

**Research Report**

# **Artificial Intelligence and Emerging Technologies in Schools**

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## Abbreviation

AI	Artificial intelligence
AITSL	Australian Institute for Teaching and School Leadership
AR	Augmented reality
ANN	Artificial neural network
AIED	Artificial Intelligence in Education
CAI	Computer assisted instruction
FATML	Fairness, accountability and transparency in machine learning
IoT	Internet of Things
IT	Information technology
ITS	Intelligent tutoring system
IVR	Immersive virtual reality
MR	Mixed reality
HMD	Head mounted display (VR or AR headset)
PA	Pedagogical agent
PD	Professional development
PL	Professional learning (sometimes referred to as teacher professional development)
SAMR	Substitution, augmentation, modification, redefinition model
STEM	Science, technology, engineering and maths
STEAM	Science, technology, engineering, the arts and maths
VLE	Virtual learning environment
VR	Virtual reality

## Glossary

Adaptive learning	An approach to delivering learning activities and resources paced or suited to the abilities or requirements of individual learners.
Adaptive system	A system that changes its behaviour in response to the environment. Commonly associated with plants, animals, humans or social groups, the adaptive change that occurs is usually directed toward achieving a goal or objective.
Affective computing	An area of computing that is concerned with the display, recognition, or influencing of human emotions.
Agent	A physical or virtual entity that makes seemingly autonomous decisions. These decisions are based on data perceived from the environment (through sensors or provided by other systems). Multi-agent systems have more than one agent, and these agents can communicate with others.
Algorithm	A process or set of instructions for completing a task. In computing, these instructions tell the computer or machine how to accomplish a task or operation.
Anthropomorphism	The attribution of human characteristics to animals and inanimate objects, including computers, robots, or learning technologies.
Artificial intelligence	Artificial intelligence refers to a machine or computer program that uses human like thinking to complete a task.
Artificial neural network	Artificial neural network (ANN) are computer programs inspired by the way the human brain processes information. An ANN acquires knowledge by detecting patterns and relationships in data, and they learn (or are trained) through experience, not from programming.
Augmented reality	Augmented reality (AR) overlays information and virtual objects on the real world environment.
Autonomy	<p>From a computer science perspective, entities have autonomy if they have control over their internal state (variables) and behaviour (actions are decided by the entity).</p> <p>From a psychological perspective, humans seem driven by a desire for autonomy, namely for being able to make choices according to their own free will, independent from outside forces.</p> <p>In ethics, autonomy refers to respecting the capacity of humans to make their own decisions.</p>
Affordance	The properties or features of a technology which suggest possibilities for action. Learning affordance refers to the properties of virtual reality which suggest ways in which learning can be designed and facilitated e.g. an affordance of VR is the ability to manipulate the size of a virtual object and this can allow for an examination of the microscopic (cell, atom).
Big data	Big data is the ability to search, aggregate, and compare large data sets which may comprise non-numeric information (e.g. text, images).
Biometrics	Automated recognition and collection of measureable data on biological and behavioural characteristics of individuals. Biological data includes facial recognition, fingerprints and iris patterns. Behavioural data includes vocal patterns, eye tracking/gaze attention, gait tracking or typing recognition.
Cognitive Computing	Software and algorithm development approaches that use programming designed to mimic human cognition.

Computational power	Computational power refers the processing capacity of computer systems. This processing capacity is enabled by how fast a computer can process data and the amount of memory in the computer system for this processing.
Cybersickness	A sickness similar to motion sickness which is bought on by the use of display devices such smartphones, tablets and head mounted displays (headsets).
Data mining	The automatic or semi-automatic process of discovering patterns in data.
Deep learning	Deep learning is a subset of machine learning. Deep learning software attempts to imitate the activity in layers of brain neurons to recognize patterns in digital representations of sounds, images, and other data (see artificial neural network).
Desktop virtual reality	Virtual reality environments that are delivered via a computer monitor and mobile device screen (tablet or smart phone). Interaction in the virtual environment is by using a keyboard, mouse, touch screen, joystick or other gaming device.
Domain knowledge	Domain knowledge refers to the knowledge that human experts hold in a specific area that an AI system is being created to operate in. This knowledge can be in the form of norms, rules, and conventions. For example, an AI system designed to recognise speech patterns would need to include the expert knowledge from the domain area of linguistics.
Educational data mining	The automatic or semi-automatic process of discovering patterns in data captured from educational settings. This data could come from learning environments or administrative systems in schools or universities.
Evolutionary computation	An area of AI that uses algorithms inspired by biological evolution to learn or solve problems. Software is developed on computers that mimics evolutionary concepts like mutation, adaptation, and selection of the fittest to find the best solution to problems.
General artificial intelligence	Also known as Strong AI, this type of artificial intelligence would be able to think and act as a human and could display theory of mind and self-awareness. At the moment this type of AI exists only in science fiction.
Head mounted display	A head mounted display (HMD) is a device (goggles or a headset) worn over the eyes that displays virtual objects and environments (e.g. Google Cardboard, VR Gear, Oculus Rift). Virtual reality HMDs completely block out the real world replacing it with a virtual world. Mixed reality HMDs allow the user to see the real world and augment or anchor virtual objects in it so that the user can interact with these objects (e.g. Microsoft HoloLens or Magic Leap).
Highly immersive virtual reality	Virtual reality delivered via a head mounted display (HMD) in which the user has a high degree of agency (ability to act) by manipulating virtual objects, interacting with other users and computer generated non-player characters, and having the ability to create within the virtual environment.
Immersive virtual reality	Virtual reality delivered via a head mounted display (HMD) - a virtual reality headset. These virtual environments give the user the impression that they are in the environment. Immersive virtual reality can range from a passive experience (looking around) to more interactive experiences where the user can navigate around the environment and manipulate virtual objects. This is also called virtual reality as HMDs are now more prevalent.
Intelligence	In psychology, intelligence is defined as the capacity to acquire and use knowledge and skills, learn in new situations, and understand abstract concepts. From a computer science perspective, intelligence refers to the ability for a software system to correctly process information in complex environments in a way that maximises the probability of success.

Intelligent tutoring system	A software system running on a computer that mimics human tutoring, for example by providing immediate feedback or customised instructions to a student without the need for human intervention.
Internet of Things	The network of devices connected to the internet that communicate with each other. The devices that comprise the Internet of Things (IoT) are everyday machines, equipment, and appliances that have embedded computer chips to collect and communicate data.
Immersion	Where the properties of a technology (visual and auditory stimuli) are designed to allow the user to feel a sense of presence ('being there') in a virtual environment.
Learning	In artificial intelligence, learning refers to specific algorithms used to increase the performance or accuracy of a system or machine over time. See Machine Learning. In psychology, learning is defined by a change of behaviour as a result of experience. Thus, learning can be intentional or unintentional and can include improving or declining performance. In humans, there are many mechanisms of learning such as association, imitation, or insight.
Learning analytics	The application of analysis techniques to data gathered from learning and educational systems.
Machine learning	A subfield of artificial intelligence, machine learning is the science of get machines to learn like humans in an autonomous way. See also Adaptive Learning, Artificial Neural Network, Evolutionary Computation, Data Mining, Deep Learning.
Memory	In computing, memory refers to the various physical storage devices used to store data (either permanently or temporarily). It also refers to the ability of software programs to retain results from previous processes.  In psychology, memory refers to the encoding, storage and retrieval of past experiences in the human mind. It is noteworthy, that some human memory systems are severely limited in capacity and do not objectively store information as a tape recorder but are highly re-constructive.
Metacognition	In psychology, metacognition refers to higher order thinking which involves knowledge of and control over our own cognitive processes. For example, learners can metacognitively monitor their comprehension and exert metacognitive control by switching their learning strategies. They might also possess metacognitive knowledge about the strengths and weaknesses of their own learning. Thus, metacognition is at the heart of self-control, self-regulation, and consciousness.
Mixed reality	Mixed reality (MR) overlays and anchors virtual objects on to the real world and often allows users to interact with these objects. Sometimes the term is used to refer to the inclusion of physical objects that can be interacted with as part of a virtual environment. The term 'mixed reality' is relatively new and still being defined.
Narrow artificial intelligence	Also called Weak AI, this type of artificial intelligence is able to perform a single or focused task and may outperform humans at this.
Pedagogical agent	A physical or virtual entity that makes seemingly autonomous decisions (see Agent) with instructional goals and strategies. For example, a human-like pedagogical agent could deliver on-screen instruction.
Presence	The feeling of 'being there' in the virtual environment. Co-presence is the feeling of 'being there with others' in the virtual environment.



Smart classroom	A physical learning space that integrates sensing technologies (eg. microphones, cameras, motion detectors) with human and/or AI analysis approaches to provide learning guidance, tools or strategies.
Superintelligence	Also known as Super AI or the singularity, this type of AI would exceed human capabilities in all areas. At the moment this type of AI is only in science fiction.
Theory of mind	In psychology, theory of mind is the ability to attribute beliefs, intents, desires and knowledge to the self and to others. This means that individuals are able to understand why other individuals act the way they do by considering the other's perspective.
Ubiquitous computing	Ubiquitous computing is the idea that computing can be done anywhere, at anytime, on any device. Ubiquitous computing is also called pervasive computing, ambient computing or everywhere computing.
Virtual reality	A 3D computer-generated world which can be a highly imaginative or realistic simulation. Depending on the VR environment, a user can experience the world in the first person (through their eyes or the eyes of a character/avatar) or in a third person (disembodied) perspective or switch between the two.
Virtual reality simulation	In this report, a 3D objects and environment developed for training and learning purposes.

# Executive Summary

## Purpose and scope of the project

This report was commissioned by the Australian Government Department of Education and Training to examine the literature, and provide advice to teachers, on artificial intelligence (AI) and the emerging technologies (virtual, augmented and mixed reality) in school education. The project was conceived of as translational research; that is, the purpose was to explore and explain often complex technical, social and ethical issues associated with the technologies in an accessible manner for the teaching profession. The project comprised:

- Three literature reviews, written for teachers on artificial intelligence (AI), virtual reality (VR) and augmented reality (AR);
- Two 'short read' documents which distilled the messages from the AI and VR/AR literature reviews;
- Four classroom poster infographics, two on AI and one each on VR and AR;
- A mapping of quality online resources and their alignment to the Australian Curriculum on each technology;
- A selection of case studies, written by teachers, on using AI and VR for learning; and
- A targeted national consultation with experts on the implications of AI and emerging technologies for schools.

## Findings

### Artificial Intelligence (AI)

- AI is a term used to describe a machine or computer program that uses features of human-like thinking to undertake a task. AI can be embodied in some robots or disembodied, that is 'infused' into computing applications (e.g. internet search engines, social media facial recognition tagging technology). Right now, we have narrow AI which is only able to do the single or focused task it was designed to do (e.g. facial recognition technology);
- AI in school education is still in the early stages of development. Educators need to develop foundational knowledge of learning about and with AI in order to empower students to thrive in an AI world;
- Learning about and with AI will require teachers to understand the economic and social changes that the technology will bring as well as its potential educational uses and ethical considerations; and
- There is much work to be done around the ethical, legal and governance frameworks to ensure that AI technology is used for good, and that transparent processes are in place to ensure accountability at classroom, school community and school system levels.

### Virtual Reality (VR)

- VR is a 3-D computer generated environment which can be a highly imaginative or realistic simulation;
- VR has unique properties known as affordances that can offer teachers and students unique learning experiences. These include the ability to have experience that might be impractical, impossible or unsafe in real life (e.g. visiting Mars), manipulate size and scale to improve

understanding (e.g. travelling as a virus in the body) or perspective swapping (e.g. looking through the eyes of others);

- Research on the effects of immersive virtual reality (IVR), which is VR delivered via a headset, on children and their learning is just emerging. There are no longitudinal studies on the effects of immersion on children, and rigorous studies on the pedagogical potential of the technology for creativity, collaboration and deep learning are emerging; and
- There are ethical and safety issues associated with immersive VR. Some of these include the potential for young children to potentially experience false memories and cybersickness (which is like motion sickness). There are ethical and legal concerns around the areas of privacy, intellectual property and copyright, especially in regards to student and teacher creating and sharing VR content.

### **Augmented Reality (AR) and Mixed Reality (MR)**

- AR overlays information and virtual objects over the real world;
- In its current form, augmented reality (AR) is a relatively new technology that has the potential to motivate and engage students, especially in learning abstract or theoretical knowledge, or allowing students to experience what may be unsafe or infeasible in real life;
- AR lends itself to collaborative learning, especially as a training tool;
- Mixed reality is a contested term. Mixed reality technologies (e.g. HoloLens, Magic Leap) anchor virtual objects such as holograms, animations and information in a real environment and can be responsive to this environment. At present, this type of technology is expensive and mainly used by developers. Mixed reality technologies hold great educational promise once they mature; and
- There are ethical and legal concerns around the areas of privacy, intellectual property and copyright, especially in regards to student and teacher creating and sharing AR content.

### **Resources on the technologies for classroom and teacher professional learning**

- There are relatively few education-specific resources on AI and emerging technologies;
- There are many educational uses for these technologies that will fit within the current Australian Curriculum. Teachers require classroom-based research and case studies to support their use of the technologies in classrooms and teaching about them; and
- Currently, there are few professional learning resources and opportunities related to these technologies. It will be important that quality professional learning opportunities are developed in this area.

### **Case Studies**

- Teachers provided a number of case studies on AI and VR that illustrate the practical aspects of introducing the technology into classrooms, how to use them effectively for learning and how to teach students about them.

### **National Consultation**

- The experts consulted identified a wide range of issues related to AI and emerging technologies in schools;
- There was concern expressed around the ethical implications associated with AI in particular, and the need to educate teachers and school communities about this technology in order to empower them to engage in debate in a manner which can influence decision-making;

- The need for transparent and accountable systems of governance related to AI and school education was considered a priority. The need for independent expert advice to schools and policy-makers was emphasised so that the policy can accommodate the rate of technological change;
- The need for teachers to develop and regularly update foundational knowledge about AI and emerging technologies was considered vital, if the profession is to support learning with these technologies and empower student to thrive in an AI world. Furthermore, initial teacher education programs need to incorporate emerging technologies so that new graduates enter the profession with an existing foundational knowledge;
- There was suggestion that it would be timely to assess where learning with and about AI and emerging technologies could be integrated within the Australian Curriculum including the Digital Technologies Curriculum;
- Equitable access to these technologies was perceived to be crucial to ensure that all students received the potential benefits;
- The lack of diversity in the current technology workforce can only be addressed by engaging girls and students from diverse socio-cultural backgrounds in authentic and engaging innovative technology learning within schools from F-12 and across learning areas; and
- The importance of developing and supporting rigorous research into the use of these technologies in classrooms and school systems was raised.

# 1. Introduction

We commonly use, in our everyday lives, computing applications powered by artificial intelligence (AI), and many of us entertain ourselves with emerging 'immersive' technologies such as augmented reality (AR) and virtual reality (VR). AI is a term used to describe a machine or computer program that uses features of human-like thinking, such as planning, problem-solving or logical action, to undertake a task. Many common computing applications, such as internet search engines, smart phone assistants, and social media facial recognition tagging technology, are powered by AI. While often mistakenly associated with robots (some of which have intelligent capability and some of which do not), AI is usually invisibly infused through computing applications that can help us enhance our knowledge and judgement, and connect with others. 'Immersive' technologies, those that use simulation to transport us to a different version of reality, have become more ubiquitous. Pokemon Go and the fun filters of social media apps, are popular examples of AR, where object and information are overlaid on the real world for personal enjoyment and to enhance human sociality. The recent advent of affordable headset-mediated VR has sparked the imagination of the global entertainment and education industries: Over 3 million PlayStation VR units have been sold to date (Lang 2018) and more than 2 million children have experienced Google Expeditions in the classroom (Charara, 2017).

AI and the immersive technologies of VR, AR and Mixed Reality (MR) are quite different in their design, uses, commonplace manifestations, and experiential interfaces and characteristics. While AI can be infused into computing applications used for learning, immersive technologies augment (overlay) or replace real learning environments with computer-generated objects, information and even alternative worlds. While there are differences between AI and 'immersive' technologies, we are in an era where these technologies are becoming intertwined: Game engines used to create virtual worlds are now being deployed to provide challenging learning environments to train AI (Lange, 2018).

As these technologies continue to be woven into the fabric of everyday life, they raise profound economic, social and philosophical questions. How can teachers prepare students, in all their wonderful diversity, to learn about and with these technologies? How can students, their families and communities be empowered to not just live, but also thrive, in a world where autonomous and intelligent computing systems will disrupt economies? What role should AI play in augmenting human intelligence and what limits need to be stipulated on the role of machines in areas of decision-making that can have serious effects on humans? What new systems of governance, accountability, standards, regulation and laws are required to ensure technologies benefit all humans and the planet? What does digital literacy for citizenship mean in an era where machines can generate and spread media that is not immediately discernible as fake or false? As the lines between simulation and reality become increasingly blurred, what new creative or potentially damaging forms of human virtuality will emerge? How can educators keep up with emerging technological developments to ask critical questions about its benefits and risks or to develop a robust and ongoing public pedagogical approach to educate whole school communities on the implications of the technology? What will need to occur to harness AI and emerging technologies or equitable educational and life outcomes? These are just some of the questions being asked by practitioners, researchers and policy-makers, across a range of disciplines, at a global level.

Fortunately, the Australian teaching profession is equipped to grapple with the complex pedagogical, practical, ethical, and governance concerns raised by AI and emerging technologies. Australian teachers have a long history of active engagement in responding to technological change through curriculum reform and instructional innovation, and in recognising and responding to the issue of digital inclusion for a fairer educational system and society. Teachers understand the importance of explicating complex

or abstract ideas: their livelihoods depend on it. Hence, the teaching profession is well placed to request explanations about the ethical implications, potential benefits and possible harms that are a consequence of new technologies. Without doubt, the teaching profession can play a pivotal role in developing a public pedagogical approach to build (evidence-based) trust and foster critical dialogue on AI and emerging technologies in their school communities. Teachers need time to equip themselves with the knowledge and skills required to harness these technologies for deep learning and for broader social good. We are in a period of 'ferment' (Anderson & Tushman, 1990) as the design of the technologies matures before mainstream classroom adoption occurs. Despite being a field of study for several decades, AI in Education is only just beginning to enter the consciousness of the teaching profession, with discussion about the potential for intelligent machines to alleviate administrative load and provide students with personalised learning. In the case of AR and new types of headset-mediated VR, the evidence based on the pedagogical potential of the technologies deployed in real classrooms rather than laboratory settings is only just starting to build momentum. Now is the time for teachers, school leaders and education policy-makers alike, to build their knowledge about AI and emerging technologies for learning and to acquaint themselves with current interdisciplinary debates about AI and the future of work and its ethical quandaries.

This report should serve as both a starting point for knowledge acquisition, and as a springboard for the teaching profession to engage in debate about the current state and future of AI and emerging technologies in schools.

In late September 2018, the Australian Government Department of Education and Training commissioned our research team to conduct the *Artificial Intelligence and Emerging (Virtual, Augmented and Mixed Reality) Technologies in Schools Project*. The purpose of the project was translational; that is, to provide the teaching profession with an accessible, evidence-based, and practical set of documents on the role and potential scope of these technologies in schools. To this end, the project produced the following:

- (1) Three literature reviews written specifically for teachers. These were on: (i) Artificial intelligence and school education; (ii) Virtual reality and school education; and, (iii) Augmented reality and school education, with a brief section on mixed reality (MR). Each literature review concluded with practical advice for teachers. These literature reviews are Chapters 2, 3 and 4 of this report, respectively.
- (2) Three 'short-read' documents on AI, VR and AR/MR which summarise some of the main points from the literature reviews and conclude with practical advice for teachers. These are published separately to this report.
- (3) Four classroom poster infographics that distil key information on the technologies from the literature reviews. These were: (i) *A Quick Guide to Artificial Intelligence*, created for teachers and older secondary school learners; (ii) *A Quick Guide to Artificial Intelligence*, created for younger secondary and primary school students; (iii) *The Power of Augmented Reality for learning*; and, (iv) *The Power of Virtual Reality for Learning*. The infographics were published separately to this report. They are available in A3 and A4 pdf printable formats.
- (4) A comprehensive mapping of quality online curriculum and professional learning resources related to each technology and aligned, where relevant, to the Australian Curriculum. The approach is reported on in Chapter 5 and the resource mapping table is Appendix 4 of this report. Chapter 5 also contains a checklist tool to assist teachers in exercising professional judgement regarding the quality of online resources related to the technologies.

- (5) A set of case studies, written by teachers, which are designed to illuminate the potential of the technologies for learning across a range of areas. The case studies are showcased in Chapter 6 of the report.
- (6) A summary of key findings from a targeted national consultation with experts on the implications of AI and emerging technologies in schools. This is Appendix 2 of the report.

Our hope is that this report prompts the teaching profession and educational policy-makers alike to have a wide-ranging and ongoing national conversation on how AI and emerging technologies can best be harnessed to enhance learning and improve equitable educational and life outcomes. These conversations will not be easy and solutions to the unique ethical, legal and governance issues associated with AI, in particular, are unlikely to garner consensus for some time. The teaching profession is, however, in a strong position to lead the national conversation on the big, complex issues in this space, and to play an expert role in developing and sustaining local public pedagogies that will be required to educate and empower whole school communities.

## 2. Artificial Intelligence and School Education

‘Artificial intelligence will shape our future more powerfully than any other innovation this century. Anyone who does not understand it will soon find themselves feeling left behind, waking up in a world full of technology that feels more and more like magic.’ (Maini and Sabri, 2017, p.3).

### 2.1 Introduction

Artificial Intelligence (AI) is a term used to describe computer systems that can undertake tasks or activities that require features of human intelligence such as planning, problem solving or logical action. AI is not a new field. However, there has been significant interest and growth in the technology over the last decade due to advances in computer processing power, algorithm<sup>1</sup> complexity, and data availability and storage. Applications of AI have also benefited from improvements in computer vision, graphics processing, and speech recognition (Mitchell & Brynjolfsson, 2017). From drone deliveries to robotics and virtual assistants, AI enabled systems are becoming an important part of our everyday lives. As Maini and Sabri (2017) remark: ‘Much of our day-to-day technology is powered by artificial intelligence’ (p. 7). AI is infused through the technology we interact with every day, however its invisibility raised concerns about how ordinary people understand and might have some control over its purpose and effects.

AI currently provides a set of tools to help collect, explore and analyse the vast amounts of data which are currently available, and it is increasingly used to assist in human decision-making and to automate tasks. While AI is becoming ubiquitous, there are significant misconceptions about its capability. There is also robust debate about its role in the future of humankind and the planet. From healthcare to agriculture, manufacturing to defence, industry is racing to simultaneously harness AI to best advantage and working to resolve its serious limitations and ethical challenges. The field of education is just beginning to respond to the opportunities and challenges of living in an AI world. For educators to realise the potential of AI, it is necessary for them to develop a solid understanding of its key concepts and characteristics, the state-of-play of AI systems, and its complex ethical and legal implications. The overarching purpose of this review is to provide a firm foundation for the education community to begin to have national and international conversations about the future of AI in schools.

We begin this review by introducing the field of AI, its terminology, historical roots and branches of interest. We then offer a useful classification framework for different types of AI designed for newcomers to the area so that they can deepen their understanding of AI capabilities as they relate to human thinking and perception. This then allows for the exploration of some of the myths and misconceptions that currently permeate our understanding of AI. We then briefly introduce the field of machine learning before providing a focused review of literature on the actual and potential application of the technology in school education. This includes a discussion of intelligent tutoring systems, pedagogical agents and the role that intelligent systems can play in assisting teachers to provide personalised learning. Smart classrooms are then considered, with a future-focus on how sensing technology may be used with AI to provide more intelligent physical learning spaces. We then provide a

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<sup>1</sup> In computing, an algorithm is a set of instructions or rules written in programming language that tell the computer how to accomplish a task or operation. BBC Bite Size provides an accessible explanation for children and adults - <http://www.bbc.co.uk/guides/zgrq7ty>



window into the use of AI in adaptive learning and learning analytics, or how data gathered from learning contexts can be used to provide more individualised approaches and deeper insights into learner behaviour. Finally, and perhaps most importantly, we present and unpack an original ethical framework that highlights the key areas for attention *and* provides a basis for educators to think through and ask critical questions about the benefits and risks of AI for school communities.

## 2.2 Defining artificial intelligence

AI is an umbrella term that refers to a machine or a computer program that uses human-like ‘thinking’ to complete a task. Recognising patterns, planning, learning, reasoning, understanding, problem-solving, motion and perception, are all aspects that we associate with human-like thinking. We can also extend this to more abstract human expressions like creativity and imagination. When machines and computer programs display these traits, they can be considered as AI systems. This also explains why definitions of AI can change over time with advances in our understanding of human thinking and intelligence. This ‘fuzzy’ definitional quality is called the AI effect:

The exact standard for technology that qualifies as “AI” is a bit fuzzy, and interpretations change over time. The AI label tends to describe machines doing tasks traditionally in the domain of humans. Interestingly, once computers figure out how to do one of these tasks, humans have a tendency to say it wasn’t really intelligence. This is known as the AI effect... Perhaps there is a certain *je ne sais quoi* inherent to what people will reliably accept as “artificial intelligence”: So, does a calculator count as AI? Maybe by some interpretation. What about a self-driving car? Today, yes. In the future, perhaps not.... (Maini and Sabri, 2017, p.10).

AI systems take many different forms, with many of the everyday items and systems we use currently assisted or powered by AI. From computer games (behaviour of non-player characters), to navigation systems (Google Maps), voice-based virtual assistants (Siri, Alexa, and Google Assistant), motor vehicles (Driver Assist), and robots (Sophia), these AI powered systems have varying levels of ‘humanness’. In some cases, AI is embodied in anthropomorphic (having human characteristics or features) ways; for example human-like robots that are developed to act as companions or tutors (Causo, Vo, Chen, & Yeo, 2016). AI can also be ‘embodied’ in animal-like robots, again to provide robot-human interactions that mimic those that occur between real entities. Other AI systems, such as robotic systems used in manufacturing, provide an embodiment or physical representation for the AI, but this physical presence is not aimed to enhance human-robot interactions in a cognitive or emotional way. The more common use of AI is in ‘disembodied’ software systems. While some of these may run on computers or machines that resemble traditional computers, many applications of AI are deployed in ubiquitous computing systems. Ubiquitous (or pervasive) computing involves incorporating the capability of a computer into the objects we interact with in everyday life. Many people may have a hard time recognising some of these disembodied AI powered systems as AI because they run in the background of computer programs invisible to the layperson.

### Highlights

AI is an umbrella term that refers to a machine or computer program that uses human-like thinking to complete a task.

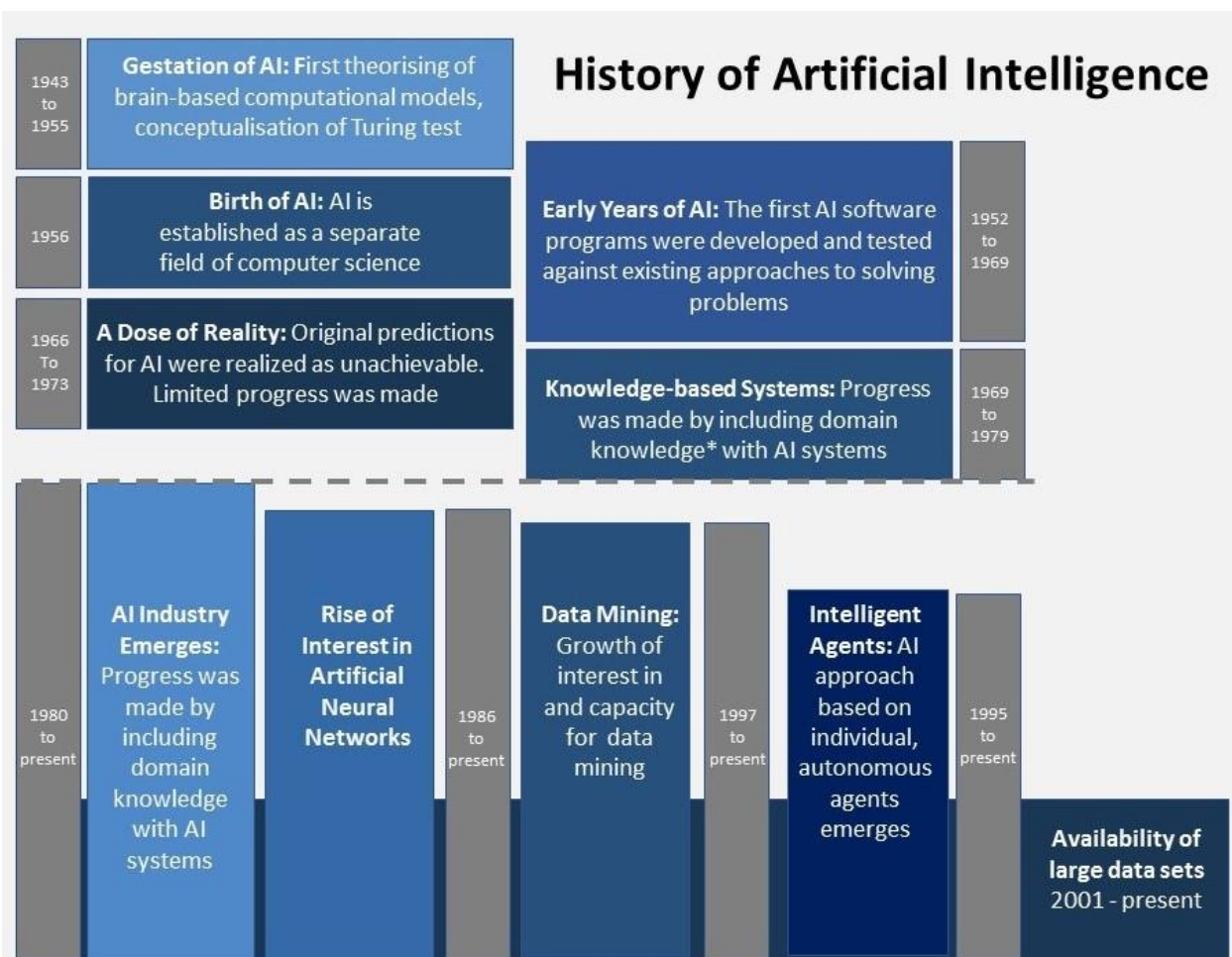
AI can take many forms. This includes robots that mimic human interaction, robotic manufacturing systems and ubiquitous computing systems. Ubiquitous systems are everyday objects with incorporate the capability of a computer, for example driverless cars and smart home devices.

Ubiquitous computer systems are more difficult for people to recognise as the computer programs are not apparent to the user.

## 2.3 The history of AI

AI is by no means a new phenomenon, with the term first coined in 1955, and the quest for machines to demonstrate human-like traits linked back to the 1940s (Bush, 1945). Alan Turing (1950) described a test that would allow people to answer the question – Can machines think? The Turing Test, and variants of it, has endured as a benchmark for assessing if a machine is able to exhibit intelligent behaviour equivalent to, or indistinguishable from, that of a human. Put simply, the Turing Test is passed if someone can interact with a machine, and from that interaction, be unable to tell if they are interacting with a machine or a real human. The Turing Test, in its original form, has been passed (Warwick & Shah, 2016). However, our expectations of what can be achieved with AI has grown, and new understandings of the Turing Test have yet to be passed (You, 2015).

Figure 1: History of Artificial Intelligence



\* Domain knowledge refers to the knowledge that human experts hold in a specific area that an AI system is being created to operate in. For example, an AI system designed to recognise speech patterns would need to include the expert knowledge from the domain of linguistics.

In the history of AI, progress has been staggered, and early development stages include periods where only incremental changes occurred (Figure 1). From the 1980s onwards, growth has been rapid, and occurring in multiple areas simultaneously. This growth has been enabled by increases in the computational power of computers, including the availability of supercomputers and decreases in the cost of data storage devices. From 2001 onwards, the development of AI has been further driven by the availability of the large data sets required to develop robust AI systems and new ways to store data. The concept of big data, or data sets that are very large in size and may comprise non-numeric information (e.g. text, images) that changes rapidly and cannot be handled with standard off-the-shelf software, have been considered since as early as 1997 (O’Leary, 2013). However, availability of these data sets was limited until large scale development of the internet and innovations in data storage capacity.

### Highlights

The term artificial intelligence was first coined in the 1950s.

Since the early 2000s, advancement in AI has been driven by the expansion of the internet, availability of ‘big data’, and more powerful computing and algorithms.

## 2.4 Different types of AI

### 2.4.1 Classifying AI

The development of AI systems, that is software or machines that display human-like thinking, has been influenced by many disciplines. These include mathematics, computer science, philosophy, economics, neuroscience and psychology (Russell & Norvig, 2010). These disciplines have also contributed the language that is used to discuss AI concepts, including terms such as memory, autonomy, learning, and intelligence. It is important to recognise that while terms such as these have specific meaning when referring to human traits, their use when describing concepts within AI is fundamentally different. For example, ‘intelligence’ usually refers to higher-order thinking abilities in humans. However, ‘artificial intelligence’ is not like higher order thinking and may be better thought of using the term cognitive computing (Aleksander, 2017).

There are various ways to classify AI (Figure 2). Within computer and mathematical science, AI is generally viewed through the subfields focussed on developing AI techniques, tools, and approaches. These include areas such as machine learning (see section 2.6), expert systems, vision, speech and natural language processing, optimisation, and robotics. Another way of categorising AI comes from neuroscience, where AI is classified using a ‘human thinking’ lens (Marr, 1977). In this way, AI can be considered as either ‘acting rationally’, ‘thinking rationally’, ‘thinking humanly’, or ‘acting humanly’ (Russell & Norvig, 2016). A common approach to describing the current and future state of the AI field makes use of the terms:

- Narrow (also called weak) AI;
- General (also called strong) AI; and
- Superintelligence (also known by the terms super AI or the singularity).

Figure 2: Types of Artificial Intelligence (Adapted from Hintz, 2016).

<b>Superintelligence</b> <u>Example:</u> None. Does not exist.		AI that exceeds human intelligence in every field.
<b>General AI</b>	<b>Self Awareness</b> <u>Example:</u> None. Does not exist.	AI at this level would extend the ‘theory of mind’ to predict the internal states of others. Having achieved human-like consciousness, it might choose to exhibit non-human abilities.
	<b>Theory of Mind</b> <u>Example:</u> None. Does not exist.	This type of AI would have an updatable representation of the world that includes an understanding that other entities in the world also have their own internal states.
<b>Narrow AI</b>	<b>Limited Memory AI</b> <u>Example:</u> Virtual assistants, self-driving cars.	This type of AI receives current input, and adds pieces of this input to its programmed representation of the world. This can change the way the AI makes current or new decisions.
	<b>Reactive AI</b> <u>Example:</u> AI chess player.	Designed for a specific task, this AI receives input, and acts on this input. They cannot be applied to different tasks, and past experiences do not affect current decisions.

### 2.4.2 Narrow AI

In today’s society, we have narrow (or weak) AI. Narrow AI are only able to do the single or focused task they were designed to do. Their efficiency or effectiveness at doing these tasks may outperform human performance (Silver, et al. 2016), and the complexity of the task can give the appearance of an intelligence greater than actually exists (by human standards). The range of AI systems that fit within the narrow AI band is considerable. A nuanced way of conceptualising Narrow AI is by delineating into reactive AI or limited memory AI (Hintze, 2016).

Reactive AI perceives situations and acts on what it sees without relying on ‘memories’, or past ‘experiences’, or concepts of the wider world. It needs good algorithms and fast computing speed to surpass humans in very narrow well-defined domains. A prominent example of this type of AI is Deep

Blue, IBM's computer that beat chess grandmaster Garry Kasparov. This type of AI is informed by decades of research on human expertise that has convincingly shown that, for example, chess experts are not more intelligent than others but rather rely on extensive domain-specific knowledge in chess that help them recognise larger 'chunks' of chess formations and immediately recall potential successful strategies (Chase & Simon, 1973). Unlike human chess grandmasters who have other skills beside playing chess (such as having a conversation or preparing food), reactive AIs do not have additional skills, but they may well surpass humans in narrow areas of expertise. Unlike humans, reactive AI will always make the same decision, or respond in the same way, to the same input data. With reactive AI approach does not vary over time, and past data and decisions do not affect current decisions.

Limited memory AI can accumulate 'memories' and add 'experiences' to pre-programmed representations of the world. It has sufficient 'memory' to make proper decisions and execute appropriate actions. This leads scientists to consider limited memory AI as having the capacity to 'learn'. As new information is added to programmed representations of the world, the decision-making process of the AI adapts. The decisions and actions that the AI makes can change over time, and past data and decisions may also affect current decisions. In this regard, limited memory AI resembles humans: Human learning means adapting behaviour based on experience. However, human memories are not objective recordings of past experiences, but rather encoding, storing, and retrieval is inherently constructive (Loftus & Palmer, 1974; Roedinger & McDermott, 1995). This might be one reason why limited memory AI can surpass humans in specific areas through computational intelligence. Self-driving cars or chat bots are examples of this type of AI. However, as with reactive AI, this is still a form of narrow AI, and it is only capable of performing the single or focused task it was designed to do. Limited memory AI does not exhibit the full characteristics we associate with human intelligence.

### **2.4.3 General AI and Superintelligence**

It is at this point in the review that we move from what is the current state of play with AI technology to forecasting (or science fiction). The concept of a general (strong) AI aligns to a future vision where computers and machines think and act like humans. Even AI scientists are unsure if or when AIs of this type will exist (Müller & Bostrom, 2016; Aleksander, 2017). However, considering this type of fictional AI raises the question of what it means to be human and what type of society we want.

General AI refers to AIs with 'theory of mind' and self-awareness. AI with theory of mind would have the ability to not only form a representation of the world but also of other agents or entities within the world. In psychology, theory of mind refers to an important developmental milestone that children usually master by age three or four. It encompasses the recognition that human behaviour is governed by internal states such as knowledge, thoughts, expectations, beliefs, motives and emotions, and that the internal states of other humans may differ from one's own. The theory of mind is essential for human social interaction. AIs have not yet managed this developmental milestone, but science fiction examples include R2-D2 from the 'Star Wars' film franchise or Sonny from the movie 'I, Robot'.

Self-aware AI would go beyond having a theory of mind to being equally intelligent, sentient, and (self-) conscious as humans. Definitions of human intelligence are inconsistent but at its core is the ability to think in an abstract way, learn, and adapt. This includes the human ability to think about and reflect on their own and others' thinking which is called metacognition. Children display rudimentary metacognitive awareness as early as three years old, but people's ability to metacognitively monitor and regulate their own behaviour and their knowledge about their own cognition continues to develop over their lifespan (Kuhn, 2000). Metacognitive self-regulation is at the core of human goal-directed behaviour. AIs have not developed this important developmental milestone, but science fiction

examples include Eva in the movie 'Ex Machina'. This notion that AI, with non-human components and biological limitations, might choose to behave in ways that cannot be conceived of or predicted by humans, leads to the final type of (fictional) AI, superintelligence (also known by the terms super AI or the singularity).

Superintelligence exists only as a hypothesised AI type and is difficult to conceptualise due to its abstract (and fictional) nature. From a philosophical perspective, the argument is made that once general AI systems are achieved, then it is likely that these self-aware systems will envisage their own capabilities and future, creating versions of themselves with superintelligence that exceeds human capability (Primiero, 2017). First speculated by Good (1965), the idea of super AI is not without critics. Key arguments against the development of superintelligent machines are grounded in philosophical concerns about existential threat and current understanding of the computational complexity of AI systems, and the inherent limitations in the possible growth in computing power that would be needed to support this complexity (Wiedermann, 2012). Superintelligent AI remains little more than science fiction at this point of time.

### Highlights

There are various ways to classify AI. One of the most common and popular ways is by the categories, Narrow AI, General AI and Superintelligence (Super AI).

At this time the type of AI we have is Narrow AI. Narrow AI refers to machines that are only able to do the single or focused task they were designed to do. Their efficiency or effectiveness at doing these tasks may outperform human performance but they do not possess the general scope of intelligent behaviour humans have.

At the moment, General AI and Superintelligence only exist in science fiction. These types of AI would exhibit the same intelligence as a human (General AI) or exceed it (Superintelligence). Philosophers and scientists have considered what effects, good and bad, these hypothetical types of AI might have on humanity.

## 2.5 Understanding and misunderstanding AI

Als are categorised on their human-like characteristics such as memory, theory of mind, or self-awareness. For teachers and students to work successfully with intelligent systems and thrive in an AI world, realistic expectations of what the technology can and cannot do is required (Gulson et al., 2018). But what do people think about AIs?

In general, humans tend to assign human-like characteristics to inanimate objects and animals (anthropomorphism). According to developmental scientists, it is normal for children to interact with dolls or toy cars as if they were human. Thus, we would expect children to ascribe human characteristics to AIs and robots.

Numerous studies have been conducted where children, adolescents, and adults have been asked to classify entities with regard to their similarity to humans and inanimate objects. Most of these studies have been about human's perception of robots and participants were rarely told anything about the robots' AI capabilities. For example, Bernstein and Crowley (2008) showed sixty children, aged 4-7 years, photographs of eight entities - namely a person, cat, plant, humanoid robot, rover robot, computer, calculator, and doll. They then asked the children to categorise all entities according to their biological (alive, growth, or reproduction), intellectual (think, remember, or learn), psychological (emotion and

volition), and artificial (made in a factory) characteristics. While over 90% of children recognised that robots were artificial, they also ascribed human-like characteristics to them. For example, children thought the humanoid robot could remember (53%), think (60%), plan (73%), and move (83%), and possessed volition (50%).

Children's categorisations of robots become more realistic with age. In a study by Jipson and Gelman (2007), children as young as 5 years classified a robodog with regard to psychological and perceptual properties similarly to adult participants. However, some aspects of robots seem more difficult to grasp. For example, only 11-year-olds started to explain their classification in an adult-like way that includes programming (Van Duuren & Scaife, 1996). Finally, adults compared thirteen entities with regard to experiences (including hunger, personality, or consciousness) and agency (including memory, self-control, or communication) in an online survey (Gray, Gray, & Wegner, 2007). The robot entity was classified low in experience but moderately high in agency - between a chimpanzee and a 5-year-old girl. This means that some adults ascribed characteristics to robots that go beyond what AI can currently do.

We can only assume that realistically evaluating the intelligence of disembodied AIs might be even more difficult. In one of the few studies on this topic, Druga and colleagues (2017) had children interact with Amazon's Alexa, Google Home, Anki's Cozmo, and Julie Chatbot. Preliminary findings show that older children aged 6-10 years considered these agents to be smarter than themselves based on their access to huge amounts of information.

Some contextual factors might influence students' and teachers' views of robots and AIs. Humanoid appearance seems to bias humans towards ascribing more human-like characteristics and this effect might happen unconsciously (Abubshaid & Wiese, 2017; Rosenthal-von der Pütten et al., 2014). However, too much resemblance to humans might result in discomfort or unease (this is called the 'uncanny valley' effect [Mori, 1970; Tung, 2016]). Furthermore, personal experience with robots and AIs are likely to shape perceptions; previous research has shown that children with experience of robots had more realistic views (Bernstein & Crowley, 2009).

Importantly, how parents or educators introduce these technologies is likely to have a significant impact. Previous research has shown children's perceptions of robots can be influenced by parental explanation about the technology (Jipson, Gülgöz, & Gelman, 2016) or how an experimenter introduced a robot as moving autonomously or via remote control (Chernyak & Gary, 2016). Without personal experience or realistic information, students and teachers may rely on science fiction or inaccurate media portrayals of robots and AIs (Broadbent, 2017). In fact, it has been noted the abilities of robots and AIs have been exaggerated by popular media and even by some AI scientists (Aleksander, 2017).

Dystopian predictions often revolve around scenarios where intelligent systems drive up mass unemployment and aggravate social inequality and unrest, or the advent of a superintelligence that makes humans redundant and takes control (e.g. Skynet from the 'Terminator' movie series). On the other hand, utopian predictions envision a world where AI powered machines and programs have taken over all menial tasks, helped humans to resolve big societal issues such as climate change or social inequality, and facilitate human creativity and happiness. The current state of AI research is still far

removed from such dystopian fears or utopian fantasies (Pinkwart, 2016). Based on this overview, it is appropriate to address the following misconceptions<sup>2</sup> that some people have about AI:

- *Misconception 1 - AI is more intelligent than humans:* Current AI has not yet mastered developmental milestones that average human children master around age four. However, current AI can outperform humans in specific domains and on certain narrow or focused tasks;
- *Misconception 2 - AI is synonymous with robots.* There is overlap between AI and robots, but most AI tools are not embodied in robots and many robots are not powered by AI;
- *Misconception 3 – AI and telerobots are the same thing:* Telepresence is the use of remote controlled technology for apparent participation in distant events. For example, a student in a remote location could use a telerobot to attend regular classes. Telepresence can be achieved without AI. The user can provide the ‘intelligence’ necessary to control the technology; and
- *Misconception 4 – AI is too hard to understand:* Even young children can learn about AI (see Milford’s [2018] book for young learners, 2018). It is up to educators across disciplines, to come together to make learning about and with AI, accessible, interesting and relevant.

While the intelligence of AI systems are frequently overestimated, narrow AI does provide significant benefit across a range of tasks and domains. In the next section, we provide a brief overview of a key subfield of AI, machine learning. This is followed by a discussion on the specialised field of AI in Education (AIED) and ethical implications of the technology for schools.

#### Highlights

Children and adults often overestimate the intelligence of embodied and disembodied AI and automated entities such as non-AI robots.

Children and adults need to have personal experience, guidance and realistic information about the capability of AI and how AI works so that they do not develop misconceptions about the technology.

## 2.6 A brief overview of machine learning

In today’s world of rapid information flows, public discussion about AI is invariably linked to the term ‘machine learning’. Fagella (2018) states that machine learning is ‘the science of getting computers to learn and act like humans do, and improve their learning over time in autonomous fashion, by feeding them data and information in the form of observations and real-world interactions’ (n.p.). Maini and Sabri (2017) define machine learning as:

(A) subfield of artificial intelligence. Its goal is to enable computers to learn on their own. A machine’s learning algorithm enables it to identify patterns in observed data, build models that explain the world, and predict things without having explicit pre-programmed rules and models.’ (p.9).

Put simply, machine learning addresses the fundamental question of how to develop machines and algorithms that learn through experience (Jordan & Mitchell, 2015). There are a number of subfields to machine learning which include supervised and unsupervised learning and reinforcement learning. Each of these fields uses different approaches to mathematical modelling to classify and produce meaning

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<sup>2</sup> For an accessible debunking of misconceptions see: <https://www.elsevier.com/connect/the-biggest-misconceptions-about-ai-the-experts-view>



from data sets (Maini and Sabri, 2017). Burrell (2016) provides this reasonably accessible ‘primer’ on machine learning, which is worth quoting in full:

Machine learning algorithms are used as powerful generalisers and predictors. Since the accuracy of these algorithms is known to improve with greater quantities of data to train on, the growing availability of such data in recent years has brought renewed interest to these algorithms. A given machine learning algorithm generally includes two parallel operations, or two distinct algorithms: a ‘classifier’ and a ‘learner’... Classifiers take input (referred to as a set of ‘features’) and produce an output (a ‘category’). For example, a classifier that does spam filtering takes a set of features (such as email header information, words in the body of the email, etc.) and produces one of two output categories (‘spam’ or ‘not spam’). A decision support system that does disease diagnosis may take input (clinical presentation/symptoms, blood test results) and produce a disease diagnosis as output (‘hypertension,’ ‘heart disease,’ ‘liver cancer’). However, machine learning algorithms called ‘learners’ must first train on test data. The result of this training is a matrix of weights that will then be used by the classifier to determine the classification for new input data. This training data could, for example, be emails that have been pre-sorted and labelled as ‘spam’ or ‘not spam.’ Machine learning encompasses a number of models that are implemented in code in different ways. Some popular machine learning models include neural networks, decision trees... and logistic regression. The choice of model depends upon the domain (i.e. loan default prediction vs. image recognition), its demonstrated accuracy in classification, and available computational resources... (p.5).

Machine learning can offer a powerful way to detect patterns in big data sets and can be useful in guiding human decision-making. However, it is not without its problems. This includes the way it is driven by access to big data and the privacy concerns associated with the harvesting and automated web ‘scraping’ of this data without informed consent. This includes mining data to discover patterns that were not anticipated by users when providing data. For example, data provided to a social media platform on hobbies and ‘likes’, that are then matched with data from other platforms to enable individualised political advertising, has recently caused significant concern. Another problem arises when training data contains social biases, that then produce machine learning applications that have also ‘learnt’ and display biased behaviour or decision making. Its ‘opaque’ or ‘black box’ quality (Burrell, 2016), stemming from the proprietary nature of algorithms *and* the complexity of some types of deep machine learning such as artificial neural networks (see section 2.7.5 and 2.8.6), in which even the scientists who develop the systems are unable to completely understand how the machine makes its decisions, is also of concern. This latter point is particularly important when decisions affect human life or life opportunities and involve vulnerable groups (more on this in section 2.8.1 on the ethics of AI).

### Highlights

Machine learning is a subfield of AI.

Machine learning involves getting computers to learn over time in an autonomous fashion by giving the computer data from the real world.

Machine learning can offer powerful ways to detect patterns in ‘big data’ sets and be useful in helping humans make decisions.

There are a number of concerns about machine learning. These include its need to learn from ‘big data’ which may have been collected without consent or used in ways that people did not anticipate. Another concern relates to biased data sets use to train AI and that allow AI to make decisions that discriminate against certain groups. The ‘opaque’ nature of ‘deep’ machine learning (e.g. artificial neural networks) also makes it difficult to understand how and why an AI makes its decisions.

## 2.7 The field of Artificial Intelligence in Education (AIED)

### 2.7.1 Overview

Since the 1970s, Artificial Intelligence in Education (AIED) has grown as a specialised interdisciplinary field that encompasses the application of the technology to learning and instruction, mainly in tertiary and higher education contexts. The goal of AIED is to enable more personalised, flexible, inclusive, and engaging learning and to automate mundane teaching tasks through automated assessment and feedback (Gulson et al., 2018; Luckin et al., 2016). In theory, AIED powered assistants could help parents to improve their infants' early language development, and assist teachers in selecting resources, organising lessons, and increase engagement and personalise learning for their students (Porayska-Pomsta, 2016). AIED assistants could be embodied in robots or virtual assistants (VAs), and they could be integrated into virtual or augmented reality environments. They might also have sensors collecting visual, auditory, and physiological data about students and teachers (see the section 2.8.1 on the ethical implications of this type of biometric data). This type of data on learning could be used to further our understanding of how learning unfolds in real time and help teachers select the most effective instructional approaches (Luckin et al., 2016). AIED tools should be able to assist in counteracting student dropout or teacher burnout (Coccoli, Maresa, & Stanganelli, 2016) and may contribute to closing achievement gaps between students due to individual or social differences. Nevertheless, despite decades of research in this area (du Boulay, 2016), current AIED tools do not fully use the potential of the technology and seem far from fulfilling these promises (Stone et al., 2016).

Some teachers may fear that their jobs might be endangered by smart machines. In fact, some 'teaching robots' have been created (Stone et al., 2016). Most experts agree that while teachers' roles may change, AIED will augment than replace educator expertise (Edwards, Edwards, Spence, & Lin, 2018; Luckin et al., 2016). Others argue that the use of AIED will be relatively slow (Gulson et al., 2018). Taking full advantage of the benefits of AI should be viewed as a transformative process, requiring a fundamental reimagining of the roles people play in many areas of work (Popenici & Kerr, 2017). Effective use of AI would free up teachers to do what humans do best: dealing with ambiguity, exercising judgement, and high-level abstract thinking (Daugherty & Wilson, 2018).

In order to realise these benefits, future teachers will need to be AI literate (Kandlhofer, Steinbauer, Hirschmugl-Gaisch, & Huber, 2016). This will involve developing a realistic understanding of AI capacities in order to successfully orchestrate and oversee the use of AIED tools in the interpretation of data for enhancing instructional approaches to student learning and engagement (Pinkwart, 2016). Teachers will need to prepare their students for a fast-changing AI world with unknown requirements for future workforce skills. Most likely, this implies more emphasis on non-routine cognitive and non-cognitive 21st Century Skills such as creativity for innovation, critical thinking, problem solving, decision making and collaboration (Gulson et al., 2018; Luckin et al., 2016). AIED may be able to facilitate lifelong learning for teachers and students by providing on-demand, online training options (Gulson et al., 2018).

There are several key trends in AIED including intelligent tutoring systems, pedagogical agents, smart classroom technologies, and adaptive learning (Figure 3 shows the relationships between these, with a caveat that, at present, AI may or may not be infused into the technology).

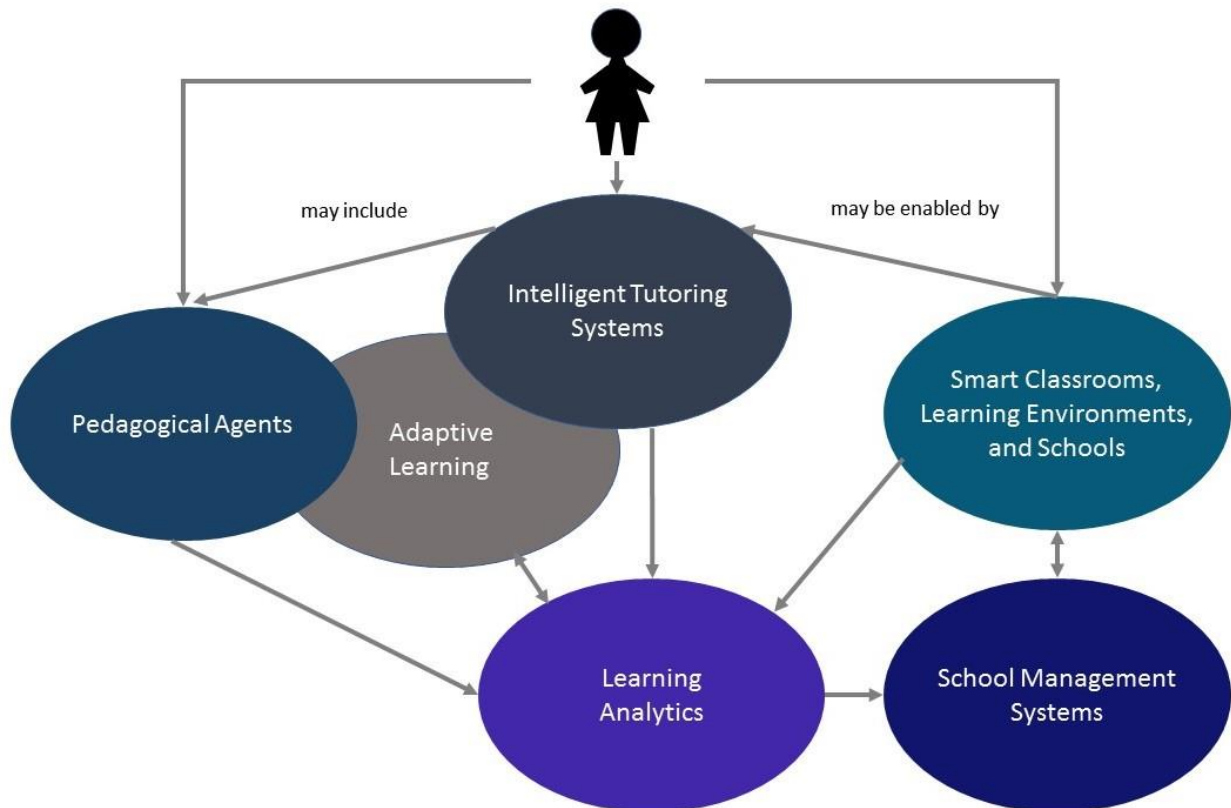
#### Highlights

Since the 1970s, the specialised field of Artificial Intelligence in Education (AIED) has grown to encompass the application of the technology to learning and instruction.

The goal of AIED is to develop systems that enable personalised flexible and engaging learning and to automate mundane teaching tasks such as assessment and feedback

AIED is interested in developing AI-powered systems such as intelligent tutoring systems, virtual pedagogical agents that act as a peer or instructor, embodied AI robots, and 'smart' classrooms.

Figure 3: Overview of typical AIED applications and their relationships.



### 2.7.2 Intelligent tutoring systems

Intelligent Tutoring Systems (ITS) simulate one-on-one human tutoring (Luckin et al., 2016). Human tutoring is widely considered a very effective type of instruction (van Lehn, 2011). Human tutors are assumed to possess deep and broad knowledge about the content domain and sophisticated tutoring strategies such as Socratic dialogues. More importantly, effective human tutors accurately diagnose their students' motivation and knowledge and personalise the selected learning activities and tasks to match their students' needs. During any task, tutors may deploy scaffolds, prompts, hints and immediate feedback to help students with each problem-solving step. Research has shown that learners do not take full advantage of human tutors as they rarely ask questions, and tutors are not perfect, for example, at diagnosing student misconceptions or personalising their learning tasks (van Lehn, 2011). Nonetheless, human tutors have been used to envision ITS, with intelligent systems choosing pedagogical and tutorial strategies, engaging students in individualised learning dialogues, and improving themselves over time (Baker, 2016).

Before the advent of ITS, Computer-Assisted Instruction (CAI) was already able to give immediate feedback to students, but only after students answered questions (Kulik & Fletcher, 2016). One of the first ITS that went beyond CAI was SCHOLAR in 1970 (Ma, Adesope, Nesbit, & Liu, 2014; Welham, 2008). From a technical point of view, ITS are characterised by the following components:

- a domain or expert model where expert knowledge is stored;
- a pedagogical model where efficient pedagogical and tutorial strategies are stored;
- a student model based on learner characteristics or students' actions in the ITS. The ITS system collects data or makes inferences about the students' knowledge; misconceptions, emotions, or motivation. From this, the ITS can diagnose divergence from the expert model and suggest personalised tasks, hints, or feedback; and
- an interface to communicate with the user. This can be either through written or natural language dialogue with or without virtual pedagogical agents representing the ITS (du Boulay, 2016; McArthur, Lewis, & Bishay, 2005; Welham, 2008).

All of these components are inspired by interdisciplinary research from cognitive science, psychology, education, and information systems. There is a wide range of ITS. These differ substantially in the programming and it is important to realise that not all ITS are powered by AI. ITS also differ substantially in their content. Some ITS focus on domains with mathematical rules, others teach reading or writing, and yet others try to teach domain-general competencies such as self-regulated learning strategies (Kulik & Fletcher, 2016; Ma et al., 2014; Steenbergen-Hu & Cooper, 2014).

Numerous studies have compared the effectiveness of ITS with human tutors, regular classroom instruction, or no instruction. Having reviewed at times more than 100 studies, most meta-analyses and systematic reviews conclude that ITS are significantly more effective than many other instructional methods such as regular classroom instruction, homework assignments, learning with CAI or with textbooks (Kulik & Fletcher, 2016; Ma et al., 2014; Steenbergen-Hu & Cooper, 2014; van Lehn, 2011). On most educational levels, ITS had similar positive effects on learning as human tutors (van Lehn, 2011; du Boulay, 2016; Ma et al., 2014), but for college students ITS were less effective than human tutors (Steenbergen-Hu & Cooper, 2014). Effects in the domain of mathematics in K-12 populations were small and most pronounced for motivated students with good self-regulatory skills (Steenbergen-Hu & Cooper, 2014). This result suggests that the use of ITS may not automatically decrease gaps in achievement for all learners.

Researchers have noted that existing ITS school implementations are frequently in well-defined domains and use very simple pedagogy and student modelling (e.g., student understands the topic if s/he solves three tasks in a row correctly); however, the most technically sophisticated ITS have not been taken up by schools (Baker, 2016; McArthur et al., 2005). For example, currently there are emotion-aware ITS which use cameras and sensors with eye-tracking and emotion recognition software (see section 2.7.4 on smart classrooms) to dynamically adapt to students' emotions such as frustration, surprise, or boredom by offering different learning materials or prompts (Harley, Lajoie, Frasson, & Hall, 2017). Using this technology for learning is still a relatively new area of development within computer science, machine learning, and cognitive psychology communities, and has prompted debate about ethical issues regarding the collection and use of sensitive data especially for vulnerable populations.

To sum up, ITS could be a useful tool for educators. An important caveat is that the ITS currently used in schools rarely reflect what is technically possible. Where ITS are available for specific domains, they can effectively complement students' learning within or outside the classroom. However, they may never

replace teachers and tutors in all domains or close achievement gaps amongst diverse groups of learners.

### Highlights

Intelligent Tutoring Systems (ITS) simulate (mimic) one-on-one human tutoring.

Existing ITS implementation in schools is usually in well-defined domains and uses very simple pedagogy and student modelling: To date, the most technically sophisticated ITS have not been taken up by schools.

On most educational levels, ITS had similar positive effects on learning as human tutors; however, it may not be suitable for all learners.

### 2.7.3 Pedagogical agents

Pedagogical Agents (PAs) are digital or virtual characters integrated into learning technologies to facilitate instruction. They were created to add a social, emotional, and motivational component to learning technologies (Gulz & Haake, 2006; Kim & Baylor, 2016), and to communicate with learners in natural human-like ways (Johnson & Lester, 2016). PAs can come in many forms and shapes (Heidig & Clarebout, 2011). More often than not, PAs are embodied which means that learners can see pictures of virtual characters or avatars on the screen that realistically or abstractly resemble humans, fictional characters, animals, or objects. For example, PA characters could be as different as realistic three-dimensional whole-bodied human persons, two-dimensional cartoon-like animals, or objects such as 'Clippy', Microsoft Office's legacy virtual assistant in the shape of a paperclip. PAs communicate with learners via written or spoken language.

The most important defining feature of PAs is their instructional function, which distinguishes them from so-called conversational agents such as Apple's Siri (Schroeder & Gotch, 2015). For example, PA can: serve as an information source; demonstrate or model learning content; coach or scaffold information processing self-regulation or motivation; or assess learners (Heidig & Clarebout, 2011). They can also act as navigational guides or guide attention via gestures and gazes (Johnson & Lester, 2016). However, most PAs seem to be used for low-level functions such as providing information (Schroeder & Gotch, 2015).

Learning systems can also have multiple PAs that embody different functions such as an Expert, Motivator, and Mentor (Kim & Baylor, 2016). For example, AutoTutor (Graesser, Li, & Forsyth, 2014) is an ITS which holds conversations with the human and has produced learning gains across multiple domains (e.g., computer literacy, physics, critical thinking). It stimulates dialogues between a virtual tutor PA (Cristina), a virtual peer PA (Jordan) and the learner ([www.autotutor.org](http://www.autotutor.org)). Cristina (PA tutor) usually explains content, and gives feedback, prompts, and hints. Jordan (PA peer) acts as a co-learner and also answers Cristina's questions or asks questions himself. Jordan competes with the human learner in answering questions correctly. Cristina and Jordan can also disagree or argue and thereby stimulate the human learner to problem solve during the process. Research indicates that AutoTutor yields 'learning gains comparable to those of trained human tutors, with effect sizes averaging 0.8' (Graesser et al., 2014, p. 375).

While some PAs act as learning-companions or peers (Johnson & Lester, 2016; Kim & Baylor, 2016), PAs can also be teachable: The human student can teach some PAs and this takes advantage of the instructional idea of teaching-by-learning and knowledge gain through explanation (the self-explanation

effect) (Biswas, Segedy, & Bunchongchit, 2016). Being artificially intelligent is not necessarily a feature of PAs, but many PAs can be classified as AI (Schroeder, Adesope, & Gilbert, 2013). However, even PA researchers acknowledge that their PAs are often not very 'intelligent' (Kim & Baylor, 2016).

Evidence regarding the effectiveness of PAs is mixed. At a theoretical level, the proponents of PAs argue that the presence of a PA persona should provide social cues and therefore make the learner interact with the learning technology as with another human being (e.g., Heidig & Clarebout, 2011; Schroeder et al., 2013). Hence, human-like voices or gestures should theoretically enhance learning and motivation. Additionally, in conjunction with ITS, PAs could provide learners with personalised and adaptive instruction. The critics of PAs argue that the embodied PAs and written dialogues might constitute 'seductive' details that distract students from concentrating on learning content (Heidig & Clarebout, 2011; Schroeder et al., 2013).

During the last two decades, numerous studies have compared the effectiveness of learning technologies with and without PAs, but the benefits remain debatable (Schroeder & Gotch, 2015). Heidig and Clarebout (2011) found no convincing evidence for the effectiveness of PAs in their systematic review, mostly due to the lack of scientific rigor of the reviewed studies. Schroeder et al. (2013) found small but significant benefits of PA systems ( $g = .19$ ) in their meta-analysis of 43 studies. Focusing exclusively on embodied agents, Guo and Goh (2015) found small to moderate impact of PAs on learner motivation ( $r = .35$ ), retention ( $r = .29$ ), and transfer ( $r = .26$ ) in their meta-analysis of 30 articles. Schroeder et al. (2013) found positive PA effects especially in the K-12 age group and in science and mathematics. Focusing exclusively on the benefits of gestures, Davis (2018) showed significant impact of gestures regarding retention ( $g = .28$ ) and transfer ( $g = .39$ ). Other studies have shown that PAs are more effective when they speak rather than communicate in writing (but see the opposite conclusions of Schroeder et al., 2013) and when they use polite phrasing (Johnson & Lester, 2016). These mixed patterns are probably partly due to the fact that existing PAs are very diverse, and it is therefore hard to isolate effects (Schroeder & Gotch, 2015), and that PAs were initially created from a technological perspective without much educational consideration (Heidig & Clarebout, 2011).

Recent technological progress continues to improve PAs (Johnson & Lester, 2016). Today it is possible to create virtual humans; advances in affective computing (systems that sense, interpret, simulate and even influence human emotion) allow learning technologies including PAs to recognise emotions and adapt to learners' boredom or frustration. Natural language processing enables PAs to communicate in limited interactive dialogues with learners. PAs can even be embodied in robots to interact with learners in a classroom environment. In the future, each person might have multiple personal PAs that accompany him or her throughout life. Thus, PAs could become very powerful from a technological perspective, although there is a counter argument for having a lifelong PA that could remind us of times when we have failed! Even after decades of research, the evidence regarding the effectiveness of PAs is mixed and we do not yet know how to design the ideal PA. For example, fully anthropomorphising agents to appear human might not be necessary (Schroeder et al., 2013). Additionally, PAs are often created for a narrow domain and audience and little is known about their cost-effectiveness (Schroeder & Gotch, 2015). At present, despite achieving high levels of visual realism in virtual characters (Feng, Rosenberg, & Shapiro, 2017), verbal AI communication using natural language processing techniques is a challenge. Moving from mere AI derived utterances taken from a dialogue database to more natural conversational modes still requires a solution (Ram, et al., 2018). Consequently, we recommend looking at the instructional function of PAs rather than at their visual appearance or verbal communication style.

Current PAs are yet to take full advantage of technological opportunities regarding instructional functions (Schroeder & Gotch, 2015). Advances in personal assistants or conversational agents such as Apple's Siri are promising for PAs. However, at this point of time, it is unclear if PAs with specific and narrow focus or more versatile conversational agents will be more helpful to learning and instruction in the long run.

### Highlights

Pedagogical Agents (PAs) are virtual characters integrated into learning technologies to facilitate instruction.

PAs were created to add a social, emotional, and motivational component to learning technologies and to communicate with learners in natural human-like ways.

Evidence regarding the effectiveness of PAs is mixed and some argue that students may be distracted from their learning by PAs.

### 2.7.4 Smart classrooms, learning environments and schools

The 'Internet of Things' (IoT) is a term used to describe the increasing capacity for everyday items to connect to the internet and interact with other devices (Timms, 2016). This extends to smart homes, including light switches, fridges and plumbing (Timms, 2016). Some further examples are smart cities, smart transport and smart environment monitoring (Mohamed, Abdelsam, & Lachen, 2018). A rise in the prevalence of smartphones and other ubiquitous computing devices (Yahya, Ahmad, & Jalil, 2010) has allowed the IoT to develop further. In essence, the IoT is a broad, overarching term that covers the increased use of sensors and technologies for capturing and transmitting data from everyday items and wearables (a gadget or device that can be worn which has sensors and computing power). This data provides powerful input to AI systems.

The IoT is essential for smart classrooms, smart learning environments, or smart schools (Heinemann & Uskov, 2018). A smart classroom is defined as a 'technology-rich classroom, equipped with wireless communication, personal digital devices, sensors, as well as virtual learning platforms' (Li, Kong & Chen, 2015, p. 46). Smart learning environments extend this definition to include multi-use flexible physical spaces that can be used for learning and teaching. Smart schools also include similar technology rich non-learning spaces. In an ideal world, smart classroom technology would work directly with teachers to:

- help analyse student learning behaviour and provide appropriate support at the right time to optimise student learning;
- facilitate student comfort and engagement by automatically adjusting the room climate to an ideal learning environment;
- provide prompts and self-analysis to help teachers with the development of their pedagogy; and
- provide immediate and long-term evaluation of the impact of classroom activities on student attention, emotions, engagement and academic outcomes (Hwang, 2014; Liu, Huang, & Wosinski, 2017).

A key tenet of smart classrooms, learning environments, and schools is that technology is used to track, monitor and observe the location, movement, and status of humans and objects in these spaces. For example, IoT technology could be used to sense environmental variables like humidity, air quality, temperature, ambient light, and airflow. In learning spaces, more individual data can be collected via

classroom-wide sensors such as cameras, microphones, or motion sensors. Students and teachers might also have wearable sensors to capture data that would feed into a smart classroom or school system. Wearable sensors could be embedded into clothing or other portable items such as RFID (Radio-Frequency Identification) tags attached to bags, and devices that strap on to the human body such as smartwatches, armbands, smart glasses, brain sensing technology, and medical monitoring devices.

Once collected, the data of smart classrooms, learning environments, or schools can be interpreted by AI systems or human agents to improve learning and instruction. Simply put, most of the technology that exists in smart classrooms are devices that measure and report 'big data' (see the next section 2.7.5). Currently, there is very little AI that exists with large scale implementation that uses this type of data to influence learning in the classroom (Kinshuk, Chen, Cheng & Chew, 2016).

There are a few examples of AI based smart schools: there are accounts of using smart classroom information to automatically adjust the physical environment (lighting, air conditioning, and heating) within schools to benefit learning (Nie, 2013; Timms, 2016; Pocero et al., 2017). In higher education, machine learning has been used to understand the impact of such environmental conditions on university student comfort and performance in exams (Novais & Konomi, 2016). Some researchers have hypothesised a system using sensed body postures and AI to determine student attentiveness (Diaz et al., 2015) or proposed a system to monitor teacher non-verbal behaviour and provide real-time suggestions to improve communication through hand gestures, facial expressions, and body language (Kim, Soyata, & Benagh, 2018).

These examples show that research on smart classrooms, learning environments, and schools is still in its infancy. Despite the availability of technology and AI tools, most smart classroom applications are only at pilot testing and feasibility study stage. The future of smart classrooms may involve full context awareness, in which every learning event can be recognised and real-time adaptive assistance can be provided. However, one of the most important barriers for fulfilling this technological potential are the unresolved ethical issues around collecting individual student biometric data via sensing technologies (see below). The use of the wearable technology that may provide the data to power an envisaged smart classroom remains especially contentious and likely to have legal implications (see section 2.8 on ethics and AI).

### **Highlights**

The Internet of Things (IoT) describes the increasing capacity for everyday items to connect to the internet and interact with other devices. Data from the IoT provides powerful input to AI systems.

The IoT will be essential for smart classrooms and schools of the future.

A smart learning environment is equipped with wireless communication, personal digital devices, sensors, and learning platforms that connect with each other to provide input into AI systems. The AI then make decisions about regulating physical aspects of the environment (e.g. climate control) or learning systems.

Most smart classroom applications are only at the stage of pilot testing and feasibility studies.

### **2.7.5 Adaptive learning and learning analytics**

Adaptive, personalised learning and teaching is an important goal of instruction and is used as a key reason for developing ITS, PAs, and smart classrooms. While ITS and PAs provide a user interface or embodied agent for AI enabled learning activities, these systems frequently use an adaptive system that



is running in the background to deliver tailored learning activities to students (Benyon & Murray, 1993). Within education, *adaptive learning* (also adaptive teaching) refers to the altering of the type of learning tasks, the difficulty of learning tasks, or the interface, to suit the needs of individual learners or groups of learners. Adaptive learning approaches focus on learner behaviour, achievement and learning preferences (Tseng, Chu, Hwan, & Tsai, 2010). Adaptive learning is also a key term in computer science where algorithms are developed to determine how and when to customise learning environments and/or tasks. For example, an ITS aimed at improving learner competence in mathematics might use adaptive learning to provide hints to students so that they are able to solve slightly more difficult problems by themselves. Adaptive learning could be used to gradually withdraw hints until competence is reached, and introduce more difficult tasks with hints, thereby keeping learners in the zone of proximal development (Arroyo, Woolf, Burelson & Muldner, 2014).

Computer based learning environments often capture significant amounts of data about how learners perform and engage with these systems. This data may include simple data such as the time spent in the virtual environment or learning system, or the time taken to perform tasks. Richer data on performance on tasks may also be provided. This data is often numeric data, but frequently involves text, images, and videos; all of this data is often temporal in nature, capturing user interactions in individual learning sessions and also providing a longer-term view of a student's learning journey. These data characteristics are associated with big data. The analysis of data gathered during learner interaction with an educational system is the domain of learning analytics. Of all the areas of application of AI within education, analysis of learner data has the greatest capacity to provide insights that can better inform the allocation of resources, and improve student learning experiences (Long and Siemens, 2011). For example, individual learners - and teachers - could use the feedback from automatic AI powered analysis of the data gathered through smart classroom sensors and other data sources to reflect upon their learning process and progress. Learning analytics leverages human judgement and makes use of automated data analysis, potentially using AI approaches, in support of this. The aim of learning analytics is to gain knowledge from educational settings that can be used by humans to make better decisions.

Educational data mining seeks to achieve similar outcomes to learning analytics, but with less emphasis placed on human judgement: this approach automates knowledge discovery using machine learning. To reiterate, machine learning seeks to develop machines and algorithms that learn through experience (Jordan & Mitchell, 2015) and includes adaptive learning algorithms. These algorithms can fall into an area called *evolutionary computation* which refers to algorithms inspired by the process of natural evolution (Eiben & Smith, 2015). An ITS might use such an algorithm to recognise learning preferences from data on learners' trajectory and speed of progress through the learning material. Only the minimum set of learner preference types that most closely match the variability in various learner approaches, or the 'fittest' combination of types, would 'survive' to be used to explain learning preferences.

Other algorithms that are used in adaptive learning mimic human cognitive processes, such as *artificial neural networks* (ANNs). ANNs use a simplified brain model consisting of layers of processing elements (neurons) connected with coefficients (weights). The weights are adjusted by the ANN when new input data is received (learning), and the weights also represent the memory of the system (Agatonovic-Kustrin & Beresford, 2000). For example, an ITS with such an algorithm would use learner answers to questions to predict whether a new question is likely to be within the student's zone of proximal learning. The adaptive nature of the algorithm means that new answers to questions are used to

continuously train the algorithm so that predictions are made in the context of all previously answered questions.

As a field, educational data mining continues to grow. Different types of data, such as images, videos, text and sound, and biometric data such as eye tracking potentially captured through smart classroom technology, pose new problems and challenges for AI algorithms. *Deep learning* is a subset of machine learning. It is one approach that is being used to find patterns, classify, and generate new content in images and videos. In deep learning the machine continually analyses data using its own 'thinking' structure to make inferences. Deep learning uses multiple ANNs at lower levels of abstraction to effectively solve parts of a problem and provide these partial solutions to ANNs at higher levels to derive a global solution (LeCun, Bengio & Hinton, 2015). For example, a future smart classroom might capture audio-visual data which is processed using a deep learning approach. Deep learning would break the audio-visual data down, and different ANNs would set to work on recognising people (torsos, limbs), faces (eyes, noses, mouths), hands (fingers, palms) and voices in the data. Other ANNs would use the results from these ANNs to classify emotional expressions from the faces and voice tones, and yet other ANNs would process all these results to assign emotional states to individuals in the class, as well as an overall classroom climate. This is a simplistic explanation of the process; however, it serves to illustrate the power of deep learning approaches to process large amounts of complex data.

Big data drawn from ITS or learning management systems can offer insights on how individual learning unfolds over time and on which instructional approaches are effective under which conditions. The analysis of this data is only possible via learning analytics and educational data mining approaches using AI powered evolutionary computation, machine learning, ANN and deep learning algorithms. These approaches may have benefits for students and teachers providing opportunities for self-reflection and self-awareness in learning, improved assessment and feedback, and to predict academic performance, behaviour, dropout and retention (Papamitsiou & Economides, 2014). One of the most important envisioned benefits is more adaptive personalised learning and instruction. However, the ethical issues around the use of AI powered systems in education and elsewhere are far from resolved. It to this issue we now turn.

### Highlights

Adaptive, personalised learning and teaching is ITS, PAs, and smart classrooms. While ITS and PAs provide a user interface, AI can power the adaptive system.

Adaptive systems can be used to gradually withdraw scaffolding until the learner reaches competence.

Big data drawn from ITS or learning management systems and can offer insights on how individual learning unfolds over time and on which instructional approaches are effective under which conditions.

The analysis of this data is only possible via learning analytics and educational data mining approaches enabled by certain types of AI systems using techniques such as evolutionary computation and artificial neural networks.

## 2.8 Ethics, artificial intelligence and education

AI is certainly not unique among emerging technologies in creating ethical quandaries... Yet ethical questions in AI research and development present unique challenges in that they ask us to consider whether, when and how machines should...make decisions about human lives – and whose values should guide those decisions. (Campolo et al. 2017, p. 30).

### 2.8.1 Background

For several decades, academic interest in the ethical implication of living with intelligent and autonomous machines and systems has grown exponentially. This field is known by many names including machine ethics, computational ethics, safe/friendly AI, artificial morality and roboethics (IEEE, 2017<sup>3</sup>). This interdisciplinary ethical project is closely linked to understanding the economic and sociocultural opportunities and consequences of living with semi or fully autonomous computing systems. Such systems include embodied AI service robots that perform tasks for humans and disembodied AI, diffused through everyday computing applications that can, purposefully or unintentionally, impact on human decision-making and agency (the ability of humans to act freely in the world) (Torresen, 2018).

The actual and conceivable ethical implications of AI have been thoughtfully canvassed for several decades. Since 2016, the US, UK and European Union have conducted large scale public inquiries which have grappled with question of what a good and just AI society would look like (see Cath et al. 2018 for a review of this). AI ethics necessitates many questions:

What does it mean for an AI system to make a decision? What are the moral, societal and legal consequences of their actions and decisions? Can an AI system be held accountable for its actions? How can these systems be controlled once their learning capabilities bring them into states that are possibly only remotely linked to their initial, designed, setup? Should such autonomous innovation in commercial systems even be allowed, and how should use and development be regulated? (Dignum, 2018, p.1).

Much popular and some scholarly attention, has been paid to the existential threat that artificial superintelligence might pose in the future: however, it is worth noting that experts think that this type of AI is many decades from being realised, if ever (Müller & Bostrom, 2016). Some contend that it is premature to spend our efforts speculating about the morality of super AI and that we should instead focus on addressing the ethical issues presently arising from 'not-so-intelligent machines' or narrow AI (Rose, Aicardi & Reinsborough, 2016). Ethical concerns about existing AI are exceedingly complex and require concerted attention, being inextricably linked to well-documented problems associated with the 'datafication' of contemporary life (Van Dijck, 2014). These include the unscrupulous harvesting and use of big data (boyd and Crawford, 2012) and harms linked to impingement on information privacy and data induced discrimination (Metcalf and Crawford, 2016).

Moreover, the growing influence of algorithms in guiding human decision making at individual, institutional and even transnational levels has raised questions about accountability if harm eventuates, especially in relation to algorithmic bias (Mittelstadt et al., 2016). The ethics of AI intersect with quandaries regarding affective computing (computing systems that sense, interpret, simulate and even influence human emotion) (Cooney et al., 2018) and biometrics (personal physical, physiological or

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<sup>3</sup> The IEEE is the acronym for the Institute of Electrical and Electronics Engineers, the world's largest technical professional association. It is composed of engineers, scientists, and allied professionals including computer scientists, software developers, IT professionals, physicists, medical doctors, and others. For this reason, the organization no longer goes by the full name, except on legal business documents, and is referred to simply as IEEE (<https://www.ieee.org/about/ieee-history.html>).

behavioural characteristic data that acts as a unique identifier, for example facial or voice recognition or eye tracking) (Dewa, 2017).

Apart from the legal imperative to act in the best interests of students, educators and those that govern them have good pragmatic reasons to display ethical leadership in the fast-moving and uncertain field with AI technology. Educators should be engaged in actively building public trust in new (and existing) technologies by asking probing questions about their purpose, efficacy, evidence base and ethical implications. The way school systems engage AI will be largely determined by the trust that the public, parents and caregivers, students and the teaching profession has in the technology. This trust must be founded on the ability of AI-powered systems to promote worthwhile and fair learning opportunities and the well-being of students and their school community as whole (c.f. Dignum, 2018).

It is not possible in this literature review to do justice to the complexity of contemporary AI ethics as an evolving and contentious field with many related strands, debates and rich multidisciplinary perspectives. This would entail writing a much more involved document (for example, the IEEE [2017] review of ethics in the design of autonomous and intelligent systems is more than 250 pages long). We do however have scope to proceed in two directions. Firstly, we establish the current state-of-play by summarising some of the key ethical concerns raised in recent publications about AI and education.

Secondly, and perhaps more importantly, we provide an original conceptual framework as a tool to enable all stakeholders, no matter where they are located within an education system — in classrooms or school communities or governing institutions — to carefully think through and ask questions about the ethical implications of AI in schools. Our Education, Ethics and AI (EEAI) framework (Figure 4) is designed as an accessible ‘thinking tool’ to enable the education sector to engage in ongoing, systematic, open dialogue and decision-making regarding the potential of AI for harm and for good. It is a conceptual device that can be used to proactively identify and respond to the ethical issues of AI in education as they emerge, a position that is far superior to reactively responding to harm.

As we journey into an AI world, any ethical framework will need to be reshaped so that unforeseen opportunities and risks can be addressed and differing social and cultural moral and normative perspectives can be included (IEEE, 2017). While the EEAI framework draws primarily from western philosophic traditions, it does provide, at this historical juncture, a solid foundation to begin ethical conversations using language, concepts, and principles which have been established within the international arena (Bird et al., 2016; IEEE 2017, Latonero, 2018; Australian Human Rights Commission, 2018). We therefore present the EEAI framework, unpack its components and provide an example of its application in prompting questions about the design, implementation and governance of AI in education. We hope that the EEAI framework empowers educators to have informed public conversations that will invariably involve asking difficult questions about the place of the technology in school communities.

### Highlights

There are decades of research on the ethics of autonomous and intelligent systems.

Many countries are engaged in thinking through ethical, regulatory and legislative approaches to ensure AI is used for the good of humanity.

The way school systems will engage with AI will be largely determined by public education that can build trust in the technology. This trust must be founded on the ability of AI-powered systems to promote

worthwhile and fair learning opportunities and the well-being of students and their school community as whole.

## 2.8.2 Ethical issues in AI and schooling

Education has been designated by AI ethicists as a 'high stakes domain' that requires urgent, ongoing scrutiny and a coordinated response to ensure that the technology is used for the benefit of students, teacher, communities and society more broadly (Campolo et al., 2017). Two recent reviews of AI in education have raised pressing concerns. For example, while Luckin et al. (2016) argues for the use of AI in education, they also highlight issues of privacy and the proprietary nature of AI systems as key concerns:

(W)e know that the sharing of data is essential to the integration of AIEd (artificial intelligence in education) systems, and that sharing of anonymised data has the potential to move the field forward by leaps and bounds by cutting back on wasteful duplicative efforts. But this type of sharing introduces a host of problems and questions, from individual privacy to proprietary intellectual property concerns. Indeed, the growing volume and diversity of data generated by AIEd systems only serves to double-down on the already existing ethical concerns about what happens to education data. What are the implications of the methods, technologies, and ideologies that underpin the generation, analysis, interpretation, and use of AIEd system data? Who owns the data, who can use it, for what purposes, and who is ultimately accountable? (p. 39).

Luckin and colleagues (2016) also identify the potential for AI teaching assistants to be used to unfairly or surreptitiously surveil the performance of teachers, a point supported by Campolo et al. (2018) who recommends that 'more research and policy making is needed on the use of AI systems in workplace management and monitoring' (p.1). Other concerns include the way in which AI aims to change learning behaviour through making recommendations, using persuasion and offering feedback, which may not ultimately be in the best interests of the learner. There are some who suggest that AI learning companions that are intended to support students on their lifelong learning journeys 'may result in the perpetual recording of learner failure to the detriment of future progress' (Luckin et al., 39).

Gulson and colleagues (2018) literature review, 'Education, work and Australian society in an AI world', provides a wide-ranging overview of key issues including the impact of AI on the future work and the importance of examining the norms and values which are imbued in the data used to train AI systems and then reflected in autonomous decision-making. The review makes the point that:

Our conceptions of machine intelligence, human minds and learning (human and non-human) are increasingly interconnected, with changes in one domain having potential impacts on thinking about the others. It is important to note that AI itself also needs to learn. Computer-based intelligent agents, particularly those based on artificial neural networks, are "machine learners"...that are trained on patterns in big data sets and reinforce these patterns in their actions. So, we must entertain the possibility that in an AI world our conception of learning and education could change, as could our perception of the world and ourselves through our engagement with AI embedded in new media. (Gulson et al., 2018, p.7).

This observation is closely linked to an ethical interest in clarifying the norms, values and assumptions reflected in AI systems so that these *enhance* human potential, creativity and well-being rather than foreclose or homogenise it. This interest in norms and values goes to the heart of the purpose of any education system: Norms and values must be deliberated on and clarified in an ongoing manner if AI is

to do good. Williamson, Pykett and Nemorin (2017) suggest that some AI in education initiatives 'proceed from a deficit view of cognition, maintaining that human cognition and intelligence can and should be enhanced and extended – by being rewired – through the integration with machine-based cognitive systems' (p. 269). Education has a deep history of both propagating and challenging deficit discourses – it behoves educators to seriously examine assumptions underpinning the rationales for 'augmenting' human intelligence.

Looking to the future, engineers and computer scientists themselves point out that societal, cultural, and group norms and values often conflict and change over time. They posit that very careful consideration must be paid to how AI is designed to respond to such change, a point that is particularly pertinent to the intensely human domain of education:

If machines engage in human communities as quasi-autonomous agents, then those agents will be expected to follow the community's social and moral norms. Embedding norms in such systems requires a clear delineation of the community in which they are deployed. Further, even within a particular community, different types of technical embodiments will demand different sets of norms.... (Autonomous and intelligent systems) may be equipped with a norm baseline before it is deployed in its target community... but this will not suffice for it to behave appropriately over an extended period of time. It must be capable of identifying and adding new norms to its baseline system... (and) also updating existing norms, as change occurs... (It can do this through) multiple mechanisms such as... (p)rocessing behavioural trends,... (a)sking for guidance from the community,... responding to instructions from the community (and)... to critique from the community when (it) violates a norm. (IEEE, 2017, pp.7-38).

There are renewed calls for ethics to be firmly integrated into curriculum and linked to digital and information literacy so that we educate citizens, including those within school communities, to be sensitised to risks associated with the misuse of autonomous and intelligent systems (IEEE, 2017, p.30). This includes more sustained emphasis on discerning and countering AI generated 'fake news' or 'deep fakes'. 'Deep fakes' refers to videos generated by a specific machine learning technique which produces very realistic simulations, often of famous people, that are increasingly resistant to detection (Chesney and Citron, 2018). The recent emergence of 'deep fakes' presents significant challenges to teaching digital and information literacy and critical thinking, and yet it will be more important than ever to focus the curriculum on these areas:

'The marketplace of ideas already suffers from truth decay as our networked information environment interacts in toxic ways with our cognitive biases. Deep fakes will exacerbate this problem significantly. Individuals and businesses will face novel forms of exploitation, intimidation, and personal sabotage. The risks to our democracy and to national security are profound as well.' (Chesney and Citron, 2018, n.p.).

Another issue requiring more attention is the integration of algorithmic 'nudging' into 'hard coded' and AI systems. Brought into the popular science domain through Thaler and Sunstein's (2008) book *Nudge*, nudge theory is a concept popular in behavioural, political, and economic sciences that promotes the use of mechanisms to influence people's choices without coercion or limiting choices. 'Nudging' can be a feature of persuasive computing and involves subtle attempts to modify the behaviour of the user. It is 'an attempt to shape behaviour without resorting to legal or regulatory means' (Borenstein and Arkin, 2016, p.33). There are numerous ethical questions associated with 'nudging' in a range of domains, as it can devalue respect for human autonomy and dignity and potentially be used for manipulation and

deception (Borenstein and Arkin, 2016, p.38). Concerns about the ethics of ‘nudging’ on vulnerable populations such as children have been raised:

(S)hould affective systems be employed to influence user’s behaviour for that person’s own good?... Several applications are possible in health, well-being, education, etc. Yet a nudge could have opposite consequences on different people, with different backgrounds and preferences... Another key... issue to be addressed is whether an affective system should be designed to nudge a user, and potentially intrude on individual liberty, when doing so may benefit someone else... Additional protections must be put in place for vulnerable populations, such as children, when informed consent cannot be obtained or when it may not be a sufficient safeguard. (IEEE 2017, p.172).

Finally, there has been discussion about the ethical implications of robot assistants, companions or carers in schools. Serholt et al. (2017) offers a nuanced analysis proffering key risks related to privacy, responsibility (accountability) should something go wrong, and the social effects on children. This last point is particularly interesting. It highlights concerns that children may begin preferring interactions with robots (and one assumes disembodied AI systems) and that this has the potential to impede how children learn to interact with humans by learning empathy, reciprocity and interpreting ambivalence, which are characteristics of human relationships (Serholt et al, 2017, p. 616). As the IEEE (2017, p.69) point out, at present there is no independent certification and review system regarding care robots that can consider both traditional health and safety issues, as well as ethical considerations. Rose, Aicardi and Reinsborough (2016) provide the following recommendation:

While there are obvious benefits of robots in the domain of care – especially for older people, those with disabilities, and perhaps children – care is a human interaction involving genuine reciprocation of feelings and obligations, and these entail the high level affective and interpersonal skills that are currently challenging for robots. It is important that policy makers recognise the limits of robots for such work, as well as their benefits. (p.460).

### Highlights

Many ethical issues related to the use of AI in education have been raised including who is ultimately accountable is something goes wrong.

It is in our ethical interest to clarify the norms, values and assumptions reflected in AI systems so that these *enhance* human potential, creativity and well-being rather than foreclose or homogenise it.

Algorithmic ‘nudging’ embedded in AI systems for education, and affective computing applications that attempt to influence a person’s emotional state, raise concerns about respect for the right of humans to make their own choices based on sufficient information.

The proliferation of machine learning generated ‘deep fakes’ – media which is a very realistic but untrue simulation of people or events – presents challenges for teaching digital literacy and critical thinking.

The effects of using AI-powered robots for caring and teaching purposes, especially with young children, needs further research and regulatory frameworks.

### 2.8.3 The Education, Ethics and AI (EEAI) framework

This section outlines our original EEAI framework (Figure 4). We proceed by carefully unpacking each component of the framework, beginning with human rights and ethical principles. We then move on to a more extensive discussion of five pillars prominent in AI ethics - awareness, explainability, fairness,

transparency, and accountability. We conclude by demonstrating the application of the five pillars by providing exemplar questions as a starting point for conversations about the use of AI in education (Table 1). The left side of the EEAI framework is a nested arrangement situating AI-embedded systems in schools in relation to foundational ethical principles and a human rights approach. The right side of the diagram specifies how the five pillars of AI ethics relate to design, implementation and governance of intelligent systems. The pillars derive from and reflect both ethical principles and human rights. We argue that observance of the five key pillars of AI ethics will go some way towards ensuring the beneficial use of the AI technology in schools, and mitigation and appropriate response to potential harm.

Figure 4: The Education, Ethics and AI (EEAI) framework.



#### 2.8.4 Human rights

In this document, human rights refers to those principles established in 1948 by the United Nations (<http://www.un.org/en/universal-declaration-human-rights/>) and subsequently synthesised by the Australian Human Rights Commission into the common principles of human rights approaches known by the acronym 'PANEL' (we quote the Commission's definition):

- ***Participation***: everyone has the right to participate in decisions which affect their human rights. Participation must be active, free and meaningful, and give attention to issues of accessibility, including access to information in a form and a language which can be understood;
- ***Accountability*** requires effective monitoring of compliance with human rights standards and achievement of human rights goals, as well as effective remedies for human rights breaches. For accountability to be effective, there must be appropriate laws, policies, institutions, administrative procedures and mechanisms of redress in order to secure human rights.



- Effective monitoring of compliance and achievement of human rights goals also requires development and use of appropriate human rights indicators;
- ***Non-discrimination and equality***: A human rights approach means that all forms of discrimination in the realisation of rights must be prohibited, prevented and eliminated. It also means that priority should be given to people in the most marginalised or vulnerable situations who face the biggest barriers to realising their rights;
  - ***Empowerment***: Everyone is entitled to claim and exercise their rights and freedoms. Individuals and communities need to be able to understand their rights, and to participate fully in the development of policy and practices which affect their lives; and
  - ***Legality***: A human rights based approach requires that the law recognises human rights and freedoms as legally enforceable entitlements, and the law itself is consistent with human rights principles. (<https://www.humanrights.gov.au/human-rights-based-approaches>).

For more on applying a human rights lens on technology with specific reference to AI see recently published papers from Australian Human Rights Commission (2018), Latonero (2018) and Mantelero (2018).

#### Highlights

The use of AI should accord with human rights which entail adherence to the principles of participation, accountability, non-discrimination and legal frameworks to support these.

### 2.8.5 Ethical principles

The development of contemporary ethical principles can be traced from the medical ethics of the Nuremberg Code (1947), the World Medical Association's Declaration of Helsinki (1964) and the Belmont Report (1978/9): Medical ethics are closely aligned, historically and philosophically with human rights frameworks such as the United Nations Universal Declaration of Human Rights and the Convention on the Rights of the Child (for an historical outline in relation to technology see Southgate, Smith and Scevak [2017]). While there is variation in the terminology used in guidelines and codes, most are underpinned by the following ethical principles: (1) integrity; (2) justice and fairness; (3) beneficence (or non-maleficence); (4) autonomy; and, (5) respect. Although originally derived from the context of research, these principles offer a powerful framework to carefully consider the potential of technology for benefit or harm to humans. The following definitions of the principles have been adapted from the Australian National Statement on Ethical Conduct in Human Research (National Health and Medical Research Council, 2007):

- ***Integrity***: There is justifiable potential benefit that will contribute to knowledge and understanding, improved social welfare and individual wellbeing. What constitutes potential benefit may require consultation with the relevant communities. Those implementing a practice must have experience, qualifications and competence and act honestly. They must disseminate and communicate results, whether favourable or unfavourable, in ways that permit scrutiny and contribute to public knowledge and understanding;
- ***Justice***: Inclusion and exclusion in an activity or program are fair. There is no unfair burden resulting from participation and the benefits of participation are fairly distributed. Nobody is exploited or manipulated. Information about participation is delivered in a timely, clear and accessible way;

- **Beneficence:** The welfare of participants is paramount. The benefits of participation should justify any potential risk of harm; however, the activity must be designed to minimise risk of harm. The potential benefits and risks must be clarified for participants; and
- **Respect:** The intrinsic value of human being must be recognised. Respect requires demonstrating regard for participant’s individual and collective welfare, beliefs, perceptions, customs and cultural heritage and sensitivities. Maintaining participant’s privacy, confidentiality and respecting their capacity to make their own decisions (autonomy) is vital. It is respectful to fully inform participants about all aspects of participation in an activity or program so that they can enact informed consent, or for children informed assent. Respect also involves empowering or providing protections for participants who are unable to make their own decisions or have diminished capacity to do so.

### Highlights

The contemporary ethical principles of integrity, justice, beneficence and respect are key to using AI-powered systems ethically and safely. These ethical principles sit within a broader human rights framework.

### 2.8.6 Ethical design, implementation and governance of AI systems in education

The AI and ethics literature is replete with concepts intended to guide ethical practice. In technical areas these are sometimes called Farness, Accountability and Transparency in Machine Learning (FATML) approach (boyd 2016). The field of education have a very deep (often turbulent) history in thinking through and responding to complex ethical questions regarding equity, values systems, sociocultural knowledge production, democratic engagement and the broader purpose of the enterprise for individual and social good. Campolo and colleagues (2017) point out addressing ethical issues in AI will require ‘listening across disciplines’ (p. 2) and acknowledging the strengths of specific fields in tackling complex issues. Some of the most powerful and persistent threads in public educational and teacher professional discourse relate to ideas about empowerment through knowledge, the benefits of holistic approaches in schooling, fairness and recognition of difference, and the fundamental role of clear explication regarding educational and welfare decision-making, within and outside of the classroom. We wish to acknowledge the ethical strengths of the field of education and synthesise these within the technical and broader philosophical literature to produce the following five (interconnected) ethical pillars for AI and education:

**Pillar 1 – Awareness.** This concept has several strands and each relates to developing awareness to empower individuals and groups to act in an informed and effective way in an AI world. Firstly, there is a need to develop general knowledge of: what current AI is; what it can and can’t do; where it is present (especially if it operates in invisible ways through non-embodied systems); how and for what purpose it is operating; and its impacts on humans and the broader environment. All stakeholders in education systems and school communities need a firm (and for students, a developmentally-appropriate) understanding of these aspects of AI so that they can be empowered to raise important questions about the benefits, risks and impact of the technology. Secondly, awareness of AI will need to be regularly refreshed and updated because it is a rapidly evolving field. Knowledge production in AI is not always predictable or visible to lay people and the proprietary nature of industry developed algorithms can make it difficult to trace the effects of these and raise awareness in real time.

boyd and Crawford’s (2012) observation regarding big data is particularly relevant in the AI context: ‘Many (people) are not aware of the multiplicity of agents and algorithms currently gathering and

storing their data for future use.’ (p.673). This leads to the third area of awareness - Students, parents and teachers should be made fully aware of AI data harvesting, storage and sharing arrangements with informed parental opt-in consent and student assent obtained. This is supported by the recommendations from the IEEE (2017):

Artificial intelligence ethics certification for responsible institutions (medical, government, education, corporations) should include education in applied legal consent principles, situation training regarding forms of consent, ethics certification testing, and perhaps a notarized public declaration to uphold ethical principles of consent. (p. 110).

Actively and continually promoting awareness of AI with informed consent and assent protocols will go some way to creating a foil to deception and allow all stakeholder an opportunity to be involved in deciding the role and parameters of the technology in education.

→ The pillar of Awareness reflects a human rights approach to Participation, Empowerment and Legality.

→ The pillar of Awareness reflects the ethical principles of Integrity, Beneficence and Respect.

**Pillar 2 – Explainability:** In the context of AI and education, explainability has two foci. The first is a pedagogical project that involves the sustained development of formal public and school-based pedagogical and curriculum approaches to explaining AI and its implications for human well-being in an accessible manner. It involves sharing knowledge about AI and providing checks on understandings of the technology so that misconceptions can be addressed, and emerging issues responded to in a timely manner. This pedagogical project seeks to provide all stakeholders with genuine, preferably public, opportunities to ask questions about the technology and its applications and have these responded to in an honest and intelligible way. The second focus involves the responsibility of manufacturers and vendors of AI technology to clearly elucidate:

- what the technology can and can’t do;
- the educational and societal values and norms on which it was/is trained and acts;
- the learning and pedagogical theory and domain knowledge on which it is based;
- evidence of its efficacy for learning for diverse groups of students;
- arrangements for data harvesting, storage and use including third party agreements and sensitive information such as biometrics or measures embedded in affective computing applications;
- if ‘nudging’ is part of the system, how it complies with ethical principles;
- how the application upholds the digital rights of the child; and
- full disclosure, in a timely manner, of potential or actual benefits and risks, and any harm that result from system (this relates to the pillars on Transparency and Accountability).

Those that sell, buy, use or are affected by AI system in education should be able to clearly explain why they are using the system, what it is intended to do and actually does (including unintended consequences as they emerge), how the system makes its decisions, and its benefits and risks. When harm is caused by AI systems, a fact acknowledged by engineers and computer scientists (IEEE, 2017), those in educational governance positions at school and system levels must publicly explain how this occurred and how they will respond, not only to the incident but in their enactment of ethical and legal obligations to school communities (this links to the pillar of Accountability).

→ The pillar of Explainability reflects a human rights approach to Participation, Empowerment and Accountability.

→ This pillar of Explainability reflects the ethical principles of Integrity, Beneficence and Respect.

**Pillar 3 – Fairness:** In discussions of AI and education, fairness is linked to several matters. The first is the very real potential of AI to radically disrupt the world of work to exacerbate social inequality (Gulson et al. 2018; Means, 2018). This raises the question about the role schooling has in countering inequality in an AI world. This will involve a much more concerted and coordinated approach from government to work *within school communities* to address digital inclusion and provide greater opportunities for diverse groups of students to explore career options, especially in technology and engineering related jobs (ACS, 2015; Southgate, 2017).

The second matter relates to the right of humans to have the power to create their own digital identities and express and document their life on their own terms (Mann et., 2016). This is reflected in cultural rights and the digital rights of children, especially in an age of ‘datafication’ and ‘dataveillance’:

‘(C)hildren have become increasingly datafied via such technologies as mobile media, wearable devices, social media platforms and educational software. The data generated by these technologies are often used for dataveillance or the monitoring and evaluation of children by themselves or others that may include recording and assessing details of their appearance, growth, development, health, social relationships, moods, behaviour, educational achievements and other features. (This raises issues of) exploitation of digital data about children, their rights about the ways in which others collect and use data about them and data privacy and security. (Lupton & Williamson, 2017, p.781).

This is related to the third matter: Children’s digital rights extend to fair inclusion. There should not be unfair burden resulting from interfacing with AI systems, with any benefits being justly distributed. This focus on benefit and burden extends to AI systems that use machine learning and autonomous experimentation. Bird et al. (2016) describe how training a machine learning system requires significant amounts of data and can include experimentation designed to ‘leverage user responses to evaluate design decisions, settings, and algorithms’ (n.p.). They suggest that this process can expose some users to experimental treatments that are either not in their best interests or may put them at risk; that is, generate an unfair burden. They demonstrate this by giving the example of AI navigation services that give users directions:

(Autonomous) experimentation is likely a core part of suggesting optimal routes. This is because service providers often lack information about traffic conditions on those routes to which they have purposefully not directed drivers. To determine whether a previously slow route is still slow, these services will deliberately send some users along it. Although such experiments may have beneficial effects for the system as a whole, they can be problematic for individual users or groups of users. For some users, taking a slow route might mean that they are slightly late for work; for others, though, it might delay a trip to the hospital. Moreover, users seldom know whether they are part of an experiment, nor do they have any way to convey that one journey is more urgent than another.’ (Bird et al., 2016, n.p.)

The fourth area, and one that has garnered great public interest, involves AI bias. There are many publicised cases of AI bias. Crawford (2016) points out that sexism, racism and other forms of discrimination are sometimes built into the machine-learning algorithms that underlie intelligent

systems and this shapes how we are categorised and targeted. Campolo et al. (2017) explain that 'biased AI can result from a number of factors, alone or in combination, such as who develops systems, what goals system developers have in mind during development, what training data they use, and whether the systems work well for different parts of the population.' (p. 14). They recommend standards be established to track the provenance, development, and use of training datasets throughout their lifecycle in order to better understand, monitor and respond to issues of bias and representational skews (p.1).

→ The pillar of Fairness reflects a human rights approach to Non-Discrimination, Accountability and Legality.

→ The pillar of Fairness reflects the ethical principles of Integrity, Justice, Beneficence and Respect.

**Pillar 4 – Transparency:** This area has received significant attention in the engineering, computer science and philosophical literature on AI. Winfield & Jirotko (2017) state that 'an important underlying principle is that it should always be possible to find out why an autonomous system made a particular decision (most especially if that decision has caused harm)' (n.p.). AI is often described as an 'opaque' technology for a number of reasons. Firstly, AI is often invisibly infused into computing systems in ways that can influence our interactions, decisions, moods and sense of self without us being aware of this (Cowrie, 2015). Secondly, the proprietary nature of AI products creates a situation where industry does not open up the workings of the product and its algorithms for public or third party scrutiny (Burrell, 2016). This creates a situation where customers must rely on industry assurances that adequate checks have been carried out regarding privacy implications for the type of personal data being harvested and shared, and that robust checks have been made for potential risks such as algorithmic bias. Related to this point is industry's legal obligations to protect data, making full disclosure difficult, in some cases, if harm does occur (boyd, 2016). Issues related to privacy extends to the surreptitious collection, storage and sharing of biometric data. This data on the physical, physiological or behavioural characteristic of a person (Dewa, 2017). Biometric data, the type often associated with smart classrooms and new trends in data analytics, is not just about a person but *of them*. Biometric data collection represents a threat to the right to bodily integrity and is legally considered sensitive data that require a very careful and fully justified position before implementation, especially with vulnerable populations such as children (Southgate, 2018).

The third reason AI is considered opaque relates to the 'black box' nature of some types of machine learning. The ethical issues relating to 'black box' AI have prompted some researchers to suggest that these should not be used in 'safety critical systems' where decisions made by AIs can have serious consequences to human safety or well-being (Winfield & Jirotko 2018, p.7). Education has been described as a 'sensitive domains' where machine mistakes have the potential to significantly impede or critically damage the life opportunities of humans (Campolo et al., 2017). In education, the metaphor of the 'black box' traditionally refers to any input-process-output system where the activities, dynamics and decisions in the central process component are not investigated, explained or well understood (Southgate and Aggleton, 2016). In the context of AI, the 'black box' is usually associated with machine learning and includes the data sets used to train the machine, the autonomous learning process which occurs with minimal human intervention, and the decisions the machine makes. Mittelstadt et al (2016) offer the following explanation:

Machine learning is adept at creating and modifying rules to classify or cluster large datasets. The algorithm modifies its behavioural structure during operation (so that this alteration of how the

algorithm classifies new inputs is how it learns.... Training produces a structure (e.g. classes, clusters, ranks, weights, etc.) to classify new inputs or predict unknown variables. Once trained, new data can be processed and categorised automatically without operator intervention (making the) rationale of the algorithm...obscured (and) leading to the portrayal of machine learning algorithms as 'black boxes'. Opacity in machine learning algorithms is (due to) the high dimensionality of data, complex code and changeable decision-making logic.... (p.6).

Some deep learning AI systems such as those that use artificial neural networks (ANN), involve non-linear decision-making structures and functions so that after the ANN has been trained, attempts to examine why and how the ANN makes a particular decision is almost impossible (Winfield & Jirotko, 2018, p.8). The dynamic, changeable decision-making logic of these AI systems presents issues that have not yet been resolved either through technical or ethical processes:

Software developers regularly use "black-box" components in their software, the functioning of which they often do not fully understand. "Deep" machine learning processes, which are driving many advancements in autonomous systems, are a growing source of 'black-box' software. At least for the foreseeable future, AI developers will likely be unable to build systems that are guaranteed to operate exactly as intended or hoped for in every possible circumstance. Yet, the responsibility for resulting errors and harms remains with the humans that design, build, test, and employ these systems.... Software engineers should employ "black-box" (opaque) software services or components only with extraordinary caution and ethical care, as they tend to produce results that cannot be fully inspected, validated, or justified by ordinary means, and thus increase the risk of undetected or unforeseen errors, biases, and harms. (IEEE, 2017, pp.69-70).

The IEEE (2017, p. 45-46) have outlined four technical ways in which AI systems can be made transparent, especially in relation to the way a system interprets and implements norms. These are:

- Traceability which refers to technical inspection of which norms have been implanted, for which contexts, and how norm conflicts are resolved by system. This can reveal biases which may have been built into a system;
- Verifiability through formal mathematical techniques. The IEEE (2017) suggest that even if an AI system 'cannot explain every single reasoning step in understandable human terms, a log of ethical reasoning should be available for inspection' (p.45);
- Non-deception and honesty where systems are designed to accurately represent what the system is capable of doing to the user; and
- Intelligibility which entails a clear requirement for an autonomous and intelligent system to 'be able to explain its own reasoning to a user when asked when suspecting user confusion: this must be undertaken at a level commensurate with the human's level of reasoning.

→ The pillar of Transparency reflects a human rights approach to Accountability, Non-Discrimination, Empowerment and Legality.

→ The pillar of Transparency reflects the ethical principles of Integrity, Beneficence and Respect.

**Pillar 5 – Accountability:** Governance of AI will entail new ways of thinking about the interconnections and tensions between proprietary interests, (public and transparent) algorithmic auditability, regulatory standards and framework, risk assessment, legal obligations, and broader social, cultural and economic

responsibilities. The IEEE (2017) eloquently captures the difficulty of accountability in an AI world when they state:

(T)he complexity of (autonomous and intelligent) technology will make it difficult for users of those systems to understand the capabilities and limitations of the AI systems that they use, or with which they interact. This opacity, combined with the often-decentralised manner in which it is developed, will complicate efforts to determine and allocate responsibility when something goes wrong with an AI system. Thus, lack of transparency both increases the risk and magnitude of harm (users not understanding the systems they are using) and also increases the difficulty of ensuring accountability (p.28)

The IEEE (2017, p.7) recommends that industry and government clearly identify the types of operations and decisions that should *not* be delegated to autonomous and intelligent system and develop rules, standards and protocols to ensure effective human control and responsibility over these. They also suggest that businesses or entities implementing autonomous and intelligent systems have insurance or guarantees for financial responsibility so that victims of AI-related harm can claim compensation (p.155). Furthermore, they suggest that governments consider regulations which require manufacturers of AI systems have policies on how these should be used in real world applications, a set of pre-conditions for effective use, and supply training for those implementing the systems (p.155). For example:

(Algorithm maintenance) is an essential part of design. Design does not stop with deployment. Thus, there should be a clear legal requirement of (1) due diligence, and (2) sufficient investment in algorithm maintenance on the part of companies that use and manufacture (autonomous and intelligent systems) that includes sufficient investment in algorithm maintenance on the part of companies that use and manufacture (autonomous and intelligent systems) that includes monitoring of outcomes, complaint mechanism, inspection, correction, and replacement of harm-inducing algorithm, if warranted. *Companies should be prohibited from contractually delegating this responsibility to unsophisticated end-users.* (emphasis added) (IEEE, 2017, p.156).

Gulson and colleagues (2018, p.5) provide a sensible set of recommendations in relation to AI, governance and education. These include developing a set of procurement guidelines that encourage ethical, transparent design of AI for Australian education systems; reviewing international data protection legislation to develop a suitable approach for Australian education; and, establishing official guidelines for adaptive and personalised learning systems that ensure equity.

Finally, accountability is more than standards, regulation, guidelines and legislation. Government and school leaders need to ensure that they have access to independent expertise and advice in order to avoid regulatory capture: Regulatory capture occurs when those in governance positions become dependent on potentially conflicted commercial interests for advice. Moreover, there is also accountability to the teaching profession and the communities that treasure the contribution of their teachers and schools. Loss of human skills is a documented risk in an AI society (Torresen, 2018). There is a risk that foundational pedagogical knowledge may be lost with the deployment of AI-power systems in education. The cumulative knowledge and wisdom of the teaching profession needs to be valued and the diffusion of AI in education should not result, even unintentionally, in the de-skilling the profession.

→ The pillar of Accountability reflects a human rights approach to Accountability and Legality.

→ The pillar of Accountability reflects the ethical principles of Integrity, Justice, Beneficence and Respect.

### Highlights

There are many complex issues related to the design, implementation and governance of AI-powered systems.

The five pillars of ethical AI - awareness, explainability, fairness, transparency and accountability – allow us to ask critical questions about AI-powered systems to ensure the technology is used to enhance learning, increase equity, and foster the well-being of all stakeholders in a school community.

## 2.8.6 Applying the five pillars of AI ethics to school education

Table 1 provides some indicative questions to ask of AI in education across the domains of design, implementation and governance based on the five ethical pillars.

*Table 1: Applying the Five Pillars of AI ethics to school education: Some initial questions to guide thinking and practice*

	Design	Implementation	Governance
Awareness	How have the manufacturers of system engaged with the education stakeholders to raise awareness of AI, its limitations, potential and risks?	Have students and parents/caregivers been made aware of the type of data harvesting and sharing arrangements required by the system?	Is there a rigorous process for seeking parental consent and student assent before systems are deployed?
Explainability	Is the system designed to explain to students, parents and teachers its purpose, process, decisions and outcomes in an accessible way?	What opportunities, approaches and public forums are available for students and parents to explore, explain and share information and experiences of AI in schooling?	Do policy-makers, procurement officers, and school leaders have access to appropriate independent technical expertise to explain and advise on AI systems?
Fairness	Has the issue of potential bias in the design of the system been proactively addressed and documented?	How will school address potential inequalities in an AI world? Does the system use autonomous experimentation and could this create an unfair burden on students and teachers? Does the AI system introduce unjust and punitive types and	What procedures and policies are there to ensure that AI systems positively address rather than exacerbate inequity, discrimination and prejudice in education? What evidence is there that an AI system can be



		levels of surveillance on students and teachers?	used to address equity concerns in schools?
<b>Transparency</b>	Is the system designed and implemented for traceability, verifiability, non-deception and honesty and intelligibility?	Can students, teacher, parents and community inspect and have opportunities to respond to AI systems training and decision making in ways that are intelligible or authentically empowering to them?	How will those in governance or procurement positions ensure genuine traceability, verifiability, non-deception and honesty, and intelligibility of AI systems prior to purchase and during implementation? How will transparency be operationalised if harm occurs?
<b>Accountability</b>	Have the designer and vendor of an AI system clearly articulated their responsibilities to ethical use of AI? What systems do they have to ensure ethical accountability?	Who is accountable for the procurement of ethical AI? Is there a school and system wide procedure for reporting and responding to AI harm? Do all stakeholders in the school community know about and how to access the above procedure?	What protocols are in place to respond to prevent and respond to harm? What early warning systems are there that harm may be occurring that can trigger action?

## 2.9 Conclusion

AI could potentially offer benefits to teachers and students in the form of personalised learning and pedagogical agents designed to deliver appropriate and sequenced content and feedback to learners. However, AI is still in a relatively early stage of development for education and there is much work to be done around the ethical and legal frameworks that can ensure that the technology is used for good and not harm, and that transparent processes are in place to ensure accountability at classroom, school community, and school systems levels. Teachers, school leaders and policy-makers should begin to engage with developments in AI for education and society, in order to empower their students in the present and for future change.

## 2.10 Advice to teachers

Whether you are a pre-service teacher, a seasoned classroom educator, or a school leader, now is the time to begin your professional learning journey on the potential of AI for education. Even with a good foundational knowledge, professional learning in this fast-moving area will need to be refreshed annually.

School communities can begin to identify places across the curriculum (inclusive of but beyond STEM) where learning about AI can be integrated so that we can begin to equip students with knowledge about

how the technology works, and how it is infused into and influences our interactions in everyday life. Provide opportunities for students to learn with and about AI across curriculum learning areas and in the general capabilities area. Free resources on learning with and about AI can be found at the Digital Technologies Hub <https://www.digitaltechnologieshub.edu.au/footer/about-dth> and CSER <https://csermoocs.adelaide.edu.au/available-moocs>

There are numerous ethical issues regarding the design, implementation and governance of AI-powered systems in education that need to be addressed, in an ongoing manner, by all stakeholders in school communities. Table 1 (directly above in section 2.8.6) provides an example of these ethical issues and the kinds of questions teachers and school leaders might ask of AI systems. It is vital that there is open, informed dialogue and transparency about the ethical quandaries of AI and education if trust is to be developed in the technology. The teaching profession has a long history of leading public discussion and providing accessible explanations on complex issues which affect students and their families and of grappling with issues of fairness, ethics, duty of care, and accountability in schooling. This makes the teaching profession well-equipped to both use AI technology for good and to ask critical questions regarding when and how machines should guide student learning and decision processes within educational settings, and whose values should be imbued into AI-powered systems.

## 3. Virtual Reality and School Education

### 3.1 Introduction

Immersive virtual reality (IVR) has arrived for mass consumption. It is estimated that more than two million school children have tried Google Expeditions (Charara, 2017), and that PlayStation VR has sold in excess of three million gaming units (Lang, 2018). Social media corporations have invested heavily in IVR: Facebook's CEO predicts one billion people will be living in IVR in the future (ABC News, 2017).

While computer desktop VR has been around for decades, publicly available and affordable IVR<sup>4</sup>, that is VR mediated via a headset (or head mounted display) is a relatively recent phenomenon. Entry-level Google Cardboard was released in mid-2014, and high-end VR such as the Oculus Rift and HTC Vive only became commercially available in 2016. Given the considerable dialogue on the potential educational application of immersive technologies, it is timely to ask questions about the learning properties (or affordances) of IVR technology, and importantly, what we currently know about its effects on children and young people (hereafter child refers to 0-18 years of age).

This literature review is written for teachers with the aim of providing a snapshot of the most current research on IVR, children and school education. The methodology for the review is outlined in Appendix 1 in this report. In general, this review does not cover the extensive and interesting literature on desktop virtual reality and education or virtual worlds for learning (for a systematic review and a meta-analysis of this literature see Mikropoulos and Natsis, 2011, and Merchant et al., 2014, respectively). The main exception to this is the section on the learning affordances of virtual reality which draws on desktop VR literature.

This review is structured according to the following topics: defining IVR; the learning affordances of virtual reality; IVR and school education; and the ethical and safe use of IVR and children.

### 3.2 What is immersive virtual reality (IVR)?

The commercial advent of immersive technologies has launched the terms virtual reality (VR), augmented reality (AR) and mixed reality (MR) into mainstream discourse. Briefly, virtual reality immerses users in a fully simulated digital environment; augmented reality (AR) overlays virtual objects on the real-world environment; and, mixed reality (MR) overlays and anchors virtual objects on to the real world and often allows users to interact with these objects (Tokareva, 2018).

Virtual reality has been around for a number of decades<sup>5</sup> and includes diverse applications from realistic training simulations used by NASA to multi-player 3D virtual worlds such as Second Life. There is no accepted definition of immersive virtual reality; however, it is usually classified as a type of VR mediated through a head mounted display (HMD). A HMD is a headset that presents visuals directly to the eyes so

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<sup>4</sup> For the purposes of this report we use the term immersive virtual reality (IVR) to refer to the type of VR that is mediated or delivered through a headset (otherwise known as a head mounted display). The term IVR is used to distinguish this type of VR from that delivered directly via a desktop computer or smart device screen (without a headset).

<sup>5</sup> For a brief history of virtual reality see <https://www.vrs.org.uk/virtual-reality/history.html>

that wherever a user looks the display is in front of the eyes and which tracks<sup>6</sup> (in various ways and degrees) the user's position in space. This technology creates a feeling of presence or 'being there' in the virtual world, or in the case of a networked computer environment, co-presence or 'a sense of being there with others' (Slater and Sanchez-Vives, 2016). For feelings of presence to occur two factors are vital. These are place illusion, which is a strong feeling that you are actually in the virtual place, and plausibility illusion, which is a powerful feeling that what is happening in the virtual place is occurring (Slater, 2009).

IVR is different to desktop VR (or that displayed on a tablet or smart phone) because there is no intermediary 'reality check'. In other words, you are not looking at a screen or interacting with what is on a screen; rather, you feel you are actually in the virtual environment and wherever you look it is surrounding you. IVR is a deeply experiential technology and can elicit distinct affective (emotional) and embodied (physiological) responses especially when place and plausibility illusion are heightened. From life-like simulations to fantasy worlds, IVR 'dramatically extends the range of human experiences way beyond anything that is likely to be encountered in physical reality' (Slater and Sanchez-Vives, 2016, p.6). However, not all IVR experiences are the same. IVR allows for different degrees of user agency or the ability to act freely in the virtual world. IVR experiences range from those that allow the user limited interaction (the person can look around in a 360° manner) to others in which a person can navigate or tour an environment in a more mobile way with limited interaction. There is also highly IVR which involves sophisticated body tracking systems and controller devices which allow for a natural gestural interface within the virtual environment (for instance you can pick up or throw a virtual object). This type of IVR allow a person to exercise a significant degree of agency (the ability to act freely) in the virtual environment through: navigation opportunities; interaction with virtual agents and other players in the environment; manipulation and creation of virtual objects; and free and bounded play (Southgate, Smith and Cheers, 2016). In highly IVR, you are not just looking at and navigating through a virtual environment, you are a creator in and of the environment. Recent developments include the release of 'stand alone' VR HMD (e.g. Oculus Go) that needs limited interaction with a smart phone and do not need a computer to operate the software (the HMD has the computing power built into it). These 'stand alone' VR systems use a hand controller which allows for navigation and manipulation but physical movement and gestural interface is currently much more limited than in the type of high end IVR that plugs into a computer. Distinguishing between different types of IVR is important because of their potential effects on children in different developmental stages and their pedagogical potential.

### Highlights

Immersive virtual reality (IVR) using a head mounted display (HMD) has only been widely available since 2014.

IVR replaces the world with an artificial or simulated reality. The head mounted display blocks out the world so that the user can be immersed in the artificial world.

Different IVR technology create different levels of immersion and feelings of 'being there' in the artificial/simulated environment. Experiences range from looking around, to those where the user has limited navigation and interaction, to highly immersive environments where a user can freely manipulate, navigate, interact and create a customised experience.

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<sup>6</sup> For more on the technical aspects of IVR see <http://www.realitytechnologies.com/virtual-reality> and for tracking systems see <https://www.wearable.com/vr/inside-out-vs-outside-in-vr-tracking-343>

### 3.3 The learning affordances of virtual reality

For several decades, VR learning affordances (properties that can allow for learning) have been documented (Winn, 1993; Youngblut, 1998; Pellas et al., 2017) with some suggesting that the technology has the potential to radically transform education (Blascovich & Bailenson, 2011). Dalgarno & Lee (2010) argue that 3D virtual learning environments (3D VLEs) can: enhance spatial knowledge; facilitate experiential learning that would otherwise be impossible or impractical in the real world; can improve transfer of knowledge and skills learned in virtual environments to real situations; and can increase motivation and engagement in learning and lead to richer collaborations. De Freitas & Veletsianos (2010) extend on this by suggesting that 3D VLEs can: present new opportunities for creativity in learning through role play and mentoring, open up learning spaces for rehearsal and exploration, experimentation and user-generated content; and broaden capabilities for learner-led problem and inquiry-based learning.

Mikropoulos & Natsis (2011) highlight the following learning affordances (properties or features) of VR which can contribute to learning:

1. First order (person) experiences that support social constructivist conceptions of learning.
2. Natural semantics or understanding the basis of something before learning about its symbols and abstractions. For example, manipulating angles before learning about why angles are important in mathematics.
3. Size and scale manipulation where users can change the size of themselves, objects or environments to interact with micro/macro worlds. For example, going into an atom.
4. Reification or transforming fairly abstract ideas into perceptible representations. For example, travelling with a virus as it mutates and spreads within a population.
5. Transduction or extending user capability to feel 'data' that would normally be beyond the range of their senses or experiences. For example, a simulation of the migration paths of whales that allows the learner to follow the paths of different species.

Recent research has highlighted the potential for IVR to act as an 'empathy machine'. This research suggests that swapping perspectives in an embodied way (a key affordance of IVR) can challenge stereotypes and bias. Highly IVR experience can induce an illusion of ownership in someone else's body, and that person might be of a different age, gender or from a different ethnic, cultural or religious group. In one experiment, Maister and colleagues (2015) had light-skinned Caucasian participants occupy either a white or black avatar body in a virtual environment where they could see their body from a first-person perspective when they looked down, as well as in a virtual mirror. A control group of similar participants had either no virtual body, or the body that was purple in colour in the virtual environment. The researchers measured the implicit racial biases of all participants, before and after the experiment. They found that participants 'who embodied a black avatar showed a decrease in their implicit biases against black individuals, which was significantly greater than for those who embodied a white avatar' (Maister et al., 2015, p. 9).

Winn's (1993) early work on the educational potential of VR captures the different mindset educators must adopt when deploying the technology beyond realistic simulation for procedural training:

(I)t is often the case that the power of VR is wasted when it is used for simulation. For example, if you enter a virtual world in which there is a virtual microscope through which you can look at a virtual drop of water, you gain nothing. Learning about the microscopic life-forms that live in the droplet is accomplished far more effectively by using a real microscope in the biology laboratory. The

microscope in the virtual world is a transducer (revealing to the eyes what would not otherwise be revealed), and the participant is on the wrong side of it! VR comes into its own when, through a massive change of size, the participant jumps through the virtual microscope's eyepiece and into the drop of water, attaining the same relative size as the microorganisms that live there. At this scale, the experience is first-person. But then you do not need the microscope at all. (p.11).

When Winn wrote this, the possibility of feeling like you were actually 'swimming' with micro-organisms and even behaving as one through interfaces that allowed for navigation and manipulation, were some decades away. This is no longer the case. The arrival of highly immersive virtual reality heralds an exciting era for learning; however, the psychological, affective and embodied intensity of the experience, especially for children, have prompted many to argue that a caution approach is required.

#### **Highlights**

Several decades of literature on desktop VR has identified the potential learning affordances (properties that can allow for learning) of the technology. These learning affordance (and perhaps others that are yet to be discovered) require robust investigation, evaluation and pedagogical consideration within the context of IVR.

### **3.4 IVR and school education**

Given the recent commercial availability of IVR, it is unsurprising that there is limited research on using IVR in school classrooms (Freina & Ott, 2015). There is a growing literature on IVR for learning in higher education, especially in engineering, science and medicine and some of this may have implications for using IVR in schools. For example, Potkonjak et al.'s [2016] reviews the benefits of virtual laboratories in science, technology and engineering higher education, highlighting the potential cost-effectiveness of high quality virtual laboratories and the way in which multiple students can access virtual equipment which is, unlike physical equipment resistant to damage. They also suggest that virtual laboratories can make the 'unseen' as the cover of equipment can be easily removed or made transparent to how the workings of the inner structure (in a robot, for example, it is possible to easily reveal all its working parts). Potkonjoak et al. (2016) do warn however that virtual laboratories are often time consuming to develop, that students may not take simulated experiences as seriously as real ones, and that in the final or advances stages of training and learning, there is no substitute for actual hands-on experience with real equipment. The results from a recent science laboratory experiment with university students, which compared learning in desktop VR with immersive (HMD) VR, suggested that while students felt a greater sense of presence in IVR they may have experienced cognitive overload resulting in poorer test performance (Makransky et al., 2017).

Interestingly, the issue of cognitive load and highly realistic simulation experiences has been explored in an experiment with 14-15 year olds, some of whom were given desktop computer space flight simulator experiences in classrooms (lower immersion) while others were allowed access to a large scale realistic space flight simulation in a customised truck (higher immersion) (Ke and Carafano, 2016). The study found that immersion levels did not affect learning outcomes but that a higher level of sensory immersion may impeded conceptual processing. While relatively small in number, methodologically rigorous studies using desktop VR in school STEM classrooms have shown that the technology can assist in developing higher order thinking skills in students (Pellas et al., 2017).

Most literature on immersive virtual reality in schools is primarily descriptive in nature; for instance, Minocha, Tudor, and Tillings (2017) exploration of how Google Expeditions might be used in the

classroom. There are some small scale experimental studies with an educational focus; for example, where certain conditions such as emotional induction (mood manipulation) and level of immersion are altered in order to measure short-term knowledge retention (Olmos-Raya et al., 2018).

An international survey of educators on the learning affordances of wearable technologies, such HMDs, identified a range of issues. These included: privacy; the potential for learner distraction; cost of equipment; a concern that the novelty of using a new 'gadget' would displace the necessary focus on pedagogy and learning design; and a lack of off-the-shelf software suitable for educational purposes (Bower and Sturman, 2015).

Studies on highly IVR and school children include research which examined the use of dance software to teach middle school (predominantly) girls computational thinking and programming in an after-school program (n=8) (Daily et al., 2014) and a summer camp (n=16) (Parmar et al., 2016). The same research team also conducted an experiment with 36 middle school students (4M, 32F) to investigate how the presence or absence of character customisation influenced learning outcomes (Lin et al, 2017). The study was offered as an opt-in activity for the school's graphics communication class but was mandatory for students in the dance/aerobics class. The research found that participants with customizable characters displayed deeper learning. Other school-based research, while not using a HMD but polarised glasses and haptic devices, found that augmented simulation was associated with deep learning of abstract scientific concepts with a significant effect on achievement (Civelek et al., 2014).

Early findings from the Australian VR School Study<sup>7</sup>, which involved embedding highly IVR (networked Oculus Rifts) in STEM high school classrooms, highlighted a number of practical, ethical, safety and gender concerns (Southgate et al. 2018a,b,c). The research team, which includes teachers, developed a health and safety screening protocol for parents/carers and students and produced resources to educate students on cybersickness. To minimise the risk of cybersickness, students were limited to 15 minutes in IVR within a 3 hour time frame and IVR experiences were not scheduled during the last lesson of the day to ensure student safety after leaving school.

Observational data for the VR School Study revealed that some students became so immersed in the virtual experience that they appeared to ignore the guardian system designed to warn users that they are straying outside of the designated safety zone (with the potential to collide with objects and other students) and that constant supervision by the researcher or other students was required to ensure safety. Furthermore, the process of assisting students to put on and take off VR equipment led to the development of a child protection protocol that would also be suitable for students who are touch adverse. The research also revealed that girls were much less likely to have tried IVR before the study compared with boys and that a minority of girls exhibited initial embarrassment about putting on the HMD and being seen by peers: this was not apparent in boys. The research also revealed that students needed more time to familiarise themselves with the IVR experience and the affordances of the technology for learning through a period of play integrated into the curriculum.

### Highlights

The applications of IVR to school education are only starting to be explored and evaluated through rigorous research.

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<sup>7</sup> [www.vrschoolresearch.com](http://www.vrschoolresearch.com)

There is some promising research that indicates IVR might be used to engage girls in computational thinking and that customisation (an affordance of IVR) can be used to enhance learning.

Some early research on highly IVR highlights a range of ethical, safety and child protection issues related to deploying the technology in classrooms and recommends constant supervision of students in IVR.

### **3.5 Ethical and safe use of IVR with children**

Researchers have raised serious ethical concerns about exposing children and young people to IVR inclusive of, but beyond, issues of the content of VR applications. Madary and Metzinger's (2016) code of ethical conduct for using VR issues a timely warning about the possible psychological risks of long term immersion for children. Indeed, there are no large scale longitudinal studies on the effects of immersion on children or adults and this represents a key challenge in assessing risk (Slater, 2014).

Some researchers have suggested that any deployment of IVR with children should be informed by a child development approach (Southgate, Smith and Scevak, 2017). Child development includes physical (motor and perceptual), cognitive, linguistic, emotional (affective), social and moral domains, and how these interact together during the broad stages of human development (Berk, 2006). Unlike previous technologies and media, some highly IVR can feel very real and, to take just one area of child development, cognition, this raises serious questions about the effects of exposing children to such virtual experiences. For example, it is important to consider the cognitive dimensions of how children discern what is real from what is not. Between the ages of 3 to 12 years, most children begin to learn the difference between reality and fantasy (Sharon and Woolley, 2004). There is ample evidence that the majority of young children accept fantastic figures and magical processes as real (Principe and Smith, 2008). Indeed, some experiments have found that when primary school children were given an IVR experience many came to believe that the virtual experience had really happened (Segovia et al., 2009; Stanford University Virtual Human Interaction Lab, 2015). Baumgartner et al. (2008) raised concerns about the ability of children to cognitively and affectively regulate IVR experiences. The experiment compared prefrontal brain arousal in adults and children (mean age 8.7 years) on an IVR roller coaster ride. They found that children were more susceptible to the impact of audio/visual stimuli and that the children seemed unable to evaluate and monitor the experience or inhibit a sense of presence. The authors concluded that there should be more reluctance to 'expose children to emotional virtual reality stimuli as currently practiced' (Baumgartner et al., 2008, p.11).

Such findings have led some to argue that IVR 'is likely to have powerful effects on children because it can provoke a response to virtual experiences similar to a response to actual experiences' and that when choosing VR content consideration should be given to whether it would be acceptable for the child to have that experience in the real world (Common Sense, 2018, p.2-3). At a psychological and profoundly philosophical level, exposure to IVR does raise questions about the ethics of (unintentionally) implanting false memories, especially for children who because of their developmental stage are unable to distinguish what is real from what is not.

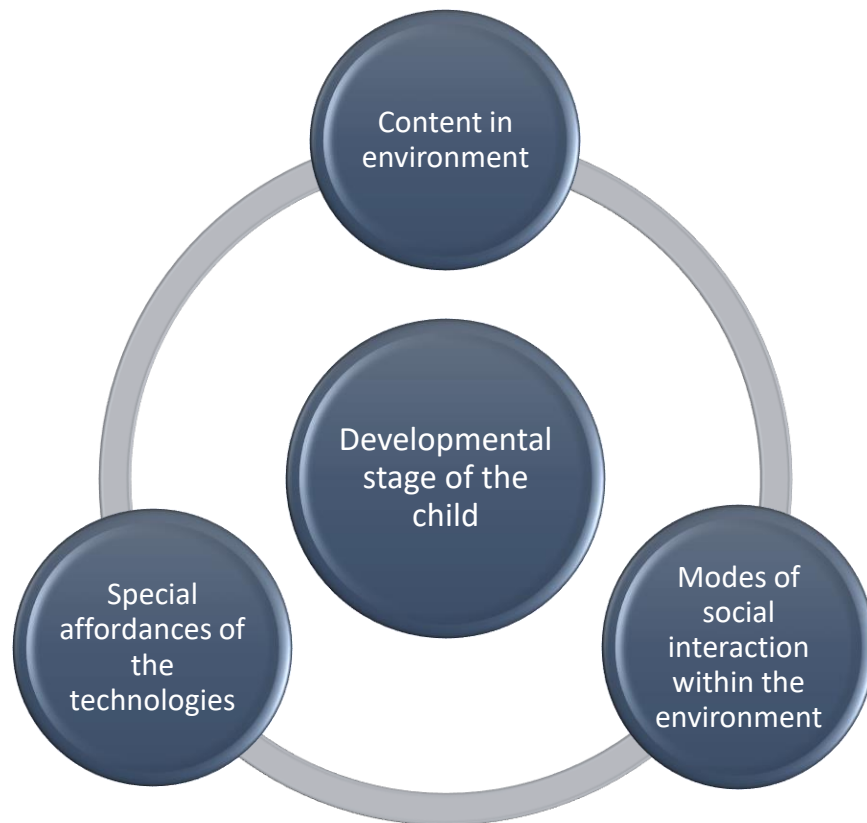
Southgate, Smith and Scevak (2017) contend that consideration needs to extend beyond content to the types of interaction in IVR to include how children in different developmental stages might react to and understand the affordances of the technology and its modes of social interaction (Figure 5). Practically, teachers must apply their knowledge of the different domains of child development and the individual differences of their learners in order to make informed decisions about the ethics of using IVR in their classrooms.



Manufacturers of HMDS have released health and safety guidelines, and most have age recommendations. For example, while Google Cardboard has no age recommendation it is suggested that the equipment should be under adult supervision. More highly IVR HMDs, including those that use mobile phones (Samsung Gear VR, Google Daydream), consoles (Sony VR) and top of-the-line versions that have sophisticated tracking systems and require expensive computers (HTC Vive, Oculus Rift), have applied age recommendations for use. These types of IVR recommend that the child be between 12-13 years of age or over. Guidelines usually stipulate adult supervision and that users taking frequent breaks. Consulting manufacturer's guidelines is vital before using IVR in the classroom.

One key risk highlighted in manufacturer's guidelines is cybersickness, a very unpleasant form of motion sickness with symptoms including nausea, disorientation, headaches, sweating and eye strain (Davis, Nesbitt and Nalivaiko, 2014). Cybersickness can be bought on even after a small amount of time in highly IVR. Surveys indicate that parents (Common Sense, 2018) and young people (Touchstone Research, 2015) are concerned about the potential health risks of IVR. For example, a recent marketing survey (Castaneda, Cechonu & Bautista, 2017) reported that a small minority of students had an IVR experience that they considered to be 'too intense' with some feeling physical discomfort. There is a considerable research effort directed at understanding cybersickness and designing environments that alleviate it. It is difficult to predict if an individual will experience cybersickness; however, children aged 2-12 years have the greatest susceptibility to cybersickness with this decreasing from the ages of 12 (Davis, Nesbitt and Nalivaiko, 2014).

*Figure 5: Conceptual framework for considering aspects of immersive environments in a developmental context (from Southgate, Scevak and Smith, 2017).*



Related to physical impacts, a recent study (Dubit, 2018) of twenty children (aged 8-12 years) who played a twenty minute game in IVR found that, for the majority of children, 20 minute game play had little impact on their stereoacuity (the ability to detect differences in distance) or balance in the short-term. The authors posited: 'The characteristics of children who might be most prone to disruption of binocular vision are currently unknown. We also do not know how long any disruption persists, nor the consequences of repeated exposure over a longer time frame. Further research into these potential factors is planned' (Dubit 2018, p. 22).

Moreover, in the age of big data where technological applications harvest information in educational and other settings (Rodríguez-Triana, Martínez-Monés, and Villagrà-Sobrino, 2016), it is worth considering the privacy implications of IVR. This includes not only collecting data about a person — for example, when accounts are set up — but information directly of the person, a type of data known as biometrics. Biometric data 'enables the use of unique physical characteristics — such as a person's face, voice or fingerprint — for verification or identification purposes' (Royakkers et al., 2018, p.2). It is information of biological/physical attributes which can be linked to behavioural data. In IVR biometrics can include data on head, body and arm movements when using a HMD and/or tracking system (Adams et al., 2018). In the near future this may include eye tracking (Soler et al., 2017), and (perhaps even pupil dilation) to assess the emotional state or engagement of users (Pan and Hamilton, 2018). The integration of biometrics in VR, AR and MR presents consent and privacy challenges. This is coupled with a lack of transparency regarding if and how this type of data is collected by manufacturers of IVR equipment and software developers. Biometrics is emerging as an area of paramount concern in legal, human rights, and technology circles.<sup>8</sup>

Teachers should also be aware of privacy, culturally sensitive images or information, copyright and intellectual property issues when producing and sharing VR content. This area requires further legal investigation and the development of policy advice. Given the ethical and legal implications for schools and their students it is important that educators keep apprised of developments in this field.

### Highlights

There are no large scale longitudinal studies on the effects of immersive virtual reality on children or adults. We do not know what the long term effects of immersion will be.

Manufacturers of IVR equipment have issued online health and safety guidelines with age limits on use. These should be consulted before implementing IVR in classrooms.

Teachers should consider the physical (motor and perceptual), cognitive, linguistic, emotional (affective), social and moral developmental stage of learners before using IVR in their classroom. IVR can evoke powerful reactions in children who may not be able to cognitively regulate the experience and, for the very young, may come to believe that the virtual experience was real.

When using IVR for learning teachers should consider how children at different developmental stages might respond to the content, modes of interaction and affordances of IVR technology.

There is no way to predict if a child might become cybersick and so teachers should educate students on identifying symptoms for early opt-out during IVR sessions, especially when using highly IVR.

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<sup>8</sup> For a recent expert podcast on IVR, privacy and biometrics see <https://www.roadtovr.com/oculus-privacy-architects-discuss-policy-jenny-hall-max-cohen/>

The privacy of students should be considered not only in setting up IVR accounts but also in relation to the possibility that biometric data might be collected by manufacturers of IVR hardware and software. At present, it is difficult to ascertain if or what type of biometric data is being collected. This is becoming an area of increasing concern for consumers, law-makers and human rights advocates.

Teachers should also be aware of privacy, culturally sensitive images or information, copyright and intellectual property issues when producing and sharing VR content.

### 3.6 Conclusion

The age of immersive learning has arrived. However, research on the effects of IVR on children and their learning is still nascent. Large scale longitudinal studies on the effects of immersion are required and rigorous studies on the pedagogical potential of IVR are essential if the affordances of the technology are to be leveraged for creativity, collaboration and deep learning. Building this knowledge base will take time. In the interim, teachers must take a cautious approach, drawing on manufacturer health and safety guidelines and the substantial research on child development in order to make informed decisions about ethical and safe use of the technology. Importantly, school systems should be supporting teachers to understand the privacy implications of using immersive (embodied) technologies with their students and of creating and sharing VR content that might have private or culturally sensitive images or information in it.

### 3.7 Advice for teachers

*A. Consider the educational value of a virtual reality product for your class by asking:*

- What can students do with this product that is different from other educational resources or tools?
- Does it offer something that students do not have access to in real life?
- How can the VR product add value to my lessons? Do I want a one-off immersive experience to prompt engagement or experiences that can be revisited or used across key learning areas? Do I want to use it for guided discovery or creative, experimental design – does the product have the affordances that suit my pedagogical approach?
- Can my school meet the technical/hardware and internet network specifications to deploy the VR product? If the school has a BYOD policy, will the student’s device support the VR application?
- Provide opportunities for students to learn with and about VR across curriculum learning areas and in the general capabilities area. Resources on learning with and about VR can be found at The Digital Technologies Hub <https://www.digitaltechnologieshub.edu.au/footer/about-dth>

*B. Stretch your pedagogical imagination with VR ‘sandbox’ or studio environments*

Students do not need to code to be able to create in VR. Look for ‘sandbox’ or studio VR environments that provide learners with easy-to-use tools to create, design, prototype, annotate, interact and navigate with. Sandbox environments such as Minecraft VR or Tilt Brush (a 3D art studio) allow students to build models, simulate places, represent relationships, iterate on design, and exercise creativity. For example, in Minecraft VR students can build models of body organs that are as large as a house, and which allow for guided tours inside and outside the model. Similarly, in history, students can represent an event by researching and creating a 3D map that can be either flown over or toured at ground level. Students reading an historical novel could research and create a map of the setting where the sequence of events are visually symbolised and enhanced with quotes from the text. Tilt Brush can be used for design and prototyping; for example, costume or set design can be created for experiential, formative

feedback before the task is undertaken in real life. When considering VR applications, think about whether the software enables creative, interactive or experiential learning, or whether the application (and the school's internet access) will allow students to collaborate on learning tasks in the virtual environment in 'multiplayer' mode.

*C. Consider how developmentally appropriate the VR experience is for your students:*

- Is the content age appropriate?
- How might students respond to modes of social interaction in a virtual environment with other students (if it is networked) and/or with computer generated characters that might populate the environment?
- How might students respond to the learning affordances of VR e.g. cognitively, can they comprehend the purpose of manipulating size and scale? If students can freely navigate in the VR environment, could they become disorientated or overly distracted (and go 'off-task')?

*D. Consider ethical, legal and safety aspects:*

- It is important to undertake a risk assessment. Have students been trained on safety issues including recognising and responding to cybersickness? Has the manufacturer's health and safety information been consulted and used to screen students who might have medical condition that leaves them vulnerable to negative effects from VR?
- When creating and sharing VR content, have you considered: privacy and cultural issues (images of people and places or information that students are sharing as part of using a VR application); intellectual property (will the platform/vendor own the VR content that we produce and is this an issue); and copyright (are we breaching copyright when incorporating different media in the content we are creating).

## 4. Augmented Reality and School Education

### 4.1 Introduction

The release of face-altering filters in Snapchat in 2015 and the Pokémon Go in 2016, signalled the use of augmented reality (AR) as a mainstream technology. The term augmented reality was coined in 1990 with some of the first fully functioning AR systems used outside of the military developed during this time<sup>9</sup>. Recent internet advances the development of mobile computing technology (smart phones and tablets), have allowed AR applications to proliferate for mass adoption. Go to any app store and search for augmented reality and a multitude of applications, many free of charge, will appear. The ubiquity of mobile computing has led to an exponential growth in research on AR in education with scholarly publications increasing in the last 5 years (Akçayır & Akçayır, 2017; Ibáñez & Delgado-Kloos, 2018). One review of the research noted that around 50% of publications in this area focus on K-12 learners (Akçayır & Akçayır, 2017).

This literature review outlines the main finding from research on AR and schooling, drawing on meta-analyses, systematic reviews, original articles and expert media reporting. The review begins by defining and explaining AR and by providing an explanation of the term mixed reality (MR). This is followed by an overview of some key findings from the literature, with a focus on benefits and disadvantages of the technology. The review concludes by highlighting some ethical and safety matters that teachers should be aware of. While the review is not exhaustive, we have attempted to cover the main issues related to learning and the practicalities of the technology in classrooms (see Appendix 1 for the literature review methodology).

### 4.2 What is augmented reality?

Unlike virtual reality which immerses the user in a computer simulated environment that shuts out the physical world, AR 'wants to keep you in your world ... by (putting a digital) layer *between* you and your world' (Sumra, 2018, n.p). Augmented reality has been variously defined as a technology:

- that allows computer-generated virtual objects to be placed on physical object in real time (Zhou, Duh & Billingham, 2008);
- that project digital materials onto real world objects (Cuendet et al., 2013);
- used to dynamically overlay coherent location or context sensitive virtual information on the real world (Diegmann et al., 2015); and
- that enables the integration of real world experience with digital content (Hwang et al., 2016).

Ibáñez & Delgado-Kloos (2018) provide the following technical explanation of how AR technology works:

Augmented reality is a 3D technology which merges the physical and digital worlds in real time. Applications based on this technology rest on three pillars: tools to track information about real-world objects of interest; hardware and software to process information; and devices to show the user the digital information integrated into the real environment... AR technology is often described with reference to its two predominant modes of tracking information from the physical world. The

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<sup>9</sup> For an infographic on the history of AR see <https://www.augment.com/blog/infographic-lengthy-history-augmented-reality/>

first is image- or marker-based AR, which requires recognition of a marker or specific object to bring up digital information; the second is location-based AR, which makes use of a device's GPS to identify locations at which computer-generated information should be superimposed. (p.11).

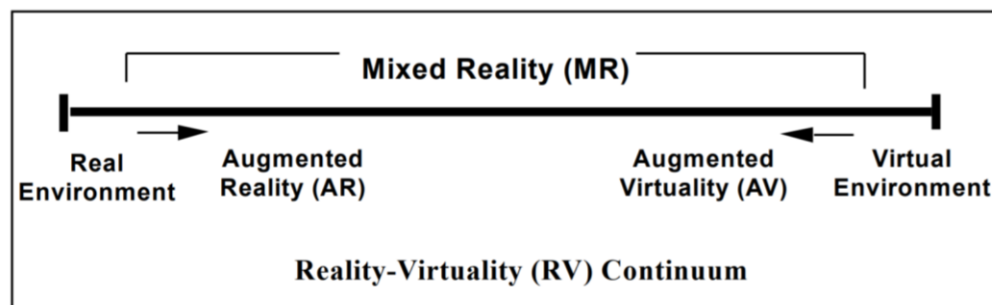
Image-based AR can be categorised according to its use of marker-based and markerless tracking. Koutromanos and colleagues (2015) explain that marker-based tracking requires labels such as quick response (QR) codes which register the position of the virtual object on the real world, while markerless systems use any part of the real environment as a target that can be tracked to place virtual objects (p.255). Location based AR uses a mobile device's GPS to trigger an AR overlay of information on a map or a live camera view<sup>10</sup>.

AR can be delivered through devices such as desktop computers, projector systems, mobile devices such as smart phones and tablets, and via head mounted displays (headsets, goggles or glasses). Currently, mobile devices are the most popular and least expensive hardware used to deliver AR experiences, especially in educational settings (Akçayır & Akçayır, 2017). Adcock (2018, n.p.) states that we are only at the 'beginning of the AR computing future' with the technology set to transform 'the way we interact with the digital world in everyday life'. He goes on to provide a glimpse of this AR future:

Computer-generated objects will increasingly become more interactive (responding to voice, gesture and even touch), more persistent over time (enabling users to leave a virtual object next to a physical one for someone else to find), and develop a greater understanding of the objects in their physical surroundings (such that they immediately react to changes in the environment) (Adcock, 2018, n.p.).

At this juncture it is worth outlining the term mixed reality. Mixed reality is term which is used in different ways in the research literature and by industry. Milgram and colleagues (1994) use it as an umbrella term encompassing the technologies on the reality–virtuality continuum (Figure 6).

Figure 6: The Reality-Virtuality Continuum from Milgram et al. (1994).



Today, the term mixed reality is often used interchangeably with AR or to denote a type of VR product. Increasingly, it is used to describe a new generation of head mounted display (headset), such as the Microsoft HoloLens (<https://www.microsoft.com/en-us/hololens>) or Magic Leap (<https://www.magicleap.com/>), in which virtual objects (often holograms) are not just overlaid on the

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<sup>10</sup> For an accessible technical explanation of how different types of AR work see <https://thinkmobiles.com/blog/what-is-augmented-reality/> or Edwards-Stewart, Hoyt and Reger [2016] for a nuanced AR classificatory scheme.

real world but realistically anchored in the real world in such a way that they dynamically interact with it. The promise of these new types of mixed reality headsets for education is just beginning to be explored, however they remain very expensive or are have limited (developer first) availability.

### Highlights

Augmented reality, a relatively young technology in terms of mass adoption, enables the overlay or integration of digital content over the real world.

Augmented reality can be delivered by desktop computers, projector systems, mobile devices such as smart phones and tablets, and head mounted displays (headsets, goggles or glasses). The most common, is mobile device enabled AR.

The term mixed reality is used in different ways but is increasingly associated with realistically anchoring digital content in the real world in ways that allow people to interact with it.

## 4.3 Research on augmented reality and school education

Although the technology is still maturing, AR has been adopted in schools through a range of products and learning experiences. These include: AR pop-up story and text books, flash cards and educational games; mobile device enabled augmented field trips where information, 3D objects and animations are overlaid on the learners real environment; superimposed AR designed for interactive training purposes; apps that allow students and teachers to create their own augmented learning resources and activities; and as a educative adjunct of visits to museums, galleries and places of historical significance. Cuendet et al. (2013) argue that well-designed educational AR should have three characteristics:

- (1) AR systems should be flexible enough for the teacher to adapt to the needs of their students;
- (2) the content should be taken from the curriculum and delivered in periods as short as other lessons;
- and (3) the system should take into account the constraints of the (classroom) context. (p.559).

While the types and uses of AR in classrooms differ, there are several recently published meta-analyses and systematic reviews of research which have synthesised findings to highlight the benefits and challenges of the technology in educational settings. For example, Radu's (2012) comparative review of the educational impacts of AR, based on 32 conference papers and journal article, found that technology had certain positive effects on learning. These were: increased understanding and long-term memory retention of content; increased student motivation; and improved collaboration. Negative learning effects included: attention tunnelling (the demands of AR systems diverting attention away from important parts of the learning experience or team task); useability difficulties; ineffective pedagogical integration; and, the potential or the technology to be ineffective in accounting for learner differences. Radu (2012) also presents a set of technological and psychological factors that might influence learning in AR. These are: the way AR can transform the representation of content from text to visual forms through more interactive images, animations and 3D objects; how textual representations can be aligned with visuals to reduce the need of the learner to switch attention between media and to direct attention to the learning task; that the embodied, interactive interfaces of AR might reduce cognitive load and increase motivation; the ease with which AR can aid collaboration; and how AR simulations can allow for impossible or infeasible learning experiences (e.g. field trips to far-away places or examining the structure of a virus close up).

Akçayır & Akçayır (2017) more recent systematic review of research based on 68 articles found that most studies reported that AR enhanced learning performance either in terms of achievement,

motivation or enjoyment. They found that while some researchers reported outcomes such as AR decreasing cognitive load or improving spatial ability, that these claims required further investigation. One of the key benefits of AR related to learner interaction and collaboration. Around 10% of the studies reported AR promoted more student-student interaction by 'learning through doing'. Furthermore, they report that AR aided learning by allowing students to visualise intangible or abstract concepts or unobservable phenomena such as magnetic fields. Akçayır & Akçayır (2017) also report on challenges to using AR for education. These include: useability of the technology and technical issues that interrupt learning; teacher ability to use the technology effectively; expense; cognitive overload due to the amount of material or complexity of the tasks designed for AR; and the potential for AR to distract students from their learning. They recommend that: there be more attention paid to designing AR for diverse populations of learners, such as students with special needs; more research is required to understand how the technology can support collaborative learning; and that pedagogical and design principles should be treated holistically and that these should be empirically tested. This final point is supported by Radu, McCarthy and Kao (2016) who recommend that developers collaborate with teachers in the design of AR educational applications to forge new ways of representing content.

A recent meta-analysis (Ozdemir et al., 2018) investigated the effects of AR on learning using 16 articles based on studies that involved pre and post-tests comparative methodologies (81% of these studies were conducted in schools). The author concluded that AR applications positively affected academic success with the effect size at a medium level (.517). Ibáñez & Delgado-Kloos' (2018) systematic review of AR for STEM learning, based on 24 articles (18 on research with school students), found that the technology sometimes proved useful in improving learners' cognitive outcome and that it fostered 'positive affective states of students such as motivation, engagement and attitude towards STEM subjects' (p.120). A minority of studies reported problems including the need to train students in use of the technology, student distraction, and that the systems did not provide immediate feedback or were slow and not intuitive. The authors recommend that future research determine the effectiveness of AR in developing high level cognitive outcomes over time.

While there are relatively few studies on the use of AR in special education, some have indicated that the technology is promising. For example, Lin and colleagues (2016) used an AR application to teach geometry to 21 primary school students with special needs. They found that the AR application helped the students to finish geometry puzzles independent of teacher's assistance and that students demonstrated improved ability to complete puzzle game tasks compared with traditional paper-based methods. The authors suggest that AR enhances motivation and decreases frustration in children with special needs. In a pilot study using a table top AR system to teach primary school aged students with special needs mathematics relating to monetary system, Cascales-Martínez et al. (2017) found that students displayed positive engagement and that their math knowledge and money dealing skills improved.

### **Highlights**

Augmented reality has been used in schools via AR pop-up story and text books, flash cards and educational games; mobile device enabled augmented field trips; superimposed AR designed for interactive training purposes; and apps that allow students and teachers to create their own AR content.

Benefits of using AR for learning include: the way it transforms content from text to visual and interactive forms; its attention grabbing, interactive qualities; its potential to enhance collaboration; and the ability of AR simulations to facilitate impossible or infeasible learning experiences (e.g. field trips to far-away places).



Some drawbacks of AR include: useability of some applications and technical issues; the potential for cognitive overload due to the amount of material or complexity of the tasks; and student distraction from key aspects of learning.

#### 4.4 Safe and ethical use of augmented reality

There are some important ethical and safety issue related to using AR in schools. The first is the age-appropriateness of content, especially with more AR apps developed for a broad or general customer base. The second involves student distraction and the potential for accidents, an issue that has been documented by AR researchers for some time (Dunleavy, Dede & Mitchell, 2009). Although students can see their environment, the portability of mobile devices coupled with student engrossment with AR technology creates risks that needs to be addressed in setting up and regulating movement in the classroom and particularly with outdoor learning activities. Thirdly, there are privacy issues to consider. This is particularly relevant when student and teachers create their own AR content which captures an individual's image, voice or other identifiable attributes, incorporates this into an AR application and shares it via AR platform licencing arrangements or open resource repositories. It is likely, in the near future, that AR wearables similar to Google Glass, will become available and that there will be another resurgence of privacy concerns. The digital rights of the child are paramount in regard to any technology that might capture data about or of the student outside of and within schools (de Azevedo Cunha & Unicef, 2017; Livingstone & Bulger, 2014; Lupton & Williamson, 2017).

Finally, emerging technologies such as AR bring with them complicated legal questions especially for artistic works and content creation. Capturing and augmenting images and soundscapes and sharing these can bring copyright and intellectual property concerns to the fore. This includes the intellectual property of students and teachers who create desirable AR content. These issues will no doubt be resolved in legislative processes including courts of law. It is however important for educational policy makers, teachers and students to consider the legal issues of intellectual property and copyright. As one legal scholar explained:

With innovations in technology come intellectual property issues. And although intellectual property rights can fall under several different buckets, due to the expressive nature of AR, copyright is likely to be a major intellectual property concern for AR users. ... As a result, it may be imperative to re-examine the way that copyright law is applied to AR; otherwise the essence of the technology will not be accessible to users without running the risk of copyright infringement. (Afoaku, 2017, p. 127-128).

#### Highlights

When considering an AR product, the teacher should evaluate the age appropriateness of the content and assess risks to students who may be moving around in a distracted manner while using mobile devices.

When creating and sharing AR content, teachers should consider student privacy and intellectual and copyright issues.

#### 4.5 Conclusion

Although AR is a relatively new technology in terms of mass adoption and use in schools, it has potential to engage and motivate students of all ages, especially in learning abstract or theoretical knowledge or allowing for experiences that might be unsafe or infeasible in real life. AR also has potential to

encourage collaborative learning. The technology lends itself to small group tasks or more teacher directed learning. The benefits of AR as a training tool are also apparent: being able to look inside or peel back layers virtual objects or superimpose images and other information on these objects, can enhance understanding and application of knowledge. AR does present some safety issues, especially in terms of student distraction and mobile devices. Perhaps the main concerns will be ethical and legal concerning the areas of privacy, intellectual property and copyright, especially in relation to student and teacher generated AR content.

## 4.6 Advice for teachers

*A. Consider the educational value of an augmented reality product for your class by asking:*

- What can students do with this AR product that is different from other educational resources or tools?
- Does it offer something that students do not have access to in real life?
- How can the AR product add value to my lessons? Do I want a one-off learning experience to prompt engagement or experiences that can be revisited or used across key learning areas? Does the application allow for student and teacher content creation? How can you use the application to augment or create another educational layer to existing (more traditional) content?
- Can my school meet the technical/hardware and internet network specifications to deploy the AR product? If the school has a BYOD policy, will the student's device support the AR application?
- Provide opportunities for students to learn with and about AR across curriculum learning areas and in the general capabilities area. Resources on learning with and about AR can be found at The Digital Technologies Hub <https://www.digitaltechnologieshub.edu.au/footer/about-dth>

*B. Consider how developmentally appropriate the AR experience is for your students:*

- Is the content age appropriate?
- How might students respond to modes of interaction with AR content?
- How might students respond to the learning affordances of AR e.g. cognitively, can they comprehend the purpose of manipulating size and scale?

*C. Consider ethical, legal and safety aspects:*

- Undertake a risk assessment to ensure the safety of students if they are moving around with devices so that distraction does not lead to injury; and
- When creating and sharing AR content, have you considered: privacy and cultural issues (images of people and places or information that students are sharing as part of using a AR application); intellectual property (will the platform/vendor own the AR content that we produce and is this an issue); and copyright (are we breaching copyright when incorporating different media in the content we are creating).

## 5. Curriculum and Professional Learning Resource Mapping

### 5.1 Background and aims

The purpose of this chapter of the report is to scope and map curriculum and professional resources on AI, VR, AR and MR. This chapter also provides a *Checklist Tool* for teachers to assess the relevance and quality of the resources they may independently locate (see section 5.4).

Specifically, the aim of this exercise was to identify resources:

- for *learning about* technology (AI/VR/AR/MR) appropriate for use with students, or for teacher professional learning;
- for *learning with* the technology; and
- that would inform the development of a teacher *Checklist Tool*.

The mapping exercise was not exhaustive. However, it was informed by a set of quality criteria and concerted attempts were made to identify appropriate resources across technologies. The resource map (see Appendix 4) provides a foundation for building knowledge and understanding of these technologies for classroom use.

Providing quality resources and professional learning for teachers in the area of AI and emerging technologies is vital. There are several relevant Australian Professional Standards for Teachers (AITSL, 2018):

- 2.6 Information and Communication Technology: implement teaching strategies for using ICT to expand curriculum learning opportunities for students;
- 3.3 Use teaching strategies: Include a range of teaching strategies;
- 3.4 Select and use resources: Demonstrate knowledge of a range of resources, including ICT, that engage students in their learning;
- 3.6 Evaluate and improve teaching programs: Demonstrate broad knowledge of strategies that can be used to evaluate teaching programs to improve student learning;
- 4.5 Use ICT safely, responsibly and ethically: Demonstrate an understanding of the relevant issues and the strategies available to support the safe, responsible and ethical use of ICT in learning and teaching;
- 5.1 Assess student learning: Demonstrate understanding of assessment strategies, including informal and formal, diagnostic, formative and summative approaches to assess student learning;
- 5.4 Interpret student data: Demonstrate the capacity to interpret student assessment data to evaluate student learning and modify teaching practice;
- 7.1 Meet professional ethics and responsibilities: Understand and apply the key principles described in codes of ethics and conduct for the teaching profession;
- 7.2 Comply with legislative, administrative and organisational requirements: Understand the relevant legislative, administrative and organisational policies and processes required for teachers according to school stage; and
- 7.4 Engage with professional teaching networks and broader communities: Understand the role of external professionals and community representatives in broadening teachers' professional knowledge and practice.

The use of the technologies as teaching tools could be relevant to a broader range of standards. Our focus here is on those standards that are directly applicable.

## 5.2 Approach

### 5.2.1 Criteria for inclusion/exclusion

Inclusion/exclusion criteria were determined by synthesis of the criteria used in the 'Education value standard for digital resources' developed by Education Services Australia (2012) and identification of the good educational resources frame of the Royal Society of Chemistry (Hessey, 2016). One of the inclusion criteria was consideration of evidence in the resource or resulting from expert opinion. The categories of types of evidence were drawn from the evidence hierarchy pyramid (Cochrane Community, 2015): categories of evidence include meta-analyses and systematic reviews, randomized control trials and case studies, and expert opinion. The following criteria were used to include a resource:

- Focus – is the material relevant and useful to Australian classroom teachers and students?
- Alignment – Does the resource align with the Australian Curriculum or the AISTL Professional Learning standards? Could the resource be used to motivate engagement with elements of the Australian Curriculum?
- Integrity – Is the material accurate? Is the source authoritative? Has the material/information been created/developed and/or updated within the past five years?
- Evidence - Is the resource evidence informed or evaluated (i.e. based on, or evaluated by, one of the evidence types in the evidence hierarchy [Cochrane Community, 2015]).

To summarise, resources that were included were:

- evidence-based or created by an authoritative source (professional organisations, education departments, curriculum authorities [integrity, evidence];
- relevant to the Australian Curriculum [focus];
- be of interest for classroom use by teachers [alignment];
- be readily available with the vast majority free of cost; and
- produced or updated within the last five years.

Resources excluded from the mapping exercise were:

- commercial hardware or software products;
- sales materials or descriptions;
- research articles;
- commentary that used secondary sources; or
- resources about coding due to the availability of the 'Coding across the curriculum: Resource review' from Falkner and Vivian (2015).

There are a number of high quality hubs that curate and provide digital technology learning resources that are well mapped to the Australian curriculum such as the Digital Technologies Hub. Where resources from such hubs were explicitly about AI and emerging technologies, they were included in this resource mapping.

## 5.2.2 Methodology

An internet scoping exercise was conducted to identify appropriate resources. This involved internet searches using Advanced Google with MetaCrawler also deployed to ensure that appropriate resources were captured. The following search terms were used:

Table 2: Search terms

Search term 1	Search term 2	Search term 3
	AND	AND
Artificial intelligence	(primary school OR elementary school)	English
Virtual reality	Secondary school	Science
Augmented reality	Professional learning OR professional development	Math
Mixed reality		Art
Machine learning		Humanities OR social science
		Health OR Physical education
		STEM
		STEAM

Search terms 1 and 2 were used as the first set of searches which provided a broad group of resources targeted at education. For example, 'artificial intelligence' AND 'secondary school'. Search terms 1, 2 and 3 were used as the second set of searches to focus on explicit subject areas. For example, 'virtual reality' AND 'primary school' OR 'elementary school') AND science. There were 54 individual searches conducted. All searches were conducted for resources in the language of English, where an update had been made within the last five years.

In addition, State Education Departments, the Catholic, and Independent Schools sector, were contacted to clarify the availability of accredited courses or opportunities, endorsed courses or opportunities, and strategies that the various authorities suggested as appropriate for teachers to use for their professional learning. The majority of departments responded with Tasmania and South Australia offering no reply. For all states, the Department websites were searched for any detail, with additional information gathered from the states replying to our queries.

Where generic resources were known to the research team, such as Google Earth VR, these were added to the resources list, although they were not found in the searches. Some results returned were websites of multiple relevant resources. In these cases, the website was recorded as the resource, for example Google Expeditions.

All resources found were checked against inclusion/exclusion criteria. The process used was to:

1. FIND the resources using the search terms and date parameters;
2. ASSESS each of these against the inclusion/exclusion criteria; and
3. INCLUDE/EXCLUDE each resource in turn.

Those resources that met the inclusion criteria were counted in order to provide an idea of educational resource availability. Once the basic searches were concluded, exploration of ten VR, AR and MR

hardware websites identified a number of additional resources. The resources list was edited to remove duplicates and inclusion criteria for each resource was checked by two researchers in the team.

A detailed record was made for each resource including: resource name (including link); source with year of publication; description; applicability to national curriculum outcome (if outcomes were identified across syllabi then the code used was 'various' - see Appendix 4).

The curriculum mapping was completed using the Australian Curriculum and Scootle. Researchers on the team checked the mapping of resources to curriculum outcomes were appropriate. All resources were mapped and checked at least twice.

Searching for professional learning identified differences between states. The only state to accredit professional learning, and professional learning providers, is NSW. All other states leave identification of professional learning opportunities to schools and individuals to identify and engage to suit their needs. Some states, for example Queensland, offer a range of online opportunities at no charge. Any recorded webinars, online courses, or workshops in this category were examined for the inclusion or consideration of emerging technologies. Very few were found to have integrated, or even mentioned, these emerging technologies. The *Checklist Tool* (Section 5.4) was created from the criteria and then iteratively trialled and refined with a selection of resources.

### 5.3 Findings

Of the resources found in the general searches, a small percentage met the criteria (Figure 7). This highlights that these emerging technologies are still being explored, evaluated and positioned within education for the purpose of supporting learning. Many resources are available at a cost, and usually would involve authoring systems, as well as hardware and software applications. Resources in this area that were free, but dependent on having the necessary hardware, were included in the resource list.

Figure 7: Comparison of resources that met inclusion criteria compared to those excluded (by number).

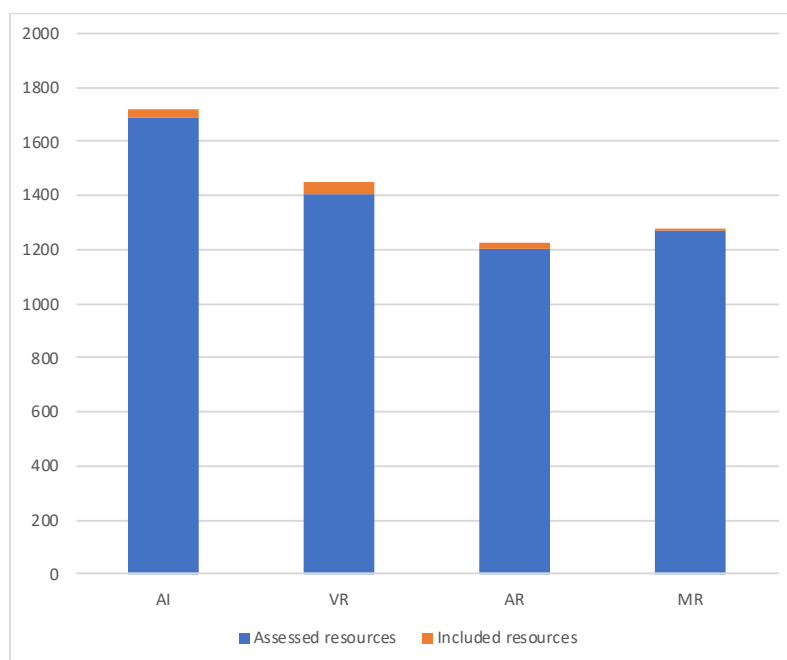
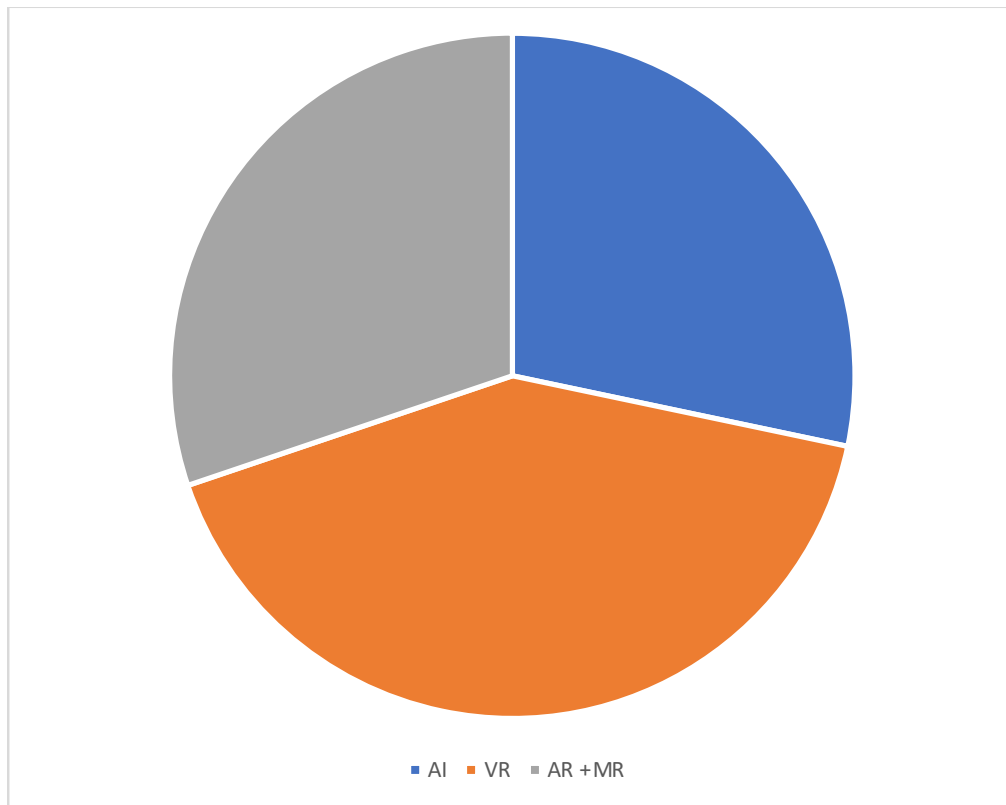


Table 3: Comparison of resources assessed during searches compared to resources included

Search area	Resources assessed	Resources included	% included
AI	1693	30	1.8%
VR	1403	44	3.1%
AR	1204	20	1.7%
MR	1270	12	0.9%
Total	5570	106	1.9%

Figure 8: Resources that met the criteria for inclusion by technology type



As Figure 8 illustrates, most resources that met the inclusion criteria were related to VR or AR/MR. Mixed reality searches returned few resources, so these are included in the graph with AR resources.

#### 5.4 Checklist tool for teachers

The following checklist is designed as a scaffold to assist teachers in assessing the quality and relevance of resources for AI and emerging technologies.

<b>Resource Name:</b>		
<b>Found at:</b>		
<b>Focus and alignment</b>	Is the resource aligned to the curriculum?	
	Is the resource appropriate for my students? (Including diversity).	
	Will the resource assist me in meeting the Australian Professional Teaching Standards?	
<b>Integrity and evidence</b>	Is the resource up to date? (Produced or updated in the last five years).	
	Has the resource been developed by an expert or is it based on evidence?	
	Has the resource been formally evaluated?	
<b>Ethics and safety</b>	Does the resource include discussion or advice on ethical, safety or legislative issues?	



## 6. School Case Studies

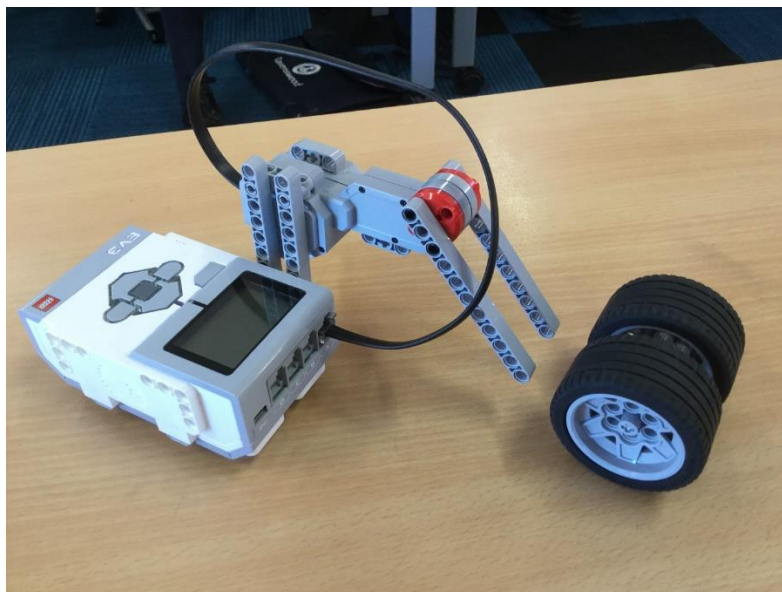
The case studies of classroom practice using AI and VR technology were located in several ways including social media (Australian Edu Twitter accounts and teacher professional learning Facebook pages), conferences, professional contacts and 'snowballing' by asking teachers if they knew of any interesting projects. The case studies are written by teachers for teachers and include examples from those who are just starting out on the journey to trail blazers in area of integrating AI and emerging technologies in the classroom.

### Innovative AI in the primary classroom

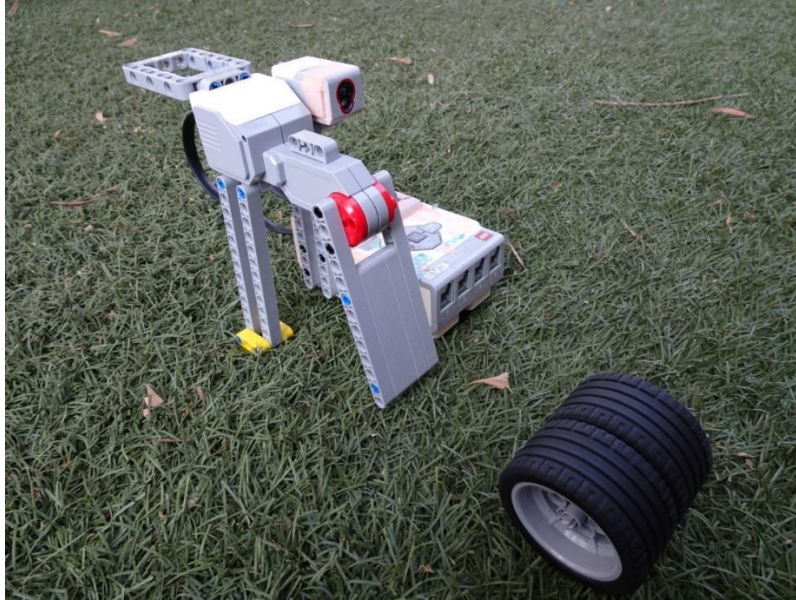
**The teacher and school:** Matthew Scadding, Ravenswood School for Girls.

#### What was the project about?

The project was designed and implemented in partnership with Dr. Joshua Ho of the CSIRO STEM Professionals in Schools program. The need for this learning was to introduce the topic of Artificial Intelligence (AI) to Year 6 primary school students and for them to see AI as fun, not scary, and something students will want to continue learning about in the future. The program unfolded over 2-3 lessons of about 50 minutes. The main goals of the course were for students to understand how robots learn and if there were similarities between the way humans learn compared to robots. The practical component of the course was to try to teach a LEGO EV3 robot to play the game of lawn bowls. The project aligned with the digital technologies strand of the NESA Science and Technology curriculum as students were tasked with defining a problem and designing a digital solution that incorporates algorithms.



Pieces of the robot developed – the 'ball' was the two wheels.



A different design for pushing the 'ball'.

### **Why use this technology?**

The technology used for this project was a laptop and a LEGO Mindstorms EV3 robot. This robot can be designed and built in many different ways because of the modular nature of LEGO blocks and other components, such as motors. Using the LEGO kit it was possible to design a robot with a movable robotic arm that was coded to push a ball in order to simulate the game of lawn bowls. The laptop included the Mindstorms software which is used to code the robot. A program was created where the robotic arm pushed the ball with a random amount of force to push a ball near to another ball called the jack. The aim of the game is to push the bowl as close to the jack as possible. If the robot used too much force the human user could tell the robot it used too much force via a button on the intelligent EV3 'brick' which houses the microcontroller. If the robot used too little force the human user could also feed this information back to the robot. Based on the feedback it received, the robot could then adjust the amount of force for the next attempt. The technology used enabled students to design a robot that could learn and behave like a human because it could learn a new skill and master it because of the feedback it received from a human. This task would not have been possible without this technology.

### **What was the biggest learning curve?**

The biggest learning curve was translating the meaning and logic of the task into computer code. Students could articulate the learning intentions and the specific actions the robot needed to perform, however, converting this understanding into an algorithm that could be implemented in to computer code was challenging. Thinking computationally was one method students used to help solve this problem. Through the processes of decomposition and abstraction students were able to break down the problem into smaller tasks that could be solved individually. This enabled students to see the task more clearly and then work collaboratively to implement the computer code needed.

## What advice would you give to teachers?

Think critically about the technology resources you have and how you can use them to enable deep learning to happen. Refer to the SAMR<sup>11</sup> model for technology integration when planning new learning to decide on the level of integration the technology is achieving. Always try to link your tasks to authentic, real-world situations to make the learning more purposeful and meaningful.

## The VR trailblazer in high school geography

**The teacher and school:** Kenan Koparan, Toongabbie Christian College (project conducted at William Clarke College).

### What was the project about?

In 2017, I created one of the most daring Project Based Learning tasks for a class of Year 9 Geography students. The project asked students to create and present a plan for how an Australian city or suburb could be further developed to maximise economic, environmental and social sustainability. The task was unique in that students needed to present their plans through a Virtual Reality (VR) tour utilising a new program called Story Spheres offered by Google in early 2017.

### Year 9 Geography- Changing Places

How can we, as “urban planners”, create a Virtual Reality tour to help educate the public about a chosen Australian city’s plan to become a more sustainable city?

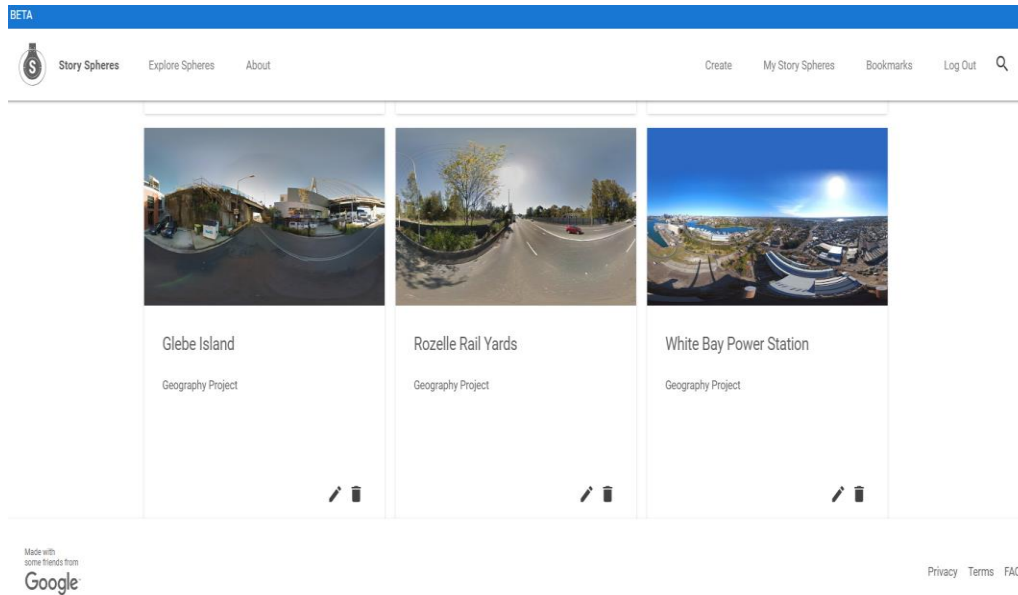


**Sustainable-** Understanding how to meet the needs of the present without compromising the needs of future generations to meet their own needs.

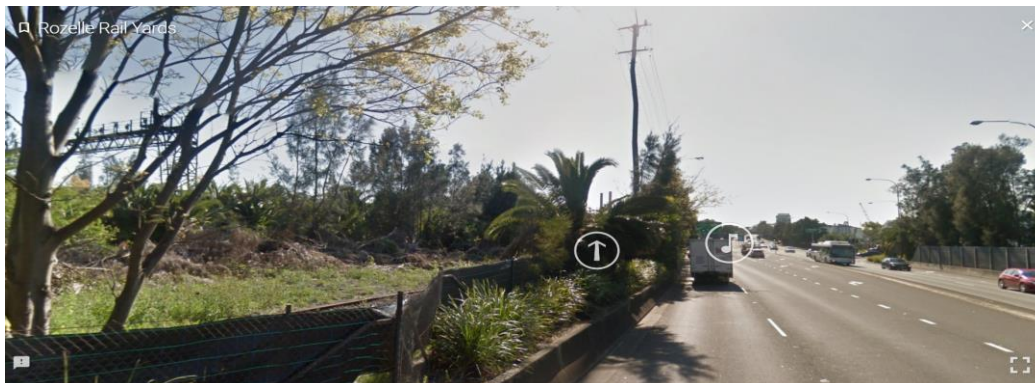
The task.

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<sup>11</sup> [Puentedura, R. \(2012\). SAMR Six Exemplars](#)



Screenshot of initial entry for three of the tours.



Screenshot in-app for the Rozelle Rail Yards tour.

### Why use this technology?

Through the project, I wanted students to learn skills that would prompt them to research, think critically and problem solve; mimicking what they would be doing beyond school in the field of Geography. I also wanted students to gain an expert understanding of how to use and apply future technologies like VR. Thus, Story Spheres was the most appropriate program for this task enabling the opportunity for students to create their own VR tours. It was also my personal mission to show colleagues that VR could be more than just passive observation of foreign environments and that students could engage and create their own worlds.

### What was the biggest learning curve?

Finding the balance between providing students with content and technological knowledge weighed against the time that students had to work on their projects was my biggest learning curve. I had on occasion assumed my students had appropriate knowledge of how to work the program and quickly

found that they needed a further explanation. In having them create a VR tour, I also needed to be an expert in how to work the program.

### **What advice would you give to teachers?**

The small nuggets of wisdom that I can provide having created and implement such a task is to firstly, take the initial risk. If you fail, try a different approach and know that persistence is key with integrating emerging technologies. 'Dogfooding' or trialing your own task is a must to ensure that all components work whether it be the program or instructions. Constantly keep an eye out for new and improved programs or technologies which make the task easier to complete. Finally, ensure that students have a model to help them understand the expectation of their final product.

## **VR School - A world first in immersive learning research**

**The teacher and school:** Amy Worth on behalf of the VR School Team, Callaghan College.

### **What was the project about?**

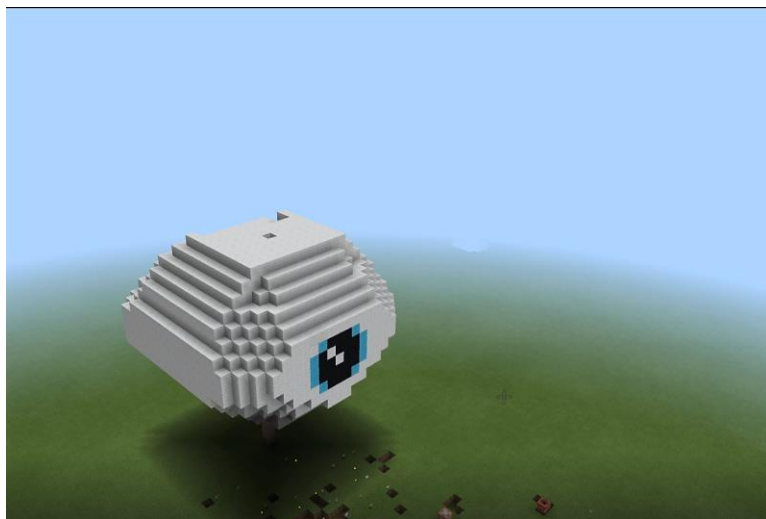
The Callaghan College VR School Project has been a two-year partnership between Callaghan College and The University of Newcastle. This project was conducted in 2017-2018 and has included over 100 Stage 4 and 5 (Year 8 and 9 respectively) Science and Technology students. This project is the first of its kind anywhere in the world to embed highly immersive VR, in this case networked Oculus Rifts, in high school classrooms in a curriculum aligned way. During the 2018 phase of the project, students attended Science lessons as normal. Within 'The Human Body' curriculum, a unit of work with a formative VR assessment task was created which complemented the remaining summative tasks and allowed students a choice to undertake their own research in groups to deepen knowledge about specific bodily organs. The students were asked to build models or cross sections in VR that represented the bodily organ and demonstrated the depth of their research. They then took others on a guided tour of their organ explaining its parts and function based on their research. For safety reasons, due to the possibility of cyber sickness, students were only allowed 15-20 minutes in the networked VR environment and not allowed to do VR if it was the final lesson of the school day. This meant that students needed to plan, in their groups, what tasks they would undertake together in VR to accomplish the assessment task.



Students using VR in the classroom.



The brain model viewed from above.



Flying high above the model of the eye.

### **Why use this technology?**

High-end VR offers unique characteristics for learning like manipulating scale and being able to actually go inside of or fly around the models you create in a way that feels real. Student learning outcomes related to engagement, achievement and prevalence of on task/off-task and metacognitive learning behaviours are currently being analysed. The qualitative data reveals many students found the task engaging, with some producing models and research of high quality. Other students were de-motivated by the technical issues. The teachers implementing the project provide the following insights:

The VR Schools Project was, overall, successful from the technology and pedagogical points of view despite there being numerous issues that needed to be overcome (and in some instances could not be overcome). It is not yet known if it improves student learning outcomes (as this data is currently being analysed), however there is strong anecdotal evidence that it increased engagement markedly for most student involved. This project has been a strong proof of concept for using VR in teaching

and learning with real content, with real students, in real schools. *(Shane Saxby – Callaghan College Waratah, Rel. Head Teacher Science)*

I can see changes that have occurred in student learning on a qualitative level. The quantitative changes will hopefully come out in the study. The biggest change I have seen is in the depth of knowledge that students have come away with about the human body through the VR creation of models that they built. *(Jivvel Kilham – Callaghan College Wallsend, Head Teacher Science)*

### **What was the biggest learning curve?**

The cutting edge nature of the project meant that there were technical issues to overcome: the team's perseverance, resilience and teamwork ensured that, for the most part, the student learning experience took advantage of the unique learning properties of immersive VR and that data was systematically collected on learning behaviours and outcomes.

Technology as well as space availability in a public comprehensive high school were some of these hurdles included: acquiring a space suitable for networking VR equipment with tracking systems that was in proximity to a teaching space; the need to purchase laptop computers powerful enough to run the Oculus Rifts; a special network set-up that occasionally dropped out or equipment needing resetting during class time; installing Minecraft Windows 10 Edition on Department of Education units which only have Windows Store for Business enabled; and ensuring continuity of student work undertaken in Minecraft on desktop computers or mobile devices and imported into the Windows 10 version of Minecraft for VR.

### **What advice would you give to teachers?**

Ensure you have a team of dedicated teachers, including senior executive members invested in the implementation of VR in your School. Develop authentic tasks with real world content creation as a part of the task to give students the opportunity for deep learning in the VR context. But most of all, if you don't succeed, try, try again... It is worth the time and effort for the level of engagement and the learning experience it provides students.

## **The Creatives - VR for theatre design in a rural school**

**The teacher and school:** Louise Rowley, Dungog High School.

### **What was the project about?**

The Year 11 students were creating a Director's Folio for a contemporary Australian play called Ruby Moon. They traditionally have to create a director's vision and explore this in their set box and costume designs. [P1.4: understands, manages and manipulates theatrical elements and elements of production, using them perceptively and creatively.] For this project, we included the VR and the program Tilt Brush for them to explore and create an audience experience of their Director's vision. This really led to more engagement with the atmosphere and audience experience. [P2.1: understands the dynamics of actor-audience relationship.]

They were working in groups to create their designs and needed to understand, manage and manipulate theatrical elements and elements of production. They were charged with the task of using them

perceptively and creatively and this was taken to a new level of creativity in the VR space. We had been inspired by the National Theatre in the UK who created an immersive experience for their audience based on their director's vision. This takes the audience to a completely new place and extended the idea of theatre as an immersive art form. [P1.4: understands, manages and manipulates theatrical elements and elements of production, using them perceptively and creatively.] The process of taking their Director's vision into the VR space allowed them to think more about the audience's experience and really immerse themselves in the director's role. It allowed them to demonstrate their directorial vision in the immersive virtual world as well as in the physical world. [P2.2: understands the contributions to a production of the playwright, director, dramaturg, designers, front-of-house staff, technical staff and producers; P2.3: demonstrates directorial and acting skills to communicate meaning through dramatic action.]

The project also aligns with key competencies in Drama with students collecting, analysing, organising information, and communicating ideas and information in new and creative ways their Director's folio and in the VR space. Students were also planning and organising activities and working with others and in teams. The level of collaboration, which developed throughout the project, was a key achievement. Students were discussing ideas like Directors and helping each other to master the new software. They had no experience with the technology before they started and were able to unleash their creativity and I saw students who were less confident really growing in their confidence and ability to take a role in the group. Using the VR deeply engaged the students in their learning. The project involved enquiry, research, analysis, experimentation and reflection contributing to the development of the key competency solving problems. Students had the opportunity to develop the key competency using technology in the study of new approaches to Drama and Theatre and dramatic forms. VR is a completely new technology and we are already exploring more ideas on how to link more programs together within the Tilt Brush software. We are playing with Google Blocks and Ploy and seeing how they can connect. The aim is to improve our skills and be able to create even more exciting projects.



Preparing the VR equipment for students.





A student hard at work designing their stage set in VR.

### **Why use this technology?**

In the design process there is a lot of experimentation and collaboration required. Tilt brush has endless features that allow this to occur. Sketches could be saved, videoed, gifs made and photographed, and this process of documenting their ideas helped the students reflect on their ideas more. The quality of their ideas developed further. The Tilt Brush program was an endless space, which incorporated many amazing creative features. Designs could be instantly erased and then re-created quickly. It was not messy and did not waste materials. It had many resources that we do not usually have in the Drama room. Endless colours and brushes, backgrounds, models to be imported and guides to draw around. Sketches could be made smaller or bigger in an instant. It allowed all students to be equal. Once in the technology they were able to each contribute in a very really and tangible way to the group idea. It also allowed our rural students to have access to quality programs, which can sometimes not be available to them because of location.

### **What was the biggest learning curve?**

We had to learn how to use the technology and how to program the classwork to make sure other tasks were being completed at the same time. This was fairly painless and the students were great. As the teacher, I had to take a risk with new technology and not be frightened of not knowing absolutely everything about the software. After a while, the students were teaching each other and me.

### **What advice would you give to teachers?**

Just do it! It isn't scary and you don't have to know everything. I have given advice to others in my school about trying new technology. There is so much to learn it can be quite overwhelming but it can be a lot of fun. I am helping a Year 10 Art class now and was the inspiration for a music teacher to try a few new technologies. So the effect has been good.

## First virtual steps – A rural school prepares for learning with VR

**The teacher and school:** Thomas Vinter, Mossman State High School.

### What was the project about?

Mossman State High school is located in tropical Far North Queensland and is the only high school within a 80km radius. Many of our year 7 to 12 students travel hours to school each day from as far as Daintree, Cow Bay, Port Douglas and Oak beach. We have a diverse cohort including students from the Kuku Yalanji peoples, students from cane farming and agricultural backgrounds and students from reef and rainforest tourism backgrounds.

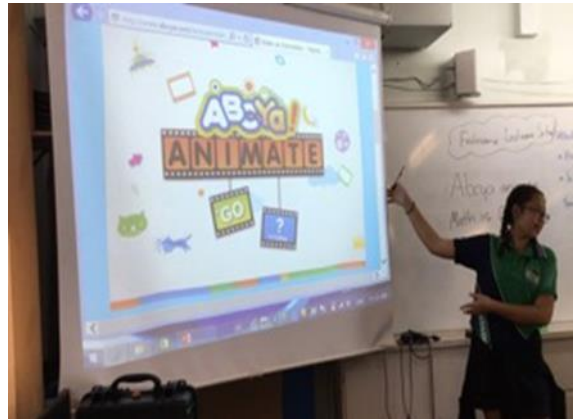
In 2018, the school committed to a focus on increasing the digital capabilities of the community. Part of this commitment has involved the development of an action research project with the Australian Curriculum Assessment Authority (ACARA) which is currently being implemented. This included a host of projects for students that included:

- Mossman High Digital Showcase project: Our year 9 digital technologies students hosted over 100 students from local feeder primary schools where our students used the limited resources available to introduce the basics of Scratch coding, Edison Robots, Drones and animations. The event received excellent feedback and will continue to grow and showcase Digital Technologies at each annual event.
- Mossman High Network Analysis project: Our year 9 digital technologies students performed a school wide network survey to document every piece of network equipment within the school. Students constructed detailed network diagrams and used this information to perform an analysis of the strengths and limitations of the school network.
- Mossman High School Induction project: Our year 9 digital technologies students are currently creating school induction app for new and existing students to the school. The app will feature interactive school maps plus informative videos from staff and support services to help new students with the transition to Mossman High.

Each of the projects above places an emphasis on authentic tasks to support students in becoming the experts in the situation. Mossman High has recently purchased Oculus Rift + Touch VR headsets in preparation for the expansion of the DGT program in late 2018 and early 2019.



Scratch Gaming demonstration for visiting Primary School students



Animation Basics

### **Why use this technology?**

Staff at MSHS have had very little training and exposure to VR as there has been limited PD on offer. The driving factor for including this technology in technologies classes has come from the students themselves. There are several avid technologies students who have their own VR equipment and often discuss how activities in the classroom could be enhanced through VR. For example, defining and designing digital solutions in VR.

### **What is the biggest learning curve?**

MSHS are at the early stages of using VR. The first challenge encountered was to do with the purchase of the VR equipment. We needed to review the specifications of the VR equipment to ensure compatibility with the existing computers. Existing computers were not capable of running VR and therefore a limited amount of new computer equipment was purchased. The second challenge was locating a supplier that met procurement conditions. Amazon Australia was the best option and the purchase was made. We currently await the receipt of the equipment and will move to testing before implementation in the curriculum.

### **What advice would you give to teachers?**

The ability to interact and create solutions with emerging technologies is vital to the future success of today's students. Notably, many students arrive to the classroom with the implicit skills to do this already. What they need from teachers is authentic tasks that constructively build on their existing skills. The result, students who are technologically capable and confident.

## 7. Concluding Remarks

Moving forward, practical steps are required to build the capacity of teachers and their students to learn about and with AI and emerging technologies, and to build their capacity to thrive in an AI world. It is an appropriate time to identify opportunities to integrate or strengthen learning about and with AI and emerging technologies within the Australia Curriculum. These opportunities exist within the Design and Technologies and Digital Technologies Learning Areas and in the General Capabilities component with its emphasis on developing student 'Information and Communication Technology Capability', 'Critical and Creative Thinking', and 'Ethical Understanding'.

As the school case studies in this report illustrate, learning about and with the technologies should be encouraged across Australian Curriculum Learning Areas. These technologies are not just tools to enhance learning and facilitate creative enterprise but are themselves the focus of some of the most thought-provoking issues of our times. Supporting authentic student engagement with the social, economic and philosophical implications of these technologies is vital if children and young people are to be equipped with the knowledge and thinking skills required to thrive in this new machine age.

AI and emerging technologies need to be carefully 'incubated' in a controlled way in a diverse range of school settings, including rural and low income school communities, in order to identify practical, safety, ethical and technical issues. This 'incubation' must be accompanied by robust, theoretically-informed research on their pedagogical potential and impacts of the technologies on learners and learning.

Most pressing is the need to identify what teachers need to know in order to begin to develop a foundational understanding about AI and emerging technologies. This is the starting point for the development of quality professional learning on the technologies and for ensuring that initial teacher education programs equip future teachers with this foundational knowledge. It is important to recognise we are currently in an era where knowledge about AI, VR, AR and MR is in a state-of-change. Any curriculum or teacher professional learning knowledge related to technical, social and ethico-legal aspects of the technologies will need to be regularly updated (perhaps annually). The project of building and sustaining a solid foundational knowledge about these technologies will require interdisciplinary expertise from, and dialogue between, the fields of education, computer science, sociology, philosophy, economics, law, and political science.

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## Appendix 1: Literature Review Methodology

The literature reviews on AI, VR and AR and school education were traditional in focus; that is, they aimed to synthesise peer reviewed research and included text book material, grey literature and expert opinion reportage where relevant and timely. A Boolean search was conducted using a combination of keywords with modifiers (AND/OR) to produce an initial set of relevant papers. Key words included: Immersive virtual reality, Virtual reality, VR, Head mounted display, Headset, Google Cardboard, Google Expeditions, Augmented reality, AR, Mixed Reality, MR, XR, Mobile Learning, Artificial Intelligence, Pedagogical Agent, Intelligent Tutoring System, ITS, Big Data, Predicative Analytics, Data Mining, Machine Learning, Artificial Neural Networks, ANN, Affective Computing, Cognitive Computing, Robot Ethics, AI ethics, Algorithmic Bias, Smart Schools, Internet of Things, IoT, AND/OR Education, Learning, School, K-12, Teachers, Teaching, Pedagogy, Curriculum, Assessment, AND/OR Children, Teenagers, Adolescents and Students. Databases searched included Education Journals and ERIC Proquest, ACM Digital Library, IEEE Explore, ScienceDirect and Scopus. A search of Google Scholar was also conducted. Recent meta-analyses and systematic reviews in the area of education and AI, VR and AR/MR were located. Reference lists from relevant articles and reports were scanned for pertinent literature. Due to the timeframe for completing the research, scholarly books and book chapters lay outside of the purview of the review. Searches restricted to papers published in English and primarily restricted to those published in the period 2013-2018; however, where relevant literature published outside this timeframe is included. This period was chosen as it marks the advent of the widespread commercial availability of immersive virtual and augmented reality.

To ensure quality, this review is primarily based on peer reviewed conference papers and journal articles that contain detailed methodology and findings based on empirical qualitative and quantitative research. Due to the relatively recent advent of commercially available IVR, some non-peer reviewed reports, web-based articles and technology reporting have been included as they provided the most recent technical information and perspectives of interest on the topic of IVR, children and education. Some related literature has been excluded from the review because it is tangential to the topic of IVR and school education. For example where research was conducted with children in a CAVE (CAVE Automatic Virtual Environment) or semi-CAVE immersive system, it was excluded from the review as putting CAVEs in schools would be prohibitively expensive. It is worth noting that, although not covered in this review, there are clinical experiments and therapeutic interventions related to: life education with hearing impaired children (Vogel et al., 2004); teen smoking prevention (Nemire et al., 1999); time on task for children with ADHD (Bioulac et al., 2012); social and affective recognition skills of children and youth with autism (Bellani et al., 2011; Didehbani et al., 2016) or cognitive disabilities (Freina et al, 2016); and road safety (Clancy et al., 2006; Plumert et al., 2004).

To conclude, while this review is not exhaustive, a concerted attempt has been made to locate and include peer reviewed and grey literature and expert reporting of research that would be of interest to teachers and school leaders on the topic.

## Appendix 2: Findings from the National Consultation

### 7.1 Introduction

A national consultation was conducted during October to early November 2018. The purpose of the consultation was to gather expert opinion on the opportunities and challenges for schools in engaging with AI and emerging technologies. The very limited timeframe for the project meant that it was not possible to consult broadly, and we view the findings presented here as a sound summary of key ‘talking points’ that can be used to continue a national conversation.

### 7.2 Approach and participants

Participants for the consultation were identified by the Commonwealth Department of Education and Training as holding expertise in the field; through researcher knowledge of experts; and by ‘snowballing’ or asking participants if they thought there was someone else the team should talk to. In all 16 individual participants took part in the consultation process (Table 4) and the Australian Human Rights Commission provided a letter on the topic (Appendix 2). Participants were contacted by email and invited to share their wisdom by responding to the following questions designed to spark discussion:

- What do you think are the main issues related to these technologies for school education?
- What opportunities exist for education on and with these technologies?
- What do you see as key areas for future practice and research?

Conversations, via phone or Skype, were between 30-90 minutes. A summary of the conversation was made and participants were given an opportunity to amend and return this to the researcher. A draft chapter was circulated for their feedback. Participants could choose to be identified or not: four chose not to be identified. Participants came mainly from education and computer science backgrounds. They were a mix of researchers and practitioners, with some having educational technology development experience.

*Table 4. Participants in the national consultation*

1	Kalervo Gulson (PhD)	Professor of Education Policy, University of New South Wales, and ARC Future Fellow
2	Claire Seldon	Instructional designer and computer games for learning specialist
3	Michael Milford (PhD)	Professor in Electrical Engineering, Queensland University of Technology, and ARC Future Fellow
4	Naomi Barnes (PhD)	Lecturer in Education, Queensland University of Technology
5	James Curran (PhD)	Associate Professor and Director of the National Computer Science School, School of Computer Science, University of Sydney
6	Neil Selwyn (PhD)	Professor of Education, Monash University

7	Rhett Loban	Associate Lecturer in Educational Studies, Macquarie University and VR game designer
8	Tim Gentle	Immersive Content Producer and App Developer, FarmVR & Think Digital
9	James Birt (PhD)	Associate Professor, Faculty of Society & Design, Bond University
10	Claudette Bateup	Director of Education, Australian Academy of Science
11	Leanne Cameron	President, Australian Council for Computers in Education
12	Jane Hunter (PhD)	Senior Lecturer, School of Education, University of Technology Sydney
13	Education Specialist 1	Education expert
14	Education Specialist 2	Education expert
15	Education Specialist 3	Education expert
16	Education Specialist 4	Education expert
17	The Australian Human Rights Commission	Letter from Edward Santow, Human Rights Commissioner (attached to the conclusion of this appendix)

Summaries of the conversations were descriptively analysed for key ideas, issues and themes and then organised into broader areas. These areas speak to the current state-of-play, opportunities and challenges, and future directions.

## 7.3 Findings

The general attitude of the participants towards AI and emerging technologies in schools could be described as ‘optimism tempered with caution’. Participants thought that AI had the potential to relieve teachers of administrative ‘drudgery’, assist with grading for certain forms of assessment, and provide students with timely feedback. There was talk of the great promise of VR/AR for immersive learning that could open up different worlds for exploration, problem solving and collaboration. There was also concern expressed about the potential for these technologies to exacerbate the existing digital divide in Australian schooling and entrench lack of digital inclusion for students from equity group backgrounds. There was a consensus that all stakeholders in education systems needed to come to grips with the complex ethical and legal issues associated with these technologies. We have organised the findings into seven key areas: curriculum; pedagogy; equity and digital inclusion; teacher professionalism and professional learning; pre-service teacher education; governance; ethics; and evidence and research.

### 7.3.1 Curriculum

All participants offered insights in curricula opportunities and challenges. Some participants expressed concern about the level of digital literacy required for students to engage with, and begin to explore, AI

and emerging technologies. They stressed that digital literacy should be more than using the technology to learn; rather, a more comprehensive approach to teaching and learning about digital literacy in practice, needed to be supported. A broader approach would pay close attention to developing authentic stage-appropriate knowledge of good digital citizenship that would serve students in negotiating an AI world. Naomi Barnes explains:

I don't think the present idea of digital literacy allows room to explore things like AI with students because they haven't even been given the vocabulary. Schools focus more on cyber safety but not on opening up to the questions of the role of technology in society and the fundamentals of how a technology like AI plays a part in the life of students or teachers.

Some participants suggested that integration of knowledge about these technologies, and particularly AI, should be *integrated across all subjects* in the curriculum. They suggested that a working group, comprising experts from different disciplines, teachers and government, be convened to review the where learning about and with AI and emerging technologies could be thoughtfully incorporated into the curriculum. They thought that this process should be accompanied by a research program, developed and conducted with classroom teachers, that would better develop our understanding of how we might harness the technologies for powerful authentic learning:

We need to give teachers clear guidance on how these technologies fit into the Australian Curriculum or State and Territory syllabuses. Some teachers may not see the connections between these emerging technologies in the Digital Technologies curriculum or how students can use the technologies in other learning areas. (*Education Specialist 1*)

There are great ways to deliver these technologies in many subjects and I hope that we don't switch from the idea like, 'Oh gosh we need extra AI curriculum for the classroom', when we already can do this within the current curriculum. I think that understanding where these technologies can be embedded as genuine engaging tools for delivering the curriculum requires research and teacher input and this should not be limited to STEM subjects. (*James Curran*)

Some argued that use of AI and emerging technologies in the classroom for learning could empower students to meaningfully engage with these technologies in their everyday lives and beyond school. This type of learning would include developing a deep understanding of and skills related to personal data management and sharing.

Some participants expressed concern over the possibility of an approach that emphasised technology rather than pedagogy. These participants suggested identifying places in the curriculum where particular technologies can provide a better learning experience with an emphasis on the development of resources for and by teachers and facilitating ways for teachers to share their resources and insights in a timely fashion. Many participants commented on a dearth of high quality, appropriate resources for teachers: 'I have yet to see many resources which are tailored to the curriculum' (*Educational Specialist 2*).

There was a consensus about the importance of explicitly exploring and educating students and whole school communities on the ethics of the technologies, particularly AI. The recent resurgence of interest in AI and its well documented ethical conundrums indicated that it was now time to seriously revisit where technology ethics and its legal implications technology could be covered across the curriculum:

We need to explore whether the existing curriculum provides enough scope to explore the ethics of AI and emerging technologies. We may need more specificity built into the curriculum to attend to these emerging technologies. When the General capabilities were written in 2010-11 people probably didn't explicitly consider the implications of AI and machine learning or the ethics of having students immersed in virtual environments and the developmental issues related to these technologies. (*Education Specialist 1*)

### 7.3.2 Pedagogy

Participants provided nuanced feedback on the pedagogical implication of AI and emerging technologies with a focus on: (a) the need for a public pedagogy to raise awareness and build knowledge of the technologies in school communities; and, (b) effective use of the technologies for learning.

Participants emphasised schools as agents of community empowerment and the responsibility of educators to lead public discussion on the implications technologies:

We are seeing all sorts of new technologies coming into our lives as human beings. The impact of AI is only going to increase. You can't bury your head in the sand and say it's not going to affect me in my lifetime. This is not really facing up to reality. (*Jane Hunter*)

Participants thought that it was vital that schools raise awareness of AI in their communities in a comprehensive and ongoing way so that all stakeholders could develop a 'baseline' understanding of what the technology was, how it worked, and its impacts in everyday life and in education. This included clarifying where it would be used, or not, in schools, and oversight and accountability processes. Addressing common misconceptions about AI was also vital, as one participant remarked:

In particular, there is popular confounding regarding coding, robotics and AI. There is a need for projects that seek to clarify these misconceptions so that people, teachers, parent and students included, develop a 'baseline' understanding of what these technologies are and how they might be related. We can then have really informed public dialogue about the impacts of these technologies on work, regulation etc. We need to use education to get everyone to a level of empowered informedness about AI. There is plenty of things to argue about with AI but doing this where people have a good basic understanding will be a massive step forward. (*Michael Milford*)

Pedagogical strategies to support learning within the classroom were viewed differently for the AI compared with the immersive technologies of VR/AR/MR. Immersive technologies were seen to have impacts on physical classroom spaces, as well as requiring pedagogical flexibility.

Teachers need to consider how they will arrange their classrooms for VR that requires students to get up and move around. Open and flexible classroom spaces are being built in schools but there are still constraints on using these types of VR experiences (that allow for significant user movement) in traditional classrooms. Safety too needs to be considered. (*Claire Seldon*)

Removing safety concerns and empowering students with VR experiences, especially content creation, was viewed as compatible with the objectives of the Australian Curriculum. AR was also a technology that could empower learners:

VR provides an opportunity for students to experience virtual experiments; that is, to do experiments where the cost or safety considerations to undertake the real experiment would prohibit it from

classroom use. Virtual or augmented reality provides an opportunity for students to demonstrate what they know and can do by producing their own virtual tours for others. Students can start to think how traditional technologies might be enhanced by emerging technologies – creating their preferred futures – and this resonates with the Australian Curriculum. (*Education Specialist 1*)

AR has been here for a very long time ... however, it is only now that AR is gaining more traction. ... The lines between digital and physical will begin to blur slightly. For instance, car engines would have their manual augmented on top of its engine, animals will have their health and pedigree history augmented on their collar etc.... I don't want people to fear the technology but instead let students explore and engage at the own levels and feel empowered through this technology. That's why I develop VR – to empower students and teachers to move into this new 3-D world and start feeling comfortable in it. (*Tim Gentle*)

Immersive technologies were thought to allow teachers and students greater freedom to explore and learn in ways that have not been previously possible:

Pedagogy needs to be flexible to accommodate what VR can do. [...] Allowing students to explore freely during real excursions is not possible, especially with younger students. However, during virtual field trips the teacher can set the learning tasks or objectives and students can then decide for themselves how they will explore the environment to meet the objective. VR excursion can (1) take you where you have never been before, and (2) allow you to understand the experience in a way that a regular excursion might not; that is, to go and freely explore at your own pace while knowing you need to complete certain learning tasks. (*Claire Seldon*)

I think that there is a huge paradigm shift happening where education is moving from 2-D information to 3-D information. From this we are creating a whole new breed of learners and educators. (*Tim Gentle*)

Allowing students to use immerse technologies for content creation and creativity was thought to facilitate higher order thinking, problem solving, creativity, research skills and collaboration. Participants suggested that immersive technologies could offer students exceptional experiences (like interacting with a human cell) and provide an opportunity to think about issues from different perspectives. Immersive technologies were thought to provide students with powerful tools for content creation that could be used for academic purposes and to authentically reflect the diverse socio-cultural and geographic backgrounds of learners. Some remarked on how immersive technologies could also provide unique experiences for students with special needs. The overall potential was captured by the following participants who remarked:

VR is great because it gives the students another option to learn through a visual and experiential styles of learning. The view of the narrator or someone else's perspective is a possibility using VR with perspective taking being important especially in the Humanities and Social Sciences disciplines. VR and other digital media can be used by students to express their understanding or analysis of a content area through creating their own content instead of just being consumers of VR products. (*Rhett Loban*)

Immersive experiences can be great for sharing and building cultural insights around Indigenous culture. I imagine that VR would work well for rich cultural sharing opportunities. We could tap into cross-curriculum priorities by immersing them in environments and cultures they are not accustomed

to.... VR could provide students with disability an opportunity to experience some things they might not be able to do in real life – it could personalise learning for them (*Education Specialist 1*)

Educator and VR game designer Rhett Loban offered some sage advice on following correct cultural protocols if considering immersive technology content creation with Indigenous communities:

When I designed my VR game which was primarily used as classroom materials for university courses, although I am Torres Strait Islander, I still talked to the wider Indigenous community and had other Indigenous people play my game to follow and fulfil the protocol of consultation. However, as a media product, this was also beneficial as it resulted in wider feedback and a better, polished and more inclusive product where you know you have community backing. If you are a non-Indigenous person developing a VR simulation which was about Indigenous culture without input or consultation you could run the risk of misrepresenting the culture, representing it superficially or in a way that could be detrimental to the Indigenous community. There are also multiple perspectives and accounts on the same Indigenous stories/content in the Indigenous community which I realised when I took my product to the Indigenous community as well as through my own research. To get diverse perspectives you need diverse consultation in the community and thorough research. From my perspective I think VR may better represent more traditional Indigenous knowledges and cultural elements than say written texts because of its visual knowledge and experiential learning style.

There was significantly less discussion about students using AI to learn and more about its potential to assist teachers (this points to a gap in pedagogical thinking in this area). Some participants suggested that AI-powered classroom assistants delivered through a learning management system might relieve some of the administrative and repetitive work done by teachers and provide real time indicators on learner engagement and progress. Jane Hunter provides this glimpse into a possible AI future of personalised learning and automated learner assistance:

I am not suggesting that anytime soon we are going to have robots teaching children in classrooms. However, I do think that in the not too distant future every teacher will have a dashboard in his or her classroom. An area that I am interested in is automated tutoring systems. These present possibilities for making learning personalised in schools but they are only part of a much larger jigsaw of AI enabled systems. We certainly don't want a Pearson style view of the world. Businesses like this are hugely interested in the AI space and tech developers in these spaces are madly developing a whole range of programs that will be sold to schools. Do we really want kids in classrooms working with their headphones – learning in an isolated way, on their own working in lab-like environments? It's probably the worst-case scenario of what it means to 'personalise learning'. I think there are lots of opportunities for AI to augment and make more efficient what teachers currently do. For example, automated grading and feedback systems – these will assist teachers if they are developed well. Imagine if in the future all teachers had an AI teaching assistant – it would free them up to get on with the business of teaching and learning, instead of having to do so much admin. It would be a kind of Siri or Alexa on steroids. For example, in an English classroom you might studying Shakespeare. After a lesson you are asking an Alexa-like assistant for feedback and the assistant notices and records that Tommy, Julie and Wendy have not read or responded with their ideas to a particular scene in Romeo and Juliet, in fact they are really struggling. Alexa lets you know .... in your end of day conversation, and then in the next lesson the teacher would take this up with the identified students. These are the types of assistants and dashboards that will be in classrooms in the not too distant future. I also like the idea of young people teaching machines. At Carnegie Mellon in the US, Professor Tom Sullivan's graduate students are actually doing this – they are having back and forth



conversations with intelligent agents. What a great way to learn algorithmic thinking. These are the sorts of AI possibilities that are not too far away.

These uses of AI-powered systems such as these were seen as beneficial because they freed up teacher time to do more higher order thinking and creative activity with students:

(AI) might relieve teachers of repetitive marking work and free up teachers to do more nuanced or creative work with students. (*Education Specialist 1*)

The possibilities of personalised learning were set against the potential problems that might occur if AI-powered systems were foisted on teachers without them being empowered to ask questions about the learning science and pedagogical foundations of the products and their efficacy for learning:

There is often no, or poorly conceived, pedagogy built into intelligent systems. And there is often no or narrow learning theories such as behaviourism evident in these systems. Most teachers don't have the time to ask questions or have the technical expertise. Teachers are often just presented with these systems as a *fait accompli*. It would be best if we slowed these things down, get ourselves informed and have a debate about whether these systems serve our learners and their communities well. We need teachers to scrutinise these systems and if they don't like what they are getting, then they can ask what type of systems they might like? (*Neil Selwyn*)

People don't realise that the people who develop the (types of intelligent applications) for classrooms are not qualified educators. It seems to me that software engineers are qualified in coding or machine learning but not in the complexities of learning and education. Having AI programs in classrooms that aren't designed and overseen by qualified educators at every phase is like having a completely unqualified person in the room teaching students, which is not right. (*Naomi Barnes*)

As Jane Hunter pointed out, '(T)here are lots of opportunities with artificial intelligence. But with great power comes great responsibility.'

### **7.3.3 Equity and digital inclusion**

The equity implications of these (and any) technology were considered complex and requiring urgent action. The issue of gender and girl's engagement with technology was raised by several participants. AI and emerging technologies were viewed both as an opportunity to (re)engage girls in STEM learning and as having the potential to further alienate them from technology subjects. The history of gender bias and technology education was explicated by participants:

There is an issue around gender-based (and many other types of) bias in technology education and we need to think about how we can integrate technologies so that we can overcome this. There are opportunities to get ahead of systemic biases. (*Michael Milford*)

Technology teachers are worried about their jobs because they are losing half their students. Quite frequently this occurs at the end of Year 10, or the end of Year 8, simply because the girls are not coming along. The girls don't want to do woodwork metalwork, and software design. These are the courses that I train teachers in. We are losing ground. (Only) 6% of the HSC cohort was female in software engineering. This is extraordinary. When you think of the implications of that – that means that guys are making the decisions of how software will work. There are a few famous cases where it

has been shown that that is a really dangerous thing. If you haven't experienced a problem, you don't put it in your software. (*Leanne Cameron*)

It is very concerning that high school technology courses (and their associated university degrees such as computer science<sup>12</sup>) are overwhelmingly attracting only male students. The figure of 6% in HSC software engineering, cited by Cameron, should act as a 'canary in the coal mine' for Australian education systems. Given the issue of gender was raised as a serious concern, it is worth contemplating the current state-of-play. We do not have a comprehensive picture of girls' engagement in technology learning at primary school level. The low participation of girls in technology courses at secondary school level endures despite considerable time and resources being directed to address the issue, with a predilection for resourcing add-on or out-of-school technology (coding and robotics) initiatives. These add-on initiatives, no matter how good their quality or intent, will not be adequate to the job of challenging powerful gender role stereotypes associated with technology as a field. This is not to say that add-on initiatives are ineffective for the girls that take part in them. However, a much greater systematic, better resourced and programmatic *in-school* effort is required, and this must span F-12 education and beyond: Only concerted, coordinated and evidence-informed efforts in schools will stand a chance of engaging girls in authentic technology learning and allow them to understand its relationship to career paths. The consequences of not developing and resourcing a comprehensive girls' technology strategy in an AI world are immense in terms of providing equal career opportunities for girls. The current situation where the design and development of AI-powered and other technological applications is being undertaken primarily by men employed the technology industry was discussed as a major concern:

It is a white, middle class male form of learning and this is what is being 'baked into' these (AI) systems as the ideal. Those who suit this type of learning will flourish but they will do so in a highly individualistic way. The philosophy of learning 'baked into' these systems means that big tech industry is deciding that they are better at knowing what's best for learners than teachers and education experts. The logic of marketisation and the individualisation of risk means there will be winners and losers with such intelligent systems. (*Neil Selwyn*)

Leanne Cameron posited that immersive technologies might have the potential to attract girls to technology subjects if they could see a broader purpose for learning about and with the technology:

From the student's point of view, there is so much that can be done with AR and VR. Particularly for the girls that we tend to be losing in technology subjects. We need to show the girls more than technical products – we need to show them that there is a 'good for humanity' in using and developing VR and AR and how they can help people out. The good for humanity argument will give real purpose for girls to use the technology. We need to find ways of making this new technology appealing to girls.

Participants suggested that there was a need to ensure that all schools, no matter where they were located or which communities they served, had fair access to hardware, software and bandwidth to run the technologies. Without equitable access, students would be left behind, unable to use the

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<sup>12</sup> National longitudinal data indicates that there is consistently low rates of female enrolment in IT degrees with little change over time – see [CSER blog](#) on IT and engineering Australian higher education enrolments. Baranyai et al. (2016, p.46) indicate low percentages of female in the graduate workforces of Engineering and Information Technology (13 and 22 per cent, respectively).

technologies for content creation or to enact global citizenship, and pedagogical experimentation and innovation of teachers would be stymied:

Equity is a key issue in this new tech space. Equity of access to hardware and software but also to local content. VR has the potential to create the exchange of experiences between students in the city and those in rural and remote areas. And to bring students who haven't been to an art gallery, for example, to the best galleries in the world. Students can also create their own VR experiences and upload and share them with others. The opportunity to produce something for a global audience is important. Similarly, VR could create cultural bridges by sharing appropriate aspects of Indigenous and other cultures with a broader audience, especially if students work with others in their communities to produce content on such topic. *(Claire Seldon)*

What happens if students can't get their hands on the technology? There is an access issue to these resources. It might be cost of hardware and software, or internet speed, or the digital divide might be evident in the expertise of teachers and students as well. *(Education Specialist 1)*

(In relation to the human right to education) Lack of access to technology can exacerbate inequality, based on factors such as age, disability, Indigenous status, and rural or remote background. Poor quality new technology can undermine this right. New technologies used in education (should) promote access, quality and equity in education. *(Australian Human Rights Commission)*

It tends to be more the independent schools which are investing in this new technology. These sorts of schools market themselves around these technologies. It would be best if we introduced a sharing model so that networks of schools could adopting this technology and share the cost burden because a huge barrier to entry is cost. *(James Birt)*

The Australian Human Rights Commission stated that new technologies should be harnessed to address equity issue in education as a top priority:

The ability to collect and disaggregate data more easily, through the use of new technologies, can improve the targeting of programs and services and support equality of access for vulnerable groups.

#### **7.3.4 Teacher professionalism, professional learning and pre-service teacher education**

There was considerable discussion about AI and its potential impacts on the teaching profession. While AI technology presents opportunities for personalised learning, some participants expressed concern about potential negative effects on the teaching profession. For example, Neil Selwyn warned that that the implementation of AI for learning in schools should not diminish the expertise of the teaching profession or be used to 'tick boxes' to satisfy managerial goals:

The most important question in technology and education is not what it will do but what it will undo. If we dumb down teachers roles so they just become facilitators of intelligent systems then it's going to be very difficult to re-professionalise teachers in the workforce. In ten or twenty years' time, we don't want a situation where most students go to massive online schools in which they are given basic instruction and pumped through schooling via distance learning, and where an elite get to experience old fashioned face-to-face teaching in small classes. That's my worry; that AI won't really be about personalisation but instead seen as an efficient way to push kids through the school system and tick a box that we are doing mass education. *(Neil Selwyn)*

The importance of educators' (and the school community's) role in shaping the AI-based systems was also emphasised by Selwyn. He advocated for an active and democratic, rather than passive consumer, approach to shaping and using AI-power systems in schools. This was considered vital if AI-powered systems were to reflect the norms, values and standards of local school communities rather than those 'baked into' them as an imported product:

Educators need to be able to push back and shape technologies – we need a democratic process. If we have a transparent algorithm, then that algorithm should be tweakable by teachers and students. School communities need the power to program the rules by which the teaching and learning take place. What values, scripts or algorithms are in systems? Who gets to decide if a dashboard goes red that this means that a student hasn't met a standard? Whole school systems need to have these conversations rather than just buying systems where the values and judgements are already 'baked into' the system by programmers from Silicon Valley. *(Neil Selwyn)*

The important role of the teacher in shaping, implementing, contextualising, and sensitively responding to AI learning systems was highlighted. This was considered vital because no learner should be pigeonholed or stereotyped by classifications generated by AI-powered systems or by predicative analytics:

Information (presented to educators) will be able to (be) dug down into (through) learning analytics. Is a person simply the sum of what they have done in their life? Therefore, they already written off because they've got this data that shows that this is what will happen. As long as the data is taken in context, and it is recognised that this is not a fait accompli. People do change. People make different decisions from time to time. *(Leanne Cameron)*

High quality, ongoing professional learning (commonly called professional development [PD]) was considered a priority if teachers were to be empowered to understand AI technology and respond to its potential for learning. As a fast-moving field of knowledge, keeping up with developments in AI technology was often difficult even for those in the field of computer science. Hence, participants stressed the need for teachers and those in charge of education systems, to refresh their knowledge about AI annually:

With AI, experts will need to update the state-of-play every 12 months because knowledge can become obsolete in this field. So, a good baseline knowledge is required first, and then expert input is needed so that government can stay abreast of this changing field. People should not get a false sense of security about their knowledge in the field because it is rapidly changing. *(Michael Milford)*

Participants were concerned that teachers would not have access to the time, resources and training required to continue to come to grips with the technical, ethical and pedagogical complications of AI technology:

I...think that when AI arrives in schools we won't give teachers enough training to handle the technologies. *(James Curran)*

The main issues are around teacher professional learning and the confidence of teachers to feel like they can keep up with the latest developments in educational technologies, whether that be as a teaching tool or teaching about emerging technologies in their classrooms. *(Education Specialist 1)*

Participants recognised the substantial task of developing and delivering quality professional learning on AI and emerging technologies in an ongoing manner but saw it as vital if they were to deliver powerful learning opportunities:

There is a lot of rhetoric around being able to use these technologies but is the professional learning there for teachers to be able to successfully use them and integrate them into teaching and learning, and understand how that is AI situated within their planning? *(Jane Hunter)*

Some participants were worried that the type of professional learning that was often on offer in relation to educational technology was more about marketing a product than scaffolding educators towards how to use technology in pedagogically sound ways that aligned with the curriculum. They spoke of relative dearth of evidence-informed, leading edge professional learning opportunities for new technologies:

Another big factor is that professional development is harming educators who don't have the time. We need to learn how to integrate PD in the system, so they are actually learning and not just ticking the box and moving on. I think teachers need to know the quality of PD which is accredited and is indeed worthwhile instead of taking courses that are more marketing exercises than PD. It is difficult for teachers to navigate their way through this plethora of expos, webinars etc. It is very complicated for teachers to find the epi-centres of rigorously understood and PD places. We have this dilemma of having teachers completing ineffective PD and a weight on the back of schools who are trying to keep up with the most current research on technology. I think it is vitally important to support teachers to find leading edge PD, especially secondary teachers. *(James Birt)*

There is the PD that shows them which buttons to press, to get something to work. A lot of teachers are selecting that sort of PD; that means they can go into the classroom and show kids how it works. That is only good for that version and product. What is not happening as much, is that level up where the overarching principles are being taught, that could be applied to the next piece of software that comes out. That is covered by good teacher PD where the teacher delivering it understands and is playing the long game. That is what I see is the difference between the vendor – we make this stuff and we'll show you how to use it – versus a teacher delivering it who embeds it into how to use it in the curriculum, what implications it has, and what dot points it ticks off. *(Leanne Cameron)*

Leanne Cameron elaborated on her concern at the trend of companies working directly with students in lieu of teacher-led pedagogy in the classroom:

I think the biggest problem I have with PD is that it seems to be almost exclusively offered by commercial companies in a way that I have not seen before.... (T)here is the extra one (training offered by commercial educational technology vendors) where you pay for this PD and (they) will come to the school and show the students how to work with the software, make sure it works on your school system: that's a huge investment. There's a number of companies now doing that. I like this in that these guys are showing the students how to use it, and they are very confident (and when I say guys, it is all guys) but it also disempowers the teachers. It is as if they are outsourcing the teaching. It will be interesting to see in those schools that have done this that the teachers get comfortable enough to do it the next time and the next time themselves. Or do they continue to bring these people in.

There was agreement that developing authentic professional learning opportunities and resources for teachers in the area of immersive technologies would require a multi-pronged approach. Claire Seldon

offered a detailed explanation of the type of professional learning and resources required for teachers to develop their pedagogical knowledge and skills related to using VR effectively for learning:

Virtual environments provide opportunities for exploration, play that engages with knowledge and collaboration. There is a need to purposefully design virtual environments that provide for the use of the learning affordances of the technology. As educators we need to take advantage of what the virtual environment or any digital tool can offer. There needs to be curriculum material such as lesson plans, mini units of work or libraries of resources developed to complement the virtual learning experience and help guide teachers and students through such learning. We need exemplars and resources that:

- Show teachers what is possible with the technology (demonstrate);
- Allow teachers themselves to try out what they can do with the technology (experiment, play, prototype); and
- Provide students with opportunities to see what they can do with the technology to allow them to share this with a broader audience (the class, the school, other schools or upload onto global sites).

Some participants highlighted the need for pre-service teachers to develop their knowledge of AI and emerging technologies and that the current technology curriculum within teacher education should be reviewed in order to ascertain if, and how, education on these technologies was occurring. Naomi Barnes pointed out that pre-service teachers should be able to engage in discussion around ethics of AI and emerging technologies for schools and that this aligned well with the AITSL teaching standards

Schools love rushing into using new applications in their classroom but have no internal brakes for implementing new technologies in their classroom. But what effect does this have? Especially with immersive VR or AI? Teachers cannot graduate unless they have fulfilled the AITSL standards and standard 3.4 and 7.1 is a place to talk about ethics with AI in the classroom.

Michael Milford suggested that a more 'systemic' approach was required so that teachers were not left 'in the dark' when AI-powered products were being sold to schools and that the profession. This approach spanned pre-service teachers through to seasoned educators: It must include the ability to access expert advice:

There needs to be planning and implementation of systemic change where teachers in their training and professional development so that they are equipped with recognising the questions they need to ask of AI product and be able to identify when they are or might be trouble with a product and where they can go to get clarification or answers. Teachers shouldn't be stumbling around in the dark with this technology or learning about it on their own initiative in an ad hoc manner (although this is great too). *(Michael Milford)*

### **7.3.5 Ethics**

Participants accentuated the importance of a strong ethical framework to guide decision making, particularly around AI in schools. Participants emphasised that the issue of ethics and safety and technology should be as central to education as it is in other fields such as health or law. As Leanne Cameron stressed:

Just because you can do something, doesn't mean you should. That's the biggest issue. The ethical issues, even if people think they are obvious, can be lost.

The Australian Human Rights Commission suggested that supporting children to exercise rights in the digital sphere was key to ethical practice:

Despite this range of (digital learning) opportunities, children and young people frequently lack the supports that they require to exercise their rights in the digital environment. This is especially true for more vulnerable children.

There were numerous issues raised including algorithmic transparency, privacy and clear lines of accountability:

We need nuanced discussions about algorithmic transparency and ‘white boxing’ systems. Most of these discussions are being held at very high levels in areas such as law, health, defence, and in philosophy. Education needs to look at those discussions around ethics and data. Education systems need to be held to the same high levels of account as, for example, predictive medicine or self-driving cars. I would argue education needs the same high level of accountability because these systems can impact on the life chances of a student. This is equally as important as these other areas such as medicine. Clearly lots of questions are about what kind of education we want, ethically and morally. However, sometimes the conversation in education turns towards compliance, such as data privacy, rather than looking at these bigger questions. *(Neil Selwyn)*

AI is like owning a car. We know the risks of using it, but we have rules to avoid accidents – this should be part of AI policy. But a faulty car is also the manufacturer’s fault. It is an important time to implement these policies and conversations about AI to avoid larger problems in the future. *(Naomi Barnes)*

New technologies used in education (should) ensure that the privacy of students is protected. *(Australian Human Rights Commission)*

Bias in AI systems was highlighted as an area that required both serious deliberation by educators and policy makers. The potential impact on educational outcomes for individuals needs to be weighed against the ease and usefulness of algorithms and big data:

In terms of AI, these systems are algorithms and are based on data points and they can be biased on certain features. Big data algorithms generalise and classify the underpinning data meaning that if the data is biased the generalised data is also biased. As reliance on this data becomes more and more, essentially we are running the risk that the biased data ignores individual differences; individuals become a point on a numerical weighted graph. When you start to delve into the philosophical and ethical dilemmas of big data things get very difficult especially from an education perspective where the individual must be considered. *(James Birt)*

The potential use in personalised learning of automated, algorithmic-based, learning sequences raised the possibility of this information harming student’s possible futures:

I think we have to be very careful about the automated classification of students-at-risk. When students are classified or seen to be achieving within a certain range of behaviours and outcomes – how much control do they have over the data that is collected about them. For example: are they in a position to be able to change it? There are many risks around the ways data are collected in these new and emerging spaces and we need to be very mindful of the ethical issues around that. *(Jane Hunter)*

There was agreement around empowering educators to engage with the ethical dilemmas involved. This should be supported by appropriate leadership and guidance from government and not be driven by technology companies and commercial interests:

We are going to have to come up with ethical guidelines for AI use in schools. Who will drive this? Who is obligated to get this done? Think tanks run by corporations should not be doing this work. These are big conversations we all need to have a role in and there needs to be governmental leadership in AI ethics in schools. It is important to have educators outside of the EdTech community involved in these conversations. The people who aren't normally involved in these conversations need to be enlisted in the debate. We need authentic engagement from educators so there is buy-in by schools in terms of AI and learning systems and the ethics of the technology. The education community needs to feel like they own the debate and whatever directions and guidance that comes out of it. *(Neil Selwyn)*

Participants agreed that there should be urgent action on developing ethical frameworks to guide decision-making at classroom, school community and school systems levels.

### **7.3.6 Governance**

There was significant discussion about the potential impact of AI and machine learning in schools, and this led to agreement that there needed to be serious consideration of the types of accountability processes and mechanism at classroom, school and systems levels:

We need to think carefully about accountability. If an intelligent system ruins a child's educational experience or adversely impacts their learning potential, then who is accountable? Will it be the company that has sold the product to the government or school? *(Neil Selwyn)*

People can impose their own social justice narratives onto computer programs. However, machines do not understand what social justice is. How do we program a machine to think in this way and deliver just outcomes? Should we really be giving the philosophical questions and tasks to machines which are not programmed to think critically? We need to question the coders and for people in policy positions to get on the same page regarding accountability if something does go wrong with AI. *(Naomi Barnes)*

We don't want the Uberfication of education: Without the research, ethics and governance there will be consequences. Is it ethical to allow experimentation and disruption with AI technology in education? So, we must have counter arguments to using potentially harmful AI technology in education. We must have pedagogy before technology. *(James Birt)*

Kalervo Gulson captured the mood when he highlighted the need for strong governance around AI in education, especially the potential risk for conflict of interest:

We need to pay careful attention to the relationship between technology companies and governance; when there are forms of automatic governance in the school sector these are less visible than other approaches such as consultation or forms of privatisation. Should technology vendors be setting up how educational decisions are to be made through the logics of their systems?



In terms of large systems and the costs of these resources, some participants identified the issue of an unintentional reliance on corporations for areas of learning that should be managed by local school and teachers:

AI systems are being built by mega corporations because they can afford these systems and have access to the data required to develop the systems. This creates a reliance on these corporations as well as handing over the governance, ethics and privacy to these groups. (*James Birt*)

Kalervo Gulson summed up the complex and fraught inter-relationship between ethical, legal, governmental, and commercial aspects of AI technology in the following explanation. He sums up many of the serious issues that need to be addressed before AI systems are invested in and embedded in schools:

Data sharing arrangements with technology companies require scrutiny. We need to better understand that technology companies are now players in the governance systems due to contractual arrangements. What is the relationship between government and technology players regarding data sharing and how does this affect accountability? For example, if you have a technical advisory board and they are making decisions that they cannot explain in transparent or understandable terms to a more traditional governance board, then the technical board is basically making policy decisions even though it might not be traditionally understood this way. A traditional advisory board should be able to review decisions and make informed decisions, but it might not be possible due to technical complexities. What would a transparent, accountable public service AI system look like? AI currently makes its way into education systems under proprietary conditions and so it isn't clear how you could assure lack of bias or accountability or explainability. Do we accept that corporations provide AI systems under proprietary conditions and that there will be decisions driven by AI that will feed into the governance of education that will never be 'knowable', that is be able to be transparently explained to those outside the corporation? Is it technically possible for some forms of machine learning to do this? We need to ask these questions.

Michael Milford adds to Gulson's picture by pointing out that there is a lack of expertise nationally to advise on how AI might affect education. The implications of this only amplify Gulson's concern about technology companies making policy by stealth because there is not the technical expertise in education or the transparency required for truly informed independent decision making. To quote Milford:

Probably the biggest risk in this space is that there is only a small number of people nationally who have a deep enough, genuine understanding of AI so that they can answer questions about the technical aspects of AI systems and how they might interact in education systems.

Participants emphasised that schools needed independent advice on AI and emerging technologies to support their investment in the technology and its ethical implementation. Only with good quality, independent research coupled with independent expert advice, could school communities democratically engage in sound decision-making around the use of AI and emerging technologies:

Some schools do have expertise to procure these types of systems but sometimes they just don't, and so maybe we need an organisation that can really investigate these systems and offer truly informed independent advice to schools and commission high quality independent research on technology and education. Big tech needs to be held accountable rather than being given a free ride in Australian schools. At school level, every stakeholder in a school community should have a say about what type of tech systems they want in their school. These are huge decisions that need a

more democratic, open process. Maybe we need a central agency that can be an ombudsmen or arbiter of these types of technology. This type of agency would offer stewardship in the governance of technology in schools, support teachers in their professional learning and assist schools in making procurement decisions that are good for students. *(Neil Selwyn)*

Many participants commented that a cautious, considered and transparent approach was required with new technologies and that this would be beneficial to Australian education systems in the long run:

I am not advocating for slow government or bureaucratic inertia but it can be an advantage with rapidly changing technologies to be slow and careful with decisions because you can discover flaws before procurement or implementation. *(Michael Milford)*

### **7.3.6 The need for research**

Participants recognised the nascent quality of the evidence base for the efficacious and ethical use of the technologies in education schools. There were calls for a programmatic approach to research on the use of AI and emerging technologies in schools:

I would be 100% supportive of these emerging technologies if we use them effectively to grab and sustain student attention and engage them with learning. We need to evaluate where this technology can really make an impact. From a Big Tech perspective, they just want students using the technology – not research or evaluation into effective use. I think that we can only trust government to do this kind of research. In the EdTech industry there is a lot of flaky research based on very small or skewed samples. I think from a research perspective that controlling all your variables is difficult in education, but we should not be making EdTech choices based on the politician's idea of the moment. Instead we should have rigorous research in EdTech – medicine has reached this point with using technology but education has not because it is largely influenced by politics, not evidence. *(James Curran)*

Research was viewed as one means of developing rigorous case studies that could trouble-shoot ethical, practical and pedagogical issues, measure learning effectiveness, and assist teachers in imagining how to implement the technologies in their classrooms. As one participant remarked:

We need to bring teachers along on the journey. We need authentic case studies to showcase what's possible and how that is meaningful for learning. Teachers need to know what's practical (with) hands-on examples with real teachers providing their insights would be valuable. *(Education Specialist 1)*

What really needs to happen is we need to focus on collecting evidence on whether technology enhances learning using focused research into each specific technology. *(James Birt)*

## **7.4 Conclusion**

The participants in the national consultation offered rich insights into the potential and risks associated with implementing and scaling up AI and emerging technologies in schools. They emphasised that now was the time to begin very serious consideration of curriculum and pedagogical potential and to engage and educate teachers on the technologies, especially AI and the ethical complications associated with it. They spoke about the crucial place of consistent, systematic and transparent governance related to AI and the need for independent expert advice to schools and to government. They stressed that it was

time to follow the lead of other sectors, such as health and law, to establish mechanisms that could bring about serious debate with the teaching profession and school communities about the place and limits of AI and emerging technologies in the very human endeavour of education.

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*For the sake of accessibility we have created a word version from the pdf supplied to the Erica Southgate by the Australian Human Rights Commission.*

## **Letter from the Australian Human Rights Commission**



30 November 2018

Associate Professor Erica Southgate  
School of Education  
University of Newcastle  
Callaghan NSW 2308 Australia

Dear Professor Southgate,

### **Information provided for the artificial intelligence and emerging technologies in schools research report**

The Australian Human Rights Commission welcomes the opportunity to provide information for the Department of Education and Training's artificial intelligence (AI) and emerging technologies in schools research report (the research report).

The Commission understands the research report will develop recommendations and best practice guidelines to shape the development of resources to support schools in delivering AI and emerging technologies within the Australian school curriculum. The Commission also understands that part of the research report will consider associated issues for schools related to the use of AI technologies more generally, including, for example, risks to privacy and ethical issues.

The purpose of this letter is to briefly outline:

1. the Commission's current project on human rights and technology, which is considering the impact of new technologies, including the use of AI, on the protection and promotion of human rights
2. the work of the National Children's Commissioner, Megan Mitchell, as it relates, more generally, to children's rights and new technology.

## **The impact of new technology and AI on the protection and promotion of human rights**

### **Human rights and technology project**

As Human Rights Commissioner, I am leading a major project on human rights and technology (the Project) to examine how Australia can best protect and promote human rights in an era of unprecedented technological change.<sup>1</sup> The Project will develop approaches to human rights compliant innovation and design of new technology.

The Commission published a Human Rights and Technology Issues Paper in July 2018.<sup>2</sup> The Issues Paper considers the social impact of technology, particularly new and emerging technologies, using a human rights framework. The Issues Paper examines how new technologies impact the human rights of all Australians and asks which issues the Commission should concentrate on. It also asks stakeholders to consider:

- whether and how new technology should be regulated and what other measures should be taken to promote responsible innovation
- how human rights should be protected in AI-informed decision making
- how we ensure technology is accessible, particularly for people with disability
- how new technology affects specific groups, such as children, women and older people.

The Issues Paper guides a first phase of consultation that is currently taking place. The Commission has received written submissions and is engaging with a wide range of stakeholders in government, civil society, industry and academia at expert roundtables.

Following this first phase of consultation, the Commission will publish a Discussion Paper in mid-2019, and this will include the Commission's proposals for change. The Commission will then undertake a second phase of consultation to seek feedback on the proposals made in the Discussion Paper.

A Final Report will be published by early 2020.

### **The use of AI in the education system and potential impact on human rights protection and promotion**

New and emerging technologies are already radically disrupting our social, economic and governmental systems. The rise of AI presents new opportunities for the education sector; it also presents a number of challenges for human rights protection.

While the Project is still in the first phase of its inquiry, early data indicates that stakeholders from a range of sectors have concerns about the operation of AI in a number of areas, particularly where AI is used by government and the private sector in decision making that affects people's basic human rights.

The human rights framework can be applied both to define the problems that may arise in AI-informed decision making and to identify potential solutions. Applying a human rights framework has the benefit of being founded on universally-agreed normative standards that can be implemented throughout the education system in policies, practices and accountability mechanisms.<sup>3</sup> A rights-based approach is similar to, but differs from, an ethics-based approach. In particular, existing ethics-based approaches to technology tend to involve more disagreement over the substantive or normative requirements that should be applied.

The use of AI and other new technologies in the education sector engages a number of human rights, including privacy, the right to equality and non-discrimination. Some of the rights engaged are considered in more detail in the table below. The column on the right contains a brief sketch of what a

human rights-based approach to the deployment of new technologies in education would involve, in relation to each of these rights.

<b>Human rights</b>	<b>Potential impacts of AI and other new technologies</b>	<b>Human rights-based approach</b>
Right to education <sup>4</sup>	<p>Lack of access to technology can exacerbate inequality, based on factors such as age, disability, Indigenous status, and rural or remote background.</p> <p>Poor quality new technology can undermine this right.</p>	New technologies used in education promote access, quality and equity in education.
Right to equality and non – discrimination <sup>5</sup>	<p>Bias and discrimination in algorithmic decision-making.</p> <p>New technologies relating to education can improve access and improve outcomes on a range of socio-economic indicators.</p> <p>The ability to collect and disaggregate data more easily, through the use of new technologies, can improve the targeting of programs and services and support equality of access for vulnerable groups.</p> <p>Unequal access to new technologies can exacerbate inequalities, especially where access is affected by factors such as socio-economic status, disability, age or geographic location.</p>	New technologies are equally accessible to all students in use and operation, with equitable outcomes for all students.
Freedom of expression <sup>6</sup>	Hate speech can be more readily disseminated by new technologies and can therefore facilitate online bullying.	Appropriate, safe and secure systems are embedded in schools to prevent, moderate and address dissemination of hate speech through technologies.

Right to privacy <sup>7</sup>	New technologies can significantly affect the ability to protect an individual's privacy.	New technologies used in education ensure that the privacy of students is protected.
Access to information and safety for children <sup>8</sup>	Online environments create opportunities for greater access to information for children while also creating challenges for their wellbeing.  New technologies provide different settings for harassment and bullying that are sometimes challenging to moderate.	New technologies in education are moderated and have systems in place to ensure that the technology is safe for children.
Accessibility <sup>9</sup>	New technologies can increase barriers for people with disability if technology is not designed in an accessible way.	New technologies used in education are accessible and do not create barriers for students with disability.

Applying the human rights framework to the use, and proposed use, of AI in the education system would initially require an assessment of education system-wide legislation, policies, practices and standards to ensure they adequately protect human rights. This would need to include all areas of the school education system including relevant international, Commonwealth, state and territory legislation, policy and frameworks. This includes, but is not limited to, the Australian Curriculum and Australian Professional Standards for Teachers and policies and practices that impact on the day-to-day running of schools.

There are a number of existing education policies that already recognise the importance of using a human rights approach in schools. For example, the Australian Student Wellbeing Framework affirms children's rights to education, safety and wellbeing under the *United Nations Convention on the Rights of the Child*.<sup>10</sup>

**Human rights education and new technologies**

Within the context of the rapidly evolving technological landscape, there is also a need to apply human rights education principles to teach students about the responsible use and application of new technologies.

The Commission was involved in the development of the Australian Curriculum and engaged with Australian Curriculum, Assessment and Reporting Authority (ACARA) on the integration of human rights across learning areas, cross curriculum priorities and general capabilities. Further information about the Commission's human rights education work in schools is available here <https://www.humanrights.gov.au/human-rights-education-and-training>

**Work of the National Children's Commissioner on children's rights and new technology**

The National Children’s Commissioner, Megan Mitchell, has a long-standing interest in the impact of digital technology on children and has conducted a number of investigative projects in this area:

- Leading the development of the National Principles for Child Safe Organisations, with the support of the federal Department of Social Services. These principles address the obligations of organisations to combat cyberbullying and deliver safe online environments for children in their care.
- Member of the national Online Safety Collaborative Working Group, chaired by the eSafety Commissioner. The Commissioner has contributed to the development of resources designed to enable children and young adults to become critical and resilient users of digital technology.
- Reported on the topic of children as online consumers of goods, services and information in the Children’s Rights Report 2015:  
[https://www.humanrights.gov.au/sites/default/files/AHRC\\_ChildrensRights\\_Report\\_2015\\_0.pdf](https://www.humanrights.gov.au/sites/default/files/AHRC_ChildrensRights_Report_2015_0.pdf)
- The Commission addressed issues relevant to children’s rights in its submission to the inquiry into harm being done to Australian children through access to pornography on the internet (2016): <https://www.humanrights.gov.au/submissions/inquiry-harm-being-done-australian-children-through-access-pornography-internet>.
- The Commission canvassed issues relating to cyberbullying in its submission to the inquiry into to the establishment of the eSafety Commissioner—Enhancing On-line Safety for Children (2014): <https://www.humanrights.gov.au/submissions/enhancing-online-safety-children>
- The Commission undertook research and conducted a survey of young people in order to better understand cyberbullying amongst young people and identify strategies that could empower witnesses to cyberbullying to take a stand against it (2013-14). The resources generated under the banner “Back me up” continue to attract interest on the Commission’s website:  
<https://www.humanrights.gov.au/our-work/childrens-rights/projects/back-me>

Discussions about children and digital technology are frequently characterised by propositions about what children should and shouldn’t be allowed to do online, but a protectionist approach fails to take into account both the huge opportunities that are afforded to children within digital spaces, and the reality of their lived experience. Digital technology can potentially promote or impede a wide range of children’s rights as recognised under the United Nations Convention on the Rights of the Child. In particular, digital spaces can enable children to access their right to:

- Education (Article 28)
- Express themselves freely (Article 13)
- Appropriate information (Article 17)
- Participate in decisions that affect them (Article 12)

Despite this range of opportunities, children and young people frequently lack the supports that they require to exercise their rights in the digital environment. This is especially true for more vulnerable children. Article 28 of the Convention on the Rights of the Child protects the right of children to an education. Digital technology can indeed enhance the educational experience—through easier accessibility, interactivity and the fast provision of information—but it also brings certain risks. Such risks include ‘information overload’, exposure to distressing images or information and ‘fake news’. Digital environments can also exacerbate negative social phenomena such as bullying.

For a child’s right to education to be protected in a manner that promotes understanding, peace and tolerance (as per article 29), children need to be equipped with an appropriate suite of digital literacy skills. For example, children need to be taught how to decode digital information effectively by learning

how to identify bias in computer systems and developing methods of avoiding such bias. They also need to acquire strategies for combatting anti-social behaviour in digital environments.

Lastly, service providers should similarly receive guidance about the best ways to develop child-centred approaches to digital technology which balance children's rights to information, expression and accessibility, with any potential risks.

It is encouraging to see the education sector's proactive work to mitigate the risks and harness the opportunities that new technology can provide. If you have any questions or require further information please contact Sophie Farthing at [sophie.farthing@humanrights.gov.au](mailto:sophie.farthing@humanrights.gov.au).

Yours sincerely

Edward Santow

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<sup>1</sup> Australian Human Rights Commission, Human Rights and Technology, Issues Paper (July 2018).

<sup>2</sup> Ibid.

<sup>3</sup> Australian Human Rights Commission, Human Rights and Technology, Issues Paper (July 2018).

<sup>4</sup> International Covenant on Economic, Social and Cultural Rights, opened for signature 16 December 1966, 993 UNTS (entered into force 3 January 1976) art 13.

<sup>5</sup> International Covenant on Civil and Political Rights, opened for signature 19 December 1996, 999 UNTS 171 (entered into force 23 March 1976) arts 2 and 26 ('ICCPR')

<sup>6</sup> ICCPR art 19.

<sup>7</sup> ICCPR art 17.

<sup>8</sup> United Nations Convention on the Rights of the Child UN GA Res 44/25 (20 November 1989). At <http://www.ohchr.org/Documents/ProfessionalInterest/crc.pdf> (viewed 12 November 2018) art 17 and 19.

<sup>9</sup> Convention on the Rights of Persons with Disabilities, opened for signature 13 December 2006, 2515 UNTS 3 (entered into force 3 May 2008) art 4.

<sup>10</sup> Convention on the Rights of the Child, opened for signature 20 November 1989, 1577 UNTS 3 (entered into force 2 September 1990).



## Appendix 3: Applying the Five Pillars of AI Ethics to School Education (accessible version)

<b>Awareness</b>	Design: How have the manufacturers of system engaged with the education stakeholders to raise awareness of AI, its limitations, potential and risks?	Implementation: Have students and parents/caregivers been made aware of the type of data harvesting and sharing arrangements required by the system?	Governance: Is there a rigorous process for seeking parental consent and student assent before systems are deployed?
<b>Explainability</b>	Design: Is the system designed to explain to students, parents and teachers its purpose, process, decisions and outcomes in an accessible way?	Implementation: What opportunities, approaches and public forums are available for students and parents to explore, explain and share information and experiences of AI in schooling?	Governance: Do policy-makers, procurement officers, and school leaders have access to appropriate independent technical expertise to explain and advise on AI systems?
<b>Fairness</b>	Design: Has the issue of potential bias in the design of the system been proactively addressed and documented?	Implementation: How will school address potential inequalities in an AI world? Does the system use autonomous experimentation and could this create an unfair burden on students and teachers? Does the AI system introduce unjust and punitive types and levels of surveillance on students and teachers?	Governance: What procedures and policies are there to ensure that AI systems positively address rather than exacerbate inequity, discrimination and prejudice in education? What evidence is there that an AI system can be used to address equity concerns in schools?
<b>Transparency</b>	Design: Is the system designed and implemented for traceability, verifiability, non-deception and honesty and intelligibility?	Implementation: Can students, teacher, parents and community inspect and have opportunities to respond to AI systems training and decision making in ways that are intelligible or authentically empowering to them?	Governance: How will those in governance or procurement positions ensure genuine traceability, verifiability, non-deception and honesty, and intelligibility of AI systems prior to purchase and during implementation? How

			will transparency be operationalised if harm occurs?
<b>Accountability</b>	Design: Has the designer and vendor of an AI system clearly articulated their responsibilities to ethical use of AI? What systems do they have to ensure ethical accountability?	Implementation: Who is accountable for the procurement of ethical AI? Is there a school and system wide procedure for reporting and responding to AI harm? Do all stakeholders in the school community know about and how to access the above procedure?	Governance: What protocols are in place to prevent and respond to harm? What early warning systems are there that harm may be occurring that can trigger action?

## Appendix 4: Resource Mapping Tables

Table 4: Artificial Intelligence (AI) resources

AI Resource	Description	Curriculum	Audience	Source
<a href="#">CSER MOOC on AI for primary and secondary teachers</a>	Free MOOC on AI		PRIM, SEC	CSER
<a href="#">6 Minute English: Do you fear artificial intelligence?</a>	A 6 minute audio resource for active listening for students to learn about AI and AI vocabulary.	ACELY1723, ACELA1528, ACELY1740.	SEC ENG	BBC Learning English, 2015.
<a href="#">A visual introduction to Machine Learning.</a>	This site explains how 'machine learning' is used to make highly accurate predictions using interactive visualisations.	ACTDIP042 ACTDIP030 ACTDIP029 ACTDIP019 ACTDIP011	PRIM, SEC	Digital Technologies Hub, 2017.
<a href="#">Artificial intelligence: But where is the intelligence?</a>	A book for younger students exploring the basic concepts of artificial intelligence.	ACHASSI122, ACHASSI152	PRIM HASS	University of London, 2018.
<a href="#">Australian Computing Academy</a>	Website with both student and professional learning resources to assist with integrating the new Digital Technologies curriculum in Australian classrooms. Includes resources for machine learning.	APTS 3.4, 4.6, 4.5.	TEACHERS PRIM, SEC	Australian Computing Academy

<b>AI Resource</b>	<b>Description</b>	<b>Curriculum</b>	<b>Audience</b>	<b>Source</b>
<a href="#">CSER MOOC on AI for primary and secondary teachers</a>	Free MOOC on AI		PRIM, SEC	CSER
<a href="#">Australian Educational Technologies Trends</a>	This report examines the potential use of digital technologies within Australian schools over 2019 – 2023 and was produced to inform teachers, school leaders, academics and the industry.	APTS 3.4, 4.5, 5.1.	TEACHERS PRIM, SEC	ACCE & digital careers, Griffith University, 2018.
<a href="#">Duolingo Chatbots</a>	Learn languages for free with chatbots. A range of languages are available with communication by text. Spoken language is under development.	VARIOUS language outcomes	PRIM, SEC LANG	Duolingo, Pittsburgh, USA, 2018.
<a href="#">Future Frontiers: Education for AI World</a>	A collated set of perspectives to encourage thinking around education in a rapidly changing technological world.	APTS 3.4, 4.5, 5.1.	TEACHERS PRIM, SEC	NSW Department of Education and Melbourne University Press, 2017.
<a href="#">Future Frontiers: The implication of AI, automation and 21st century skill needs</a>	Background to AI and education in terms of trends in society, business and employment.	APTS 3.4, 4.5, 5.1.	TEACHERS SEC	NSW Department of Education, 2017.
<a href="#">Future Frontiers: Preparing for the best and worst of times</a>	Considers the impact of emerging technologies with particular attention to what this might mean for education.	APTS 3.4, 4.5, 7.1. 7.4.	TEACHERS PRIM, SEC	NSW Department of Education and University of Sydney, 2018.

AI Resource	Description	Curriculum	Audience	Source
<a href="#">CSER MOOC on AI for primary and secondary teachers</a>	Free MOOC on AI		PRIM, SEC	CSER
<a href="#">Google Arts and Culture</a>	Arts & Culture app that lets students match their selfies to faces in famous paintings.	ACAVAR124, ACAVAR131	SEC VISART	Google, 2018.
<a href="#">Google Auto Draw</a>	AI/ML app drawing tool. AutoDraw guesses drawings and suggests a professional image.	ACAVAM107 ACAVAM111, ACAVAM115 ACAVAM119 ACAVAM126	PRIM, SEC VISART	Google, 2017.
<a href="#">HAL</a>	A teacher's pack for lessons developed to teach science communication skills to students in grades 5 and 6. The work unit is based around HAL in the movie 2001 A Space Odyssey examining artificial intelligence in order to teach science communication skills.	ACSIS093 ACSIS110	PRIM SCI	Cork Electronic Industry Association, UK, 2018.
<a href="#">Imagining other uses for robotics technology</a>	Considering robots beyond what is commonly seen and considered.	VARIOUS	PRIM, SEC	ABC, Australia.
<a href="#">Learn with Google AI</a>	Information and exercises to help anyone learn about AI. Level can be chosen by participant. Covers a range of outcomes dependent	VARIOUS APTS 3.4, 4.5, 5.1.	TEACHERS PRIM, SEC	Google

AI Resource	Description	Curriculum	Audience	Source
<a href="#">CSER MOOC on AI for primary and secondary teachers</a>	Free MOOC on AI		PRIM, SEC	CSER
	on choice of audience and level of understanding.			
<a href="#">The internet of things for banking, energy and utilities, and insurance</a>	<p>The video on AI big data uses an example character and tracks her interactions with technology through her day, including restaurant booking, online purchases, appliance monitoring and exercise tracking.</p> <p>As the video examines the interactions it also explains how businesses can track these interactions and make use of the data she is creating, raising questions of privacy, data ownership and customer benefits.</p>	<p>ACTDIP043</p> <p>ACTDIP036</p>	SEC	IBM corporation, 2014.
<a href="#">Scratch</a>	Provides a platform for students to collaborate to produce interactive stories, games and animations.	<p>VARIOUS</p> <p>ACTDIK014</p>	PRIM	MIT, USA.
<a href="#">Teaching artificial intelligence in kindergarten</a>	Article detailing curriculum links and outcomes for AI in kindergarten.	<p>ACMSP011</p> <p>ACMNA015</p> <p>ACMSP262</p>	<p>PRIM</p> <p>MATH</p>	Gadzikowski, Ann. Executive Director, Preschool for the

AI Resource	Description	Curriculum	Audience	Source
<a href="#">CSER MOOC on AI for primary and secondary teachers</a>	Free MOOC on AI		PRIM, SEC	CSER
				Arts, Madison, Wisconsin, 2018.
<a href="#">The complete guide to artificial intelligence for kids</a>	A book by Professor Michael Milford explaining artificial intelligence for younger children.	ACHASSI002 ACHASSI053 ACHASSI095	PRIM HASS	Professor Michael Milford, Queensland University of Technology, COST.
<a href="#">Toward ethical, transparent and fair AI/ML: a critical reading list</a>	For those interested in machine learning and AI: a list of suggested reading that includes relevant 'must read' background and deeper optional reading for the many areas of AI that will impact society and education.	APTS 3.4, 3.6, 4.5, 5.1, 5.4, 7.1.	TEACHERS PRIM, SEC	Eirini Malliarki, Medium, 20 Feb, 2018.
<a href="#">Understanding the four types of AI from reactive robots to self-aware beings</a>	An AI researcher discusses the White House report on AI and the mainstream AI tools of machine learning and deep learning. Reviews four types of AI with examples.	APST 3.4.	TEACHERS PRIM, SEC	The Conversation, 14 Nov, 2016.
<a href="#">Will artificial intelligence destroy us?</a>	Discussion of a recent article published by Stephen Hawking that suggests AI could lead to the downfall of humanity.	ACELT1619 ACTDIK034 ACTDIP042	SEC ENG DT	YouTube, DNews, 2014.





Table 5: Virtual Reality (VR) resources

VR Resource	Description	Curriculum	Audience	Source
<a href="#">1943 Berlin Blitz</a>	Puts the viewer into a Lancaster bomber as it navigates its journey to Berlin in 1943.	ACDSEH024	SEC HASS	BBC Media Applications Technology Ltd, 2018.
<a href="#">Affordances of Mobile Virtual Reality and their Role in Learning and Teaching</a>	Discusses the use of Google Expeditions for education.	VARIOUS APTS	TEACHERS	Open University, 2017.
<a href="#">AR VR blog</a>	A VR and AR blog updating knowledge about VR and AR for educators.	VARIOUS	TEACHERS	Stephan Kojouharov, 2018.
<a href="#">BBC Earth: Cat Flight</a>	Explores the way that caracal catch their prey.	ACSSU073 ACSSU176	SEC SCI	BBC Earth, 2017.
<a href="#">BBC Home</a>	A spacewalk 250 miles above the surface of the Earth. Inspired by NASA's training program with memorable views of planet Earth.	ACSHGS050	PRIM, SEC	BBC Media Applications Technology Ltd, 2017.
<a href="#">BBC Life on Earth - California Coastline</a>	VR app that allows students to explore the Californian coastline.	ACSSU073	PRIM SCI	BBC Worldwide Limited, 2018.
<a href="#">BBC we wait</a>	An Aardman production based on interviews with refugees.	ACHMH211	SEC HASS	BBC Media Applications Technology Ltd, 2016.
<a href="#">Bear Island</a>	Find a safe feeding ground for a hungry young black bear who is searching for the perfect fishing spot.	ACSSU073 ACSSU176	PRIM	BBC Worldwide, 2017.

VR Resource	Description	Curriculum	Audience	Source
<a href="#">Beyond VR- Public speaking</a>	VR app that enables speaking practice in front of a virtual audience for students developing public speaking skills.	<a href="#">ACELY1699</a> <a href="#">ACELY1811</a>	PRIM, SEC ENG	Beyond VR, USA, 2018.
<a href="#">Carbon VR</a>	Explore the carbon element at the molecular level in Virtual Reality.	ACSCH035	SEC SCI	EduChem, Sweden, 2018.
<a href="#">Chemistry VR</a>	A variety of applications for exploring molecules through VR including: macromolecules, stereoisomers and various forms of carbon.	ACSCH035	SEC CHEM BIO	EduChem, Sweden, 2018.
<a href="#">Cleanopolis VR</a>	An interactive narrative and informative game for young students to learn about climate change and the affects humans behaviours have on the environments.	ACSHE034 ACSSU043 ACSSU094 ACSSU073	PRIM, SEC SCI	EDF, 2018.
<a href="#">Coral Compass: Fighting climate change in Palau</a>	Explore how the island of Palau is adapting to climate change.	ACHGE075 ACSSU189	SEC HASS SCI GEO	Stanford University Virtual Human Interaction Lab, 2018.
<a href="#">CoSpaces – Virtual Reality Application</a>	Create 3D worlds on a computer and then explore them using this app and, optionally, a virtual reality headset. Teachers and children can be creative as they bring	VARIOUS ACAVAM11	SEC DT VISART	Educational App Store, 2018.

VR Resource	Description	Curriculum	Audience	Source
	aspects of their lessons to life in their 3D scenes.			
<a href="#">Diggers Trench experiences</a>	Work with the ANZAC diggers of World War 1 at the Battle of Somme.	ACDSEH095	SEC HASS	Frame VR, 2016.
<a href="#">Discovery VR</a>	Exploring new places, Discovery VR provides options to stream or download VR and 360 videos. With content from popular education Discovery Channel content, like Shark Week and Deadliest Catch, immerse in the VR experience using your mobile device and VR headset. The Discovery VR app supports Android and iOS devices.	VARIOUS	PRIM, SEC	Discovery VR, 2018.
<a href="#">Dreams of Dali 360degree YouTube video</a>	Go inside and beyond Dali's painting Archaeological Reminiscence of Millet's Angelus and explore the world of the Surrealist master in this 360° video.	ACAVAR131	SEC VISART	Dali Museum, 2016
<a href="#">EON Reality Education</a>	EON Reality Education is a non-profit organisation focused on advancing the cause of Augmented and Virtual Reality (AVR) education and research. Education VR resources include ancient Egypt, anatomy, the journey of Howard Carter, Offshore virtual training, Magi Chapel VR, engine explorer and ophthalmology VR.	VARIOUS	SEC HASS DT	EON reality Inc., 2018.
<a href="#">Farm VR</a>	A collaboration that offers farm experiences in VR. There are lesson plans available	ACSES076	SEC	Think Digital, 2017.

VR Resource	Description	Curriculum	Audience	Source
	across a range of stages. Currently lesson plans are centre around salmon and salmon farming.	ACSES077	BIO	
<a href="#">Fukushima (ENG)   360 VR Video</a>	A virtual reality feature that investigates how the 2011 Japanese tsunami changed the course of the country's history.	ACSSU096 ACSES019 ACSES100	PRIM, SEC SCI	El Pais, 2016.
<a href="#">Google Earth VR</a>	A series of immersive VR experiences from around the globe.	VARIOUS	PRIM, SEC	Google, various.
<a href="#">Google Expeditions</a>	Google Expeditions develops educational VR content designed for classroom learning. It allows students and educators to take immersive virtual journeys by having the ability to allow a teacher to guide or students as explorers. With the broadest coverage of content, Google Expeditions provides 360 degree pictures for VR field trips and career shadowing. The VR videos can be experienced through a mobile device or desktop when paired with a VR headset. This app also offers VR training for educators through the Google for Education Training Center.	VARIOUS	PRIM, SEC	Various, Various.
<a href="#">Google Spot light stories</a>	Storytelling for VR from Google. A range of short immersive stories to implement in the classroom. Artists and technologists making	ACELT1610 ACELT1613 ACELT1620	PRIM, SEC ENG	Google, 2018.

VR Resource	Description	Curriculum	Audience	Source
	immersive stories for mobile 360, mobile VR and room-scale VR headsets, and building the innovative tech that makes it possible.	ACELT1627 ACELT1635 ACELT1642		
<a href="#">Infographic and Teacher tip sheet on VR for learning</a>	Infographic available in A3 or A4 size. Top tips considers VR in terms of educational value, pedagogy and developmental appropriateness of Vr experience.	<u>ALL</u>	PRIM, SEC	A/Prof Erica Southgate, University of Newcastle, 2018.
<a href="#">In Mind 2</a>	InMind 2 is an adventure game which places emphasis on the chemistry behind human emotion, greatly inspired by the Pixar/Disney movie 'Inside Out' and (more scientifically) Lövheim's theory of emotions.	ACPPS075	SEC HPE	Ludin, 2018.
<a href="#">InMind VR</a>	InMind allows the player to experience the journey into the patient's brains in search of the neurons that cause mental disorder. Submerge into the microworld and experience the miracles of the human mind.	ACPPS075	SEC HPE	<u>Ludin, 2015.</u>
<a href="#">Interactive 3D virtual reality field trip program</a>	HistoryView allows students from all over the world to travel anywhere from the comfort and safety of their classroom.	VARIOUS	PRIM, SEC	LLC Educational Virtual reality Marketing Company, 2018.
<a href="#">International Space Station Tour VR</a>	Explore the International Space Station as you join Samantha Cristoforetti from the European Space Agency on board. Yu can move between the 40 key areas of the space station between the 8 modules that include the science laboratory and living quarters.	ACMEM154 ACSES010 ACSBLO08	SEC SCI BIO	The House of Fables, 2018.

<b>VR Resource</b>	<b>Description</b>	<b>Curriculum</b>	<b>Audience</b>	<b>Source</b>
<a href="#">Introduction to virtual reality</a>	An introduction to VR through a range of different experiences.	ACTDIK014	PRIM, SEC DT	Felix and Paul Studios, 2016.
<a href="#">Littlestar VR</a>	360 degree videos with VR inclusion.	VARIOUS	SEC	Littlestar, 2018.
<a href="#">Learn about HMB Endeavour</a>	Learn about the HMB Endeavour with a virtual tour, an interactive online game sailing the ship across the globe, and downloadable classroom resources.		PRIM	Australian Maritime Museum, 2018.
<a href="#">Mission ISS</a>	Take a trip into orbit and experience life on board the International Space Station. In this Emmy-nominated simulation, learn how to move and work in zero-gravity using Touch controllers. Dock a space capsule, take a spacewalk, and let real NASA astronauts guide you on the ISS through archival video clips.	ACSHE119 ACSHE192	PRIM, SEC SCI	Steam VR, 2018.
<a href="#">Nearpod</a>	Free (silver edition) and pay (gold and school edition) interactive presentation system. Includes virtual experiments and activities. Simulations across many curriculum areas.	VARIOUS	PRIM, SEC	Nearpod, USA, 2018.
<a href="#">Nefertari: Journey to eternity</a>	Step into the fabled tomb of Queen Nefertari and explore the art, history, construction and mythology through interactive elements.	ACDSEH129 ACHASSK174	SEC HASS	Experious VR, 2018.

VR Resource	Description	Curriculum	Audience	Source
<a href="#">NYTVR</a>	NYT VR is a mobile app that allows students to experience stories in an immersive 360-degree video experience. Explore real-time stories and news by The New York Times journalists. Students can climb to the top of the One World Trade Center or unwind by the California coast. Download the app on Android and iOS. Also available for VR headsets.	VARIOUS	SEC HASS	New York Times, 2018.
<a href="#">Our Solar System VR</a>	Explore the solar system through a flight through space.	ACSSU048 ACSSU078 ACSSU115 ACSSU117	PRIM SCI	Crenovator Lab Corporation, USA, 2016.
<a href="#">Our Universe in Light</a>	Explore our Universe and some of the objects in it through the different wavelengths of light. From Radio, to infrared, to optical and X-Ray, our universe looks different in each type of light.	ACSSU182 ACSPH047 ACSPH048 ACSPH049 ACSPH050 ACSPH051 ACSPH052	SEC SCI PHY	UK Astronut Productions, 2016.
<a href="#">Rome VR</a>	VR Rome reconstructs Rome city of 320 AD. You can walk in a continuous 2km * 2km play zone to visit the eternal city 1700 years ago. The reconstruction has archeology and	ACDSEH056 ACLCLU058 ACHASSK172	SEC HASS LANG	Steven Luo, 2018.

VR Resource	Description	Curriculum	Audience	Source
	architecture materials supports, and in the game you can view descriptions, photos and 1:500 models for each important buildings.			
<a href="#">Rosetta And Philae</a>	The European Space Agency mission Rosetta explored and landed on the comet 67P in 2015. To celebrate this amazing space mission, you can now explore the Rosetta satellite, comet 67P and Rosetta's journey through our solar system in Virtual Reality using Google Cardboard.	ACSHE119 ACSHE192 ACSHE081	SEC SCI	UK Astronut Productions. 2016.
<a href="#">Samuel's Fairtrade Story (VR field trip)</a>	Samuel the coffee farmer is inviting your Primary school class on a wonderful immersive journey to Kenya where you will meet his family and community. Use this Primary lesson plan alongside our video 'Samuel's Fairtrade Story' where your students can have a 360° exploration of everything including joining a class at the local school. Site includes downloadable lesson plans, videos and follow-up activities. Requires VR glasses.	ACHASSK071 ACTDEK044	PRIM, SEC HASS DT	Fairtrade Foundations, 2018.
<a href="#">Shackleton 100</a>	A virtual tour of Antarctica that allows students to explore a number of sites related to the Shackleton expedition.	ACHASSK113 ACHGK048	PRIM, SEC HASS	Shackleton Exhibition, 2014.
<a href="#">sharecare VR Visualise your health</a>	Navigate and explore an anatomically correct #D model of the human body. Can explore disease with customisation of	ACPPS076	SEC HPE	Sharecare Inc., 2017.



VR Resource	Description	Curriculum	Audience	Source
	severity. Treatments can be added to explore medical options.			
<a href="#">Smithsonian Journeys: Venice</a>	A tour of Venice with an Italian history Professor as your guide.	ACDSEH056	SEC HASS	The Great Courses, 2017.
<a href="#">The Body VR</a>	Travel through the bloodstream and discover how blood cells work. Enter one of the living cells and find out how organelles work together to fight disease.	ACSBL030 ACSBL031 ACSBL032 ACSBL033 ACSBL034 ACSBL035 ACSBL036	SEC BIO	The Body VR LLC, 2016.
<a href="#">The History of Augmented and Virtual Reality, From 1838 to the Present (Infographic)</a>	Infographic detailing history of AR and VR.	ALL	PRIM, SEC	LMT online, 2018.
<a href="#">Titans of Space</a>	Titans of Space is a short guided tour of our planets and a few stars in virtual reality. Works with Google Cardboard.	ACSSU078 ACSSU117 ACSSU188 ACSSU048	PRIM, SEC SCI	DrashVR, 2018.
<a href="#">Trinity Square Video</a>	Free virtual reality art galleries. Trinity Square Video, Canada's oldest media arts artist-run centre, presents V/Art Projects, a mobile virtual reality app gallery, created to	ACAMAM066 ACAMAM077 ACTDIP014	SEC DT	Trinity Square Video, Canada, 2018.

<b>VR Resource</b>	<b>Description</b>	<b>Curriculum</b>	<b>Audience</b>	<b>Source</b>
	help promote new understandings of what the virtual can be, and to ask the questions; What does technology allow us to feel, what are its ethics, and what does it mean to be immersed in an artificial reality in a time of political urgency?	ACTDIP042 ACTDIP043 ACTDIP044		
<a href="#">Unimersiv</a>	Library of educational VR experiences	VARIOUS	PRIM, SEC	Unimersiv, Various.
<a href="#">Virtual Antarctica</a>	A virtual tour of Antarctica including Signy Research Station, Bird Island Research Station, RRS James Clark Ross and Aurora Cambridge.	ACHGK048 ACHGS063 ACHGK075 ACSHE157 ACSHE191 ACSSU176	SEC HASS SCI	British Antarctic Survey, 2017.
<a href="#">Virtual reality in the classroom</a>	This online course explores the principles of designing virtual reality (VR) content using Adobe creative tools. The course also covers integration of the VR projects developed into the curriculum.	APST 2.6, 3.4, 4.5, 5.1, 5.4, 7.4.	TEACHERS	Adobe Education, 2018.
<a href="#">Virtual Speech - VR courses</a>	Practice public speaking, answering interview questions, sales pitches, networking, presentations and language learning.	ACELY1699 ACELY1811	SEC ENG	Virtual Speech Ltd, 2018.

<b>VR Resource</b>	<b>Description</b>	<b>Curriculum</b>	<b>Audience</b>	<b>Source</b>
<a href="#">VR Anti-bullying</a>	Bullying behaviour may happen all year round in many ways. With bullying being a global issue, our Anti-Bullying Virtual Reality workshop encourages students and teachers to witness, dissect and negotiate a typical scenario of bullying behaviour to combat it. We do this by opening a safe communicative environment guided by our professional trained facilitator. This workshop puts Anti-Bullying campaigns, school rules and wellbeing programs into practice through interactive simulations using our exclusive Virtual Reality software.	ACPPS037 ACPPS055 ACPPS074 ACLVIC177	SEC HPE	EG Incursions, 2018.
<a href="#">VR Gorilla</a>	A virtual tourism project that examines the world of the gorilla.	ACSHE120	SEC SCI	Ape Alliance international, 2018.
<a href="#">VR Math</a>	An interactive educational application helping students understand 3D geometry, graphs and vectors - via Virtual and Augmented Reality.	ACMMG037 ACMMG087 ACMMG115 ACMMG200 ACMMG216 ACMMG242	PRIM, SEC MATH	VR-AR Education Inc., 2018.
<a href="#">VR/AR Education</a>	VR/AR communities of practice - Sydney chapter of the global association. Offers	APST 2.6, 3.3, 3.4, 7.4.	TEACHERS	VA/AR Association, 2018.

VR Resource	Description	Curriculum	Audience	Source
	educators workshops and sessions exploring both VR and AR.			
<a href="#">War of Words VR</a>	'War Of Words: VR' uses virtual reality to take you back to 1916, and into a vision captured by Siegfried Sassoon in his controversial poem 'The Kiss'.	ACELA1528 ACELT1807 ACELT1635 ACELY1749  ACDSEH097 ACHHS190	SEC ENG HASS	BBC, Burrell Durrant Hifle, 2014.
<a href="#">Water VR</a>	App for exploring the water molecule on a molecular level. Learn how and why water molecules arrange themselves into phases such as liquid, solid and gas.	ACSSU151	SEC SCI	EduChem, Sweden, 2018.
<a href="#">Wonderful You</a>	An interactive virtual reality experience, immersed inside the womb.	ACTDIK014	SEC DT	BDH Immersive, 2017.
<a href="#">Woofbert VR</a>	Explore the world's best art exhibitions.	VARIOUS	SEC ART	WoofbertVR, 2016.

Table 6: Augmented and Mixed Reality (AR/MR) resources

AR/MR Resource	Description	Curriculum	Audience	Source
<a href="#">AR Flashcards - Animal Alphabet</a>	Made for younger students, this immersive AR flashcard game teaches students words while bringing it all together with some colorful augmented animal friends.	ACELA1440	PRIM ENG	Peak Reality LLC, 2018.
<a href="#">AR VR blog</a>	A VR and AR blog updating knowledge about VR and AR for educators.	VARIOUS	TEACHERS	Stephan Kojouharov, 2018.
<a href="#">Astro Reality</a>	AstroReality offers an AR experience of the solar system and planets. AstroReality offers 3-D handheld products which provide information about each planet in AR.	ACSSU078, ACSSU188 ACSSU048 ACSSU117	PRIM SCI	Lunar and Iplanetary Institute, Californian Institute of Technology , 2018.
<a href="#">Augmented Reality 101</a>	An engaging multi-modal documentary explain the past, present and future of augmented reality	ACTDIK614 ACTDEP049	SEC DT	How Stuff Works, 2016.
<a href="#">AugThat!</a>	AugThat! uses augmented reality to bring to life education using printed images and powerful AR.	VARIOUS ACTDIK014	SEC SCI DT	Shara Newman, 2016.

AR/MR Resource	Description	Curriculum	Audience	Source
<a href="#">Blippar the AR browser</a>	This app allows students to use the camera on their phone to 'blipp' everyday objects, products or images. This will provide helpful information, interact with your favourite brands, play videos, games, and music.	VARIOUS	PRIM, SEC	Blippar.com Ltd., 2018.
<a href="#">Civilisations AR</a>	Civilisations is an app that allows users to look at treasures from museums around the worlds that allows viewing in 3D. Students can see inside the various artefacts, listen to narrations, learn about the origins, history, and cultural backgrounds of each artefact.	VARIOUS	SEC ART	BBC Arts, BBE R&D, Nexus Studios and 30 museums and galleries from across the UK, 2018.
<a href="#">Daqri App</a>	Build your own AR applications for free. Suits student and teacher use.	VARIOUS	PRIM, SEC	Daqri, Los Angeles, CA, 2018.
<a href="#">Earth AR</a>	Earth AR is a demonstration of CG and motion sensing. The view of the Earth rotates synchronising with the device.	ACSSU048 ACSSU078	PRIM, SEC SCI	Gamedokan, 2014.
<a href="#">Engage</a>	Supplies the free to use social education and presentation Engage platform. You can hold meetings,	VARIOUS	PRIM, SEC	Immersive Education, 2018.

AR/MR Resource	Description	Curriculum	Audience	Source
	classes and lessons with people from anywhere. You can record and add in virtual objects for interaction.			
<a href="#">Fetch Lunch Rush</a>	For younger students, an AR application focusing on basic mathematics skills.	ACTDEK044 ACMNA054 ACMNA018	PRIM DT MATH	PBS Kids, 2011.
<a href="#">GeoGebra Augmented Reality</a>	Augmented reality application which allows students to place math objects on any surface, walk around them, and take screenshots from different angles.	ACMMG165 ACMMG115 ACMMG087 ACMMG117	SEC MATH	International GeoGebra Institute (IGI), 2018.
<a href="#">Google Expeditions</a>	Google Expeditions develops educational VR content designed for classroom learning. It allows students and educators to take immersive virtual journeys by having the ability to allow a teacher to guide or students as explorers. With the broadest coverage of content, Google Expeditions provides 360 degree pictures for VR field trips and career shadowing. The VR videos can be experienced through a	VARIOUS	PRIM, SEC	Various, Various.

AR/MR Resource	Description	Curriculum	Audience	Source
	mobile device or desktop when paired with a VR headset. This app also offers VR training for educators through the Google for Education Training Center.			
<a href="#">Google SkyMap</a>	A handheld planetarium for Android devices. Use it to identify stars, planets and other sky-based objects.	<a href="#">ACSSU188</a> <a href="#">ACSSU019</a> <a href="#">ACSSU048</a> <a href="#">ACSSU078</a>	PRIM, SEC SCI	Google, 2018.
<a href="#">HAL</a>	A teachers pack for lessons developed to teach science communication skills to students in grades 5 and 6. The work unit is based around HAL in the movie 2001 A Space Odyssey examining artificial intelligence in order to teach science communication skills.	AC SIS093 AC SIS110	PRIM SCI	Cork electronic Industry Association, UK, 2018.
<a href="#">HP Reveal (Aurasma)</a>	App to create and use AR environments. For teachers and students.	VARIOUS	PRIM, SEC	HP, 2018.
<a href="#">iClass Shapes</a>	This app demonstrates the 3D images of common shapes using AR. Images generated can be moved around.		PRIM MATH	e-Learning Development Laboratory, HK, 2018.



AR/MR Resource	Description	Curriculum	Audience	Source
<a href="#">Layar - Augmented Reality</a>	Augmented reality application called Layar. Scan your pictures, magazines, posters, newspapers as well as other products, to give them an enhanced look through augmented reality. Layar makes printing fun by introducing a whole new range of interacting elements that can be used to enhance your printing experience.	ACAMAM069 ACAMAM075	SEC MEDIA	Educational App Store, 2018.
<a href="#">Leap with Alice</a>	Leap With Alice provides a variety of EdTech tools, including augmented reality. Four applications/tools include AliceLabs, AliceLens, AliceExchange and AliceClassroom. Educators can create, buy and sell educational materials.	VARIOUS	PRIM, SEC	University of Central Florida, 2018.
<a href="#">London with AR: Students create a guide</a>	Anson Primary School, London used AR in grade 5 and 6 to create a London guide for tourists. This youtube video explains how it was done from the student perspective.	APTS 2.6, 3.3, 3.4,	TEACHERS PRIM	Anson Primary School,London, 2013.

AR/MR Resource	Description	Curriculum	Audience	Source
<a href="#">Managing a group project: Augmented Reality</a>	A collaborative project to plan, implement and monitor an AR project. 12- 20 hours of work.	APTS ACTDIP042 ACTDIP038 ACTDIP043 ACTDIP044 ACTDIP041 ACTDIP040 ACTDIP039	TEACHERS	Digital Technologies hub, Australia.
<a href="#">Our Universe AR</a>	Our Universe AR allows you to see models of the planets in our Solar System anywhere in the world, using your phone or tablet.	ACSSU048 ACSSU078	PRIM SCI	Faulkes Telescope, 2018.
<a href="#">Paint 3D</a>	Make 2D masterpieces or 3D models that you can play with from all angles. Your creations can be placed into AR and in your classroom.	ACAVAM111 ACAVAM115 ACAVAM119	PRIM, SEC VISART	Microsoft, 2018.
<a href="#">Photo Math</a>	The app can read and solve problems ranging from arithmetic to calculus instantly by using the camera on your mobile device. With Photomath, learn how to approach math problems through animated steps and detailed instructions or check your	ACMNA01 ACMNA029 ACMNA054 ACMNA076 ACMNA291 ACMNA127 ACMNA153 ACMNA189	PRIM, SEC MATH	Photomath Inc., 2018.

AR/MR Resource	Description	Curriculum	Audience	Source
	homework for any printed or handwritten problem.	ACMNA211 ACMNA239		
<a href="#">The History of Augmented and Virtual Reality, From 1838 to the Present (Infographic)</a>	Infographic detailing history of AR and VR.	ALL	PRIM, SEC	LMT online, 2018.
<a href="#">Virtual Antarctica</a>	A virtual tour of Antarctica including Signy Research Station, Bird Island Research Station, RRS James Clark Ross and Aurora Cambridge.	ACHGK048 ACHGS063 ACHGK075 ACSHE157 ACSHE191 ACSSU176	SEC HASS SCI	British Antarctic Survey, 2015.
<a href="#">VR/AR Education</a>	VR/AR communities of practice - Sydney chapter of the global association. Offers educators workshops and sessions exploring both VR and AR.	APST 2.6, 3.3, 3.4, 7. 4,	TEACHERS	VR/AR Association, 2018.
<a href="#">Why augmented reality will transform education.</a>	Information poster explaining and providing practical advice for implementing AR in education	VARIOUS	TEACHERS PRIM, SEC	New Jersey Institute of Technology, 2017.
<a href="#">Zappar</a>	Zappar connects the digital world with the things round about you using AR.	ACTDIP020 ACAMAM063 ACAMAM066	PRIM, SEC DT	Zappar limited, 2018.

<b>AR/MR Resource</b>	<b>Description</b>	<b>Curriculum</b>	<b>Audience</b>	<b>Source</b>
		ACAMAM073	MATH	

Table 4: Professional Learning courses and resources

PL Resources	Description	APTS map	Audience	Source
<a href="#">Affordances of Mobile Virtual Reality and their Role in Learning and Teaching</a>	Discusses the use of Google Expeditions for education.	APTS 3.4, 3.6.	PRIM, SEC	Researchers from The Open University and the Five Studies Council, UK.
<a href="#">AI Unleashed: An argument for AI in Education.</a>	Written for the non-specialist to help the reader understand what AI is. What AIED can offer learning, now and in the future, is examined.	APTS 3.4, 3.6, 4.5, 5.1, 5.4, 7.1.	PRIM, SEC	UCL Knowledge Lab, University College, London, 2016.
<a href="#">Artificial Intelligence that can teach? It's already happening.</a>	An article that examines what is currently possible in schools with AI, and what might be available soon.	APTS 3.4.	PRIM, SEC	Carl Smith, ABC Science, 2018.
<a href="#">Australian Computing Academy</a>	Website with students and professional learning resources to assist with integrating the new Digital Technologies curriculum in Australian classrooms. Has a section on machine learning.	APTS 3.4, 3.6, 4.5.	Prim, SEC.	Australian Computing Academy, 2018.
<a href="#">Australian Education Technologies Trends 2018</a>	Report on technologies that will impact education for the next five years. Includes digital presentations, maker/spaces, cloud computing, and learning management systems.	APTS 3.4, 4.5, 7.1,	PRIM, SEC	ACCE, digital futures, Griffiths University.

PL Resources	Description	APTS map	Audience	Source
<a href="#">Demystifying Artificial Intelligence</a>	A webinar focused on AI and how it can be taught to primary and secondary school students.	APTS 2.6, 3.4, 4.5,	PRIM, SEC	Professional Learning, Digital Technologies Hub, 2018.
<a href="#">Digital Citizenship</a>	Extensive lesson plans for k-12 for developing digital citizenship skills. Designed and developed in partnership with Project Zero at the Harvard Graduate School of Education -- and guided by research with thousands of educators -- each digital citizenship lesson takes on real challenges and digital dilemmas that students face today, giving them the skills they need to succeed as digital learners, leaders, and citizens tomorrow.	APTS 2.6, 3.3, 3.4, 3.6, 4.5.	PRIM, SEC	Commonsense Education:
<a href="#">Digital Technologies Institute</a>	Offers support for teachers and students with professional learning and a digital learning system (B4 Tech Learning System). Although the focus is on ICT, there is an AI section.	APTS 3.4, 4.5, 7.4.	PRIM, SEC	Digital Technologies Institute Pty Ltd, 2018.
<a href="#">Doing IT: Practical tech advice for children's learning and development</a>	What role can early childhood teachers play to support effective use of technology for learning? Presentation by researcher and play designer Daniel Donahoo gives	APST2.6, 3.3, 4.5, 7.1. 1 hour	PRIM	Early Childhood Australia, 2019.

PL Resources	Description	APTS map	Audience	Source
	practical examples from his technology projects.			
<a href="#">EduTech 2019</a>	A free expo that includes VR, AR, seminars and teach meets.	VARIOUS	PRIM, SEC	EduTech, 2019.
<a href="#">Empowering Digital Citizens</a>	Online course examining the key ideas digital citizenship and how schools and teachers can integrate these into the classroom.	APST 4.5. 2 hours	PRIM, SEC	Teach.com.au 2018.
<a href="#">Future Frontiers: Education for an AI world</a>	A collated set of perspectives to encourage thinking around education in a rapidly changing technological world.	APTS 3.4, 4.5, 5.1.	PRIM, SEC	NSW Department of Education and Melbourne University Press, 2018.
<a href="#">Future Frontiers The implication of AI, automation and 21st century skill needs</a>	Background to AI and education in terms of trends in society, business and employment.	APTS 3.4, 4.5, 5.1.	PRIM, SEC	NSW Department of Education, 2017.
<a href="#">Future Frontiers: Preparing for the best and worst of times</a>	Considers the impact of emerging technologies with particular attention to what this might mean for education.	APTS 3.4, 4.5, 7.1, 7.4.	PRIM, SEC	NSW Department of Education and University of Sydney, 2018.
<a href="#">Highly Immersive Virtual Reality</a>	What teachers should know about highly immersive virtual reality with insights from the VR School Study in NSW.	APTS 3.3, 3.4, 4.5,.	PRIM, SEC	Southgate, E., Buchanan, R., Cividino, C., Saxby, S., Eather, G., Smith, S.P., Bergin, C., Kilham., Summerville, D. & Scevak, J. (2018b). What teachers should know about

PL Resources	Description	APTS map	Audience	Source
				highly immersive virtual reality: Insights from the VR School Study. <i>Scan</i> , 37(4).
<a href="#">Infographic &amp; teacher tip sheet on VR for learning</a>	Find out more about virtual reality with this Infographic on the Power of Virtual Reality for Education. Also available is the Top Tips for Teachers sheet. Free download.	APTS 3.4, 4.5.	PRIM, SEC	A/Prof Erica Southgate, University of Newcastle, 2018.
<a href="#">Is Oculus Go ready for enterprise and education?</a>	Comparison of different VR systems and devices.	APTS 3.4	PRIM, SEC	Tales from the RIFT Blog, 2018.
<a href="#">InTEACT</a>	Information Technology Educators in the ACT	VARIOUS	PRIM, SEC	InTEACT, Canberra, 2018.
<a href="#">London with AR: Students create a guide</a>	Anson Primary School, London used AR in grade 5 and 6 to create a London guide for tourists. This youtube video explains how it was done from the student perspective.	APTS 2.6, 3.3, 3.4.	PRIM	
<a href="#">Managing a group project: Augmented Reality</a>	A collaborative project to plan, implement and monitor an AR project. 12- 20 hours of work.	ACTDIP042 ACTDIP038 ACTDIP043 ACTDIP044 ACTDIP041 ACTDIP040 ACTDIP039		Digital Technologies hub, Australia.



<b>PL Resources</b>	<b>Description</b>	<b>APTS map</b>	<b>Audience</b>	<b>Source</b>
<a href="#">Practical PD</a>	A range of both external and in-school PD.	VARIOUS	PRIM, SEC	PracticalPD, WA.
<a href="#">Teaching artificial intelligence in kindergarten</a>	Article detailing curriculum links and outcomes for AI in kindergarten.	ACMSP011, ACMNA015, ACMSP262	PRIM MATH	Gadzikowski, Ann. Executive Director, Preschool for the Arts, Madison, Wisconsin, 2018.
<a href="#">Technology in early childhood</a>	A PL module examining the role of IT in a quality curriculum.	APST 2.6 1 hour	PRIM	Early Childhood Australia, 2019.
<a href="#">Seven myths about young children and digital technology: Where are we in 2017</a>	Video keynote from 2017 Live Wires International by Professor Lydia Plowman. The focus is on rich and positive learning opportunities with technology, with examination of current international research around impacts and benefits of technology on learning and development of young children.	APST 3.3, 3.4, 3.6. 1 hour	PRIM	Early Childhood Australia, 2019.
<a href="#">Virtual reality in the classroom</a>	This online course explores the principles of designing virtual reality (VR) content using Adobe creative tools. The course also covers integration of the VR projects developed into the curriculum.	APTS 2.6, 3.4, 4.5, 5.1, 5.4, 7.4.	PRIM, SEC	Adobe Education, 2018.

PL Resources	Description	APTS map	Audience	Source
<a href="#">VR/AR Education</a>	VR/AR communities of practice - Sydney chapter of the global association. Offers educators workshops and sessions exploring both VR and AR.	APST 2.6, 3.3, 3.4, 7.4.		Sydney, Australia. Also in Melbourne, Perth and New Zealand.
<a href="#">Why augmented reality will transform education.</a>	Information poster explaining and providing practical advice for implementing AR in education	VARIOUS	PRIM, SEC	New Jersey Institute of Technology , 2017.
<a href="#">Will artificial intelligence destroy us?</a>	Discussion of a recent article published by Stephen Hawking that suggests AI could lead to the downfall of humanity.	INFO	PRIM, SEC	Youtube video.

## About the Authors



Left to right: Stephanie Pieschl, Erica Southgate, Karen Blackmore and Susan Grimes.

**Dr Erica Southgate** is an Associate Professor of Education (University of Newcastle, Australia). She is recognised as ‘surfing the next wave’ of technology enhanced learning for social justice. Erica is lead investigator on the Virtual Reality (VR) School project, the first study to explore learning using of highly immersive VR in high school STEM and CAPA classrooms. She is also a developer of serious computer games designed to improve literacy. Erica is interested in the philosophical, social and educational challenges and potential of human virtuality and augmented intelligence. To find out more - <https://ericasouthgateonline.wordpress.com/>

**Dr Karen Blackmore** is a Senior Lecturer in Information Technology (University of Newcastle, Australia). Karen is a spatial scientist with expertise in the modelling and simulation of complex social and environmental systems. Her research interests cover the use of agent-based models for simulation of socio-spatial interactions, and the use of simulation, virtual environments, and games for serious purposes. Her cross-disciplinary and empirical research explores the ways that humans engage and interact with models and simulations. She has expertise in affective processing, data mining and analytics, experimental design and physiological measurement.

**Dr Stephanie Pieschl** is Professor of Learning, Development, and Psychological Methods at the Technical University of Darmstadt, Germany. She is an educational psychologist with a broad interest in how humans interact with digital technologies for learning and communication. She has lead numerous interdisciplinary projects that combine fundamental and applied empirical research. These projects cover phenomena ranging from self-regulated learning with digital learning technologies and how these processes are affected by learner characteristics to (the prevention of) cyberbullying among adolescents and digital privacy of users on social media.

**Susan Grimes** is an educational researcher with an interest in technology. She has worked in both school and higher education sectors, as well as in the IT industry. Susan's research is concerned with equity, particularly as it relates to disability and diversity. As a pragmatic humanist, Susan has a keen interest in technological changes in education and its impacts on learners and learning.

**Jessey McGuire** is a teacher (English and Drama) and a research officer. Jessey has an interest in emerging digital technologies in education and how to enhance student engagement through these technologies. Jessey is keen to teach students about the possibilities of artificial intelligence and virtual reality so that they can reach their potential in our digital world.

**Kathleen Smithers** is a teacher (History, Society and Culture) and a PhD candidate. Kathleen has worked as a content developer for serious literacy games. As a research officer, she has worked on the VR School project. You can follow her PhD journey here - <https://adventuresinaphd.wordpress.com/>