EARNING OUR FUTURE

Australian Academy of Science

THE PLATFORM OF THE AUSTRALIAN ACADEMY OF SCIENCE

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Australians have every right to expect a coherent and visionary plan to establish a secure, sustainable and prosperous nation. There are no short cuts, there is no room for complacency, and no scope for inertia.

In an increasingly uncertain and challenging world, we Australians will need to make every effort to build an economy and a workforce able to support the future we choose: a future that will be heavily constrained by national and global factors.

Science, technology, engineering and mathematics (STEM) underpins almost every aspect of societal advancement—from solving major global problems to spawning new businesses, keeping existing ones competitive and creating jobs. It will be a fundamental foundation on which our chosen future will be built.

For the purpose of our document "science" means the fundamental scientific disciplines including mathematics.

Science will determine the health of our people and the sustainability of our nation; it will influence how we think, and the judgements we make as a community that will influence the very nature of our country and its future as a prosperous, secure, just and valued member of the international community.

It will change the way we work. The demand for STEM skills in the Australian workforce is growing[1]—the Australian Bureau of Statistics estimates professional, scientific and technical jobs will grow by 12.5% over five years[2], and employment company SEEK reported a 22% jump in Australian job advertisements requiring STEM skills between 2017 and 2018[3].

THERE ARE NO SHORT CUTS, THERE IS NO ROOM FOR COMPLACENCY, AND NO SCOPE FOR INERTIA

Global initiatives also highlight the growing need for science. The efforts of many other nations, made after long and careful consideration, lead the way[4]. Their strategic positioning and their actions emphatically demonstrate that unless we build our science capacity, our choices will be limited and will depend largely on the predilections of others. We must identify then meet our own needs and priorities while we continue to contribute to global issues that require concerted multilateral action.

Australia therefore needs a solid and competitive science capacity. This must be science of such quality and intensity that it will allow us to solve, manage and mitigate Australia's unique challenges, while playing a role in addressing the global problems that are as much ours as any other nation's.

Our contribution to the global effort must be valued for its depth, breadth and quality. In return, Australia will have ready access to the best and most current insights from the world's science.

The Australian Academy of Science concludes that a high-quality science sector must embrace policies to develop the following key interdependent elements:

1 Australian Industry Group, 2018. Developing the Workforce for a Digital Future: Addressing critical issues and planning for action.
2 Labour Market Information Portal 2017. http://lmip.gov.au/default.aspx?LMIP/EmploymentProjections
3 SEEK Employment Trends. https://www.seek.com.au/career-advice/latest-trends-job-opportunities-are-up-147-and-stem-skills-are-in-demand
4 STEM Country Comparisons. Australian Council of Learned Academies, 2013. https://acola.org.au/wp/PDF/SAF02Consultants/SAF02_STEM_%20FINAL.pdf

1. A SHARED COMMITMENT

A declared relationship between scientists and government—based on trust, respect and mutual obligation—will benefit the Australian community.

1.1. **A charter with government** be developed in which the expectations and obligations of scientists to the Australian people are clearly established and the commitments and reciprocal responsibilities of scientists and government are declared.

1.2. **Provision of science advice to government and the parliament**—Australia will benefit from formal structures that produce independent, timely and relevant science advice to government, and to parliament.

2. NATIONAL CAPACITY BUILDING

Australia's capacity in science must have the breadth and depth that will allow our community to make rational decisions about our future when given choices, while making a valuable contribution to the search for effective solutions to great global challenges.

2.1. **STEM education**—Every Australian needs the basic knowledge to function effectively in a STEM-led world, and a significant cohort needs the high-level skills to ensure that our domestic enterprise remains globally relevant.

2.2. **Research**—Australia must articulate an ambitious but achievable expectation for the research sector, and support institutions and individual researchers to pursue it.

2.2.1. **The funding of research**—investment must be at a level to meet the ambition of sustaining globally competitive science research and innovation, and must have the capacity to attract, develop and retain highly-skilled researchers

2.2.2. **Research infrastructure**—Globally competitive science in Australia needs state-of-the-art infrastructure aligned to research directions and supported by long-term strategy.

2.3. **Global connectivity**—Australian researchers must be globally connected to draw from the best in the world, while actively participating in the search for solutions to global problems where we have capability.

2.4. **Diversity and access**—Australia's science must be supported to draw from all the talent available to the nation.

3. SCIENCE FOR COMMUNITY BENEFIT

The Australian community has a right to expect that it will benefit from its investment in science.

3.1. **Responsible research and innovation**—Australia's research system must nurture integrity and diversity along with a sense of national purpose, giving clarity to the sector and confidence to Australians.

3.2. **Strategic priorities**—Australia must ensure that our science capabilities meet our unique national needs, where no country could or would do for us what we need done, while maintaining a strong research base with the capacity to pursue transformational change over the long haul.

3.3. **Research with impact**—Australia must support the full spectrum of research. Fundamental research is vital because it *...creates an environment for the inspired risk taking that is essential for the technological discovery*[5] within which relevant breakthroughs can be used to produce marketable innovations in goods and services.

5 A moment of truth for America: An open letter to Congress from the executives of some of America's leading technology companies. May, 1995. https://homes.cs.washington.edu/~lazowska/cra/ceo.letter.html

1. A SHARED COMMITMENT

A declared relationship between scientists and government—based on trust, respect and mutual obligation—will benefit the Australian community.

1.1. A CHARTER WITH GOVERNMENT

A charter will be developed between scientists and the Australian Government that articulates the expectations and obligations of each to the Australian people.

The charter will make clear that there are reciprocal responsibilities and obligations: scientists to conduct their work ethically and in a manner consistent with a social licence that is reviewed and refreshed as circumstances change; and the Australian people through their government will ensure that Australian science is supported to play its full role in national development, culture and prosperity while securing Australia's position as a contributing and respected global citizen.

The charter will also outline the obligations on both scientists and government to ensure that independent scientific advice is provided, and that decisions are made and directions chosen that accord with the expectations and requirements of the Australian community.

A charter would therefore commit the science sector and government to:

- clear roles and responsibilities, including acknowledging:
  - the value of freedom to pursue further understanding of our physical and natural world and to follow leads judged by peers to be meaningful and important
  - the professional status and expertise of scientists
  - the conditions attached to the social licence accorded to science
  - the importance of mutual trust
  - the formulation of effective science policy advice requires consideration of the social and cultural contexts within which policies operate
  - the provision of appropriate support for science so that its obligations can be met
  - a commitment to diversity and inclusion.
- independence, including:
  - freedom from political interference
  - the right of researchers to publish and communicate their outcomes, subject to security or other limitations mutually agreed in advance.
- the validity of a government mandate, including:
  - the democratic rights of government to seek advice from multiple sources and to use that advice in accordance with any mandate granted by the Australian people
  - the right of government to identify national priorities and overall directions.
- transparency and openness, including:
  - scientific advice to government to be public, and the use (or not) of advice and its timing in consequential policy development, to be clear and public.

Recommendation 1: Development of a charter in which the expectations and obligations of scientists to the Australian people are clearly established and the commitments and reciprocal responsibilities of scientists and government are declared.

The Academy stands ready to assist the Australian Government in developing such a charter.

1.2. PROVISION OF SCIENCE ADVICE TO GOVERNMENT AND THE PARLIAMENT

Australia will benefit from formal structures that produce independent, timely and relevant science advice to government, and to parliament.

The expectation globally is that STEM will play an increasingly important role in the way communities shape their future. It is important that leaders have the best available advice as they develop policy to capture that future for their community.

Many countries have formal mechanisms to secure science advice that is independent of government. Some draw on their respective national academies of science and establish through them advisory councils or committees. Their primary role is to provide science advice to underpin public policy that is informed by evidence.

Australia does not have such a mechanism. Most formal advice is from within government developed through ministers' departments, or agencies. While the response is sometimes clear, the advice is often not public.

The Academy is willing to work with government to establish formal processes to provide science advice, in line with the agreed charter. The Academy would draw from both its Fellowship and from other scientists and other academies, when the expertise is relevant to the advice being developed.

This could be accomplished by linking to government through the Commonwealth Science Council or its successor bodies.

Recommendation 2: The Academy, drawing on expertise as required, will support:

a. the Commonwealth Science Council by providing independent and timely scientific advice on matters referred to it

b. all parliamentarians through the provision of independent, accessible and timely reviews of the scientific evidence base that underpins legislation before the Australian Parliament.

Investment: $16 million over 4 years.

2. NATIONAL CAPACITY BUILDING

Australia's capacity in science must have the breadth and depth that will allow our community to make rational decisions about our future when given choices, while making a valuable contribution to the search for effective solutions to great global challenges.

The world is facing an unpredictable future, although one certainty is widely acknowledged: science, technology and innovation will play an increasingly important role in resolving challenges and creating prosperity[6].

Within that context Australia has a choice: determine our future and develop a plan to achieve it, or be swept along trailing the decisions of others.

If we choose the first option, STEM in Australia must be comparable in range and depth to that in other advanced countries. The fact is that Australia's performance in the foundations of STEM—school education in science and mathematics—is slipping by comparison with countries such as the UK, the US and Japan[7]. There should be no disincentives or barriers to student interest in pursuing science. Not only is Australia's capacity weakened, there is the obvious risk of not providing relevant workforce skills.

6 See for example Australia 2030, Navigating our uncertain future. May, 2016. CSIRO Futures; Technology, Jobs and the Future of Work, February 2017. McKinsey & Company.

7 TIMSS 2015: Reporting Australia's Results. Australian Centre for Education Research, 2017.

2.1. STEM EDUCATION

Every Australian needs the basic knowledge to function effectively in a STEM-led world, and a significant cohort needs the high-level skills to ensure that our domestic enterprise remains globally relevant.

Steps have been taken to reverse the decades-long downward drift in enrolments and performance in STEM subjects in schools.

In December 2015, Australia's education ministers endorsed the National STEM School Education Strategy 2016–2026. The strategy aims to ensure that[8]:

1. all students finish school with strong foundational knowledge in STEM and related skills, and
2. students are inspired to take on more challenging STEM subjects.

The strategy must now be implemented comprehensively, at scale and in all regions of Australia—metropolitan, regional and remote.

The Academy can facilitate this implementation. It has national reach and a strong track record in developing and delivering proven programs to support science and mathematics teachers and students in schools[9]. The greatest strength of the Academy's education programs is the delivery of effective training to in-service and preservice teachers which is essential to improving student learning outcomes.

The Academy can deliver:

- a single consolidated STEM program that will target all schools in Australia, including regional and remote schools
- guided inquiry-based approaches across all years of schooling
- effective digital delivery of contemporary, content-rich resources.

Independent longitudinal evaluation will gauge changes in student performance as indicated by:

- NAPLAN and other testing
- real-time testing of individual students
- increased enrolments in science and mathematics subjects in senior secondary years
- increased enrolments in more challenging STEM subjects throughout secondary school.

An adequately supported program could achieve much needed national scale and reach.

Recommendation 3: The Australian Government supports the Academy's proven STEM education programs so as to reach substantially more schools, teachers and students in Australia with a focus on professional learning for teachers.

Investment: $21.8 million over 4 years.

2.2. RESEARCH

Australia must articulate an ambitious but achievable expectation for the research sector, and support institutions and individual researchers to pursue it.

Research is an important element in building the Australian and global foundation in science—we do not exist alone and science is naturally a collaborative venture. We learn more about the natural and physical world, and about our civilisation.

More locally:

- there are matters that are unique to Australia. We cannot expect researchers in other countries to look after our interests because we are not prepared or strategic enough to look after ourselves.
- not everything discovered or 'invented' elsewhere can be bought 'off-the-shelf' and plugged in; researchers need the capacity to use their expertise to critique, amend, adjust, renew and manage the introduction of new ways of thinking, or new technologies, into Australia.
- Australians with well-developed talent in science should have every opportunity to use their knowledge and skills in Australia to the benefit of Australians, particularly because the skills are developed initially with support from the Australian community.
- Australian researchers are embedded within a community that must make decisions about its future direction and choose between options that will depend heavily on science, technology and innovation. They can facilitate constructive discussion by providing expert advice and commentary in an Australian context.
- there are certain fields of knowledge and expertise where a sovereign science capability is of strategic national importance.

8 http://www.educationcouncil.edu.au/site/DefaultSite/filesystem/documents/National%20STEM%20School%20Education%20Strategy.pdf
9 Hackling, M. W. & Prain, V. (2008). Stage 3 Interim research and evaluation report on the impact of Primary Connections on students' science processes, literacies of science and attitudes towards science.

2.2.1. THE FUNDING OF RESEARCH

> *The full direct and indirect costs of research and its workforce must be funded: by Government to meet the obligation to support research in the public interest; and by business to facilitate innovation.*

Direct Australian Government investment in research (i.e. grants and program allocations, excluding tax concessions) has declined as a percentage of gross domestic product (GDP) by more than half, from 0.41% in 1992–93 to 0.19% in 2015–16; at the same time business spending on research and development increased from 0.64% of GDP to a peak of 1.37% in 2008–09. By 2015–16 that had fallen to 1.01%[10].

This long-term decline in public funding for research in Australia—barely keeping pace with inflation over the 25 years to 2015–16—stands in contrast to either sustained increases in countries such as Germany, Austria and New Zealand, or stable funding in Denmark and the Netherlands[11]. It also reflects a shift away from support for 'public good' research—research in the pursuit of knowledge or research that *creates an environment for the inspired risk-taking that is essential to technological discovery*[12].

THE FUNDING OF RESEARCH IN AUSTRALIA NEEDS A NEW APPROACH

There has been a transfer in emphasis towards using intellectual capital and away from generating it. The long-term public interest is not well served by this approach.

Not only is there a downwards drift in the funds available, *…successive governments practice of funding long-term [research] investments on short-term funding cycles*[13] compounds the issues facing both researchers and industry investors.

Because support is both decreasing as a proportion of GDP and is dominated by short funding cycles, research careers in science have become less attractive at the very time Australia needs more and different skills and perspectives. The implications for the pipeline are obvious: early- and mid-career researchers leave universities and publicly funded research institutes for more secure careers, even then only 27% of Australia's 151,000 employed PhD graduates remain in professional research roles over time[14].

Research in Australia is not fully funded. Indirect costs of maintaining and sustaining research programs are not covered by the majority of research grants, with a result that research organisations must meet these costs from other revenue streams[15]. This stands in contrast to other countries and leaves Australia as one country where there is effectively a financial penalty whenever research activity commences. The lack of full cost funding of research also hinders the development of research capacity in regional campuses. This is particularly true within the university sector, where the bulk of Australia's publicly funded research is undertaken[16].

In the absence of a comprehensive national strategy for science, the profile of research is heavily influenced by trimming and cutting (and undergraduate enrolments) rather than a strategic intent.

The Academy acknowledges that there are no simple solutions. But without some understanding of the impact of compounding problems, the hard questions can't even be framed.

For Australian research to be able to effectively address our own challenges as well as being a valued contributor to global solutions, the level of investment must at least be on parity with other developed countries.

The funding of research in Australia needs a new approach.

The Academy stands ready to work with the Australian Government to identify the means by which a set investment target could be achieved, the time frame for its achievement, and the ways it could be used to provide incentives to researchers and business to cooperate more effectively than at any time in our history.

RESEARCH WORKFORCE

Australia's research enterprise must have the capacity to attract, develop and retain highly-skilled researchers.

Short-term funding, declining resources and a system that makes it more difficult to attract and retain new entrants combine to make careers in

10 Australian Bureau of Statistics, "Research and Experimental Development, Businesses, Australia, 2015-16", released 15 September 2017; "Research and Experimental Development, Government and Private Non-Profit Organisations, Australia, 2014/15", released 6 July 2016.
11 OECD R&D Statistics, 2018. Government Allocations for R&D (GBARD). http://www.oecd.org/science/inno/researchanddevelopmentstatisticsrds.htm
12 A moment of truth for America: An open letter to Congress from the executives of some of America's leading technology companies. May, 1995. https://homes.cs.washington.edu/~lazowska/cra/ceo.letter.html
13 Research Infrastructure Review, 2015. p.viii.
14 ABS Census Data. Occupation and highest educational attainment, 2016.
15 Recognising the full cost of university research. Allen Consulting Group report to the Department of Innovation, Industry, Science and Research, 2008.
16 Science, Research and Innovation (SRI) Budget Tables, 2018. https://www.industry.gov.au/data-and-publications/science-research-and-innovation-sri-budget-tables

research less attractive. This is manifest by the number of temporary and short-term contract positions in universities at postdoctoral level[17].

Stable and increased funding for research is required for Australia to draw maximum benefit from its investment in the first stage of a research career—in universities, research agencies or business. It is noteworthy that Australia has only 43% of researchers employed in business; a lower percentage than countries such as Germany (53%), South Korea (79%) and Israel (84%)[18]

Australia cannot afford to let careers for researchers drift.

Recommendation 4: A strategy should be developed that aims to:

a. double the present success rate of research proposals by Australia's research councils from the present 20%

b. cover the full direct and indirect costs of research

c. provide longer-duration research grants, with a focus on providing five-year grants and fellowships to early- and mid-career researchers enabling more ambitious research to be undertaken

d. enable diverse career paths and opportunities for STEM graduates.

Investment: The Academy strongly argues that Australia should increase expenditure on research and development from all sources to 3% of GDP over a decade.

2.2.2. RESEARCH INFRASTRUCTURE

> *Globally competitive science needs state-of-the-art infrastructure aligned to national needs and supported by long-term plans.*

If Australia is to play its role as a leading science nation, then the support for scientists to do their best work has to be the equivalent to that provided to scientists in other developed countries: quality science is impossible without quality infrastructure. It allows:

- Australia's scientists to undertake world-class research
- significant science industry linkage, including the capacity for innovative Australian companies to access high-tech infrastructure
- international research collaboration, which provides substantial economic and intellectual value to Australia.

Support facilities require an appropriate, long-term investment. It is imperative this investment remains stable and predictable, so the infrastructure can be maintained and operated over its lifetime. The physical facilities and the expertise and staffing must be maintained to ensure continued effective operation.

Advice to government in 2014 highlighted the critical need for infrastructure. The National Commission of Audit recommended that *Australia take a more strategic, whole-of-government approach to the funding of research and development, including by committing to ongoing funding for critical research infrastructure in Australia informed by a reassessment of existing research infrastructure provision and requirements*[19].

A subsequent independent review of research infrastructure requirements (the 2015 Clark review) prepared for the Minister for Education identified high-priority investments over 10 years totalling approximately $6.6 billion; this is equivalent to the long-term rate of 8% of direct government research funding on infrastructure[20]. The review panel recommended that this funding be sourced through a combination of an Australian National Research Infrastructure Fund (with initial capitalisation of $3.7 billion), investment earnings from the fund of $1.5 billion, and industry or other sector co-investments of $1.4 billion.

17 Hardy, M. C., Carter, A. & Bowden, N. 2016. What do postdocs need to succeed? A survey of current standing and future directions for Australian researchers. Pallgrave Communications, 2, 16093.
18 National Innovation and Science Agenda Report, 2015. https://www.industry.gov.au/data-and-publications/national-innovation-and-science-agenda-report
19 National Commission of Audit, 2014. p. 172. https://docs.education.gov.au/system/files/doc/other/research_infrastructure_review.pdf
20 The Clark Review: Research Infrastructure Review: Final Report, September 2015.

While some of this investment has been realised through commitments in the National Innovation and Science Agenda ($2.3 billion over 10 years in 2015[21]) and through the National Research Infrastructure Investment Strategy in 2018 ($1.9 billion over 12 years from 2017[22]), there is still a shortfall in funding research infrastructure compared with the aspiration developed by the Clark review.

Recommendation 5: Acknowledging the Australian Government's existing research infrastructure commitments, a further investment of $1.85 billion is required, through a long-term mechanism such as an Australian National Research Infrastructure Investment Fund, to meet the Clark Review recommendations.

2.3. GLOBAL CONNECTIVITY

> *Australian researchers must be globally connected to draw from the best in the world, while actively participating in the search for solutions to global problems where we have capability.*

Science is a global enterprise and many of the existential challenges, such as the health and sustainability of the planet, are too complex for any one country to undertake alone.

There are very few nations that do not contribute in some way to the global effort in science. Australia's contribution is reasonable given our population size: some 3% of global research output. In terms of highly cited work, Australia fares well: in the top 1% of highly-cited publications per million population, Australia is ranked 8th of the 36 OECD+ countries.[23]

A key to further advancement of Australian science is to build global connectivity that links to the other 97% of global research output. This requires strategic and sustained investment. It provides Australia with the opportunity to contribute to the search for solutions to the large and complex problems that require multilateral effort. But the investment is not only to secure external influence. The return is substantial: a valued contributor with early insights into new developments can benefit the Australian community.

SCIENCE IS A GLOBAL ENTERPRISE AND MANY OF THE EXISTENTIAL CHALLENGES, SUCH AS THE HEALTH AND SUSTAINABILITY OF THE PLANET, ARE TOO COMPLEX FOR ANY ONE COUNTRY TO UNDERTAKE ALONE

Diplomacy through science also has very real benefits. Australia's national interest is well served when scientific collaborations open doors and broker dialogue with other nations, especially where geopolitical issues might slow positive cooperation. Science is an under-used element in diplomacy and in Australia it is not yet recognised as a key soft power asset. In countries around the world science diplomacy is fast becoming a strategic part of the national tool kit. This includes engaging in strategic international collaborations; drawing on discipline-specific expertise and international networks held by national academies of science; facilitating communication between government departments involved in science and technology and those traditionally involved in diplomacy, trade, development assistance and national security; and engaging government officers posted abroad who are well positioned to advance Australia's national interests internationally.

Recommendation 6: The Academy will participate in the development of an international engagement strategy for science, technology and innovation[24] with long-term resourcing to:

- **a.** maintain participation in key international decision-making science bodies
- **b.** support bids to attract international scientific conferences to Australia, an investment with a proven multiplier effect for the economy
- **c.** contribute to bilateral and multilateral partnerships and research programs where they align with research priorities, or serve our diplomatic objectives
- **d.** allow Australia to meet its agreed Sustainable Development Goal obligations
- **e.** develop a program for early- and mid-career researchers to establish partnerships with international leaders in their field, building networks that will be beneficial to Australia
- **f.** expand the network of science counsellors and attachés in Australian embassies in priority countries and regions around the world
- **g.** target programs to provide scientific support to assist Australian foreign affairs and trade policy objectives.

Investment: $150 million over 10 years.

21 National Innovation and Science Agenda Report, 2015. https://www.industry.gov.au/data-and-publications/national-innovation-and-science-agenda-report
22 https://docs.education.gov.au/node/50601
23 OECD (2016) Main Science and Technology Indicators, 2016-1. Accessed at https://stats.oecd.org/Index.aspx?DataSetCode=MSTI_PUB
Thomson Reuters (2016) InCites. Accessed at https://incites.thomsonreuters.com/
24 https://www.science.org.au/files/userfiles/support/reports-and-plans/2015/innovation-requires-global-engagement.pdf

2.4. DIVERSITY AND ACCESS

> *Australia's science must be supported to draw from all the talent available to the nation.*

Australia is characterised as a culturally diverse community, however, the demographic profile of STEM in Australia does not reflect diversity: there are fewer females than males in the key science subjects of physics and chemistry, and advanced mathematics in senior school[25], for example, and regional and remote students too often do not have access to the well-supported teachers and facilities that are enjoyed in metropolitan areas[26]. Even in metropolitan areas there are differences in participation between suburbs[27]. The effect is a STEM demographic profile that is the consequence of barriers to access rather than of interest or capacity.

It is inexcusable for Australia to continue to exclude large sections of the community from full participation in STEM because of who they are or where they are.

The barriers to participation are well known and improvements are being made slowly. If Australia is to draw from all the talent available, however, barriers to participation, such as those related to diversity of background, gender, indigeneity, or geography, must be eliminated.

The Academy, in partnership with the Australian Academy of Technology and Engineering, have delivered the 3-year Science in Australia Gender Equity (SAGE) pilot across the 45 universities, medical research institutes and government research agencies that coinvested in this initiative. The evaluation of SAGE demonstrates the effectiveness of this targeted program in bringing about cultural change[28].

A separate targeted program should be developed in consultation with Aboriginal and Torres Strait Islander STEM professionals, to remove barriers to participation by Indigenous Australians and to facilitate cultural change at an institutional level.

Recommendation 7: Allow Australia to draw from all the talent available by:

a. supporting the national roll out of SAGE and placing it on a self-sustaining footing within a 10-year period in partnership with the higher education and research sector

b. facilitating action for all stakeholders through the Women in STEM Decadal Plan[29]

c. facilitating an Indigenous STEM Network to assist participation of Aboriginal and Torres Strait Islander students and STEM professionals

d. focusing on regional and remote Australia; professional development and support for STEM teachers; and curriculum resources

e. ensuring that investment in facilities are appropriate—and are used appropriately—for the teaching of science and mathematics so that it's engaging, enlightening and contemporary.

Investment:

- Investment by the Australian Government of approximately $18 million over 10 years to allow the SAGE pilot to be rolled out nationally and be self sustaining by 2030.
- Investment of $1 million per year to develop a culturally appropriate and targeted program to support Aboriginal and Torres Strait Islander people in STEM.

AUSTRALIA NEEDS ACCESS TO ALL ITS AVAILABLE TALENT REGARDLESS OF WHO OR WHERE THEY ARE

25 Justman, M. & Mendez, S., 2016. Gendered selection of STEM subjects for matriculation. Melbourne Institute Working Paper No. 10/16.
26 Challenges in STEM learning in Australian schools: Literature and policy review. 2018. Australian Council for Educational Research. https://research.acer.edu.au/policy_analysis_misc/28/
27 What price the gap? Education and inequality in Australia, 2018. Public Education Foundation.
28 https://www.sciencegenderequity.org.au – expected publication date December 2018
29 Women in STEM Decadal Plan. https://www.science.org.au/support/analysis/decadal-plans-science/decadal-plan-women-stem

3. SCIENCE FOR COMMUNITY BENEFIT

The community has a right to expect that it will draw value from its investment in science.

EDUCATION AND SCIENCE LITERACY

In a world led by STEM, citizens will be asked to make choices that could have a profound impact on their lives. The choices will require us to respond to new ways of doing things: work, lifestyle, technologies and knowledge.

Many of the options available will be based on evidence derived from the efforts of scientists. A basic understanding of how science and its method works, and an understanding of statistics and how they can be used and misused, will make individuals and communities more likely to engage with a process that leads to better outcomes.

Science poses and attempts to answer hard questions, and responses require judgement. An obligation of scientists is to explain what they are trying to achieve and gather facts and explain their significance. An obligation of the community is to be open with facts and make judgements on the basis of evidence without prejudice.

Education is the key. A receptive community with a reasonable threshold understanding of science and mathematics will be more likely to choose better options when given the opportunity.

Education is an investment that yields lifelong benefit. In a STEM-led world, education in STEM allows Australians to make better informed decisions when the time comes to choose the future they want. It *inspires active citizens who are able to participate in shaping the future and provides them with the tools to do so*[30].

RESEARCH

Governments invest in research and innovation because they benefit the community.

Science is an integral part of the fabric of a civilised and confident nation. It is knowledge. Former British prime minister Tony Blair said of science: *It allows us to do more, but it doesn't tell us whether doing more is right or wrong*[31].

While Australia can and must benefit from scientific advances, sometimes the pace is so rapid and the steps so large that the community expresses legitimate unease at the pace of change and its magnitude; sometimes the concerns are about ethical or moral questions—doing something because we can does not mean we should.

The scientific community must therefore work to build trust and confidence that scientific evidence is based on a genuine and objective pursuit of knowledge.

IN A WORLD LED BY STEM, CITIZENS WILL BE ASKED TO MAKE CHOICES THAT COULD HAVE A PROFOUND IMPACT ON THEIR LIVES

30 Royal Society and British Academy joint report: Harnessing educational research, October 2018.
31 https://www.theguardian.com/politics/2002/may/23/speeches.tonyblair

3.1. RESPONSIBLE RESEARCH AND INNOVATION

Australia's research ecosystem must nurture integrity and diversity along with a sense of national purpose, giving clarity to the sector and confidence to Australians.

Research is in many senses a self-regulating system—as it should be. Experts discuss, debate and even dispute outcomes and conclusions, and as a result knowledge is advanced, and the best ways to proceed are identified.

Good research has a purpose, however: greater understanding that yields knowledge that leads to an enriched future—economically, socially and culturally.

To be most effective, researchers and the outcomes of their research must be trusted. This mandates high ethical standards and conduct that is alert to the socially acceptable framework within which research is conducted—the social licence.

Scientists must be aware, therefore, of community expectations and limits, and be willing to engage with the community openly to reset or refresh the social licence as appropriate.

Complex, even daunting, problems are likely to cause contention, even when the overwhelming majority of scientific evidence points to one conclusion. Sometimes the contention is trivial and designed primarily to erode trust or provide commercial advantage. Sometimes there is real cause.

The effect, however, is that the basic trust in science and evidence can evaporate without constant attention. In this context it is no longer sufficient to rely almost exclusively on the participants to resolve differences.

Australian research would be well served by a framework based on responsible research and innovation. In addition to the ethical pursuit and use of science and technology, the framework could include adoption of best-practice approaches to transparency and evaluation through open science and open data[32].

Recommendation 8: The Australian Government develops, in consultation with this Academy and other learned academies, a best practice framework for responsible research and innovation to guide Australian research and innovation, including:

a. guidance on ethical pursuit and use of science and technology

b. approaches to transparency and evaluation through open science and open data

c. facilitation of a constant and direct dialogue between researchers and the community.

3.2. STRATEGIC PRIORITIES

Australia must ensure that our science capabilities meet our unique national needs, where no other country could or would sustain us, while maintaining a strong research base with the capacity to pursue transformational change over the long haul.

The Academy's national committees for science have identified cross-disciplinary priorities and opportunities for Australian research[33] that build on our advantages and strengths.

Some examples derived from the work of the Academy include:

- improving understanding of Australia's climate systems (atmosphere, land and ocean) both as the natural stewards of Southern Hemisphere climate information and to better inform Australia's own climate mitigation and adaption efforts
- developing new and improved knowledge, products and services to support dryland agriculture
- continuing to explore the southern skies through optical, radio and potentially gravitational astronomy
- continuing to lead scientific efforts in the Antarctic
- increasing the rate of discovery of Australia's biodiversity, of which approximately 80% of species remain unknown or unnamed
- developing and applying energy technologies with particular relevance to Australia
- increasing understanding of Australia's fisheries and marine environments, particularly with respect to the Great Barrier Reef

32 Wilkinson, M. et al., 2016. The FAIR Guiding Principles for scientific data management and stewardship. Scientific Data, 3, 160018.
33 See: https://www.science.org.au/supporting-science/science-policy-and-analysis/decadal-plans-science

- enhancing geological knowledge and geoscience data to develop improved understanding of the hidden vertical makeup of our continent and the resources it contains
- exploring neurotechnologies, including applications well beyond the treatment of disease.

Such priorities and opportunities must be considered in the context of a national science strategy that includes resourcing and infrastructure.

Recommendation 9: The Academy encourages the Australian Government to embed strategic national research priorities in a comprehensive science strategy including resource commitments.

3.3. RESEARCH WITH IMPACT

> *Australia must support the full spectrum of research from the search for fundamental understanding of our world through to marketed innovations in goods and services.*

Australians must benefit from the application of new knowledge and new ways of thinking. There is a spectrum of research that leads from discovery to application and use, and all of it is essential to future prosperity and sustainability.

It is clear that not all the great advances in, for example, medical science were the predetermined outcome of research commenced decades ago. The same is true for technology development—the smartphones of today, for example, are a mix of university-based and industry-based research and patents put together by innovative engineers and entrepreneurs[34].

The question of how and who pays is a constant in Australia and elsewhere. It was neatly captured as far back as 1995 by 16 leaders of American industry writing to the US Congress:

This partnership—the research and educational assets of American universities, the financial support of the federal government, and the real-world product development of industry—has been a critical factor in maintaining the nation's technological leadership through much of the 20th century…'

…University research makes a tempting target (for cuts) because many people aren't aware of the critical role it plays. It can take years of intense research before technologies emerge that can 'make it' in the marketplace. History has shown that it is federally sponsored research that provides the truly 'patient' capital needed to carry out basic research and create an environment for the inspired risk-taking that is essential to technological discovery. Often these advances have no immediate practical usability but open 'technology windows' that can be pursued until viable applications emerge…[35]

This enlightened view is relevant in Australia today.

The full spectrum from the search for fundamental understanding of our world through to marketed innovations in goods and services must not be impeded. And incentives should be properly targeted.

Various Australian programs, such as CRCs, Linkage projects of the ARC, and R&D tax concessions, are aimed at encouraging suitable interactions. Are the incentives well enough targeted, are the objectives appropriate, particularly when they cross portfolios, and are some of the programs too short term?

The Academy is willing and able to participate in comprehensive reviews of these issues.

Recommendation 10: The Australian Government comprehensively reviews the structure, and evaluates the effectiveness of, research support and incentives to ensure maximum benefit can be returned.

34 e.g., iPhone: How did we get there? https://quartsoft.com/sites/default/files/iphone-tech-history-infographic.jpg
35 A moment of truth for America: An open letter to Congress from the executives of some of America's leading technology companies. May, 1995. https://homes.cs.washington.edu/~lazowska/cra/ceo.letter.html