor internet connections during remote learning) and financial barriers (for this reason, the school provides devices to families unable to afford their own).

Appendix B: Philanthropic investment in education technology

A growing number of major philanthropy foundations are investing in education technology to enhance student outcomes, especially for disadvantaged and vulnerable students. These investments typically encourage:

- Greater research into effective education technology design and use;
- Capacity-building for schools and teachers, and networks of shared practice;
- Open source and trustworthy information to guide better decision-making;
- Investment – direct or through venture capital partnerships – in promising new teaching and learning technology;
- Public policy development and consensus-building activity across the edtech ecosystem.

Table 5 provides examples of charitable activity related to advanced education technology.

Table 5: Summary of select philanthropy initiatives related to advanced education technology

Foundation	Endowment or assets (USD)	Goals/framing	Examples of investments
The Jacobs Foundation	7.6b	• Learning Minds – enhance personalised learning and adaptive teaching • Learning Schools – connect 10% of global schools to increase use of evidence-based innovation • Scientific capital to identify quality factors	• More research and building an edtech research ecosystem • Investing in venture capital funds to stimulate higher-quality products • Policy design and influence • Creating an alliance of foundations investing in edtech
The Bill & Melinda Gates Foundation	51.9b	• Innovation where governments and business leave gaps • Greater global cooperation • Shifting market incentives • Generating high-quality data and evidence	• Grants to research institutions and intermediary bodies, such as the International Society for Technology in Education; The EdTech Hub (with the UK Government); The World Bank; and universities • Testing and replicating innovative school approaches (e.g. New Technology High School)

			• Examining policy and practice barriers and opportunities for adoption of edtech • Capacity-building for school leaders and teachers
Carnegie Foundation for the Advancement of Teaching	4.7b	• Enhance disadvantaged students' access to new tools and approaches for more engaging learning	• Identifying effective innovations • Supporting leading schools • Designing policy frameworks for wider school system take-up and continuous improvement
The Annie E. Casey Foundation	3.6b	• Improving education outcomes for vulnerable children and families	• Inaugural and continuing funder of the website *Evidence for ESSA*, an influential U.S. non-government resource that tracks the evidence quality behind education interventions, including edtech
The Hewlett Foundation	13.3b	• Supporting greater access to 'open education' resources and effective pedagogy	• Funds *EdReports*, an independent body that reviews evidence for education interventions, including technology tools
Global Innovation Fund	56.6m	• Impact investment to develop, test and scale new edtech products and policy reforms • Focus on innovations with strong potential for social impact at large scale	• Financing ranges from $50,000 to $15 million, with priority for innovations with demonstrated success and evidence foundation • $2.3 million grant to *Mindspark*, an adaptive learning software, and support for integration into teacher-led instruction • Experimental design research to test and confirm impact
Schmidt Futures		• Building talent networks to solve complex challenges, with good use of technology and shared prosperity	• Learning Engineering – partnerships between universities and digital tech platform owners to apply best learning science, through customised

		• Establishing open source platforms of data, partnerships and systems to generate and extend best ideas and research	learning, to lift student outcomes at scale • Opportunity Engines – increasing low-income workers' wages through job training that uses technology to support greater numbers of trainees
The Patrick J. McGovern Foundation		• Connecting artificial intelligence, data science and social impact • Creating shared understandings and visions for how advanced technology can be ethically developed and applied for widespread good	• Helping not-for-profits better use data and AI-generated insights (e.g. World Resource Institute work on sustainability) • Accelerating development of new applications • Advocating for governance and policy reform
Pew Charitable Trusts	7.3b	• Improve higher education teaching and learning	• Pew Learning and Technology Program – an early, four-year initiative (now completed) to increase attention to how edtech can be better deployed in universities, including research grants and convening a community of practice

Sources: Jacobs Foundation 2022, The Bill & Melinda Gates Foundation 2022, Carnegie Foundation for the Advancement of Teaching 2022, The Annie E. Casey Foundation 2022, The Hewlett Foundation 2022, Global Innovation Fund 2022, Schmidt Futures 2022, The Patrick J. McGovern Foundation 2020, Pew Charitable Trusts 2022, The Technology Source, May/June 2001

Appendix C: Public policy context

Australian public policy engagement with the education technology ecosystem and industry has been modest thus far. With AI-enabled education technologies and machine learning techniques rapidly becoming more common, Australia risks falling behind other countries if it fails to introduce stronger policy leadership, better incentives to encourage edtech for social benefit, and stricter governance. The stakes are high: automated technologies can be used for the purposes of economic and social progress, but can also cause grave harm, as in the case of the Australian Government's disastrous 'Robodebt' program (begun in 2015 and fully terminated in October 2022).

In a survey of international movement towards governing automated technology systems, Stanford University's 2021 AI Index identified more than 30 national strategies already being implemented around the world, and another 6 soon to be activated. The AI Index placed Australia in its *last* category ('Strategies Announced'), alongside 16 other nations, such as Argentina, Turkey, Latvia and New Zealand (Zhang et al. 2021). Encouragingly, some of the items on Australia's 'to do' list now are progressing.

A delicate balancing act lies at the heart of global policy developments: supporting innovation for economic, employment and social benefits, while mitigating risks and providing appropriate public and individual protections. A mix of fiscal, legislative and administrative systems are deployed to meet these aims.

In their national approaches, most countries intend to shape the broader ecosystem surrounding advanced technology, stretching across investment, research, governance, economic development, and equity.

Education is most often treated as a critical enabler, increasing the stock of innovation and digital and data skills. However, a growing number of national strategies also see advanced education technologies playing a key role in better supporting teachers and students to lift education attainment. Singapore lists edtech as one of its top five AI-development priorities, for example.

An outline of some current key global developments, with a focus on AI-related education initiatives, is provided below.

Australia

Midway through 2021, the Australian Government (2021) released its AI Action Plan, which rests on four pillars:

(1) develop AI to support Australian business and economic growth;

(2) attract and grow AI talent and skills;

(3) accelerate use of AI to solve national challenges and ensure widespread benefits;

(4) establish Australia as a global leader in trustworthy and inclusive AI.

A National AI Centre, housed within CSIRO's Data61, will coordinate the implementation of the AI Action Plan and, together with four Digital and AI Capability Centres, help drive wider take-up and development of advanced technologies. Public capital is available for promising start-ups. CSIRO will also auspice machine learning and data science initiatives directed towards solving tough-to-crack national issues.

Other measures include:

- Knowledge-building and knowledge-diffusion through the existing Australian research infrastructure, with some specialist research and development funding. Defence and health are key priorities.
- Voluntary ethics principles to guide private and public sector design and use of AI-based technologies, along with planned review of the Privacy Act; consumer data rights for greater choice and control; and a national data strategy to leverage public data more effectively, safely and securely.

The action plan sits with a Digital Economy Strategy that seeks to expand Australia's technological entrepreneurship, take-up of leading-edge tools and AI knowledge and skills capacity. Achievements in this arena, according to the Australian Government, include: new businesses to be 'born' digital; 95% of SMEs using e-commerce tools; 100% of public services available online; 15,000 tertiary graduates annually with advanced digital skills (Commonwealth of Australia 2022).

The Australian Human Rights Commission brought important attention to gaps in technology guardrails in its 2021 Human Rights and Technology Report (Farthing et al. 2021). The Commission's 38 recommendations include:

- Mandatory human rights assessments before AI-informed decision-making systems are used;
- Clear communication about what, where, how, and why AI is being used, along with recourse for harm;
- An AI safety commissioner and independent advisory group to embed human rights considerations across public and private use of advanced technology;
- Stronger regulations and enforcement;
- Human rights decision-making built into procurement processes.

In March 2022, the Australian Government initiated public consultation on possible regulatory reforms to better balance benefits and risks of AI and automated decision-making technology. Options for "modernised legal frameworks" are planned for public consideration later in 2022 (Commonwealth of Australia 2022, p. 1). Separately, a review of the Privacy Act seeks to strengthen consumer digital and data-related protections.

New South Wales (NSW)

NSW (2021) has provided substantial leadership on AI and data-based innovation through a comprehensive suite of formal policies, mandatory actions, and investments in smart digital tools and capability-building. Elements include:

- *An AI Strategy* with specific actions to ensure government agencies can maximise effective and safe use of data resources, AI, and related technologies;
- *Mandatory ethical principles* for all NSW government agencies, including community benefit, fairness, privacy and security, transparency, review mechanisms, and accountability;
- *AI Assurance Framework* that requires agencies to design, build and use AI ethically and appropriately;
- *Data infrastructure* to enable better insight into public challenges, along with data governance rules;
- *Capability-building* for public sector employees;
- *Procurement guidance* and a central repository of identified AI-enabled products;
- *AI Advisory Committee* with legal, technical, research and policy expertise to provide independent advice to the State's Chief Data Scientist, who oversees the AI Strategy and related initiatives.

Education

Australian technology policy currently places education in a limited supporting role, providing some university scholarships, a digital cadetship program, funding for skills training, and digital skills units in the Australian school curriculum and in vocational training packages. The Commonwealth Department of Education, Skills and Employment from 2018-2022 provided some $1 million per year to create and curate curriculum materials to support teaching and learning about AI and emerging technologies (OECD 2021b).

State education systems and schools, the chief stewards and providers of school education, have invested significantly in education technology, from smart whiteboards to Wi-Fi, and therefore exert substantial influence over the direction of education technology in Australia. Yet they, too, have thus far avoided extensive engagement with newer learning platforms. Hardware and connectivity are essential, but learning management systems, curriculum resource hubs, adaptive learning applications, collaborative learning spaces and outside-the-classroom instruction tools are all now becoming a larger part of education delivery. State digital education strategies, however, generally do not address advanced technology or, importantly, its implications.

Most states and non-government schools had to scramble when the COVID-19 pandemic forced teachers and students into remote learning, which exposed a general lack of attention to how technology could be effectively woven into education. Teachers had to get themselves up to speed, find resources and tools, and develop new forms of instruction and student support, and their enormous effort is why Australian student achievement and educational engagement was sustained. Yet despite that effort, the digital divide widened during the pandemic between disadvantaged students and those in wealthier schools (Sonneman & Goss 2020), highlighting the need for adequate and sustained support directed to disadvantaged schools and students.

European Union

The EU in 2021 outlined the world's potentially strongest proposed legislative framework and regulatory scheme to govern AI and advanced technology tools. The approach, yet to be approved, wants to promote 'trustworthy' AI development and use, while spelling out strong legal struts and risk restraints based on the principles, values and rights of the EU (European Commission 2021).

The regulation focuses on high-risk technologies, defined by actual or potential harm, vulnerability of user cohort, intended purpose, and capacity to reverse harm, among other criteria. Four methodologies are proposed for outright ban: subliminal techniques to change behaviour; exploitation of vulnerable populations; social scoring with discriminatory impact; and 'real time' facial recognition or other biometric identification for law enforcement (though child protection, terrorism investigations, and pursuit of known criminals are possible exemptions) (Schaake 2021).

European Digital Education Plan (2021-2027)

Supported by a dedicated resource hub for teachers and an expert advisory commission, the European Digital Education Plan contains two core priorities: fostering an effective digital education ecosystem and enhancing digital skills. It recommends 14 specific actions, including equitable digital access, best practice and ethical use of digital learning tools, targeted resources, and cross-national data sharing.

The European Commission views advanced technology as a key mechanism to boost learning and reduce inequality, though it concedes that there are critical challenges in teaching capability to overcome. During consultations on the plan, some 95% of respondents expected COVID-19 to permanently shift how education and training sectors will use technology. Meanwhile, a 2018 OECD study found that less than 40% of EU educators felt ready to use digital technologies in teaching (European Commission 2020).

United Kingdom

The UK's ten-year National AI Strategy commits to long-term planning and numerous initiatives to develop the AI ecosystem of skills, finance, innovation, equity, and governance. Connected government strategies include data stewardship, national and cyber security, and economic development and innovation, among others (Office for Artificial Intelligence 2021).

Specific policy and regulatory guardrails are being introduced, building on existing data and human rights rules, and on sector-specific regulatory regimes (such as for finance and health). A network of government bodies guides the plan, starting with the AI Council, an independent expert advisory group.

Education Technology Strategy and EdTech Innovation Fund

Optimistic about the capacity of advanced technology to transform learning in schools, the UK launched its Education Technology Strategy in 2019. As with similar blueprints, the government wants edtech to alleviate pressures on teachers' time and improve educational outcomes, and sees integration of technology and classroom learning as consistent with trends in students' wider environment.

A note of difference, however, is the plan's focus on better assistive technology for students with disabilities and other special needs. Additional priorities include: formative assessment, automated marking, teacher professional development, access to digital infrastructure, data and privacy protections, parental engagement, and providing schools with better advice on which products to purchase and how best to incorporate them into teaching and learning (Department for Education 2019).

An EdTech Leadership Group, comprising educators, industry and experts, oversees the strategy. Groups of demonstrator schools will develop and showcase best practice integration of these tools, building towards a network of peer-to-peer support. The EdTech Innovation Fund provided funding for organisations to work with schools to enhance effective use of high-quality technology products (Nesta 2019-21).

Independent public purpose bodies

Two national independent bodies play an important role in the UK's education and technology sectors:

- EEF – the Education Endowment Foundation, created in 2011 by philanthropy The Sutton Trust, has become the UK's most trusted source of education evidence, with a focus on helping teachers access and use this evidence. EEF commissions and reviews research on education technology, assessing both impact and implementation effectiveness.
- NESTA – established in 1998 with a publicly-funded endowment, NESTA (National Endowment for Science, Technology and the Arts) is an independent innovation agency focused on social benefit. Having invested in emerging technologies and built research and policy expertise, NESTA joins EEF as a key influencer of both government policy and the wider industry firmament. NESTA is explicitly charged with helping deliver the UK National AI Strategy (such as adaptive tech for students with disability), and partnered with the Department for Education to help schools effectively use edtech.

United States

American technology policy spreads across Congress, the States, the courts, and multiple government agencies at federal and state level. More than 130 AI-related bills were introduced in the U.S. Congress in 2021, up from just one in 2015, and state legislatures likewise are drafting multiple statutes (Zhang et al. 2022).

The White House

Through its Office of Science and Technology, the White House has begun consultation on a 'bill of rights' to clarify what Americans can expect from data-driven advanced technologies (Lander & Nelson 2021). The policy contemplates both intended and unintended consequences of advanced tools, acknowledging there are insufficient incentives for ethical and data protections in current product design, development and use. The 'bill of rights' may incorporate an entitlement to know when an AI system has influenced a discriminatory decision; freedom from surveillance; and recourse to pursue remedy. The White House expects complementary regulatory enforcement and rules for public agencies, such as banning procurement of systems lacking robust processes to comply with the bill of rights.

National agencies

U.S. federal departments are pursuing a range of mission-specific grants, standards, decision-making and auditing requirements, procurement guidelines, and regulatory procedures to advance new technology for public benefit.

Nearly half of 142 surveyed U.S. federal agencies have explored using AI and machine learning, with Justice, Securities and Exchange Commission, and Food and Drug Administration among the top users (Engstrom et al. 2020). Automated systems rank high on defence priorities, but non-defence advanced technology investment also was US$1.5 billion in 2020-21, and rising.

Asked by Congress to set standards for AI-based technology, the National Institute of Standards and Technology (NIST) has drafted voluntary yardsticks to guide AI risk management by product developers. NIST hopes its 'soft law' approach will encourage the tech industry to build ethical and equitable culture and practices, rather than rely on a regulatory or compliance scheme.

National Office of Education Technology

Situated within planning, evaluation and policy functions that report directly to the Secretary, the U.S. Department of Education's Office of Educational Technology (OET) leads national edtech policy by:

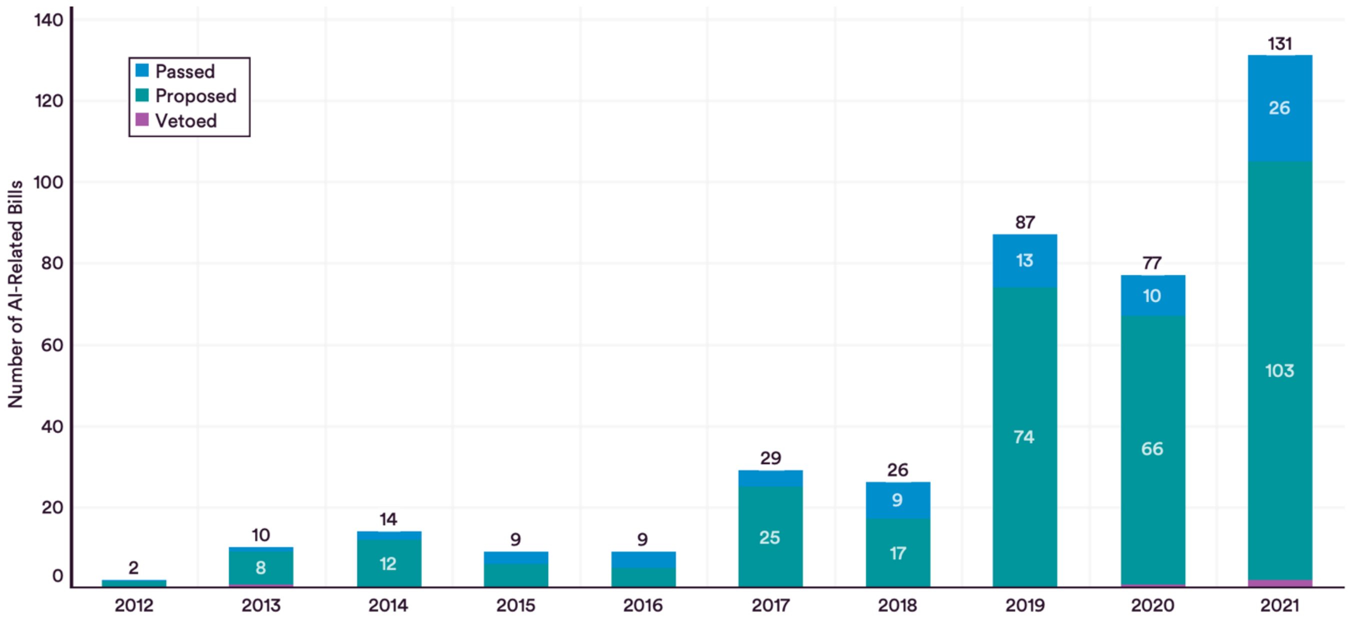
- Promoting equity of access to technology-enabled learning;
- Supporting professional development for system officials, school leaders and teachers;
- Working with stakeholders in the edtech ecosystem, including entrepreneurs;
- Funding research and evidence collation.

Advanced and emerging technologies are a specific priority, particularly to guide educators on impact, quality, procurement, and key issues for successful use. Funding also has been directed to intermediary institutions and research bodies to stimulate and diffuse evidence for advanced technology.

State governments

States are stepping into the frame with a sharply rising number of bills introduced or adopted recently (see Figure 12). The California Assembly, for example, has approved an Automated Decision Systems Accountability Act (AB-13) of 2021 (now pending Senate consideration). This Act would require public contracts to minimise adverse and discriminatory impacts as part of 'value for money' procurement criteria (Le 2021). A new Massachusetts law regulating facial recognition tries to balance uses like identifying sex offenders with tight privacy protections by requiring mandatory judicial and administrative approval prior to use (Hill 2021).

Figure 12: Number of state-level AI-related bills in the United States, 2012-21



Source: Stanford University AI Index Report 2022 (Bloomberg Government 2021 in Zhang et al. 2022)

Local and state taxes fund most of U.S. school education, but federal dollars have substantial impact on state and local education decision-making. *ESSA*, the main vehicle for federal education funding, now requires states, local education bodies and schools to prioritise evidence-based learning, using four levels of rigour as a guide (see Box 5). These evidence standards also apply to education technology, and analysts and edtech companies report a growing focus on independent evaluations.

Singapore

Singapore's *Smart Nation: National AI Strategy* selects five 'high value' project areas: personalised education; freight planning; municipal services; chronic disease prevention; and border operations. The Strategy also identifies five key enablers: AI talent; research-industry-government connection; data infrastructure; trusted environment; and international collaboration. A dedicated national AI office stewards the strategy.

Singapore sees advanced education technology as a support for teachers: saving time, boosting insights through assessment data, and enabling greater personalisation. For Singapore, long an international leader in education achievement, personalisation becomes part of its strategic shift toward developing student agency, higher order skills (like critical thinking), collaborative learning, and responsiveness to student interests.

The Education Technology Plan (Ministry of Education Singapore 2021) maps out a ten-year series of interventions to support that shift across:

- Blended learning, with devices for every secondary school student, support for schools to build integrated instructional programs, and teacher and student access to an individualised digital Student Learning Space;

- AI-enabled technology to support personalised student learning support, digital resources and learning analytics for teachers;
- Formative assessment on a wider range of skills;
- Greater digital literacy and collaborative learning opportunities.

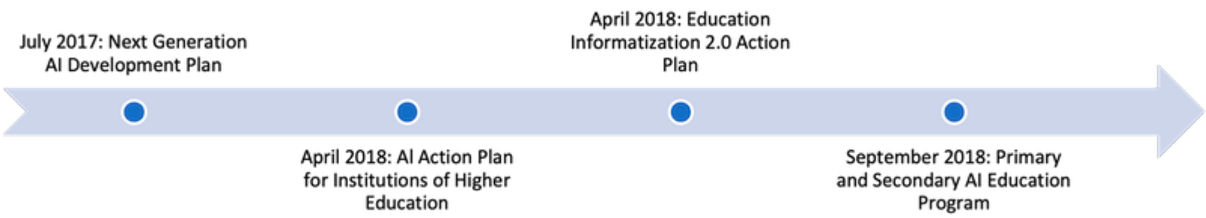
China

China's ambition to become the world's leading nation in AI research, development and use by 2030 is comprehensively laid out in its *AI Strategy: A New Generation Artificial Intelligence Development Plan*.

The AI Strategy outlines three targets: catch up to global competitors by 2020; start leading in specific domains like voice and facial recognition by 2025; and become the world's primary locus for AI innovation by 2030. Contributing elements include industry-academic-government partnerships; pure and applied research in AI science; incentives for innovators and entrepreneurs; ethical expectations; national security; and talent attraction and development (Webster et al. 2017).

The Strategy reserves a key role for education: to develop talent and expertise to enable global leadership; and to use universal AI education to lift general population competency. Investments straddle tertiary sectors – some 344 universities and colleges now have four-year AI-related degrees (Song et al. 2022) – and schooling, where the Ministry of Education expects to have formal AI-related coursework (such as coding and AI concepts) incorporated into primary and secondary curriculum in 2022 (Liu 2022) (see Figure 13). Industry partnerships will play a role in meeting increased demand for AI instruction expertise.

Figure 13: A brief timeline of major national policies on primary and secondary AI education in China



Source: Asia Pacific Foundation of Canada (Liu 2022)

Appendix D: Consultations

More than 150 teachers, school and system leaders, researchers, edtech developers, technology experts, social benefit organisations and many other stakeholders informed this fellowship and report. As well, two roundtables explored central questions facing advanced education technology and its capacity to address education disadvantage (summaries provided below).

In addition, a group of nine NSW public school teachers and national education researchers agreed to review some adaptive learning applications. The aim was to get a practitioner perspective on the utility of these tools and related issues. Twenty options were drawn from three priority categories (student-, teacher- and system-oriented tools). Participants accessed the tools solely through readily-available public websites and information.

Participants scored the potential value of the application on a five-point scale from 1 (low) to 5 (high) across pedagogical quality, value for teachers, for students and for schools or systems, and implementation ease or challenges. Short answer questions and open-ended additional comment opportunities offered qualitative insights.

Key findings from this exercise include:

- Teaching support applications like smart curricula systems were self-selected most often, comprising 64% of the reviewed tools;
- Feedback emphasised the importance of the integration of applications within school and teaching programs;
- Comments highlighted the value of teaching support tools for relief teachers, early career teachers and teaching support staff.

Roundtable: Shaping AI-based Education Technology in Australia – A discussion of opportunities and challenges

Centre for Social Justice and Inclusion, University of Technology Sydney

July 4, 2022

Overview

This roundtable gathered some 20 teachers, leaders from education systems, social and public sector organisations, industry representatives, and other experts for discussion of the opportunities and benefits of AI-augmented education technology and the challenges and crucial conditions that will need to be addressed or put in place to ensure these powerful tools are safe and deliver benefits to disadvantaged schools and students.

Several key themes emerged, all of which were amplified when addressing disadvantaged student outcomes:

- The need for evidence-based design of edtech to distinguish products on quality dimensions and to give teachers, schools and systems the confidence that investments are well-placed – along with the closely related need for more high-quality research and evaluation.
- The critical challenge of supporting schools, teachers and others (such as tutors) with best practice advice in the use of these tools.
- The requirements for clearer governance, led by governments through policy, program design, regulation, resourcing, and procurement, to maximise opportunity, minimise risk and, importantly, create the incentives that will help bend the development curve of edtech towards better student outcomes and social benefit.
- The significant potential for innovative philanthropic leadership, public-private collaborations, impact investment and other mechanisms to ensure edtech is used to lift disadvantaged student outcomes.

Discussion Summary

Use and adoption

- Education systems, schools and teachers are using a wide range of advanced technology to support teaching and learning. Key benefits include: differentiated class material and assessment; formative assessment tools and data; insights into individual and class learning progress; student engagement; and time-saving for teachers (noted as 300 hours annually for some products).
- High-quality curriculum content offered by advanced technology tools can be important for supporting at-risk students. Disadvantaged students can be in greater jeopardy of disrupted learning progress as they change schools or communities, and the architecture of these tools (incorporating learning progressions, clear connection to curriculum outcomes, and access to evidence-based teaching and learning materials) can play an important role in ensuring smoother transitions and sustained learning gains. Additionally, the mastery models of adaptive technology were suggested to counteract low expectations that can undermine student progress, especially for disadvantaged students. Industry leaders highlighted that early designs of applications failed to anticipate that students move further and faster through units than expected, and well-designed edtech tools can cater for such advancement.
- Access to adequate devices, internet connection, and supportive learning environments were flagged as foundational for equitable outcomes. There were concerns that access to high-quality adaptive learning tools will emerge as another frontier of the digital divide with the greater take-up of these supplementary learning opportunities by better-resourced schools and students.
- Within schools already using such technology, teachers highlighted that licences can consume large shares of faculty budgets, and that despite efforts from providers to adjust fees, resourcing remains difficult and time-intensive, especially for schools from low-SES communities.

- There is a risk of 'provider capture' if learning tools are not able to be easily found and integrated with schools' digital infrastructure, lack flexibility, become out of date, or require expensive fees and adjustments to replace.
- Ensuring effective implementation of these tools is important. High-quality learning products typically are intuitive with easily-accessed interfaces. The implementation issues therefore relate more to confidence in how they can support core aspects of teaching, such as planning and programming, formative assessment, feedback and reports, and data analysis. Advice on how to integrate the tool in lesson plans, and time or frequency limits for student use, are crucial for optimum outcomes and ease of integration.

Product design and industry

- Quality was seen as an important and measurable distinction across teaching and learning applications. While the overall quality of Australian edtech products was acknowledged, the lack of consistent and transparent evidence standards undermines the capacity for schools, systems and other purchasers to make effective decisions about the expected benefits and impact of these tools. Engaged industry leaders agree such standards play an important role in shaping the market and rewarding the substantial investment it takes to produce and maintain well-designed and effective products; too often, purchasing decisions are based on word-of-mouth recommendations or lowest cost.
- U.S. statutory and regulatory frameworks mandating explicit consideration of evidence for education interventions are having a significant impact on school decisions and the direction of the education technology industry. Legislated through the national *Every Student Succeeds Act (ESSA)*, four levels of evidentiary quality are aimed at shifting national, state and local education funding towards the most reliable learning interventions, including those involving edtech. Public and philanthropic-supported resources are playing a key role in this shift toward evidence and quality through, for example, *Evidence for ESSA*, *What Works Clearinghouse*, and *EdReports*.
- Product quality can be assessed through two broad types of evidence: input evidence (particularly the cognitive science and pedagogical strategies underpinning such tools); and outcome evidence (based on proven effectiveness and impact). It was recognised that third-party reviews are important. Examples provided by industry participants include:

  Outcome evidence:

  - *Mathspace*: The Utah STEM Action Center's 2018 report demonstrates a statistically significant increase in student Maths proficiency and growth for *Mathspace* students.
  - *Education Perfect*: The New Zealand Qualifications Authority's 2015 National Pilot Online Assessments Program in Maths, Science and French shows a positive connection between the amount of *Education Perfect* learning material a student has completed prior to an assessment and their performance.

Input evidence:

  - *Maths Pathway* has published its pedagogical model, is working towards *ESSA* Tier 1 certification, and is certified by the Education Alliance Finland.
  - *Inquisitive*'s website outlines the pedagogical model and teaching strategies that inform the ongoing development of the product.

- User co-design is critical to ensuring tools can be easily and effectively implemented without need for extensive training or support, and to reflect good practice from experts in teaching and learning, not just digital processes and design. Expertise is not limited to teachers and schooling, and it is important to integrate perspectives of lived experience and affected communities. The experience of social impact organisations working with disadvantaged students also can provide a crucial lens on the reality of access and utility. The long-term co-design process of the Aboriginal Literacy Numeracy Foundation's *First Language platform* and phonics game-based app has delivered multiple dividends: an early years learning progression; AI-supported simultaneous First Language and English early learning; and recognised computer program design skill certification for the community members involved in the project.

Governance opportunities

- **Information on quality design, efficacy and use** – the need for reliable and consistent information on product quality within a criterion-based framework; and rigorous metrics connected to enhanced student outcomes.
- **Public-private partnerships** – substantial potential for better collaboration between government, private and social sectors to realise the benefits of these powerful tools and to help shape the industry towards serving students with greatest need. For example, edtech companies have mapped the skills needed to achieve learning goals at finely-grained levels both vertically (on an achievement scale) and horizontally (across curriculum areas and/or capabilities). This data provides much richer insight into learning outcomes than standardised testing like NAPLAN, or even periodic formative assessments. Finding safe ways to share data can assist in developing better tools, ensuring they align with public priorities, and in providing richer research and policy insight.
- **Philanthropic and impact investment** – there is scope to invest in impact-oriented research and capacity-building resources to improve the effectiveness of advanced technology in addressing long-standing education challenges. This could include innovative investment vehicles where financial returns are adjusted to recognise the public benefit of improved outcomes for disadvantaged and special needs students. An added benefit is the incentive for independent evaluations to determine impact.
- **Continuing dialogue and exchange** – there are currently very few forums that bring together the diverse perspectives and contributors that make up the ecosystem of education and technology. Even fewer explicitly consider the opportunities for better social outcomes and how the influences across government, education, industry, research, and social purpose

sectors will boost (or undermine) opportunities to better shape the direction of edtech in Australia. There was consensus among participants that ongoing dialogue will be important.

Roundtable: Status and Issues in AI-supported Education Technology

Centre for Social Justice and Inclusion, University of Technology Sydney

August 4, 2021

A roundtable involving academic and education experts discussed the current state of AI-supported education technology and critical issues for continuing investigation.

Key themes:

- Edtech cannot be seen as a stand-alone tool; it needs to be integrated by teachers for best effect. In fact, there is a multiplier effect when these tools allow teachers to focus on what they do well and lessen the risk of burnout and overwork, especially as class sizes and complexity are growing. Teacher co-design of tools becomes an important mechanism.
- Social justice is critical and often overlooked; there could be more attention to disadvantaged and special needs students, noting that some governments, like the UK, are now making this a priority. These systems should be defined by what benefits they will deliver and for whom, and educators should avoid being seduced by the technology without this framing. Social justice principles should include equity, access, participation, self-determination and privacy.
- Many educators don't understand AI or advanced tools and there is little transparency or clear explainations to help them use the tools with agency and confidence. Pre-service teacher education does not adequately address digital literacy to increase teacher confidence in using these new tools or integrating them into their practice. This means there's a risk teachers will trust the 'machine' too much. There is a related critical question of what data is being collected and how it is used.
- Student agency is also important, not just teacher agency, to up the equity quotient. One of the important enablers of student agency is metacognition; tools should actively encourage this kind of feedback on learning practice.
- Regional and remote communities, and disadvantaged metropolitan households, schools and communities, suffer from the significant digital divide. That divide is no longer just about access to computers or laptops (though that remains a problem); the divide now extends to accessing edtech learning tools and the capacity to use them effectively. Well-off schools have teachers and support staff who know how to 'orchestrate' edtech tools to best effect.
- There is a critical question of what data is collected and how it is used, which is particularly concerning when children's data is being harvested. Open data platforms can have perverse outcomes: for example, surgeons subject to such platforms are avoiding operating on terminal patients for fear it will affect their public ratings. The harmful effects of MySchool-based league tables are another case in point.

- Two of the most promising uses of adaptive technology identified by participants are: its use in formative assessment (giving teachers, schools and systems much better information and avoiding high-stakes summative exams); and providing feedback to teachers and schools so that they can adjust their approach or introduce interventions to address learning gaps.

Appendix E: Sample inventory of advanced learning technology tools

A sample inventory of some 200 commercially available advanced education technology applications was collated in the initial stage of this fellowship investigating how such technology could lift disadvantaged student outcomes. The methodology approached it from the perspective of a school, teacher, family or student, utilising what information was easily and widely accessible.

The inventory concentrates on three broad categories of more developed and available education technology (student-, teacher-, and system-oriented applications). Other applications are available, such as facial recognition and related biometric devices, or classroom social robots, but these tend to be less progressed and researched, raise sharp ethical questions, and likely would require larger shifts in school and teaching decision-making to become acceptable.

This inventory, and the fellowship research, concentrate on schooling years, though there are many other innovative applications in early childhood and tertiary education. It excludes back office administrative and general learning management systems. Lastly, the inventory captures only a small part of the fast-growing education technology market, which often directly markets its products to schools and parents and is considered by many analysts as ripe for an investment and innovation boom.

Given available resources, the inventory could not assess the quality of each platform, nor should it be considered a comprehensive review, but it does provide useful insights into the edtech market.

Conclusion

Independent research confirms the growing efficacy of certain edtech tools, with some, but not all, showing substantial effect sizes in student learning gains. Yet the collation of this inventory revealed significant gaps in accessible information to help identify quality advanced edtech. The lack of trustworthy information undermines effective decision-making by teachers, schools, parents and others, and weakens incentives for high-quality products.

Methodology

Three key areas of interest framed the collation process and consideration of implications for schooling:

- To what extent has education evidence been incorporated into the design of these products, including evaluations of effectiveness?
- How widely are these systems used, by whom, and in what settings? Could they be considered for Australian schools, and particularly for disadvantaged students?
- Is artificial intelligence an element of the application function and efficacy?

An initial review of literature and other sources helped identify applications and issues for the subsequent analysis, including:

- Policy and research reports on advanced edtech development by the OECD, NESTA, RAND Corporation, education research journals, and other sources;
- International education evidence clearing houses, such as the U.S.-based What Works Clearinghouse and Evidence for ESSA (a philanthropy-supported initiative by Johns Hopkins University to identify technology and programs that meet the evidence standards of the Every Student Succeeds Act, the main U.S. federal law governing K-12 education), and the UK Education Endowment Foundation;
- Commercial and investment-oriented inventories, such as the Australian EdTech Directory and HolonIQ;
- Awards and recognition programs by EdTech Digest and CODiE.

Only English language and commercially available applications were included in the survey given the research and accessibility questions.

This basic inventory was structured around six core elements:

- Evidence – including transparency of evidence-base and evaluation of impact
- Usage – including key audience (student, teacher or system), scale and equity focus
- Content – including learning areas, curriculum outcomes and pedagogical approach
- Governance – including ownership and location of decision-making
- Technology design and requirements – including ease of access

Analysis

Diverse product development, with limited Australian investment

American and Chinese entrepreneurs and global technology companies dominate the advanced education technology sector, followed by India and the EU. Australia's edtech sector is small though the number of start-ups is growing despite limited private capital and very little, if any, public investment shaping product design or quality.

A wide range of intelligent tutoring systems (ITS) are available and used, while smart curriculum, intelligent assessment tools, and data analysis products represent an emerging market. Less-common applications include classroom management systems, robotic teaching assistants and socio-emotional gauges or chatbots.

Potential implications: Global products can lack clear alignment with Australian curriculum and education priorities; international governance and ownership of edtech means that decisions and data are external to Australian schooling; and private capital can drive heavy marketing.

Little publicly available evidence of impact or quality education design

Only a quarter of the inventory contains products with published academic research or detailed information on pedagogical building blocks, despite the collation process emphasising those criteria. Even fewer (slightly above one-fifth) offered any evidence of impact from an independent source. Most show impact through customer testimonials, not independent evaluation. Very few suggested how the product could be useful in addressing disadvantaged student learning, and the involvement of teachers in product design was unclear.

Potential implications: Lack of reliable evidence risks undermining proven learning strategies, resulting in poorer educational outcomes and wasted investment in low-quality products.

Lack of transparency or consistent standards

Global regulatory and ethical standards increasingly emphasise the need for AI-based systems to be 'explainable' so the user can readily understand the system's purpose, design and dynamics; how and where data is collected and used; and ethical protections, among other elements. Few of the inventory products met that basic standard in their public material (though it is potentially available when purchasing).

It was also difficult to compare products, but noteworthy that some of the most popular (and researched) products emphasise their inclusion in the *What Works Clearinghouse* (*WWC*) and *Evidence for ESSA* evaluations, two information sources expressly intended to help schools, teachers and systems discern quality education approaches based on consistent and comparative criteria. Supported by the U.S. Department of Education's Institute of Education Sciences, the *WWC* aims to be a trusted source of evidence for effective learning approaches. *Evidence for ESSA* evaluates research on education interventions (including technology) for authoritative information and enables educators and others to make more effective selections.

Potential implications: Australian consumers have very little access to independent, reliable information to understand and compare edtech products. This risks poorer decision-making and misses an important opportunity to incentivise the market towards higher-quality design and education priorities, including disadvantaged student outcomes.

Equity and special needs are a lower priority

Few of the inventory product developers suggested how their applications would be particularly useful to disadvantaged students, students with learning disabilities, or those from non-English speaking backgrounds. That said, there is encouraging evidence relating to edtech tools aimed at dyslexia and dysgraphia, two common educational disabilities. Some of these applications can provide faster and more finely grained analysis of those disabilities, and connect teachers automatically with suggested remediation exercises. As well, intelligent tutoring systems are typically built on a scaffolded mastery model with learning progressions to ensure utility for all types of students and ability levels.

Key issues for disadvantaged schools and students are the potentially substantial costs for edtech products and the professional development and technological requirements.

Potential implications: Teachers, schools and parents have less opportunity to understand how an edtech application will best integrate with a wider learning program and address student needs. Significant costs and technological requirements potentially introduce a new frontier of the digital divide, where better-off schools and families access more effective learning tools.

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