



EDUCATION: FUTURE FRONTIERS

The implications of AI, automation
and 21st century skills needs

INTRODUCTION

There's been much written about the profound impact that technological advances will have on the way we live and work. Developments in automation and new frontiers in artificial intelligence (AI) are predicted to fundamentally alter the nature of society and work by 2040.

The kindergarten students who entered the school gate for the first time in 2017 will be graduating by 2030. These students and the 8 million young people estimated to finish school over the next two decades will be the workers of 2040. While it is difficult to imagine the world and the way we will work in 2040, it is this world for which these students must be prepared.

Developments in AI are one of a number of interrelated 'megatrends' changing the nature of the labour markets in Australia and across the world. This includes the implications of ageing populations, offshore outsourcing and the need to lift productivity to sustain high standards of living. Many experts are concerned that a number of advanced economies appear to be trending toward increasing intergenerational income inequality at a time when younger generations are facing a labour market with less permanency or certainty in opportunities.

Over the past 20 years, Australia has successfully ridden waves of global economic upheaval with a resilience and optimism that has been the envy of many. High quality education and training has resulted in significant boosts to productivity and the development of a skilled workforce that has been able to adapt to the changing nature of work.

This positions Australia well to transition to an innovation economy and reap the benefits of unprecedented technological advances. International research suggests that AI has the potential to double annual economic growth rates in many developed countries by 2035 – if they have the skills and innovation agenda in place to support this.¹

The profound changes ahead demand an education approach that will provide young people with enduring capabilities and skills to harness the opportunities of technological change. This starts with the educational foundations of strong literacy and numeracy, and goes well beyond these skills. The next wave of education reform will need to lift the bar higher and make education 'smarter' to ensure that today's kindergarten students have the skill and confidence required to navigate an increasingly complex world.

THE PROFOUND CHANGES AHEAD DEMAND AN EDUCATION APPROACH THAT WILL PROVIDE YOUNG PEOPLE WITH ENDURING CAPABILITIES AND SKILLS TO HARNESS THE OPPORTUNITIES OF TECHNOLOGICAL CHANGE.

BREADTH AND PACE OF TECHNOLOGICAL CHANGE

There is significant uncertainty about the full impact of artificial intelligence and automation on employment but the effects are already starting to be felt.

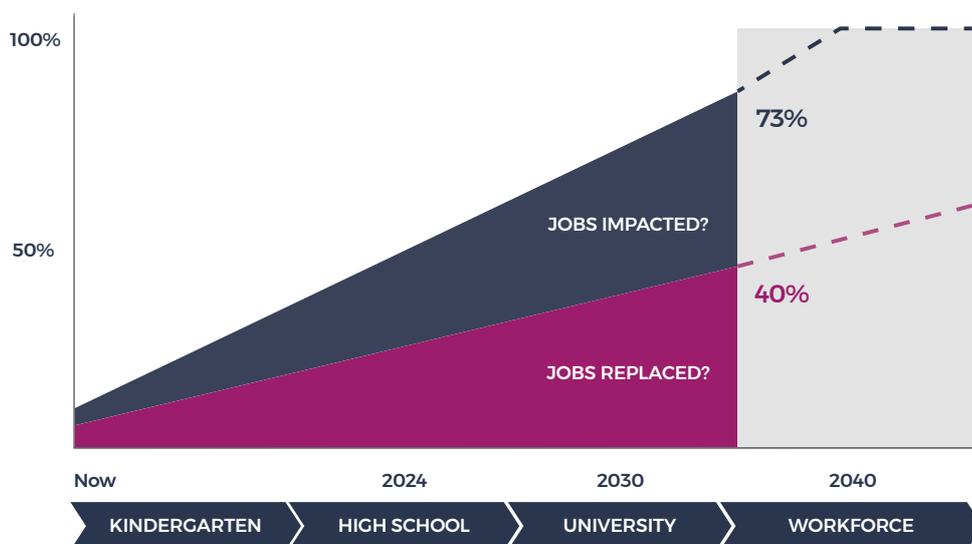
Modelling by the Oxford Martin School which predicted that 47 per cent of total employment in the United States is at risk of becoming automated, rightly raised alarm bells.ⁱⁱ Australian estimates predict about 40 per cent of Australian jobs have a high probability of being automatable and over 70 per cent are likely to be substantially affected by automation and artificial intelligence in the next two decadesⁱⁱⁱ

Many experts believe AI will, in the short-term, replace or augment humans in undertaking certain tasks, rather than replacing jobs entirely. Recent analysis focusing on the potential for task automation in the OECD has put the proportion of whole occupations at risk of automation closer to 10 per cent^{iv}

Clearly, firm predictions about the effects of technology on specific occupations are difficult. Bank tellers, for example, were forecast to all but disappear with the widespread introduction of automatic teller machines. Instead the skillset required of those remaining extended beyond routine cash handling to ‘relationship banking’ necessitating skills in customer sales and providing financial advice services.^v Indeed the number of bank tellers actually grew in the US.

The notion of jobs disappearing and changing is not new, and a wide range of jobs have already been exposed to trends in technology. While periodic concerns about the risk of automation and technology on employment are over two centuries old, the distinctive feature of present trends is the predicted breadth and pace of change.^{vi}

Some 8 million students will leave school between 2017 and 2040



Whereas once automation was thought to be contained to low-skilled or routine tasks, advances in technology are resulting in the automation of more highly skilled, cognitive tasks. Improvements in mobile robotics and sensory technologies are leading to far more sophisticated automation of processes. Developments in cognitive computing are enabling computers to adapt themselves, learn over time and to understand and communicate using human language. In effect, these technologies are redefining the type of human capabilities machines are able to perform (see Appendix).

Though much of its potential is yet to be actualised, AI-related technologies are already becoming integrated into daily living, from voice-recognition software in phones and laptops (Siri, Google Assistant) to the content recommendation engine underpinning Netflix. AI is changing and disrupting jobs and augmenting increasingly complex tasks across many occupations. Though many acknowledge the obvious risk to jobs such as truck-driving and home cleaning, the effects of AI are also expected to significantly affect lawyers and doctors and other skilled professionals.

There are many examples of the emerging impact of AI and advanced automation across industries:

- IBM Watson made headlines when it diagnosed a rare form of cancer faster and more accurately than doctors.
- The LA Times generated attention when it published a story about an earthquake in the US that was written entirely by algorithm.
- Peer-to-peer models in insurance and financial lending are using bots and machine learning to generate quotes and approve requests without the need for human brokers.
- Contract law, legal research and accounting are already experiencing increased automation of what were considered high-skilled tasks.
- Across sectors, advances in cognitive computing which combines natural language processing and machine learning will enable people to ask their smart computer to undertake specific tasks that are not pre-programmed and which currently involve significant human labour – analyse data, synthesise research and model outcomes.
- Automated pharmacy systems have been launched in two US hospital medical centres, where robots dispense individual medications.
- Domino delivered its first pizza by drone in 2016; with developments in drones and self-driving vehicles expected to fundamentally alter transport logistics.
- The world's first fully automated lettuce farm is due to be launched in Japan this year and self-driving tractors are being trialled in the US.
- AI-based platforms, including games and simulations, are being used as recruitment tools and for training, including in military settings.

AI IS CHANGING AND DISRUPTING JOBS AND AUGMENTING INCREASINGLY COMPLEX TASKS ACROSS MANY OCCUPATIONS.

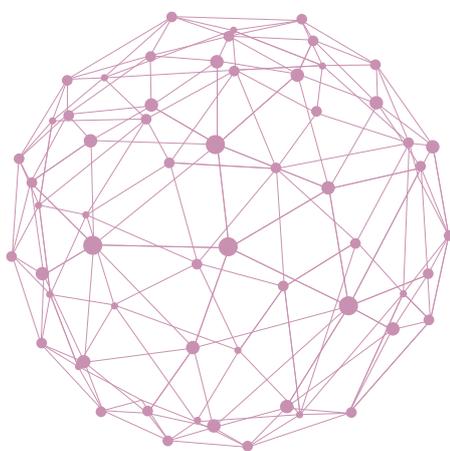
While many people are yet to experience changes to their jobs as a result of AI first-hand, few doubt the potential for AI to radically disrupt the types of work that we will do and how we do our jobs in the very near future.

The cumulative effects of these maturing and intersecting fields will have profound implications for the way humans and technology interact in all fields of work and life. The immediate impact is being felt on low-skilled and entry level roles, and some industries will be more affected in the short and medium term than others. But the diffusion of artificial intelligence is expected to occur across sectors as change is accepted and the technology becomes increasingly affordable; augmenting and possibly replacing an array of existing high-skilled roles in the process.

Significant advances in these technologies are being matched by substantial investment in the new frontiers of AI, including by global tech companies. Global investment in AI start-ups alone was estimated at US\$2.4 billion in 2015, up from US\$415 million just three years earlier.^{vii}

While the impact of new forms of automation is being described as ‘blind to the colour of your collar’^{viii}, technological change also brings with it opportunities for innovation and job creation. New roles will emerge as a result of technological developments and demand in some occupations will grow. Australian industry is already embracing the possibilities of new technologies – in fields ranging from software development, medical diagnostics and research, visual effects, renewable energy and agriculture. A critical factor is for people to have the right set of skills to make the most of those opportunities.

TECHNOLOGICAL CHANGE ALSO BRINGS WITH IT OPPORTUNITIES FOR INNOVATION AND JOB CREATION ... A CRITICAL FACTOR IS FOR PEOPLE TO HAVE THE RIGHT SET OF SKILLS TO MAKE THE MOST OF THOSE OPPORTUNITIES.



CONVERGENCE OF FACTORS

While technology has always affected work and society, the complex interaction between the new frontiers of automation and AI, global economic trends and demographic shifts underscores the critical importance of investing in education and skills development.

Few doubt that the coming decades will hold significant challenges for developed economies, including in generating long-term productivity growth and sustaining high standards of living.

As in other advanced countries, the ageing population is placing significant demands on the Australian economy, and will reduce growth in GDP per capita in the absence of a lift in productivity.^x The proportion of workers to non-workers in Australia has fallen significantly over the last four decades.

The number of people aged 15 to 64 for every person aged over 65 has dropped from 7.3 people in 1975 to 4.5 in 2015. Although the participation of older workers has increased and is predicted to increase further, the number of workers to people over 65 is estimated to almost halve again to 2.7 people by 2054.^x

Intersecting with this is a number of ‘megatrends’ changing the nature and composition of developed economies the world over. Historically, in countries like

Australia, technological development has supported competitive advantages that have resulted in broad lifts in productivity and wages. Australia has experienced a shift away from lower-skill and capital intensive industries and a swing toward industries requiring higher-skilled, and higher-paid, workers. Now, technological developments, particularly digitisation and improved ICT connectivity globally, are facilitating potentially detrimental trends such as offshore outsourcing of labour-intensive processes to both low- and high-skill workers at a lower wage rate relative to the local labour market.

Around the globe, technological developments are exacerbating concerns about increasing labour market polarisation; hollowing out middle-skill jobs and accelerating trends toward increased inequality. As an increasingly global labour market is changing the demand for particular skills across developed countries, there has also been a corresponding broad shift away from permanent employment to more casual and short-term contract arrangements.

At the same time, many are concerned by evidence of a widening gap in intergenerational wealth. A recent McKinsey Global Institute study estimates that the real market income of two-thirds of households in the US and Western Europe had flat-lined or fallen in 2014 compared to 2005, with less educated and younger people hit hardest.^{xi}

AROUND THE GLOBE, TECHNOLOGICAL DEVELOPMENTS ARE EXACERBATING CONCERNS ABOUT INCREASING LABOUR MARKET POLARISATION

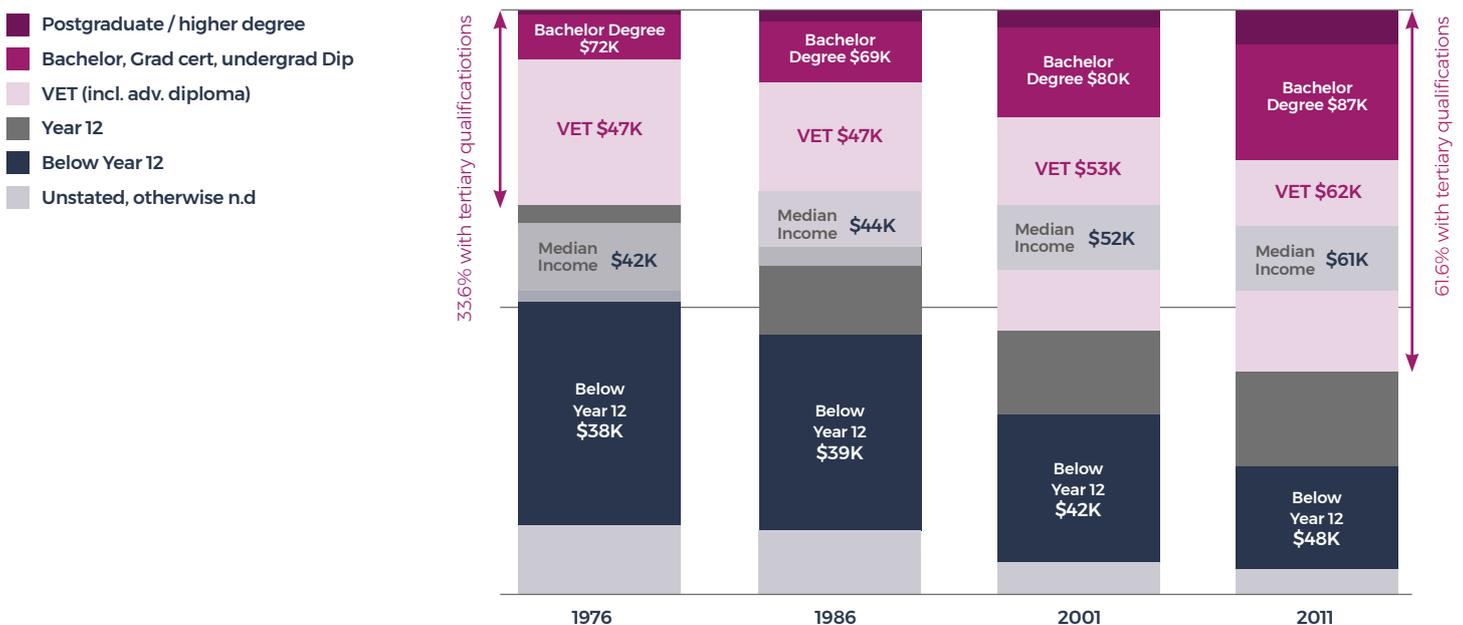
While Australian trends don't precisely mirror international experience, income growth has been uneven over the last two decades and there is a growing perception that those 'in the middle' are not reaping their share of the benefits of economic growth. Income growth in Australia has been strongest at the top of the earnings distribution and weakest at the bottom, with widening inequality since the mid-1990s. Over the last two decades income for the top 20 per cent of households in Australia has risen twice as much as for the lowest-income households, but it also grew at one and a half times that of middle-income households.^{xiii}

Australian studies have found mixed evidence of the extent to which job polarisation has occurred here. Recent analysis suggests employment shares have increased significantly in the highest skill categories and declined in the middle and, to a lesser extent, the lowest skill categories since the 1970s.

While there was evidence of job polarisation in the 1980s and 1990s, subsequent changes in employment shares appear to be due in part to general upskilling and changes in the occupational structure of the labour market with job losses occurring in occupations involving highly routine tasks.^{xiv}

Analysis of average income of full-time, male Australian workers by educational attainment since the 1970s shows that the proportion with tertiary qualifications almost doubled (from 33.6% to 61.6%), with the most significant wage increases occurring at the highest qualification levels. Whereas in the 1970s, the average income of full-time employed men without Year 12 qualifications was close to the median income for full-time workers, by 2011 a tertiary qualification was required (see graph).

Share of full-time employed males by qualification level, and median annual income (in \$2011), Australia, 1976-2011



Source: NSW Department of Education analysis of ABS Census of Population and Housing data, 1976-2011. Uses median individual income and counts of full-time employed males aged 15 and over, by level of highest educational attainment. Qualifications classifications are not strictly comparable over time. Dollars adjusted using Reserve Bank of Australia inflation calculator tool.

AI will help address but also exacerbate these types of economic and societal megatrends – but in ways that are difficult to predict. While AI has the capacity to disrupt the wage premiums for some highly-skilled occupations, there is consensus that in the short term those with low skills will be among the earliest and hardest hit by AI disruption and the most vulnerable to job loss and job churn.^{xv}

Developments in automation and AI in the context of these economic and demographic trends will have significant employment implications for the next generation. The extent to which the majority will benefit from the effects of AI will depend on public policies, and societal and institutional responses.

The key for countries such as Australia is to make significant investments in human capital to produce skills that are complemented, rather than substituted, by technological change.

This means a focus not only on skills to harness the cutting edge of technology but on opportunities to expand middle-skill employment as well. Analysis of recent US employment trends for example indicates growth in middle skill jobs which demand a mix of skills – specific technical and vocational skills as well as strong literacy and numeracy and capacity for problem solving, adaptability and interpersonal interactions – not all of which are easily susceptible to automation.^{xvi}

EDUCATION WILL BE A KEY DRIVER FOR THE DELIVERY OF THE INNOVATION ECONOMY.

DELIVERING THE INNOVATION ECONOMY

In the context of these trends, innovation is a critical plank to ensuring Australia maintains productivity growth. The core competitive advantage that nations such as Australia have is the skills and capabilities of its firms and people.

Research undertaken for the Australian Council of Learned Academies (ACOLA) on skills for Australian innovation highlights the critical importance of investing in human capital to drive higher levels of innovation.^{xvii} But innovation requires more than research, science, technology and entrepreneurialism.

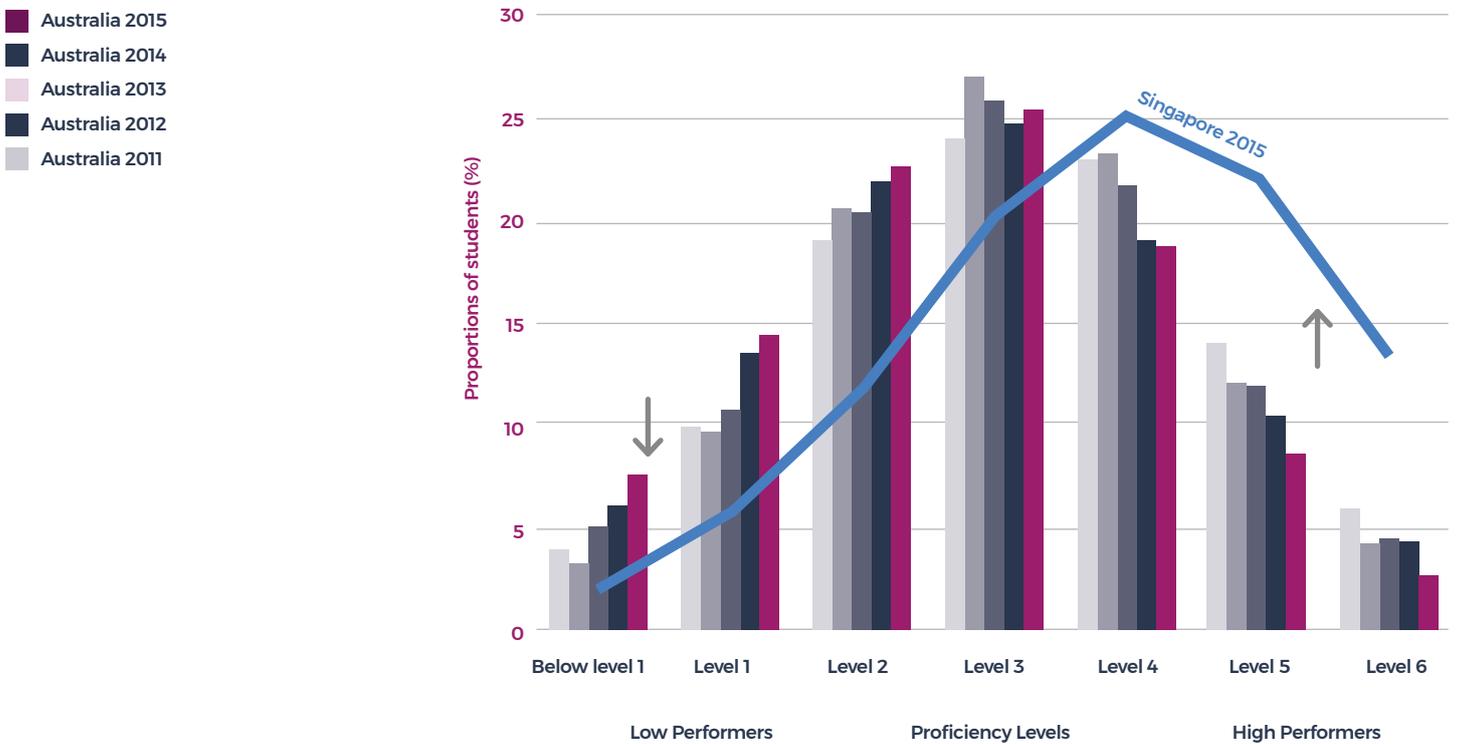
It also needs the intellectual, creative and organisational capacity to translate new ideas and discoveries into innovation.

In 2016, Australia ranked 19th overall out of 128 countries on the Global Innovation Index, which assesses the innovation performance of 128 countries.^{xviii} This ranking was down from 17th in 2015 and behind the United Kingdom (3), United States (4), Singapore (6), Korea (11) and Canada (15). Australia has a lower performance in relation to the outputs of innovation on this Index, suggesting that shortcomings exist in the capacity for Australian enterprise to bring innovation to application.

As the ACOLA report identifies, a more complex picture has emerged of the skills needed for innovation given the interaction of global, technological, demographic and other economic trends. Technical skills are necessary but not sufficient for sustained innovation. Successful innovation will depend not only on continuing to increase skill levels generally but ensuring individuals and enterprises have the right mix of cognitive, interpersonal and intrapersonal skills.

Education in all its guises – school, the tertiary sector and in the workplace – will be a key driver for the delivery of the innovation economy. But looking just at the school level, the performance of Australian students has plateaued and not kept pace with the top performers internationally (see graph). The significant reforms implemented in school education in NSW over the last five years will take time to shift performance. A focus on literacy and numeracy alone, however, will not provide the lift we need.

PISA, maths performance 2003 - 2015



IMPLICATIONS FOR EDUCATION

The passport that today’s kindergarten students will need for life and work in 2040 includes the strong foundations provided by a great school education which starts with literacy and numeracy and which goes well beyond it; and the higher order skills provided by quality post-school education and training.

The profound changes ahead in the nature of work demands an education approach that lifts the proficiency of all students if we are to ensure they have the level of cognition, confidence and skill required to navigate a more complex world. We will also need to lift our top performers to a level of cognitive skill higher than we’ve previously anticipated to harness the opportunities of the innovation economy.

We cannot predict exactly what the workers of 2040 will need to know and be able to do to succeed. However, in the context of greater uncertainty and change arising from these global trends, there is an emerging view that young people, in addition to strong literacy and numeracy, content knowledge and technical skills, will need well developed ‘21st century skills’ to ensure they are

able to engage with and capitalise on technological change.^{xx} And while there is no single definition of what the ideal set of ‘21st century skills’ should be and there are differences in how individual factors are defined, broadly they tend to include both cognitive and non-cognitive skills – in particular problem solving, critical thinking, digital literacy, collaboration and communication.

While 21st century skills are by no means new, it is particularly in recent years that educators have explored whether they need to be explicitly taught, included in academic content standards and routinely assessed, and the extent to which these skills are subject specific or transferrable. There is also an increasing awareness of the interrelated but distinct role of the early years, school and tertiary education in developing these skills.

The increased focus on 21st century skills in the school context has also served to highlight the gaps in our understanding of them. While the development of 21st century skills requires strong disciplinary foundations, there is a general lack of specificity about some of these skills – what teachers need to teach in the classroom and the learning outcomes expected of students.^{xxi} Unlike the teaching of literacy and numeracy, there is not the extensive body of evidence for schools to draw on about effective teaching practice for some of these

“ In the past... the job of schools was to identify talent, and let it rise to the top. The demand for skill and talent was sufficiently modest that it did not matter that potentially able individuals were ignored. The demand for talent and skill is now so great, however, that schools have to be talent incubators, and even talent factories. It is not enough to identify talent in our schools anymore; we have to create it. ”

Dylan Wiliam, Institute of Education, University of London^{xix}

skills, nor the same rich understanding about how students build foundational skills and support deeper learning, or the established suite of tools to assess different dimensions of their attainment.

Advances in developmental psychology and research on the science of learning are increasing our understanding of how particular capabilities are acquired. But the evidence base is more developed for some of these skills than others and research is pointing to some complex interrelationships between them.

There is little doubt that for today's kindergarten students to succeed in tomorrow's more complex world, they will need to be resilient to change, confident and adaptable learners, capacities which are developed through the mastery of subjects and development of skills. For schools and education more broadly it will be more critical than ever to support engagement, encourage lifelong learning and create a culture of high expectations for all students.

THE CHALLENGE FOR EDUCATION...

This discussion paper has been prepared to inform strategic discussions about the implications for education of some of the global challenges of the 21st century.

The next wave of education reform will need to consider the challenges and opportunities of an AI future and what this means for education and learning for all students both in school and beyond. It will need to consider what the 'right' set of future skills is, the role of school in fostering them and the way in which schools should teach and assess them.

As part of these discussions, there are a number of key questions that need to be explored:

- If we need to lift the skill level of all students, including our best and brightest, what changes might need to be made to curriculum and assessment?
- If we expect tomorrow's kindergarten students to be able to know more, learn more and do more, what does this mean for teaching and teachers?
- If schools must prepare students for a world profoundly altered by automation and AI, what implications does this have for today's education infrastructure?
- If schools are to be more responsive to the needs of a rapidly changing world, what is the role of VET, higher education and industry in supporting this?

REFERENCES

- i Purdy and Daugherty, 'Why Artificial Intelligence is the Future of Growth', Accenture Institute, 2016. USA Executive Office of the President, 'Artificial Intelligence, Automation and the Economy', Dec. 2016.
- ii Frey, C. & Osborne, M. 2013, 'The Future of Employment: how susceptible are jobs to computerisation?' Oxford Martin School Working Paper No. 7.
- iii CEDA 2015, *Australia's Future Workforce?*, Committee for Economic Development of Australia; Hajkowicz, S. et al 2016, *Tomorrow's Digitally Enabled Workforce: megatrends and scenarios for jobs and employment in Australia over the coming 20 years*, CSIRO, Brisbane, January.
- iv Arntz, M., Gregory, T. & Zierahn, U. 2016, 'The Risk of Automation for jobs in OECD countries: a comparative analysis', *OECD Social, Employment and Migration Working Papers*, No.189, Paris.
- v Bessen, J. 2015, *Learning by Doing: The Real Connection between Innovation, Wages, and Wealth*. Yale University Press: New Haven.
- vi Autor, D. 2015, 'Why are there still so many jobs? The history and future of workplace automation', *Journal of Economic Perspectives*, volume 29, number 3, Summer.
- vii CB Insights 2016, 'Artificial Intelligence Explodes: New Deal Activity Record For AI Startups', 20 June.
- viii An expression coined by Jerry Kaplan author of *Humans Need not Apply*, see 'Automation and anxiety: will smarter machines cause mass unemployment?', *The Economist*, 25 June 2016.
- ix Coelli & Borland, 2015.
- x Commonwealth Treasury, *2015 Intergenerational Report: Australia in 2055*.
- xi Dobbs, R. et al 2016, *Poorer than their Parents? Flat or falling incomes in advanced economies*, McKinsey Global Institute, July.
- xii NSW Government 2016, *Intergenerational Report 2016: Future State NSW 2056*.
- xiii NSW Government 2016.
- xiv Coelli, M. & Borland, J. 2015, 'Job polarisation and earnings inequality in Australia', Department of Economics, University of Melbourne, 24 February.
- xv Frey, C. & Osborne, M. 2013; Arntz, M., Gregory, T. & Zierahn, U. 2016.
- xvi Autor, D. 2015; Carnevale, A. 2016, 'Trump has promised manufacturing jobs, but high school grads may want to seek credentialed "middle-skills" posts instead', *The Hechinger Newsletter*, 15 November.
- xvii Cunningham, S., Theilacker, M., Gahan P., Callan, V. and Rainnie, A. 2016, *Skills and Capabilities for Australian enterprise innovation*, Report for the Australian Council of Learned Academies, June.
- xviii The index is produced jointly by Cornell University, INSEAD and the World Intellectual Property Organisation, 2016 report available at www.globalinnovationindex.org.
- xix William, D. 2011, *How do we prepare students for a world we cannot imagine?*, Salzburg Global Seminar, December.
- xx See for example, Trilling and Fadel 2009, Partnership for Teaching 21st Century Skills (P21); National Academies Press 2012, *Education for Life and Work: developing transferable knowledge and skills in the 21st century*.
- xxi iRotherham, A.J. and Willingham, D.T. 2010, '21st-century skills: not new but a worthy challenge', *American Educator*, Spring.

APPENDIX

‘Artificial Intelligence’ – a combination of developing and interconnected technologies applied to specific tasks

DIGITISATION, BIG DATA AND ICT CONNECTORS

Digitisation: the ability to digitally represent objects, images, sounds and text is supporting our capacity to process, store, connect, transmit and leverage information more efficiently than ever before

Big data: extremely large data sets that are converting the unprecedented quantity of available data now available into a form that can be mined and interrogated

Internet of things; cloud hosting: infrastructure that digitally-connects not only computers and communication ‘smart’ devices but any digitally-connectable object, including potentially nanotechnology embedded in materials (e.g. implanted medical devices) that can collect and share sensory data

MACHINE LEARNING, DEEP LEARNING

Data visualisation and pattern recognition: using voice and image recognition algorithms on a massive scale (e.g. facial recognition software employed for immigration processing; alternative text tools that provide an audio description of photographic content for visually impaired people)

Predictive analytics: analysing big data for patterns of behaviour and developing algorithms to predict future behaviour with a great degree of accuracy (e.g. US government exploring potential use to improve child welfare system)

Deep learning: designing artificial neural networks inspired by the structure and function of brains, aims to mimic human thought processes such as decision making and self-directed learning by processing large amounts of data (e.g. learning game rules and winning strategies; developing medicines tailored to individual’s genomes)

MULTI-SENSORY TECHNOLOGY

Speech: computer technology interface using human language rather than program language commands (e.g. IBM Watson; Siri / Google Assistant / Alexa / Cortana; social robots designed to help autistic children learn how to navigate social interaction)

Sight: computer vision; pattern recognition, image analysis; extracting and processing information from images; interpreting facial expressions (e.g. supports navigation by autonomous vehicles; interpreting X-ray images)

Olfactory technology: (e.g. robobees - small drones that will be able detect scents, such as explosives, from long distances; or perform search and rescue; or autonomously pollinate crops)

MOBILE ROBOTICS AND NANOTECHNOLOGY

Improved mobility and sophisticated articulation; the ability of machines to navigate and interact with their physical surroundings (e.g. using 360 degree sonar and GPS; humanoid and quadrupedal robots with 3D-printed limbs that can negotiate rough terrain, and lift and manipulate objects)

Improved plastics technology is supporting the development of robots with greater elasticity and expressive facial expressions and dexterous sensitivity

Increasing development of nanotech and bio tech to image, measure, model and manipulate material at the most minute level, with the potential to develop new ‘smart’ hybrid materials and manipulate cellular processes

