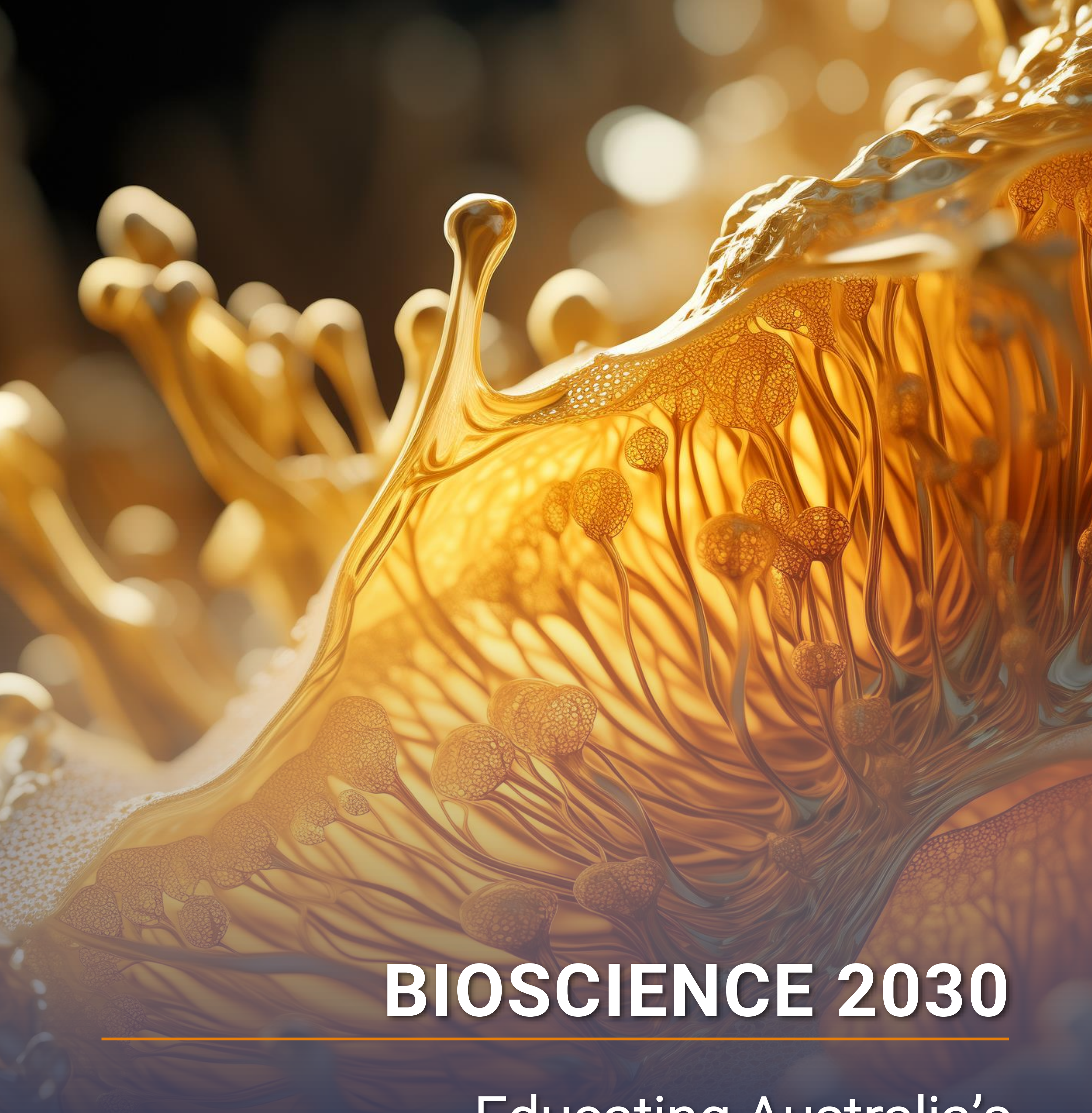


NATIONAL COMMITTEE FOR
BIOMEDICAL SCIENCES

Australian Academy of Science

BIOSCIENCE 2030

Educating Australia's future bioscientists

December 2023

ACKNOWLEDGMENT OF COUNTRY

The Australian Academy of Science (the Academy) acknowledges and pays respects to the Ngunnawal people, the Traditional Owners of the lands on which the Academy office is located. The Academy also acknowledges and pays respects to the Traditional Owners and the Elders past and present and acknowledges emerging leaders of all the lands on which the Academy operates, and its Fellows live and work.

We recognise the continuous living culture of Aboriginal and Torres Strait Islander peoples and their diverse languages, customs and traditions, knowledges and systems. Aboriginal and Torres Strait Islander people have been learning and teaching on this land for millennia. We also acknowledge and pay respect to the Aboriginal and Torres Strait Islander bioscience students and educators learning and teaching across this country today and their rich contributions to bioscience education.

A NOTE ON THE COVER ART

The cover image 'Golden Hour — 2023' was created by internationally recognised new media artist and creative technologist Jessie Hughes using generative AI through an iterative process of natural language prompting. The final image, generated through a process of varying and refining designs, shows optimism and appreciation for the beauty of biological forms, despite being generated through an artificial process.

Jessie Hughes has been named one of Australia's Future Changers for her commitment to using digital innovation for positive social impact and was awarded Australia's prestigious 2020 Sir John Monash Scholarship. She has designed creative solutions for tech giants such as Oculus, Facebook, and Adobe, and for cultural leaders such as the Queensland Gallery of Modern Art as their Digital Resident for 2022. Jessie is an American Australian Association Arts Scholar, Winston Churchill Fellow, Lord Mayor's Creative Fellow and a United Nations Sustainable Development Goals Ambassador. Professionally, Jessie works as a creative technologist, toying at the intersection of design, technology, art, research and strategy for social innovation. She actively shares her learnings with the wider community and lectures in design at universities across Australia and globally.

ISBN 978-0-85847-878-7

How to cite this report: National Committee for Biomedical Sciences (2023). Bioscience 2030: educating Australia's future bioscientists (Australian Academy of Science).

Cover: 'Golden Hour – 2023' by Jessie Hughes

DEDICATION

During the compilation of this report, we lost a dear colleague, Elizabeth (Liz) Davis. Liz was one of the initial champions of this project and was exceptionally passionate not only about education but also about driving innovation and challenging why and how we teach. She had an enthusiasm for untangling tricky, wicked problems and inspired colleagues and students to join her along the way. We were so very fortunate to have had Liz's input into this project, and hope that like Liz, the report inspires and promotes progression and innovation.

ACKNOWLEDGMENTS

WORKING GROUP

This report was prepared by a working group of the Australian Academy of Science's National Committee for Biomedical Sciences.

Chair: Professor Philip Poronnik

Lead authors: Associate Professor Michelle Rank and Professor Pauline Ross

Members:

Dr Melissa Cameron	Professor Susan Howitt
Christen Chisholm	Dr Thomas Newsome
Professor David Cook FAA	Dr Jason Ng
Dr Nathan Croft	Dr Yossi Rathner
Associate Professor Elizabeth Davis	Dr Emily Remnant
Dr Julia Ellyard	Associate Professor Darren Saunders
Dr Jessica Gibbons	Professor David Williams

The working group also gratefully acknowledges Januar Harianto's assistance with data analysis.

AUSTRALIAN ACADEMY OF SCIENCE SECRETARIAT

Current and former contributing staff members Jirana Boontanjai, Meaghan Dzundza, Alexandra Lucchetti and Dr Hayley Teasdale are gratefully acknowledged.

BEAN
Biosciences Education Australia Network

BIOSCIENCES EDUCATION AUSTRALIA NETWORK

The National Committee for Biomedical Sciences supports the work of the Bioscience Education Australia Network (BEAN). BEAN is a platform for academic professionals involved in bioscience education to gain recognition, credibility and the opportunity to engage in policy discussions and relevant forums.

TABLE OF CONTENTS

EXECUTIVE SUMMARY

In this report, we surveyed the bioscience community to inspire and inform next-generation bioscience higher education to ensure graduates are prepared to tackle future problems, from 2030 and onward.

We found that many institutions are already equipping bioscience graduates with essential skills, but that there is room to improve when it comes to critical thinking, data analysis, and dealing with uncertainty. These skills are also critical to enabling graduates to meet new and emerging challenges and opportunities such as artificial intelligence (AI).

Many of the essential skills for bioscience graduates are highly transferable and shared by higher education graduates from other disciplines.

Universities have a particular role to play in preparing the nation for its future: educating people to think critically, to question, and to critique with the confidence to challenge and to lead change as more is learnt.

The survey also underscored the practical nature of science. In-person practical education experiences are fundamental to bioscience education.

We found that bioscience education of the future should comprise a hybrid model, based on lessons learnt during the ongoing COVID-19 pandemic. Higher education should combine practical, face-to-face learning on-campus with online delivery of content to achieve the best bioscience education possible.

The survey also highlighted key challenges faced by the bioscience community. These include a lack of awareness and appreciation of bioscience among the public (exacerbated by social-media-fuelled misinformation), funding and job market concerns, and difficulties engaging with decision-makers.

Analysing these challenges reveals the importance of qualities of our future diverse bioscientists, such as interdisciplinary capabilities and effective communication with different audiences.

Our vision is to strengthen our bioscience higher education programs and maintain Australia's excellence in bioscience through student-centred, real-world-focused education. This report by and for higher education bioscience educators provides a roadmap of the skills and experiences bioscience graduates need to achieve this future.

TRANSFERABLE SKILLS

Bioscience graduates should be equipped with the following transferable skills:

- critical thinking
- problem solving
- interdisciplinary teamwork
- communication
- advocacy
- ability to cope with uncertainty
- ability to engage with and understand the value of Indigenous Knowledges and perspectives.

PRACTICAL RECOMMENDATIONS

Higher education bioscience teaching should:

1. Use knowledge and experience gained from the COVID-19 pandemic to reposition practical and hands-on learning experiences and student engagement as an essential cornerstone of modern bioscience higher education programs.
2. Use technology to strategically deliver content which does not displace practical instruction but extends it.
3. Increase connectivity between industry and education institutions, to improve employability outcomes for future bioscience graduates and to better enable innovation.
4. Integrate more active learning pedagogies, including real-world learning and authentic assessment and feedback.
5. Reposition student participation and engagement as central to all aspects of university education, lifelong learning and academic culture.
6. Build and strengthen the connections between humanities and social sciences, design, engineering, and medicine and health through new interdisciplinary initiatives.

INTRODUCTION

Science seeks to build knowledge through observation and experimentation in order to understand and make predictions about the world around us. In particular, the biosciences (short for biological sciences) strive to understand the living world. Bioscience fields of study include biomedicine, biotechnology, biochemistry, genetics, ecology, evolutionary biology, plant sciences, microbiology, molecular biology, and marine, freshwater and animal biology.

Knowledge generated through science can subsequently be applied in many different social and civic spheres for the betterment of humanity and the planet. For example, knowledge from the biosciences can help us cure or prevent illness and disease, as well as sustain and secure biodiversity on Earth.

Scientific knowledge can also be applied to wicked problems: social or cultural issues or challenges that are inherently ambiguous, multilayered and evolve in unpredictable ways. Prime examples of such problems include climate change, terrorism and pandemics. These problems require complex solutions, often incorporating global interdisciplinary cooperation and expertise. The path to overcome a wicked problem is characterised by uncertainty and often profound multi-faceted change.

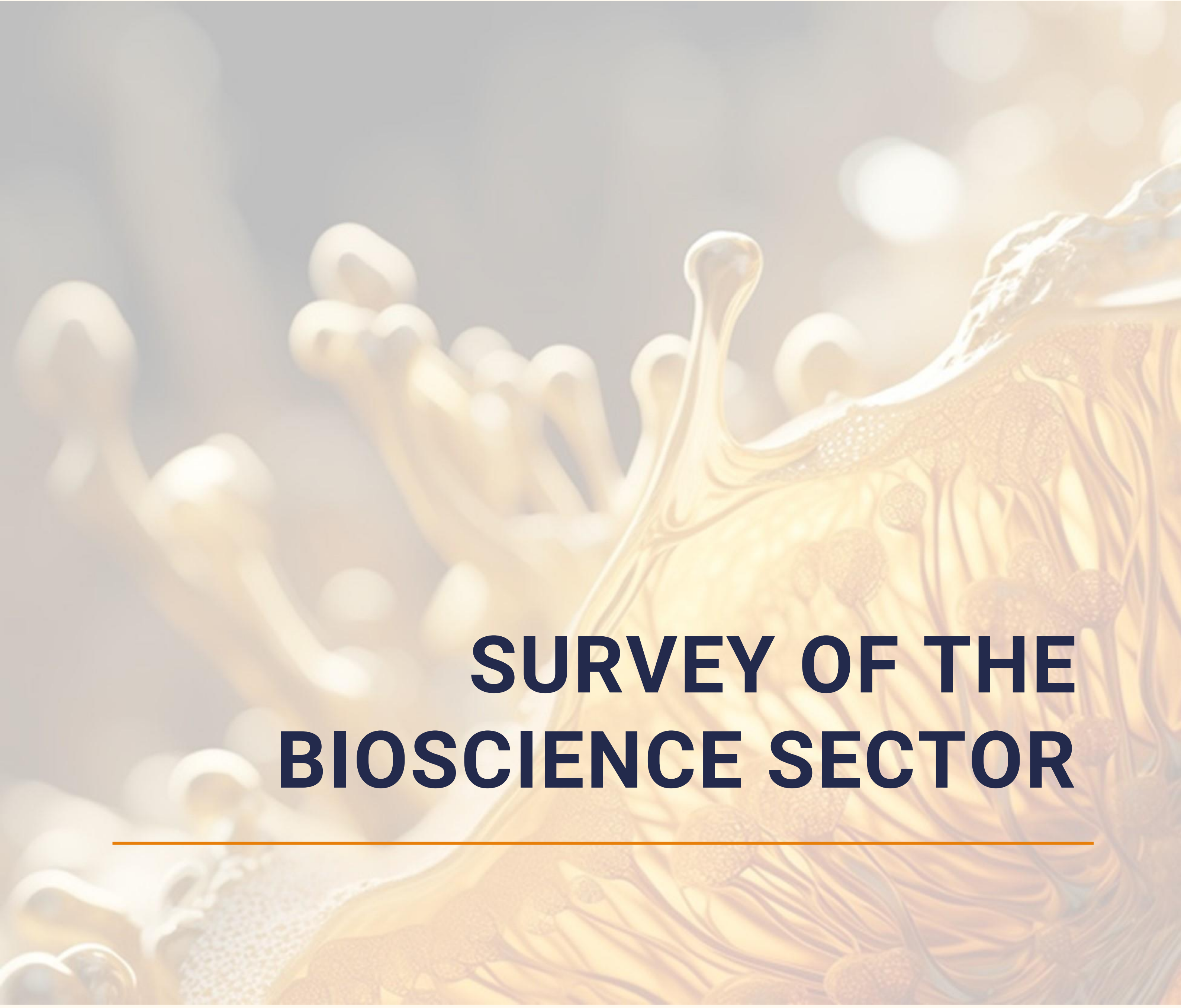
Society faces an ever-increasing number of complex challenges across agriculture, biodiversity, climate change, energy, health, sustainability, education, and the economy. These challenges are compounded by mis- and disinformation, low levels of scientific literacy, and both public and political distrust of science. Science—including bioscience—is critical in solving current and emerging global challenges.

The importance of bioscience in addressing global challenges is highlighted by the ongoing COVID-19 pandemic, in which bioscientists have played an integral role as trusted expert communicators. Skills such as leadership and social influence, critical thinking and analysis, complex problem-solving, and uncertainty tolerance came to the fore.

The rapid shift to virtual teaching and learning in response to COVID-19 has also revealed lessons about the teaching methods and learning environments that will best facilitate bioscience education.

In the wake of the pandemic, it is timely to reflect on how we are preparing Australia's future bioscientists to tackle the challenges we face both as a nation and globally. What skills will future bioscience graduates need in an increasingly complex and uncertain world? How can we design bioscience education programs that equip students with the knowledge and skills that will be essential? What gaps can we bridge to create a next-generation bioscientist education framework? This report explores these questions, and has been informed by a survey of, and consultation with, the bioscience sector.

This report was prepared by and for higher education bioscience educators. It aims to identify opportunities and challenges for bioscience teaching in the coming decade and provide a positive, introspective, and aspirational view towards the future.



SURVEY OF THE BIOSCIENCE SECTOR

In this report, we surveyed bioscientists, students, bioscience educators, community members, and bioscience industry representatives from March to June 2021 about the current state of bioscience education in Australia, and the future direction of bioscience education up to 2030.

Participants were recruited through bioscience societies, universities, and groups in the Australasian region. The fields represented by participants include agriculture, pathology, environmental consulting, bioinformatics, veterinary medicine, government, biopharmaceuticals, and biotechnology. The breakdown of participants in each category is as follows: 134 students, 123 educators, 12 industry professionals, 5 from the broader community, and 16 participants who did not specify their role(s).

The survey included both qualitative and quantitative questions. For example, respondents were asked to rank various aspects of current and future bioscience education on a Likert scale from strongly agree to strongly disagree. The specific and open-ended questions in the survey can be found in Appendix 1.

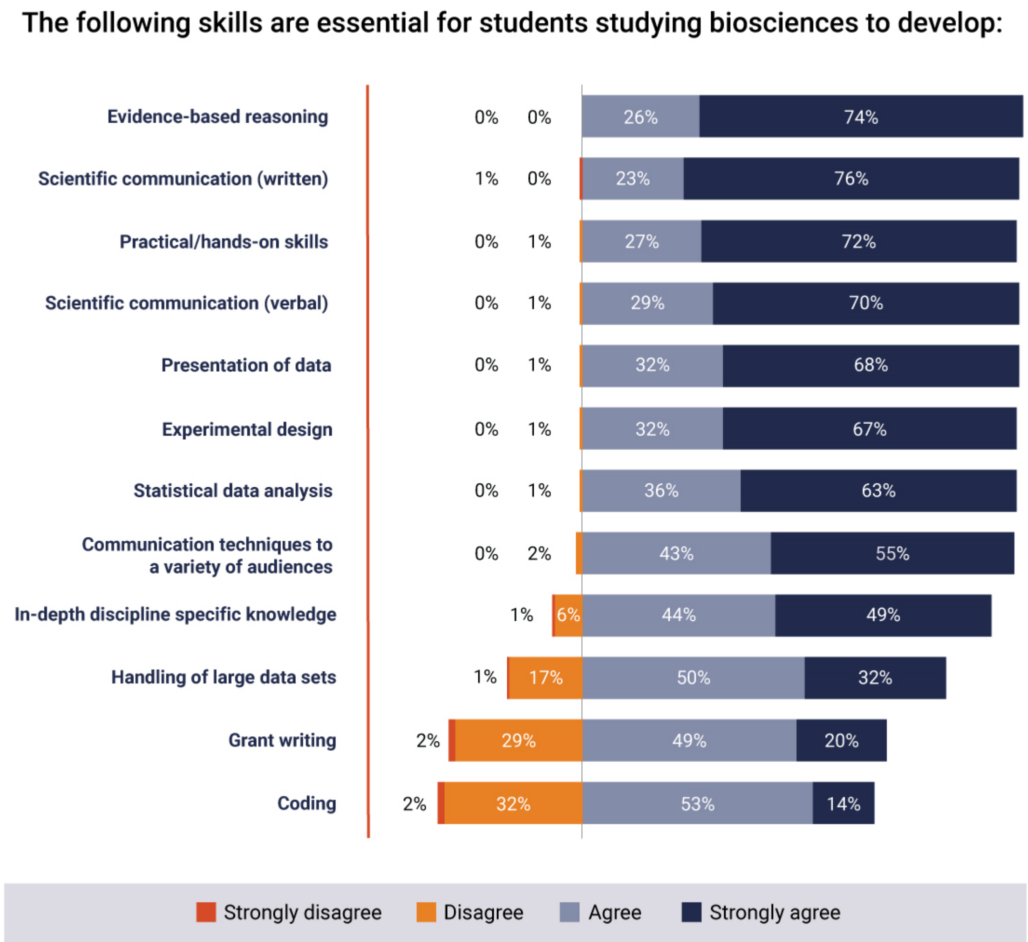
The survey period coincided with COVID-19 lockdowns. It was also conducted prior to the release of ChatGPT and subsequent focus on the potential impacts of generative AI on higher education.

THE CURRENT STATE OF BIOSCIENCE EDUCATION

The essential skills for bioscience students include evidence-based reasoning; written and verbal communication; presentation and statistical analysis of data; discipline-specific practical skills; and overall scientific literacy (Figure 1).

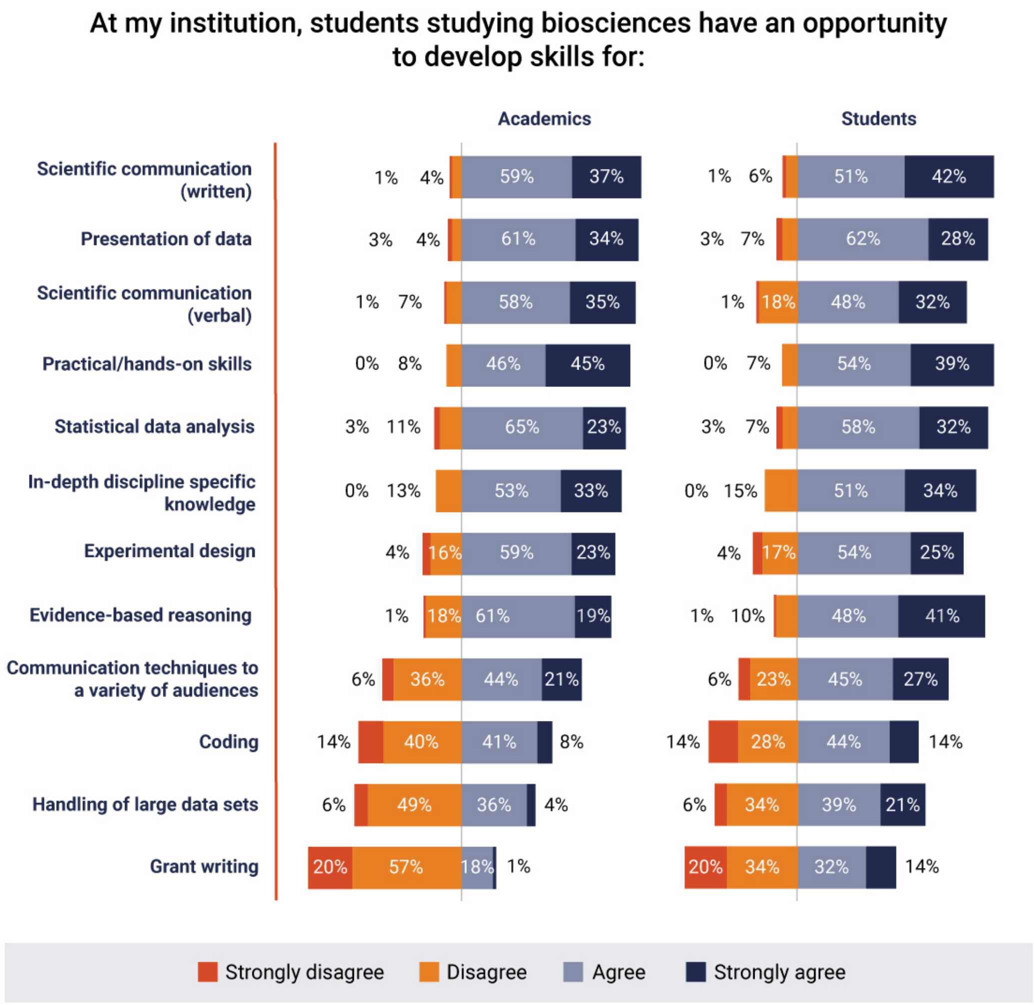
These skills are largely in agreement with those sought by employers hiring bioscience graduates. Communication, hands-on practical skills, the ability to work in interdisciplinary teams, and critical thinking skills are all highly valued by potential employers across diverse bioscience industries.

Figure 1: Survey results on the skills that national bioscience education programs should include to prepare graduates for 2030.



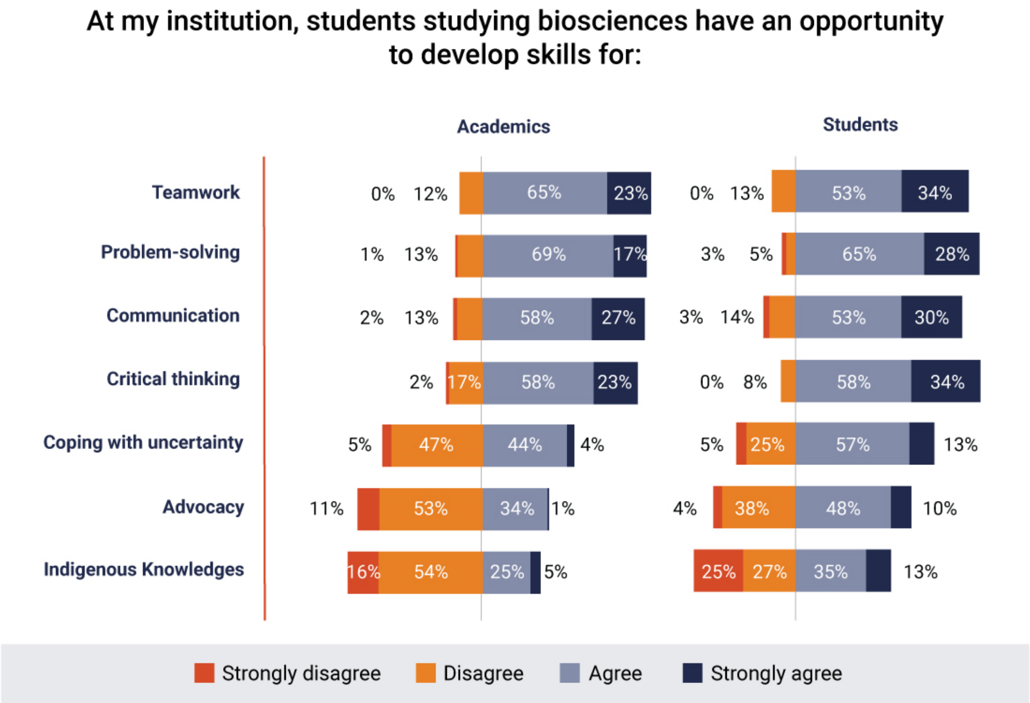
Perspectives on whether institutions are currently providing sufficient opportunities for students to develop these fundamental skills are optimistic. Both educators and students agree that institutions are providing sufficient opportunities to develop essential bioscience skills, although more could be done regarding communication to a variety of audiences, coding, and handling large datasets (i.e. big data) (Figure 2).

Figure 2: Survey results show that educators believe bioscience students have fewer opportunities to develop skills in coding, handling large datasets, and grant writing.



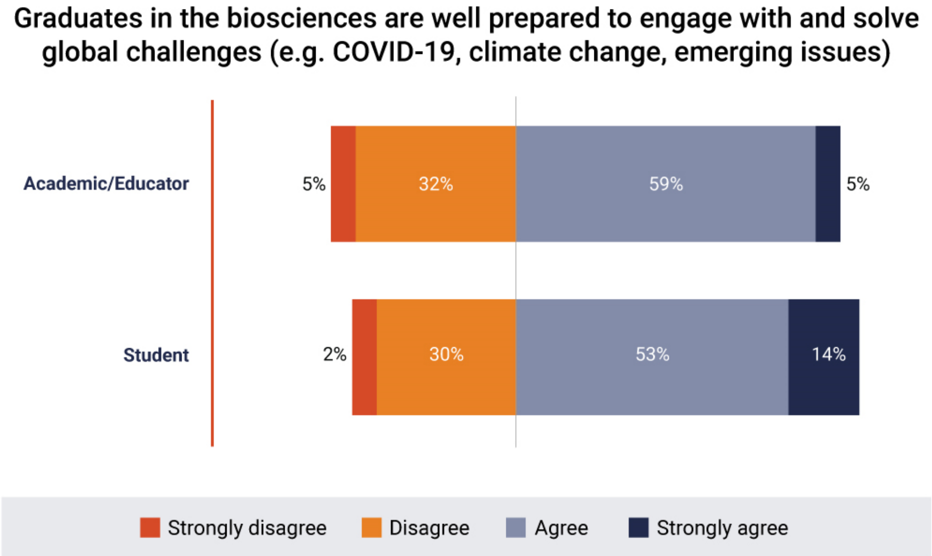
When it comes to transferable skills, educators and students alike believe there are significant opportunities in higher education bioscience programs for teamwork, problem-solving, critical thinking, and communication (Figure 3). Both groups place a high value on an equal balance of work-ready skills versus deeper scientific knowledge. There are less opportunities, however, to develop skills for coping with uncertainty, leading advocacy, and engaging with Indigenous Knowledges and diverse ways of knowing. More than half of the educators and students surveyed disagreed or strongly disagreed that students studying biosciences at their institution have an opportunity to develop skills for understanding Indigenous Knowledges.

Figure 3: Survey results show that both educators and students believe their institutions offer opportunities to develop skills such as teamwork, communication, and critical thinking. There are less opportunities for advocacy, Indigenous Knowledges and coping with uncertainty.



Close to two thirds of bioscience educators and students surveyed agree that graduates in the biosciences are well prepared to engage with and solve emerging global challenges (Figure 4). While results indicate that we can have some confidence in the preparedness of bioscience graduates there is room for improvement.

Figure 4: Survey results show that bioscience students feel they are well prepared to engage with and solve global challenges, while educators are not so certain.



It is encouraging that students, educators, and employers generally agree that Australian institutions are currently meeting expectations in teaching students essential bioscience skills. When educators and students were asked what needs to be improved at their institution, they reflected on the need for and ongoing importance of in-person, practical and hands-on experiences for bioscience students' learning experiences, job readiness, and wellbeing.

When educators and students were asked what needs to be improved at their institution, they reflected on the need for and ongoing importance of in-person, practical and hands-on experiences for bioscience students' learning experiences, job readiness, and wellbeing.

THE IMPACT OF THE COVID-19 PANDEMIC

Prior to the pandemic, bioscience educators were confident about how to teach effectively and efficiently in the 21st century and how to train bioscience graduates with the appropriate knowledge and skills for a multitude of possible careers. Multiple pedagogical pathways and theories have been discussed nationally at bioscience education conferences to achieve these outcomes, from the learning sciences,[1] inquiry-based learning,[2] concept inventories,[3] productive failure,[4] universal design for learning,[5] research-led or research-informed teaching,[6] and uncertainty pedagogies.[7]

During prolonged lockdowns, bioscience educators across Australia reshaped higher education to provide students with online opportunities to achieve their learning goals, in both theory and hands-on laboratory-based knowledge. A diversity of strategies and resources were used, with varying degrees of success.

The pandemic and the shift to online learning spurred by lockdowns has brought significant challenges, such as the loss of essential experiential and practical learning. However, the flexibility of asynchronous learning has also offered benefits. This forced 'experiment' in emergency remote learning provides a unique opportunity to align teaching more powerfully with the needs of both students and bioscience employers.

There have been a number of commentaries on the difficulties, opportunities and long-term consequences of COVID-19 on learning and teaching.[8,9] For example, emergency remote instruction is a poor substitute for laboratory-based disciplines that are central to learning across nearly all bioscience fields.

This was echoed in the responses to our survey for this report, in which we asked specific questions about the impact of the COVID-19 pandemic on teaching practice (for educators) and on the learning experience (for students). The survey indicated that the rapid shift to online teaching and learning was coupled with poor satisfaction from both staff and students for some activities (like practical laboratories that were moved online) and assessment and feedback, especially online exams, which had technical difficulties or were proctored. Both staff and students placed a high value on hands-on learning, thus reinforcing the need for on-campus practical and experiential learning as an integral component of science degrees.

Both staff and students placed a high value on hands-on learning, thus reinforcing the need for on-campus practical and experiential learning as an integral component of science degrees.

Indeed, emerging data suggests that critical skills required by bioscience graduates, such as discipline-specific knowledge, communication, and hands-on problem-solving and teamwork, are difficult to teach in an online environment and instead require face-to-face social learning approaches.[10],[11],[12] Beyond formal learning, the on-campus experience is an essential component of a well-rounded educational endeavor for many students.

However, there is also recognition by both staff and students that some teaching and learning activities were well suited to online and flexible delivery modes, and potentially could lead to improved academic outcomes when presented in this way. Educators have subsequently upskilled in best practice use of technology for delivery, resourcing, interaction and delivery of learning. As a result, educators are now more creative and confident in the use of technology and are seeking to maximise student learning benefits through flexible online teaching into the future.

… there is also recognition by both staff and students that some teaching and learning activities were well suited to online and flexible delivery modes …

The survey showed that there is good alignment between student and staff preferences for a hybrid learning model: a mix of online and face-to-face teaching.

THERE IS GOOD AGREEMENT BETWEEN WHAT EDUCATORS AND STUDENTS LIKE AND DISLIKE MOST ABOUT THE MOVE TO REMOTE TEACHING.

Most successful online activities:

- Interaction via polling and Padlet boards
- Online discussion forum
- Pre-recorded video content for practicals
- Pre-recorded lectures

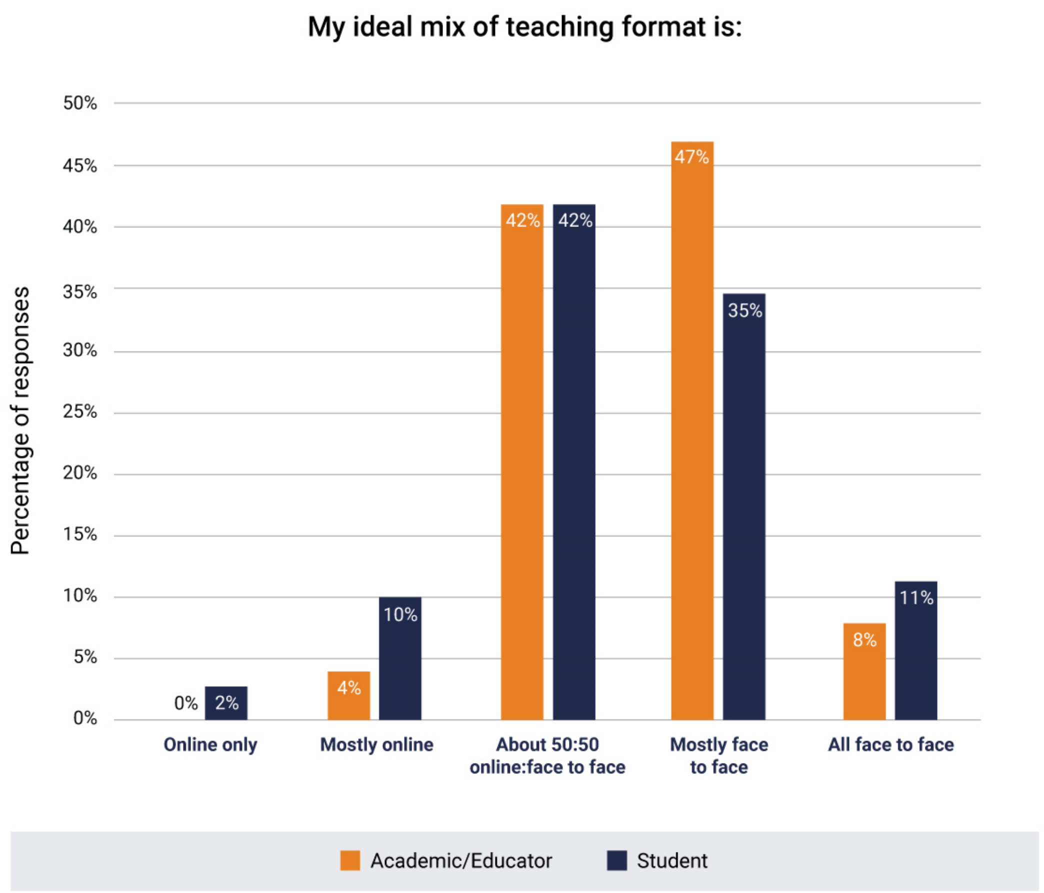
>80% of staff will retain or try these and >60% of students found them helpful

Least successful online activities:

- Online practicals
- 72% of staff will discontinue
- Proctored online exams
- 56% of staff will discontinue

<20% of students found each activity helpful

Figure 5: Survey results from educators and students on the teaching and learning preferences in national biosciences education programs.

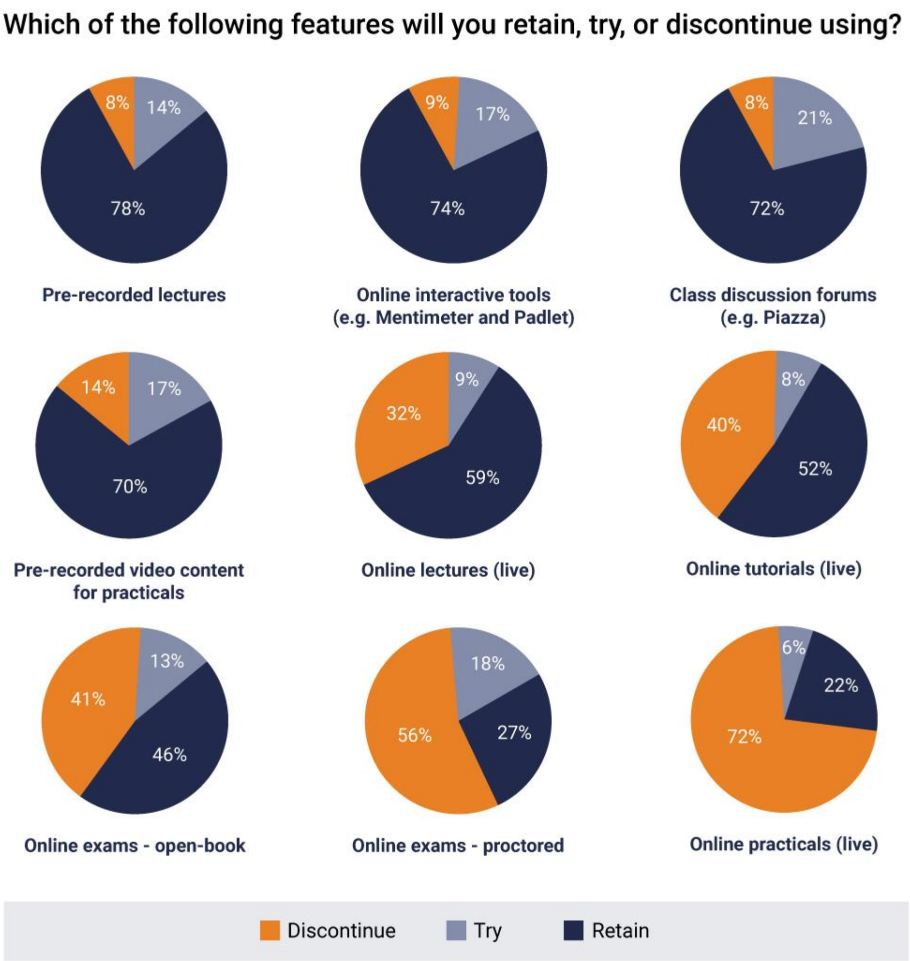


Educators are evaluating the successes and challenges of flexible technology-enhanced learning and online delivery, and deciding which practices and principles to retain, and which we can do better without. For educators to assess this effectively requires a robust evidence-based approach. Experts in the field of higher education are also currently leading open discussions about what pedagogies should drive new forms of hybrid learning and higher education institutions are using such discussions as a launching pad for new policies on best-practice teaching for next-generation degrees.

A first step is to establish a rich body of evidence around whether students are engaging in online content, and how. New data analytics tools allow us to track elements of student engagement online to provide insights into how students are using content and hence potentially tailor and individualise student learning offerings. Here, upgrades in technological infrastructure will be critical to gather evidence and deliver modern high-quality bioscience education programs.

When educators were asked what they will retain and discontinue, most said they would no longer continue with online proctored exams or practicals, but would retain asynchronous (pre-recorded) lectures (Figure 6). The challenge in this approach is to ensure that students engage with the online content.

Figure 6: Survey results from educators on what they would retain, try and discontinue after the COVID-19 pandemic in bioscience education programs.



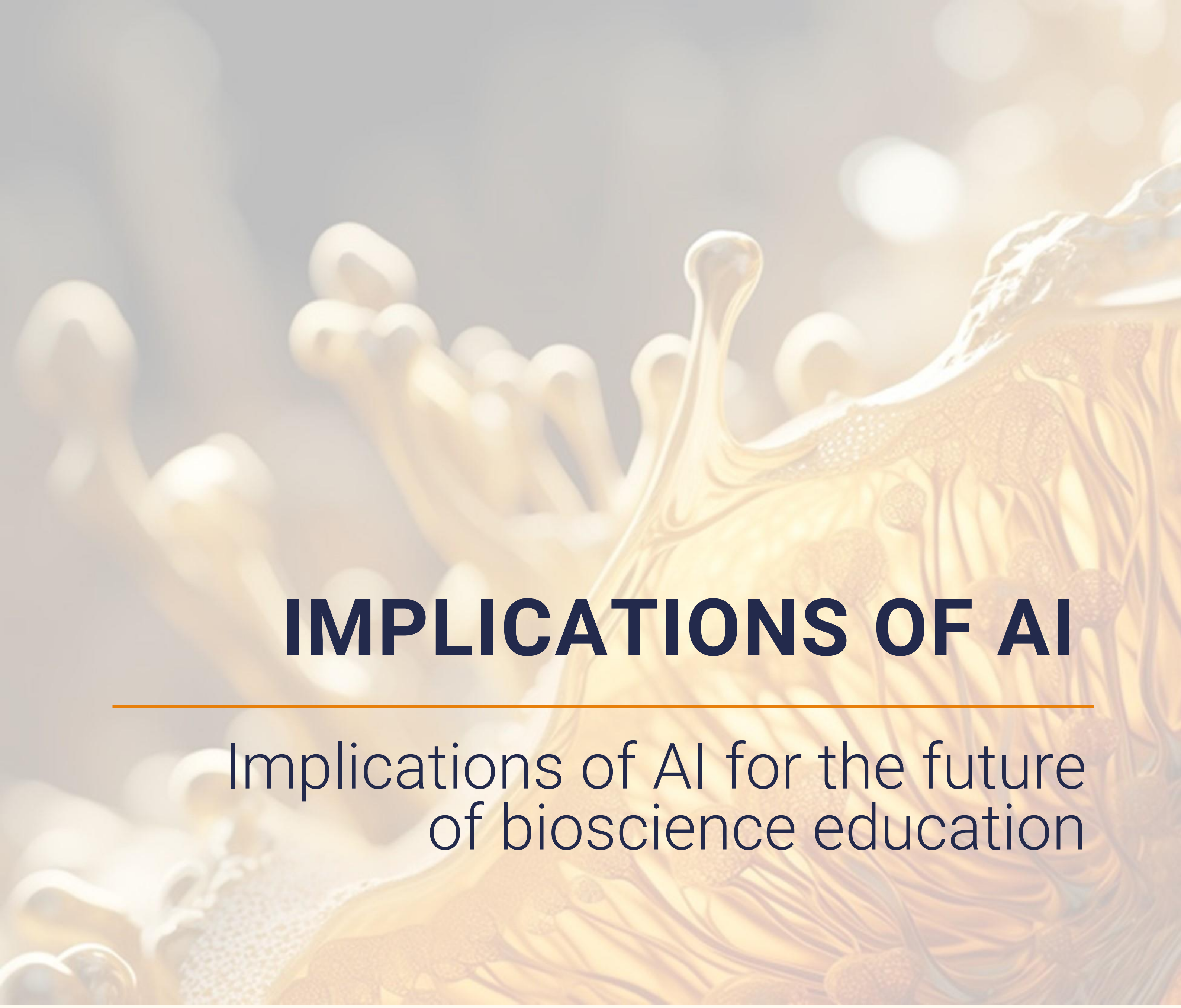
BIOSCIENCE FACES CHALLENGES

Now that we are emerging from the rapid shift to online learning at the onset of the pandemic, many questions remain about what the future of high-quality bioscience eduction programs will look like, and what challenges lie ahead.

We asked survey respondents what they thought the greatest challenges are to bioscience. The top five challenges were:

1. lack of funding for science
2. decision-makers (e.g. political leaders) not informed about bioscience research or issues
3. quality and quantity of jobs for existing trained bioscientists
4. lack of advocacy for science funding
5. public's lack of appreciation for bioscience.

These challenges are intertwined. While 65% of educators and students agree that bioscience graduates are prepared for global challenges, under-appreciation and subsequent lack of stable funding contributes to a deficit of quality bioscience jobs. Without clear pathways to employment, talented individuals may leave bioscience. Without a skilled bioscience workforce, Australia is vulnerable in the face of as-yet unforeseen problems. Such considerations are essential underpinnings when considering the future of bioscience education in Australia.



IMPLICATIONS OF AI

Implications of AI for the future of bioscience education

Next-generation higher education bioscience education programs will need to be able to adjust to and prepare students to adapt to the emergence of new technologies that reshape the way we learn, teach and work.

Since our survey of the bioscience community was conducted, generative artificial intelligence (AI) tools became widely available to the public for the first time, with the launch of ChatGPT in November 2022. The availability of generative AI tools like ChatGPT has forced the higher education sector to consider the nature of academic integrity, research integrity, and assessment and how to best prepare students for a rapidly changing work environment.

While public awareness of AI advancements has been heightened with wide access to generative AI tools, this is just one aspect of a wider surge in the development of AI.

This chapter provides an initial exploration of the opportunities and challenges posed by AI for higher education bioscience programs and its impact on various aspects of teaching and learning. While AI was not specifically addressed in the survey, key skills highlighted in the survey, like critical thinking, will be key to students' ability to use and adapt to developments in AI.

ARTIFICIAL INTELLIGENCE AND ITS APPLICATIONS IN BIOSCIENCE

The CSIRO defines AI as "a collection of interrelated technologies used to solve problems autonomously and perform tasks to achieve defined objectives without explicit guidance from a human being".[13] Examples of these technologies are machine learning and natural language processing. Generative AI, more specifically, encompasses a set of technologies that have the "capacity to generate novel content, as varied as text, image, music and computing code, in response to a user prompt".[14]

Future bioscience education programs will need to prepare bioscience students for the ways AI may change how science is conducted. On one hand, generative AI tools may help reduce the burden of preparing journal papers and grant applications. They also have the potential to assist with tasks including brainstorming, code generation and debugging, and science communication. However, AI has a wide range of potential applications in bioscience beyond the current focus on generative AI. Developments in AI will impact how science is conducted; for example, AI tools may speed up the rate at which scientists can collect and analyse data. Specific examples of applications of AI in bioscience include predicting the 3D structures of proteins, identifying animals from images collected from motion-sensor cameras placed in natural habitats and accelerated advancements in drug discovery, genomics, and diagnostics.[13] Additionally, bioscience graduates need to be supported to not just use AI tools but also identify, comprehend, and where possible, manage potential risks and challenges associated with the use of AI to conduct science such as the generation of biased or false data, plagiarism, and irreproducible research.

EQUIPPING STUDENTS WITH THE KNOWLEDGE AND SKILLS THEY NEED

The results of our survey of the bioscience sector indicate key skills for bioscience education to target, many of which will also enhance students' ability to effectively engage with AI, including critical thinking, evidence-based reasoning, problem-solving, teamwork, and tolerance of uncertainty. For example, new developments in bioscience research applying AI technologies may require graduates to work in multidisciplinary teams with computer scientists and AI experts. While a bioscience graduate will primarily bring their domain expertise to this work, it is critical they are also effectively able to engage with AI tools and experts. Core skills including critical thinking, communication and teamwork will be key to this as well as specific content to enable AI literacy.

These core skills and AI literacy need to be embedded and comprehensively scaffolded across all years of a degree program so that students can progressively advance and develop these capabilities.

With human oversight and specialised domain input, including that which bioscience graduates can offer, AI tools have the potential to contribute to meaningful advancements in science.[13] Bioscience students need education programs that support the skills and knowledge to effectively contribute to and harness these advances for science and society.

NEW WAYS OF LEARNING AND TEACHING

In addition to changing what skills and knowledge students need to learn, AI has the potential to change how bioscience is taught. AI tools may provide methods to enhance learning and teaching. For example, AI tools may be used to provide personalised text-based tutoring. AI tools also have the potential to reduce the administrative burden on educators, for example by assisting with grading student work and providing student feedback on interim or early drafts of work.

IMPLICATIONS FOR ASSESSMENT AND ACADEMIC INTEGRITY

The implications of generative AI for assessment and academic integrity have emerged as key areas of concern in the higher education sector following the release of ChatGPT. Generative AI tools challenge the reliability of traditional take-home written assessment tasks. Conversely, if AI is used to support the marking of assessments other validity issues may be introduced in the marking process through embedded biases.

This issue has multiple dimensions, including detecting and defining breaches of academic integrity and ensuring that assessment adequately captures a student's level of ability. In this context, assessments may need to be reformulated to reduce the risk of academic misconduct and new policies and procedures developed. Some assessment tasks may also explicitly call for the use of AI tools.

ACCOMPANYING ETHICAL CONSIDERATIONS

While detailed exploration of the ethical dimensions of AI and their governance is beyond the scope of this paper, it is important that they are acknowledged in the design of education programs related to AI and AI teaching tools, as well as explicitly in the content taught to students. Key concerns and considerations in relation to AI include environmental impacts, human rights impacts, privacy concerns, and misinformation and disinformation.

Concerns in the context of education include ensuring equity in access to AI tools if they are integrated into or expected to be utilised as a part of learning and assessments and addressing privacy issues related to the adoption of AI tools in education.

AN AGILE APPROACH TO EDUCATION

As with the rapid shift to virtual online learning environments due to the COVID-19 pandemic, education providers have had to rapidly adjust their approaches, policies and procedures in response to generative AI. Bioscience educators are already experimenting with new ways to integrate generative AI into teaching. For example, embedding prompting and critically engaging generative AI outputs as assessment tasks.

This is a rapidly evolving space and will require agile responses and a willingness for educators to learn, adapt and re-evaluate how they teach. However, the essential skills for bioscience students which should underpin future bioscience education are only reinforced by the growing availability of AI tools. Critical thinking skills, communication, and the ability to work in interdisciplinary teams, all highlighted in our survey, will be critical for bioscience graduates entering an AI-enabled workforce.

OUR VISION

Australia's bioscience community in 2030

Imagine it's 2030: Australia is globally recognised for fostering thought leaders and innovators in bioscience. Australian-trained bioscience graduates demonstrate exceptional skills, enthusiasm and ethics. They are resilient, excellent communicators, can advocate for critical policy in areas such as Indigenous health, and reflect the diversity of the nation. Our national bioscience education program produces graduates that are job-ready for fields as diverse as allied health, medicine, research and biomedical engineering.

While they're sought after globally, our bioscience graduates often remain in Australia, where a robust national bioscience industry is thriving. University researchers regularly work with industry professionals and decision-makers to better Australian communities, the country, and the planet.

Australia is well-placed to achieve this vision. Our research and education training programs are among the highly ranked on a global scale, and our country has diverse strengths in bioscience innovation and emerging capabilities in translation to industry.

To ensure that Australia can continue to produce exceptional bioscience innovators, it is necessary to further support and build on these impressive capabilities. In the face of deepening global challenges and a protracted period of economic austerity ahead, what should a well-resourced bioscience education program provide?

ESSENTIAL SKILLS AND QUALITIES

Higher education institutions are already developing bioscience students' essential and transferable skills. The survey data provides a valuable roadmap of graduate attributes for bioscience education to target.

Such skills include self-managed learning, evidence-based reasoning, scientific communication, 'big data' management, interdisciplinary teamwork, in-depth discipline-specific knowledge, critical thinking, understanding of Indigenous perspectives and ways of knowing, social influence, leadership, resilience, and tolerance of uncertainty. Many of these also enhance graduates' ability to effectively engage with AI.

Survey results suggest that particular attention should be paid to skills in data analysis, critical thinking, and problem-solving for increased employability of graduates.

Bioscience education should be comprehensively scaffolded across all years of a degree program to support students in progressively developing and advancing these skills throughout their degrees, rather than in isolated courses.

TRANSFERABLE SKILLS OF BIOSCIENCE GRADUATES TO MAINTAIN AND ENHANCE

- Critical thinking
- Problem solving
- Interdisciplinary teamwork
- Communication
- Advocacy
- Coping with uncertainty
- Engaging with and understanding the value of Indigenous Knowledges and perspectives

Teaching complexity and uncertainty

The pandemic has emphasised how important it is for bioscience education to foster the capacity and skills to cope with uncertainty.[15] As our world becomes more complex, the levels of uncertainty also rise. This is the so-called super complex world, as described by Barnett:[16] a world in which science- and bioscience-based disciplines are well placed to deal with these complexities.

Some, but not all, current bioscience pedagogies are equipping our future graduates with the skills to become effective bioscientists in this most certainly uncertain world, but the outcomes are patchy. Previous studies of Harvard graduate students by Perry[17] in the 1960s and Schommer[18] in the 1990s provided evidence that as students progress in their learning they start to see knowledge as less deterministic, more uncertain and complex, and more integrated across sub-disciplines in biosciences.[19,20] Perhaps the time has come to develop a formal pedagogy of uncertainty, adapting those already discussed in the literature[21] and implemented in undergraduate research projects.

CASE STUDY 1: FINDING TREASURE: WHAT ARE STUDENTS LEARNING FROM UNDERGRADUATE RESEARCH EXPERIENCES?

The Australian National University, University of Western Sydney and University of Canberra undertook a project with the title 'Teaching research: Evaluation and assessment strategies for undergraduate research experiences' (TREASURE). This project evaluated student thinking around research experiences in both a final semester capstone unit as well as independent research units. More than 60 students kept a reflective blog of their learning in these research experiences. It was encouraging to observe that the entire cohort demonstrated appropriate use of standard scientific research processes. However, few of the students in the capstone unit were able to extend their understanding to encompass the concept that science knowledge and processes can be uncertain, complex and indeterminate. This is of concern in the context of the newly articulated threshold learning outcomes in science, in particular: 'Demonstrate a coherent understanding of biomedical science by articulating the methods of science and explaining why current scientific knowledge is both contestable and testable by further inquiry'. This observation suggests that we may be overestimating our expectations of the level of learning achieved in current undergraduate research experiences. This in turn raises the question of whether we are satisfied that many of our graduates do not attain this threshold standard?

Case study provided by Professor Pauline Ross (University of Sydney).

Communication, advocacy and diversity

Funding and job-related challenges highlight the need for bioscience graduates who can bridge the science-policy gap, extending their spheres of influence into government. By making themselves visible and accessible to decision-makers, bioscientists can provide sound science advice that influences policy.

This is indeed a significant departure from the current norm—a transition from scientists perceived as simply 'men in white lab coats' to a modernised view of diverse, inclusive, collaborative cross-disciplinary communicators.

Bioscience professionals also need to be effective communicators. The COVID-19 pandemic has shown that parts of society distrust or misunderstand science. Bioscientists can play a role in combatting waves of damaging misinformation propagated through social and traditional media and promoting critical thinking and scientific literacy across society.

Australia's bioscience workforce needs to be capable of working across many different stakeholder groups. As such, future bioscience graduates themselves must include and be representative of people with diverse backgrounds, capabilities and interests. We must enhance access to opportunities for a range of students to study, research and work within the biosciences.

Modern bioscience education needs to recognise the value Indigenous people and Indigenous Knowledges bring to bioscience teaching, create safe and positive learning environments for Indigenous students, and embed opportunities for all students to genuinely engage with Indigenous Knowledges. Our survey identified this as an area requiring improvement. Over half of educators and students surveyed disagreed or strongly disagreed that there were opportunities for biosciences students to develop skills for understanding Indigenous Knowledges at their institution.

A HYBRID DELIVERY MODEL THAT BUILDS ON LESSONS LEARNT DURING COVID-19

PRACTICAL RECOMMENDATION 1

Higher education bioscience teaching should use knowledge and experience gained from the COVID-19 pandemic to reposition practical and hands-on learning experiences and student engagement as an essential cornerstone of modern bioscience higher education programs.

The COVID-19 pandemic has highlighted the strengths and weaknesses of remote and on-campus study. Now, we must implement the lessons learnt from COVID-19 to take the best from the online and on-campus experiences and create a new and robust hybrid model of teaching and learning.

At the higher education level, educators should engage and collaborate with students to co-create transformative learning experiences. To achieve this, institutions must prioritise the recruitment and retention of talented teaching specialist staff and educators able to deliver a student-centred learning experience.

There is widespread acknowledgement that the COVID-19 pandemic has crystallised the value of practical experiences that foster collaboration and teamwork, as well as problem-solving skills. These skills are embedded in learning, whether in the laboratory, field, or workshop. Institutions require sufficient infrastructure and facilities to support and sustain opportunities for on-campus hands-on learning in small, team-based groups.

Using technology to deliver content strategically

PRACTICAL RECOMMENDATION 2

Higher education bioscience teaching should use technology to strategically deliver content which does not displace practical instruction but extends it.

The survey results show that many students and educators found value in some online learning, and preferred a hybrid model of delivery. Disciplinary expertise can be effectively delivered online asynchronously; however, student learning is exemplary when asynchronous delivery is paired with opportunities that foster collaboration and allow students to skilfully construct new understandings from and with one another in face-to-face activities. Therefore, there is room to integrate online, self-paced modules—in a way that does not displace the practical instruction but rather extends it. Technologies which are accessible and can be integrated into a bioscience context, such as coding, are also strategically important to embed in education programs.[22] This is because graduates face a future where handling big data and coding will be a critical skill—and as our survey found, this skill is challenging for students. Similarly, there are emerging opportunities to embed AI tools and content to better prepare graduates to work in the context of these emerging technologies.

While technology adds value to subject delivery and assessment to students and staff, it also requires bolstered professional development resources to sustain a high-quality student experience. Evidence from studies across the globe indicates the significant issues of staff burnout because of emergency remote instruction. Faculty redundancies and declines in student numbers post pandemic may have the consequence of decreased support and changed workloads for educators. High-quality hybrid course design requires resources including expert technological support and improved professional development pathways to aid in managing new workload demands.

Real-world learning

PRACTICAL RECOMMENDATION 3

Higher education bioscience teaching should increase connectivity between industry and education institutions, to improve employability outcomes for future bioscience graduates and to better enable innovation.

Teaching and learning through the pandemic has demonstrated that online video resources, such as interviews, panel discussions and other community and industry interactions, are exemplary methods to incorporate employability skills and work-integrated learning into bioscience programs. Efforts to further solidify and embed industry and community connections should be supported and enhanced. There is also a compelling opportunity to use the pandemic, and other contemporary issues like human diseases associated with climate change, to enhance the real-world focus of our bioscience degrees. Incorporating contemporary issues into teaching provides multiple benefits for bioscience education: assisting students in seeing the relevance of their degree; engaging them with the inherent uncertainty of science; and promoting critical thinking and use of evidence.

Authentic assessment and feedback

PRACTICAL RECOMMENDATION 4

Higher education bioscience teaching should integrate more active learning pedagogies, including real-world learning and authentic assessment and feedback.

Assessment tasks should be matched to learning that develops and measures analytical and critical thinking skills. Feedback on competencies and capabilities should also be designed to reflect authentic contexts. Assessment and feedback should be delivered in a way that better supports an inclusive learning environment for students from low socio-economic and culturally and linguistically diverse backgrounds.

CASE STUDY 2: VIRTUAL TOURS IN HUMAN BIOLOGY

Engagement with learning activities is difficult to achieve at scale, especially in a remote learning environment. Many of the 550 first-year human biology students at The University of Sydney see the medical science program only as a gateway to studying medicine. To broaden student appreciation for medical science and encourage reflection about broader applications of their medical science degree, the university offered virtual tours of the Chau Chak Wing Museum. This is a facility built to co-locate many of The University of Sydney's collections. A 360° camera and 3DVista© software were used to reconstruct the museum in virtual space. The virtual tour comprised 30 artefacts, including mummified remains from the Egyptian collection, Jericho skull, and anatomical clastic model, a taxidermied thylacine, and other items of historic medical science interest, such as a prototype anti-gravity suit. Navigation of the tour is intuitive to anyone who has used Google Street View. The pointer-driven interface also allowed attachment of resources and relevant informational and research suggestions to each artefact.

That local and remote students had an identical experience of the collections meant that all students were able to engage positively with an activity that was not demanding. Most students reported a newfound understanding of how medical science uses historical models to advance our understanding, especially response to disease.

3D virtual experiences are becoming popular for asynchronous learning, notably for workplace induction. This is also a relatively inexpensive, easily developed and deployed option for online teaching in the medical sciences, especially in laboratory demonstrations, and readily modified for application in other disciplines.

Case study provided by Dr Craig Campbell and Matthew Sellwood (University of Sydney).

FURTHER INITIATIVES

Fostering student engagement with university life, learning and culture

PRACTICAL RECOMMENDATION 5

Higher education bioscience teaching should reposition student participation and engagement as central to all aspects of university education, lifelong learning and academic culture.

A major impact of the pandemic was an increase in student stress levels and a concurrent decrease in student engagement. Remote learning impacted the wellbeing of many higher education students and made them feel isolated and stressed, which was exacerbated by the loss of income from casual jobs during lockdowns. Most universities have reported increased use of student mental health support services during the pandemic and have increased investment in critically important student mental health and wellbeing resources. Returning to a culture where students spend time on campus and engage with the entire university experience will undoubtedly take some effort to re-establish, but will benefit student wellbeing, skills development and academic performance.

Students need to be introduced and immersed in the value of on-campus experiences, and strategic, well-designed experiences, both those linked to course learning outcomes but also to student social and wellbeing priorities, should be central in all return-to-campus planning. Attention should additionally be focused on block timetabling of experiences and extracurricular activities that can help students more efficiently organise their time on campus to accommodate necessary off-campus commitments, such as caregiving and working. Creating an engaging on-campus community means prioritising student health and wellbeing and creating meaningful reasons for students to value their campus community.

Connecting bioscience to other disciplines for a holistic perspective

PRACTICAL RECOMMENDATION 6

Higher education bioscience teaching should build and strengthen the connections between humanities and social sciences, design, engineering, and medicine and health through new interdisciplinary initiatives.

Integrating bioscience with other disciplines (including humanities and social sciences, arts and design, and engineering) can grow awareness of the biosciences to new audiences and enhance the diversity of the bioscience community. For example, bridging the arts and science—a shift from STEM to STEAMM (science, technology, engineering, arts, mathematics and medicine)—can improve critical thinking, engender empathy and tolerance and, perhaps most importantly, build resilience.[23] As Radziwill asserts, STEAM "provides a non-judgmental space to cultivate the question-making aspect of inquiry, the ability to comfortably hold uncertainty, and a sensitivity to the process of discovery".[24]

Integrating aspects of arts education into bioscience education can be a first step towards inspiring creativity and intuition in students.[25,26] Formalising this interconnectedness through the establishment of specific courses can already be seen across Australian universities, such as in the University of Melbourne's Contemporary Art and Biomedicine (see Case Study 3) and the Australian National University's Exquisite Corpse – Insight into the Human Body. Public-facing initiatives can foster alternative approaches, such as the Australian Network for Art and Technology, which focuses on the collaborative potential of art and science by hosting artists in residence within Australian research organisations.

CASE STUDY 3: CONTEMPORARY ART AND BIOMEDICINE

Contemporary Art and Biomedicine: Looking Making Thinking is a fully online University of Melbourne subject taught via podcast, in which students deepen their understanding of how biomedicine issues can be represented creatively. Each element of the course is grounded in the understanding that contemporary art provides a unique access to understanding and articulating some of the most pressing biomedical research concerns of our time. In-depth discussions with leading biomedicine and contemporary art researchers about cancer, non-binary personhood, stem cells, chimera and post human, death and mortality, respiration, consciousness and the brain immerse students in an innovative and artistic consideration of human experience.

Case study provided by Dr David Sequeira (University of Melbourne).

CONCLUSION

Our adoption of new ways of learning and working has not only been accelerated by the COVID-19 pandemic, but has also highlighted inequities, challenges and opportunities in the way we teach bioscience in higher education. This report combines findings from educators, students and external stakeholders to develop a holistic vision for bioscience higher education as we approach 2030.

Bioscience education will thrive if we continue to focus on a student-centred approach, with the practical on-campus experience being one of collaborative discovery and exploration through co-creation and knowledge exchange. As Einstein famously wrote, “All religions, arts and sciences are branches of the same tree”. Mutual integration of bioscience with the arts, humanities, design and engineering will not only provide our students with the skills and capabilities to work in interdisciplinary ways, but also create a more fertile and fulfilling workplace for our educators. We also need to help our students feel more comfortable with uncertainty in this less certain world, practise critical thinking, and be confident with data analysis and coding. Such skills will enable our students to meet new challenges, for example in using generative AI to enhance, rather than replace, learning.

In parallel, we need to be strategic and proactive to ensure that our voices are heard at the political level, in industry, and among the general public. Finally, higher education leaders must recognise the diversity, resourcing and infrastructure that is required for excellence in higher education institutions.

In 2015, the then Australia’s Chief Scientist Professor Ian Chubb AC FAA FTSE said, “We need graduates who will be curious, nimble and not constrained by the narrow confines of the particular discipline they focus on today. Graduates who will see opportunity in challenge and be quick to react. Graduates who understand the value of values.” These words remain as powerful as ever as the world faces many global challenges requiring outstanding and capable bioscience graduates as part of the solution.

REFERENCES

[1] Tokuhama-Espinosa, T. (2019). The learning sciences framework in educational leadership. *Frontiers in Education, 4*, 136. https://doi.org/10.3389/feduc.2019.00136

[2] Department of Education. (2021, June 21). *Inquiry-based learning*. Department of Education, Skills and Employment. https://www.education.gov.au/australian-curriculum/national-stem-education-resources-toolkit/i-want-know-about-stem-education/what-works-best-when-teaching-stem/inquiry-based-learning

[3] Michael, J., & McFarland, J. (2011). The core principles ("big ideas") of physiology: Results of faculty surveys. *Advances in Physiology Education, 35*, 336–341. https://doi.org/10.1152/advan.00004.2011.

[4] Manu Kapur. (n.d.). *Productive failure*. https://www.manukapur.com/productive-failure/

[5] NSW Government. (2023, October 27). *Universal design for learning*. NSW Government – Education. https://education.nsw.gov.au/teaching-and-learning/curriculum/planning-programming-and-assessing-k-12/about-universal-design-for-learning

[6] Jenkins, A., & Healey, M. (2012). Research-led or research-based undergraduate curricula. In L. Hunt & D. Chalmers (Eds.), *University teaching in focus* (pp. 128–144). Routledge. https://doi.org/10.4324/9780203079690-8

[7] Shulman, L. S. (2005). Pedagogies of uncertainty. *Liberal Education, 91*(2), 18–25.

[8] Peters, Micah D.J., Marnie, C., Tricco, A.C., Pollock, D., Munn, Z., Alexander, L., McInerney, P., Godfrey, C.M., & Khalil, H. (2020). Updated methodological guidance for the conduct of scoping reviews. *JBI Evidence Synthesis, 18*(10), 2119–2126. https://doi.org/10.11124/jbies-20-00167

[9] Watermeyer, R., Crick, T., Knight, C., & Goodall, J. (2021). COVID-19 and digital disruption in UK universities: Afflictions and affordances of emergency online migration. *Higher Education, 81*, 623–641. https://doi.org/10.1007/s10734-020-00561-y

[10] Chang, Y., & Hannafin, M. (2015). The uses (and misuses) of collaborative distance education technologies. *The Quarterly Review of Distance Education, 16*(2), 77–92.; Cho, M. H., Kim, Y., & Choi, D. (2017). The effect of self-regulated learning on college students' perceptions of community of inquiry and affective outcomes in online learning. *The Internet and Higher Education, 34*, 10–17.; Kelley, T.R., & Knowles, J.G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*, 11. https://doi.org/10.1186/s40594-016-0046-z

[11] Cho, M. H., Kim, Y., & Choi, D. (2017). The effect of self-regulated learning on college students' perceptions of community of inquiry and affective outcomes in online learning. *The Internet and Higher Education, 34*, 10–17.

[12] Kelley, T.R., & Knowles, J.G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*, 11. https://doi.org/10.1186/s40594-016-0046-z

[13] Hajkowicz, S., Naughtin, C., Sanderson, C., Schleiger, E., Karimi, S., Bratanova, A., & Bednarz, T. (2022). *Artificial intelligence for science – Adoption trends and future development pathways*. CSIRO Data61, Brisbane, Australia. https://www.csiro.au/en/research/technology-space/ai/artificial-intelligence-for-science-report

[14] Bell, G., Burgess, J., Thomas, J., & Sadiq, S. (2023, March 24). *Rapid response information report – Generative AI: Language models and multimodal foundation models*. Australian Council of Learned Academies. https://www.chiefscientist.gov.au/GenerativeAI

[15] Stephens, G.C., Rees, C.E. & Lazarus, M.D. (2020). Exploring the impact of education on preclinical medical students' tolerance of uncertainty: A qualitative longitudinal study. *Advances in Health Sciences Education, 26*, 53–77. https://doi.org/10.1007/s10459-020-09971-0

[16] Barnett, R. (2000). Supercomplexity and the curriculum. *Studies in Higher Education, 25*(3), 255–265. https://doi/10.1080/713696156

[17] Perry, W.G. (1968). *Patterns of development in thought and values of students in a liberal arts college: A validation of a scheme*. Final report. https://eric.ed.gov/?id=ED024315

[18] Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology, 82*(3), 498–504.

[19] Ross, P., Howitt, S., Wilson, A., Higgins, D., Gill, B., & Poronnik, P. (2013). Do undergraduate research experiences influence student understanding of the uncertainties inherent in scientific knowledge? https://openjournals.library.sydney.edu.au/index.php/IISME/article/view/6999

[20] Ross, P., Howitt, S., Wilson, A., Higgins, D., Gill, B., & Poronnik, P. (2013, September 24). Do undergraduate research experiences influence student understanding of the uncertainties inherent in scientific knowledge? [Presentation abstract]. In *Proceedings of The Australian Conference on Science and Mathematics Education.* https://openjournals.library.sydney.edu.au/index.php/IISME/article/view/6999

[21] Barnett, R. (2007). Assessment in higher education: An impossible mission? In Boud, D. & Falchikov, N. (Eds.) *Rethinking assessment in higher education: Learning for the long term* (pp. 29–40). Routledge.

[22] Gough, P., Bown, O., Campbell, C.R., Poronnik, P., & Ross, P.M. (2022). Student responses to creative coding in biomedical science education. *Biochemistry and Molecular Biology Education, 51*(1), 44–56. https://doi.org/10.1002/bmb.21692

[23] Skorton, D. (2019). Branches from the same tree: The case for integration in higher education. *PNAS 116*(6), 1865–1869. https://doi.org/10.1073/pnas.1807201115

[24] Radziwill, N., Benton, M., & Moellers, C. (2015). From STEM to STEAM: Reframing what it means to learn. *The STEAM Journal, 2*(1). https://doi.org/10.5642/steam.20150201.3

[25] Gurnon, D., Voss-Andreae, J., & Stanley, J. (2013). Integrating art and science in undergraduate education. *PLoS Biology, 11*(2), e1001491. https://doi.org/10.1371/journal.pbio.1001491

[26] Ross, P.M., Mercer-Mapstone, L., Pozza, L.E., Poronnik, P., Hinton, T., & Field, D.J.. (2022). An idea to explore: Interdisciplinary capstone courses in biomedical and life science education. *Biochemistry and Molecular Biology Education, 50*(6), 649– 660. https://doi.org/10.1002/bmb.21673

APPENDIX 1: SURVEY QUESTIONS

General questions (all respondents)

- Which of the following groups do you most closely associate with? [Single select]
  - Academic/Educator
  - Student
  - Industry
  - Community
- How well do you think bioscience is valued by: [Scale: Not at all valued; Undervalued; Valued; Very Valued]
  - the general community
  - political leaders in Australia
  - world leaders
  - the media
  - young people (<18 years of age)
  - university leadership
- What do you see as the greatest future challenge in the biosciences? Choose up to 5 options. [Multiple select]
  - Decision-makers (e.g. political leaders) not informed about biological research or issues
  - Lack of funding for research
  - Public's lack of appreciation for biology
  - Rejection of evolution as the central tenet of biology
  - Quantity and quality of jobs for existing trained biologists
  - Lack of advocacy for science funding
  - Failure to educate non-majors to engage in a lifelong appreciation of biology
  - Lack of support for biologists to spend time on teaching or community outreach activities
  - Fragmentation of biological disciplines
  - Decreasing science coverage in popular media
  - Issues with scientific data—access, raw data publication, disclosure
  - Lack of people entering biological fields for employment
  - Biology majors are not prepared for biology careers
  - Lack of diversity in academic leadership
  - Others (Please specify) [Open text]
- If you want to expand on your answer, please comment here. [Open text]
- Graduates in the biosciences are well prepared to engage with and solve global challenges (e.g. COVID-19, climate change, emerging issues). [Single select]
  - Strongly disagree
  - Disagree
  - Agree
  - Strongly agree

Questions for academics/educators only

- At my institution, students studying biosciences have an opportunity to develop skills for: [Scale: Strongly Agree; Disagree; Agree; Strongly Agree]
  - Coping with uncertainty
  - Critical thinking
  - Communication
  - Problem-solving
  - Advocacy
  - Understanding Indigenous Knowledges
  - Teamwork
- How regularly do you update your curriculum to include contemporary bioscience issues (e.g. COVID-19, climate change, emerging issues) in your teaching? [Single select]
  - Every semester
  - Every year
  - Annually
  - Biennially (every 2 years)
  - Never
  - Not applicable
  - Other [Open text]
- My ideal mix of teaching format is: [Single select]
  - Online only
  - Mostly online
  - About 50:50 online:face to face
  - Mostly face to face
  - All face to face
- Which of the following online learning features have you used in the past? [Scale: Used pre-COVID-19; Adopted for COVID-19; Never]
  - Online lectures (live)
  - Online tutorials (live)
  - Online practicals (live)
  - Pre-recorded lectures
  - Pre-recorded video content for practicals
  - Online interactive tools (e.g. Socrative/Mentimeter questions, Padlet boards)
  - Class discussion forums (e.g. Piazza)
  - Online exams – proctored
  - Online exams – open-book
  - Other (please specify)

- Which of the following online learning features will you retain, try or discontinue using? [Scale: Retain; Try; Discontinue]
  - Online lectures (live)
  - Online tutorials (live)
  - Online practicals (live)
  - Pre-recorded lectures
  - Pre-recorded video content for practicals
  - Online interactive tools (e.g. Socrative/Mentimeter questions, Padlet boards)
  - Class discussion forums (e.g. Piazza)
  - Online exams – proctored
  - Online exams – open-book
  - Other (please specify)

Questions for students only

- At my institution, students studying biosciences have an opportunity to develop skills for: [Scale: Strongly disagree; Disagree; Agree; Strongly agree]
  - Coping with uncertainty
  - Critical thinking
  - Communication
  - Problem-solving
  - Advocacy
  - Understanding Indigenous Knowledges
  - Teamwork
- Which of the following online learning approaches do you feel aids your learning? [Scale: Not helpful; Helpful; Not Used]
  - Online lectures (live)
  - Online tutorials (live)
  - Online practicals (live)
  - Pre-recorded lectures
  - Pre-recorded video content for practicals
  - Online interactive tools (e.g. Socrative/Mentimeter questions, Padlet boards)
  - Class discussion forums (e.g. Piazza)
  - Online exams – proctored
  - Online exams – open-book
  - Regular quizzes
  - Essays and reports
  - Other (please specify)
- My ideal mix of learning format is: [Single select]
  - Online only
  - Mostly online
  - About 50:50 online:face to face
  - Mostly face to face
  - All face to face

- How important is face-to-face contact for your effective learning? [Single select]
  - Not at all important
  - Slightly important
  - Very important
  - Extremely important
- How important is laboratory/field-based experiential learning? [Single select]
  - Not at all important
  - Slightly important
  - Very important
  - Extremely important
- Graduates in the biosciences are well prepared for employment. [Single select]
  - Strongly disagree
  - Disagree
  - Agree
  - Strongly agree

Questions for academics/educators and students

- The following skills are essential for students studying biosciences to develop: [Scale: Strongly disagree; Disagree; Agree; Strongly Agree]
  - Statistical data analysis
  - Presentation of data
  - Coding
  - Experimental design
  - Practical skills/hands-on skills
  - Scientific communication (written)
  - Scientific communication (verbal)
  - Communication techniques for a variety of audiences
  - Grant writing
  - Evidence-based reasoning
  - Handling of large datasets
  - In-depth discipline-specific knowledge
- At my institution, students studying biosciences have an opportunity to develop: [Scale: Strongly disagree; Disagree; Agree; Strongly Agree]
  - Statistical data analysis
  - Presentation of data
  - Coding
  - Experimental design
  - Practical skills/hands-on skills
  - Scientific communication (written)
  - Scientific communication (verbal)
  - Communication techniques for a variety of audiences
  - Grant writing
  - Evidence-based reasoning
  - Handling of large datasets
  - In-depth discipline-specific knowledge
- One thing that is done well in bioscience education at my institution is: [Open text]

- One thing that needs improvement in bioscience education at my institution is: [Open text]
- How well do you think undergraduate bioscience curricula are keeping up with the demands of contemporary society? [Single select]
  - Very poorly
  - Poorly
  - Well
  - Very well
- What do you see as the greatest future challenge in the biosciences? Choose up to 5 options. [Multiple select]
  - Public's lack of appreciation for bioscience
  - Quantity and quality of jobs for existing, trained bioscientists
  - Lack of advocacy for science funding
  - Lack of support for biologists to spend time on teaching or community outreach activities
  - Fragmentation of biological disciplines
  - Decreasing science coverage in popular media
  - Issues with scientific data access, raw data publication, disclosure
  - Lack of diversity in academic leadership
  - Decision-makers (e.g. political leaders) not informed about bioscience research or issues
  - Lack of funding for science
  - Failure to educate non-majors to engage in a lifelong appreciation of bioscience
  - Rejection of evolution as the central tenet of biology
  - Lack of people entering biological fields for employment
  - Bioscience majors are not prepared for bioscience careers
  - Others [Open text]
- If you want to expand on your answer, please comment here. [Open text]
- What should be the balance of focus between bioscience graduates being trained for work and employment versus deeper scientific knowledge? [Single select]
  - Mostly deeper scientific knowledge
  - Equal balance
  - Mostly employability skills
- Please provide reasons for your answer. [Open text]

Questions for industry only

- How important is it for graduates to have had hands-on in-person lab/field/practical experience? [Single select]
  - Not at all important
  - Slightly important
  - Very important
  - Extremely important
- When hiring a bioscience graduate, what is the most important skill you seek? [Open text]
- What industry are you employed/do you work in? [Open text]
- What level is your position? [Open text]

Demographic information (all respondents)

- What is your highest level of qualification? [Single select]
  - Less than Year 12 or equivalent
  - Year 12 or equivalent
  - Certificate I
  - Certificate II
  - Certificate II
  - Certificate IV
  - Diploma
  - Advanced Diploma/Associate Degree
  - Bachelor Degree
  - Bachelor Honours/Graduate Certificate/Graduate Diploma
  - Masters Degree
  - Doctoral Degree
  - Prefer not to say
- If applicable, how many years since your PhD conferral (adjusted for career disruption)? [Single select]
  - >5 years
  - 5–15 years
  - >15 years
- What age are you? [Single select]
  - <18
  - 18–24
  - 25–34
  - 35–44
  - 45–54
  - 55–64
  - 65–74
  - 75–84
  - 85–94
  - 95 and over
- Gender: How do you identify? [Single select]
  - Male
  - Female
  - Non-binary
  - Not listed [Open text]
  - Prefer not to say
- Which best describes your usual geographical location? [Single select]
  - Metropolitan
  - Regional
  - Rural
- Do you identify as being of Australian Aboriginal and/or Torres Strait Islander origin? [Single select]
  - Yes
  - No
  - Prefer not to say