Mapping University Prerequisites in Australia

A joint Office of the Chief Scientist and Australian Mathematical Sciences Institute paper

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AT A GLANCE

- Completing fundamental subjects in secondary school, such as history, languages, mathematics, and science, combined with a strong foundation in English, is essential to equip young Australians with the agility and flexibility to navigate life post-school, regardless of whether they continue to tertiary studies or enter the workforce directly.
- Where they exist, university prerequisites allow universities to select students who have shown interest in and aptitude for relevant subjects and set the baseline for first-year university teaching. They also provide an incentive for secondary school students to choose subjects that provide the best preparation for university study.
- This paper examines prerequisites requirements at Australian universities in 2019 (for 2020 entry). Overall, in the eight disciplines measured, few undergraduate courses in Australia have prerequisite requirements.
    - 11 of 40 universities in Australia have no mathematics prerequisites for any of their courses and 14 universities have no science prerequisites.
    - Of the 1,587 courses examined, only 19 courses require higher mathematics.
    - Prerequisite requirements differ across the states and territories, and between universities. On balance, universities in Victoria and Queensland are more likely to have mathematics and science prerequisites than universities in the rest of the country.
- Amongst other factors such as perceived difficulty and increasing numbers of out-of-field teachers, diminishing mathematics and science prerequisite requirements for undergraduate university entry in Australia is likely to be contributing to the decline in student uptake of such subjects in secondary schools nationally over the past decade.
- Notwithstanding the efforts of individual universities and states, there is currently no coordinated approach to providing advice to secondary school students as to which subjects they should study.
- While returning to prerequisites may not be compatible with Australia's current higher education landscape, students still need authoritative advice about which subjects to study in Years 11 and 12 so that they can be as prepared as possible for university study without relying on catch-up or bridging courses.
- Although a large percentage of students enter undergraduate study without an ATAR, the singular focus on ATAR scores in some schools means that many students choose their subjects to maximise their ATAR score rather than to prepare for university study.
- An agreed body of advice provided by leading universities would go some way towards overcoming the declining signal from universities about the importance of fundamental subjects.

Chapter 1
Introduction

> "The COVID-19 pandemic has shown Australia the importance of mathematics. With research showing that jobs in STEM occupations have grown almost twice as fast as in other occupations, Australia needs to address its mathematics culture. Issues such as out-of-field mathematics teaching and lack of university maths prerequisites need to be remedied to ensure that the future skills supply is available as the demand continues to grow."
>
> **Professor Asha Rao, interim AMSI Director and Superstar of STEM**

Australia's ongoing economic success depends on its continued ability to harness technological advances and respond to the changing nature of work by arming workers with skills relevant for the future. Occupations requiring science, technology, engineering and mathematics (STEM) skills grew by 16.5% between November 2013 and November 2018, which is 1.6 times higher than the growth rate in non-STEM jobs.[1] This trend is set to continue over the coming years, and it is therefore critical that students are equipped with adequate skillsets to cope with a changing world.[2] The Australian Government has recognised this trend and is seeking to encourage students to choose STEM courses through its Job Ready Graduates Package, announced in June 2020.[3]

Completing fundamental subjects in secondary school, such as mathematics and science, combined with a strong foundation in English, is essential to equip young Australians with the skills and flexibility to navigate life post-school, regardless of whether they continue to tertiary studies or directly enter the workforce.

For students who choose to attend university, fundamental subjects are vital to allow them to excel in their chosen degrees, regardless of their discipline. Students need a solid foundation of knowledge in these subjects, which is built layer upon layer through secondary school. It is difficult for students to acquire the necessary competencies quickly at the beginning of university studies.

Despite this, student uptake of fundamental subjects in secondary school such as higher mathematics, intermediate mathematics and science subjects has declined nationally over recent decades (see Section 2.3). There are a range of causes for this decline, including perceived difficulty,[4] increasing numbers of out-of-field teachers,[5] and ATAR maximisation.[6] One area of particular concern for the Australian Mathematical Sciences Institute (AMSI), the Office of the Chief Scientist (OCS), and others[7] is the diminishing mathematics and science prerequisite requirements for undergraduate university entry in Australia (see Chapter 3).

These changes in university entrance requirements signal to school principals, teachers, careers advisors, students, and parents that fundamental subjects such as mathematics and science are unimportant. This combination of factors mean that increasing numbers of students are entering university underprepared.[8]

> "Learning mathematics offers the student core foundational skills for success. Until universities step up to the plate and send a clear signal to students that if they want to keep their options open they should study intermediate or higher mathematics in school it is left to principals and teachers to encourage their students."
>
> **Dr Alan Finkel AO, Australia's Chief Scientist**[9]

In early 2019, AMSI and the OCS commenced a joint project to develop a stocktake of current university mathematics and science prerequisites for domestic undergraduate courses in the disciplines of Architecture, Computer Science, Economics and Commerce, Education, Engineering, Health and Medical Science, and Science. These disciplines were selected for analysis given the high impact and strong link to fundamental secondary subjects such as mathematics, and in most cases, science (for more information see Chapter 3). This paper presents the results and analysis of this prerequisite mapping project, supported by a background literature review on the importance of subject choice in secondary school for successful university study. As a key enabling discipline, much of the literature and data analysis focuses on mathematics. However, science prerequisites are also presented to draw a more complete picture of Australian university entrance requirements.

This paper does not advocate for any particular solution,[i] but instead aims to provide an important evidence base to:

- support ongoing work in the university and secondary education sectors to better inform students during subject selection; and
- improve rates of success in first-year university courses, for students who choose that path.

[i] More background and further reading on solutions informed by the evidence in this paper can be found in Australia's Chief Scientist's Informed Choices Position Paper, available at www.chiefscientist.gov.au.

1.1 Terminology

The use and definition of educational terms are not necessarily consistent across Australia, internationally or within the academic literature. For clarity, this section sets out a number of key terms and their definitions as used in this paper.

Term	Definition
Subject	an area of study taught in secondary school, and for the purposes of this paper, specific courses within that area of study e.g. mathematics (including all levels) and intermediate mathematics (specific level)
Course	a university program that leads to a qualification at the bachelor level or above
Discipline	a broad area of study at university that may encompass a number of university courses
Prerequisite	a subject required for entry to a university course determined by individual universities
Assumed knowledge	the university course or unit is taught on the *assumption* that the student has a specified level of knowledge
Recommended study	subjects that would be *useful* for students to have as background knowledge in undertaking the university course
Mathematics	AMSI classifies senior secondary mathematics subjects as 'elementary', 'intermediate' and 'higher' based on their content (see Table 2). The key differentiating factor is the level of calculus required. Intermediate mathematics refers to the Year 12 subject most commonly named 'Mathematics Methods', while higher mathematics refers to 'Specialist Mathematics'

Chapter 2
Subject Choice in Secondary Schools

2.1. Secondary School Subject Selection Process

In Australia, most secondary students are required to study the same subjects as their cohorts until the end of Year 10, with some electives from Year 9. In Year 10, at the age of 15 or 16, students select subjects to study in Years 11 and 12 in preparation for their senior secondary certificates.[ii] The exact subjects on offer and the number of subjects required to qualify for this senior secondary certificate varies across Australia's states and territories. On average, however, most students select four to six subjects to study in senior secondary school.

The motivations behind subject selection are complex. Students may be influenced by a range of factors including interest in the subject,[10] pressure or influence from parents and teachers,[11] availability of courses on offer at their school,[12] or the need to balance heavy workloads.[13] Among all this pressure it can be difficult for students to see the value of individual subjects, particularly those which may be perceived to be of greater difficulty or involve a greater time commitment (see Section 2.3).

There is a plethora of information on subject choices available for students to access, but the "burgeoning number of websites to assist people….carries with it the risk of a confusing maze of information".[14] The Tertiary Education Quality and Standards Agency (TEQSA) has similarly found that with the expansion of higher education providers, courses, and places, "admissions requirements have become more complex and harder to understand, making it difficult for prospective students to make informed decisions about study".[15]

The Australian Government's Course Seeker website, launched in October 2018, goes some way towards meeting this need by providing a 'one stop shop' for information about admission requirements by course and institution.[16]

There is, however, no clear visibility of the range of university incentive structures or the benefits of fundamental subjects for university fields of education that is independent and distinct from individual university publicity.

2.2. University Entrance Requirements

The ATAR is a percentile ranking from 30 (lowest) to 99.95 (highest) of overall academic results for all students who were due to complete senior secondary education in a given year.[iii] The ATAR is considered equivalent across all jurisdictions and is increasingly being used as the only representation of student achievement.[17]

Originally the ATAR was designed to coexist alongside clear expectations and signals from universities about secondary school subject choice.[18] However, the softening of university entrance requirements and the removal of prerequisites from many courses, means that around 70% of school leaver applications to university are now determined on ATAR alone,[19] despite an increasing range of additional university entry schemes (see Box 1). In the absence of clear and consistent signals about university subject requirements, the Australian Tertiary Admission Rank (ATAR) has acquired greater prominence than was intended.[20]

[ii] The awards that are available to be awarded on completion of senior secondary education vary in Australia across states and territories. For more information see: http://www.acaca.edu.au/index.php/senior-secondary-certificates/.

[iii] This includes those students who left school early or otherwise did not actually complete senior secondary studies.

Box 1: University Entrance Schemes – Adjustment Factors

There are numerous university entry schemes used by Australian universities. The New South Wales University Admission Centre (UAC) states that students are admitted to courses on the basis of their UAC Selection Rank, not their ATAR. "The Selection Rank is calculated for university courses separately and, for many applicants, includes additional evidence such as interviews, portfolios, additional tests and school recommendations. The use of such additional evidence by universities had been growing and, together with the use of bonuses, meant that a student's Selection Rank could be different from their rank by ATAR".[21]

ATAR-only
Entrance to university courses can be based purely on ATAR, whether this is explicitly stated or whether entrance schemes list an ATAR score alongside non-compulsory study suggestions such as *assumed knowledge* or *recommended study subjects*.

ATAR-plus other entry requirements
The most common of these schemes require students to have a certain ATAR *and* have completed specified *prerequisite* subjects.

Some courses require students who have not completed prerequisite subjects to complete *bridging courses* taught by the university.[iv] These bridging courses vary in length from two weeks to 18 months and as such have mixed levels of success.[22] To date, no particular strategy has provided a complete solution.[23]

Multi-stage entrance schemes are used in some disciplines, where an ATAR score can be combined with results from an aptitude test and interview. For example, the University Clinical Aptitude Test (UCAT) is used for some medical degrees.[v]

Schemes to boost the ATAR
A number of universities use schemes to boost the ATAR of certain students, which changes a student's Selection Rank and improves his or her chances of being selected for a given course. The complexity of these various adjustment factors has led to controversy and media commentary.[24] For school leavers, the ATAR (either used alone or in combination with other requirements) is by far the most common pathway to university enrolment.

Bonus points can be added to an ATAR to improve the selection rank of students based on either the completion of desirable subjects, or on equity considerations.

Middle band selection awards extra ATAR points to students at the lower end of acceptance into a course, based on special consideration or on the completion of desirable subjects.

Education access schemes allow educationally disadvantaged students with an ATAR lower than the cut-off to access certain courses.

Alternative entry schemes
Alternative entry schemes do not use an ATAR to rank students. Instead, other entrance pathways such as exams, assessment centres, interviews, auditions or portfolios are used.

[iv] In this paper, 'bridging courses' are defined as university courses which 'bridge' the gap between a university's entry requirements in mathematics and the actual level that students have achieved.

[v] The University Clinical Aptitude Test (UCAT) is an admissions test used by the UCAT ANSZ Consortium of universities in Australia and New Zealand for their medical, dental and clinical science degree programmes. The test helps universities to select applicants with the most appropriate abilities and professional behaviours required for new doctors and dentists to be successful in their clinical careers. It is used in collaboration with other admissions processes such as interviews and academic qualifications.
UCAT Consortium (2019). *University Clinical Aptitude Test for Australia and New Zealand (UCAT ANZ)*. Retrieved from: https://www.ucat.edu.au/.

> "Many people referred to the powerful and dominating role ATAR plays in the consciousness of students, parents and many teachers […] It led students to choose subjects not on the basis of individual interest or aptitude, but on beliefs about how ATAR might be maximised – for example, by choosing 'easier' HSC subjects over 'harder' subjects."
>
> **NSW Curriculum Review (2020), pp. 36-37**

There are a range of valid reasons for the gradual removal of prerequisites across Australia, and therefore, it is not possible, or indeed of any benefit, to return to a system wholly based on prerequisites. There are alternative methods through which universities, and by extension, secondary schools, can incentivise students to study fundamental subjects at school.
This concept is the basis of a body of work called 'Australia's Informed Choices' conducted by the Office of the Chief Scientist and heavily informed by the evidence presented in this paper. The findings from this paper have also informed the Australian Mathematical Sciences Institute's updated policy position on the matter.

As shown in Box 1, there are numerous university entrance schemes for students to navigate. These requirements vary from one university to another, across states and territories and from course to course. Notwithstanding the efforts of individual universities and states, there is no coordinated approach to providing advice to secondary school students as to which subjects they should study in order to be properly prepared for university courses.

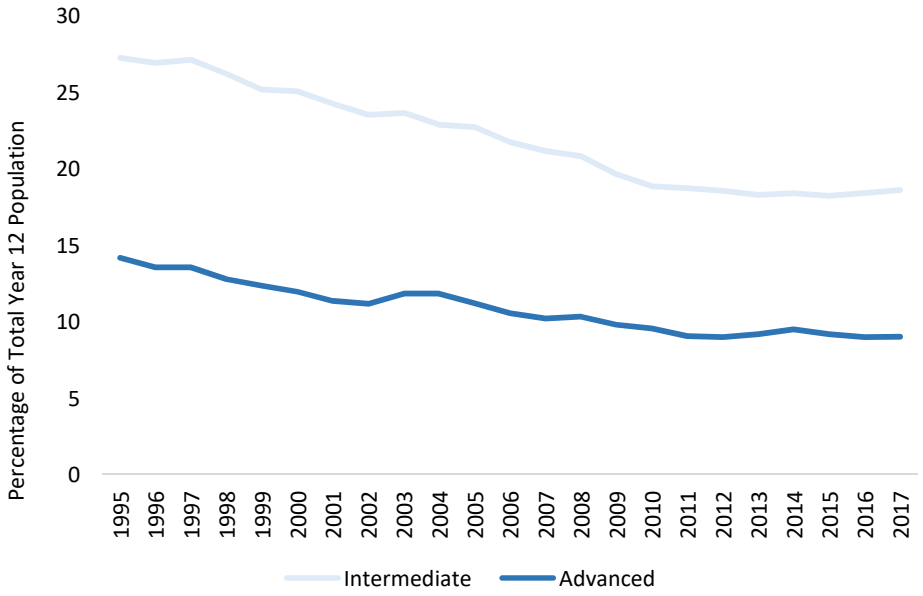
2.3. The Decline in Student Participation in Higher Mathematics and Science

Since the 1990s, the number of students completing Year 12 in Australia has steadily increased.[25] However, over the same period, there has been a substantial decline nationally in participation in science and higher mathematics subjects in secondary school, both in absolute numbers and proportionally, with enrolments in these subjects at their lowest levels in 20 years.[26] This decline set in in the 1990s but seems to have stabilised at a consistently lower level in the past decade.

Figure 1 shows the overall national decline in higher mathematics (intermediate and advanced) enrolments since 1995. In 2017, only one in ten Year 12 students enrolled in a higher mathematics course. Over the same period, enrolments in elementary mathematics have continued to grow.[27] For an overview of higher, intermediate, and elementary mathematics subjects see Table 2 in Chapter 3.

There are differences in mathematics enrolments across the country. Figure 1 shows enrolments nationally, but enrolments might have fluctuated to include temporary measures.

Figure 1: Proportion of Year 12 mathematics enrolments*



Source: Mathematics figures supplied by the Australian Mathematical Sciences Institute (AMSI), population data from the Australian Bureau of Statistics.
***Notes:** To avoid double enrolments caused by a number of students undertaking both intermediate and advanced mathematics, only enrolments in the highest level course are counted.

There are a range of complex reasons for the national decline in student participation in higher mathematics and science in senior secondary schools. Some of these are systemic challenges facing the education system broadly, such as access to equitable school funding, while others are more personal to the individual student, such as heavy workloads in Years 11 and 12 and lack of perceived use for the more challenging STEM subjects.

A 2008 *Maths? Why Not?* project identified five categories of reasons why students chose not to study higher level mathematics in their last two years of secondary school, based on the views of teachers and guidance counsellors: school influences, university influences, sources of advice influences, individual influences, and other influences.[28]

Some common reasons, from a range of academic studies, include:

- there are no mandated requirements to study a mathematics or science subject in Years 11 and 12 in some states;[29]
- student access to teachers with expertise in specific disciplines and access to higher level courses in schools (see Section 2.4);
- perceived lack of 'use' of mathematics and science for university studies and/or life in general;[30]
- a lack of awareness of the importance of mathematics which leads to low levels of student motivation and performance from early secondary school onwards;[31]
- student choosing easier mathematics subjects, below their ultimate capabilities, and a lack of incentives to choose 'harder subjects';[32]
- subject selection based on the potential for university acceptance rather than preparation for university study, also known as ATAR maximisation;[33] and
- lack of clarity from universities about which school subjects are needed to study mathematics-rich subjects and erosion of the status of academically challenging subjects over time (see Chapter 3).

Whether student perceptions about the best strategies to maximise ATAR scores are correct or not, it is fair to say that the increased focus on the ATAR score as an admission tool combined with the softening of university entrance requirements have shifted student priorities and contributed to the decline in participation in some senior secondary subjects. This has had an impact on university teaching practices and curricula. For example, to "compensate for the change in requirements, universities adapted their curricula by introducing new subjects that allowed students to study intermediate and higher mathematics as part of their degree. However, there is evidence that this approach has not been entirely satisfactory, since students find it difficult to absorb the content and develop the necessary skills for further study in the shortened time period at university".[34]

Furthermore, there is concern that the increasing numbers of students selecting easier mathematics subjects when they would otherwise be capable of studying intermediate or higher mathematics and then not improving their mathematical skills at university due to a lack of exposure in some degrees, "adds weight to the widespread concerns that the numbers of students with high-level quantitative skills graduating from universities are not keeping pace with Australia's future needs for scientists, engineers, teachers and more".[35]

2.4. The Importance of Prioritising Equitable Access

Today, more Australian students than ever have access to a university education. In June 2019, the Productivity Commission reported that while the 'demand driven system' has succeeded in increasing the number of students attending university and improving equity of access, many students are ill-prepared when they enter university, struggle academically, and are less likely to complete their studies.

The share of young people who had attended university by age 22 increased from 53% in 2010 to an estimated 60% in 2016.[36] While the 'additional students' (those whose attendance can be ascribed to the expansion of the system) were drawn from many backgrounds, they typically had lower literacy and numeracy skills and a lower ATAR – most had an ATAR less than 70 – than other students.

By age 23, 21% of the 'additional students' had left university without receiving a qualification, compared with 12% of other students.[37]

> "The school system has arguably not adapted to the role needed of it to prepare more young people to succeed at university, or more broadly to meet the growing demand in the Australian economy for complex and adaptable skills. Average literacy and numeracy of school children needs to rise to fill this role, reversing the sharp falls since 2003."
>
> **Productivity Commission (2019), The Demand Driven University System: A Mixed Report Card, p.2**

Equitable access to education for all Australian students must remain a priority. Access to certain school subjects is not evenly distributed across Australia. Students in metropolitan areas tend to have much better opportunities to study science and mathematics at higher levels. In regional areas, the chance that school students are taught by out-of-field mathematics teachers is much higher, and their enrolment in higher mathematics subjects much lower.[38] University admissions policies necessarily reflect this and rightly aim to remedy inequalities of opportunity.

There will always be a need for alternative pathways into further study for capable students who, through lack of access to specialist school teachers or other circumstances, are unable to meet entry requirements at a particular time. However, the Productivity Commission's report shows that providing access to university alone does not solve the equity issue. Without providing clear and consistent information to all schools, students and parents about how best to prepare for future study and work, existing inequalities are perpetuated.

> "An important issue with admissions transparency is to ensure that entry into higher education is equitable, and that no type of student is favoured over another through admission processes based on gender, cultural background, socio-economic circumstances or demographic background."
>
> **Tertiary Education Quality and Standards Agency (2019), Good Practice Note: Making higher education admissions transparent for prospective students, p. 2**

There are important lessons to be learned from the decline in prerequisite requirements in Australia (see Chapter 3). These lessons can be applied to all students across Australia regardless of their educational or socio-economic backgrounds.

2.5. The Relevance of Subject Choice for University

There are many factors that contribute to a student's academic success at university, including overall ATAR achievement and academic capacity, level of social comfort at university and school, and socio-economic background.[39] One of these factors is the level of academic preparedness of the student based on the subjects they chose to study in Years 11 and 12.

The completion of a certain subject at school can be evidence of a student's interest and potential to study a course that relies on that subject at university. It is a reasonable assumption that a student who takes a particular subject in Year 12 is more equipped and better suited to study that subject at university than a student who does not. For example, studies have shown that students who have studied higher mathematics in secondary school generally achieve better grades in first year mathematics subjects than students who have not studied higher mathematics.[40] Equally, students who commenced university mathematically underprepared for their university mathematics subjects were significantly more likely to withdraw from or fail those subjects.[41]

A 2019 report[vi] commissioned by the Australian Council of Deans of Science and conducted by the Australian Council for Educational Research found that "when it comes to passing first year mathematics and science subjects, the *level* of mathematics undertaken in senior secondary school counts, but so does Year 12 mathematics *performance*".[42] Two key findings were that:

- students who studied elementary level mathematics had lower first-year subject pass rates than students who had taken higher levels of mathematics in secondary school; and
- students who were strong performers in Year 12 mathematics irrespective of the level of mathematics undertaken had very high first-year pass rates.

Fundamental subjects such as English, mathematics and science also prepare students well for future study across the full suite of undergraduate courses. For example, many science courses require the problem-solving and quantitative knowledge skills obtained through the study of mathematics, doctors require solid language skills to communicate with their patients, and historians require mathematical ability to analyse historical data sets and conduct detailed deep source analysis. Studies show that mathematics is beneficial for university physics,[43] health sciences,[44] and chemistry.[45]

[vi] The report was the first attempt in Australia to collate the school subject choices and achievement of science students, and examine them alongside progression through the initial semester of a science degree across multiple universities in a range of states. The study included a sample of 12 Australian universities and that data collected covered the university outcomes and school achievement of 16,436 students who had left school in 2014, 2015, or 2016.

Therefore, it is important that Australian secondary students receive the message that they are more likely to succeed in their undergraduate university courses, regardless of the discipline that course is in, if they have completed studies in relevant, fundamental subjects. Without a strong foundation in English, mathematics and other fundamental subjects, students run the risk of being ill-prepared when they reach university.

Many Australian universities have recognised the correlation between Year 12 performance in mathematics and science and performance in first-year subjects at university and have introduced schemes to encourage students to select certain subjects. These include the First Year in Maths Network (see Box 2), the University of New South Wales' HSC Plus Program, and the University of Adelaide's Subject-Based Entry programme. There are also several universities across the country which have introduced bonus point schemes, and other incentive programs.

> "Academic attainment (and disadvantage) commences in the early years of schooling. High schools with little or no ATAR focus risk the danger of low attainment in years seven-ten; they fail to "unlock and fulfil their [students'] learning potential". Schools must be encouraged – by state departments, universities, business and communities – to offer the most challenging courses possible. Universities have been complicit in lowering attainment levels. Too many students who are capable of completing one or more ATAR subjects in Year 12 are gaining university entry with no ATAR subjects completed."
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> **Emeritus Professor Andrew Taggart, Murdoch University**[46]

Box 2: First Year in Maths Network

University teaching staff have been concerned about the performance of first year mathematics students for some time. In 2013, the First Year in Maths (FYiM) project was an Australian Government Office for Learning and Teaching funded project that collected national data to investigate the role of first-year coordinators in mathematics and the challenges they faced.[47] FYiM was led by the University of Melbourne in partnership with the University of Adelaide, Curtin University and the University of Sydney.

The project grew from an interest in the link between the decline in the number of final year school students studying intermediate and higher mathematics and the effect of this decline on performance in first year mathematics subjects. The initial two-year project targeted first year university subjects and course coordinators and built networks, established a website and held workshops to promote information sharing on the culture and challenges for first year university mathematics students.

Beyond the initial project, the FYiM network has expanded to include undergraduate and secondary mathematics teachers and mathematics support staff across Australia and New Zealand. The network strives to build connections between secondary and tertiary mathematics education and to contribute to public debate around mathematics university entrance requirements by conducting research and gathering data.

Chapter 3
Data Analysis: Mapping of University Prerequisites

3.1. Methodology Overview

From March to May 2019, the OCS and AMSI conducted a joint desk-based audit of mathematics and science prerequisite requirements at Australian universities nationwide for entry into the 2020 academic year.[vii]
The purpose of this study was to understand the current status of prerequisites in Australia and pinpoint the signals students are receiving in certain disciplines.

The study was limited in scope to undergraduate courses in eight broad disciplines, as set out in Table 1. Only undergraduate degrees open to domestic secondary school leavers were included.

The study excluded 'double degrees' to avoid double counting. Courses were only counted as having a prerequisite when a university explicitly listed a secondary school subject as a prerequisite. Four-year Honours degrees were included, but Honours degrees listed separately as 1-year degrees following the Bachelor (Pass) degree were not, unless there are additional secondary school subject prerequisites required for admission to the 1-year Honours degree.

Subjects listed as assumed knowledge or recommended study were not included, although it is recognised that such information may also signal to students the importance of a given secondary subject

Table 1: Disciplines of education and an overview of included and excluded courses

Discipline	Examples of included courses	Examples of excluded courses*
Architecture	Architecture, construction management, design (architecture), surveying, urban and regional planning/development	Interior design
Computer Science	Computer science, data science, game design, information technology, software engineering	
Economics and Commerce	Accounting, actuarial studies, commerce, economics, finance, financial planning	Business (unless an economics, finance, accountancy or commerce specialisation)
Engineering	Engineering, engineering technology, spatial sciences	
Education	Primary education, secondary education	Early childhood education
Health and Medical Sciences	Biomedical science, medical laboratory sciences, medical science, nutrition, physiotherapy, sports science	Midwifery, nursing
Science	Agriculture, aviation, biotechnology, environmental science, genetics, science, mathematics, psychological sciences, veterinary sciences, physics and astronomy, chemical sciences, earth sciences	

*All 'double degrees' with two or more courses, courses that were not undergraduate degrees (including diplomas and postgraduate degrees), and any courses where information was not publicly available were excluded.

[vii] English is also a common prerequisite requirement but as English is required in all states and territories to obtain a senior secondary certificate, English was not considered as part of this study.

In total, the prerequisite requirements of 1,587 courses from 40 Australian universities were examined.

Across Australia, secondary students can choose to study different levels of mathematics in Years 11 and 12. AMSI classifies these subjects as 'elementary', 'intermediate', or 'higher' based on their content, with the inclusion of calculus level mathematics distinguishing elementary and intermediate levels (see Table 2).

Where universities used terminology on their websites that was not specific to a particular level of mathematics (e.g. listing 'any mathematics' as a prerequisite) this was counted as elementary level mathematics. If more than one mathematics subject was listed as a prerequisite option (e.g. Mathematics or Mathematics Extension 1), then the lower level of mathematics was counted, as this would be the minimum requirement for entry into the course.

Not all courses at universities will require students to have prior knowledge of the highest level of mathematics, as these skills can be learnt through university-level mathematics courses. It would, however, be difficult for students to succeed in many university-level mathematics courses with only elementary mathematics, which does not require a knowledge of calculus for completion.

While chemistry, physics and biology were the most common science subjects listed as prerequisites, many universities have a requirement for 'any' science, which may include agricultural science, earth science and geology, as well as chemistry, physics, and biology.

Currently, secondary school curricula vary between states and territories and these differences may also be reflected at the university level, adding extra complexity to the challenges students face when making choices about their Year 11 and 12 school subjects and undergraduate degrees. Addressing this complexity was beyond the scope of this study.

Table 2: Classification of senior secondary mathematics subjects by state and territory

State	Elementary	Intermediate	Higher
Australian Capital Territory	Mathematics Applications Further Mathematics	Mathematical Methods Specialist Methods	Specialist Mathematics
New South Wales	Mathematics Standard 2	Mathematics Advanced	Mathematics Extension 1 Mathematics Extension 2
Northern Territory	General Mathematics	Mathematical Methods	Specialist Mathematics
Queensland	General Mathematics	Mathematical Methods	Specialist Mathematics
South Australia	General Mathematics	Mathematical Methods	Specialist Mathematics
Tasmania	General Mathematics	Mathematical Methods	Mathematics Specialised
Victoria	Further Mathematics	Mathematical Methods	Specialist Mathematics
Western Australia	Mathematical Applications	Mathematical Methods	Mathematics Specialist

3.2. Summary of Findings

The percentage of undergraduate courses across Australia with mathematics prerequisites and science prerequisites are shown in Figures 2 and 3, respectively. Overall, there are relatively few undergraduate courses in the disciplines examined with prerequisite requirements. On average across all states and territories, Engineering courses most frequently require mathematics prerequisites (61% of courses), while Health and Medical Sciences most commonly require at least one science subject (29% of courses; see Figure 2 and Figure 3).

Architecture courses are least likely to require mathematics (17% of courses), and Architecture and Economics and Commerce courses are least likely to require science subjects (0% of courses).

Of the 1,587 examined courses, only 19 courses in Australia require higher mathematics. Higher mathematics is, however, frequently listed alongside intermediate mathematics as a recommended requirement, which does signal to students the importance of mathematics for relevant courses.

Figure 2: Percentages of undergraduate courses with mathematics prerequisites, by level (data labels show number of courses)

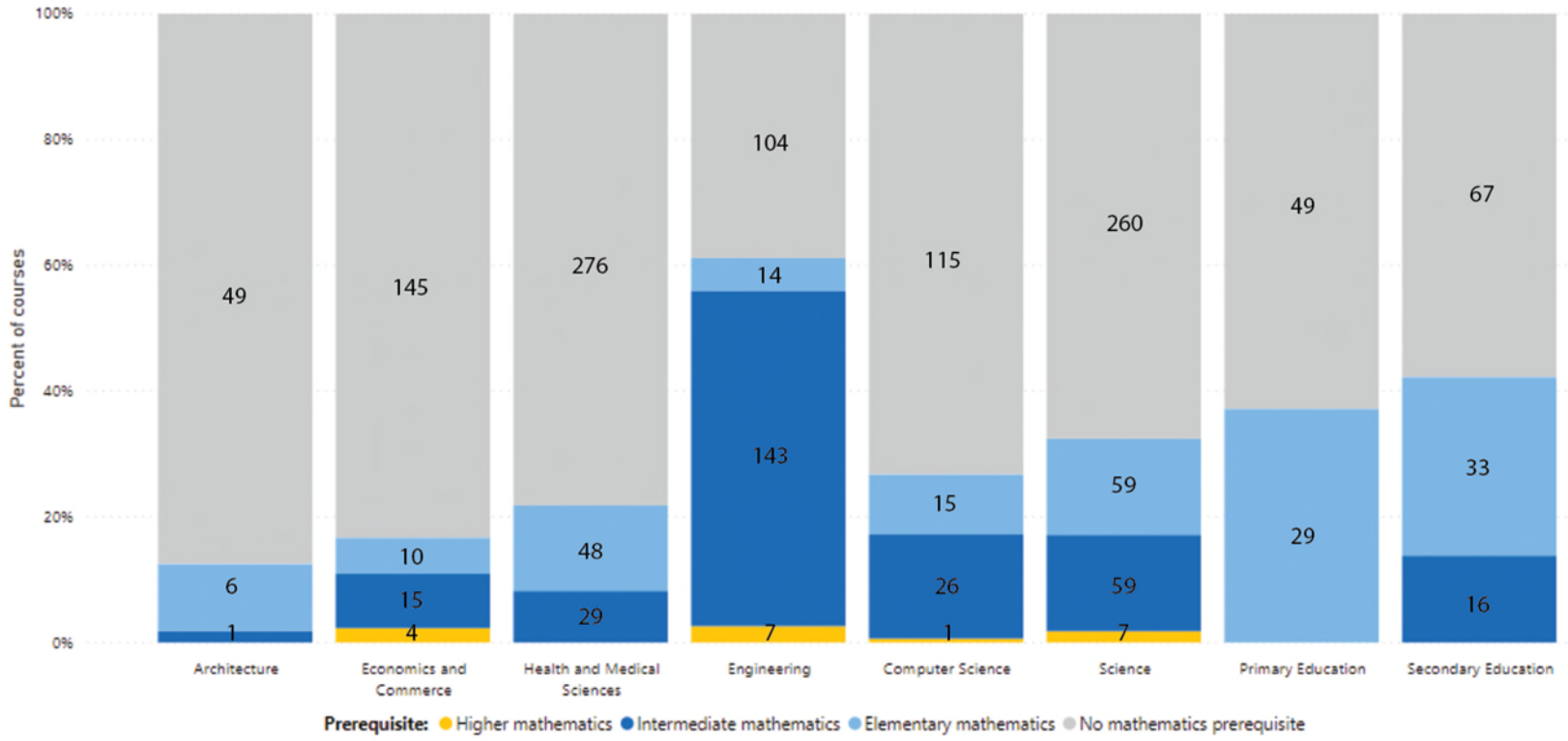
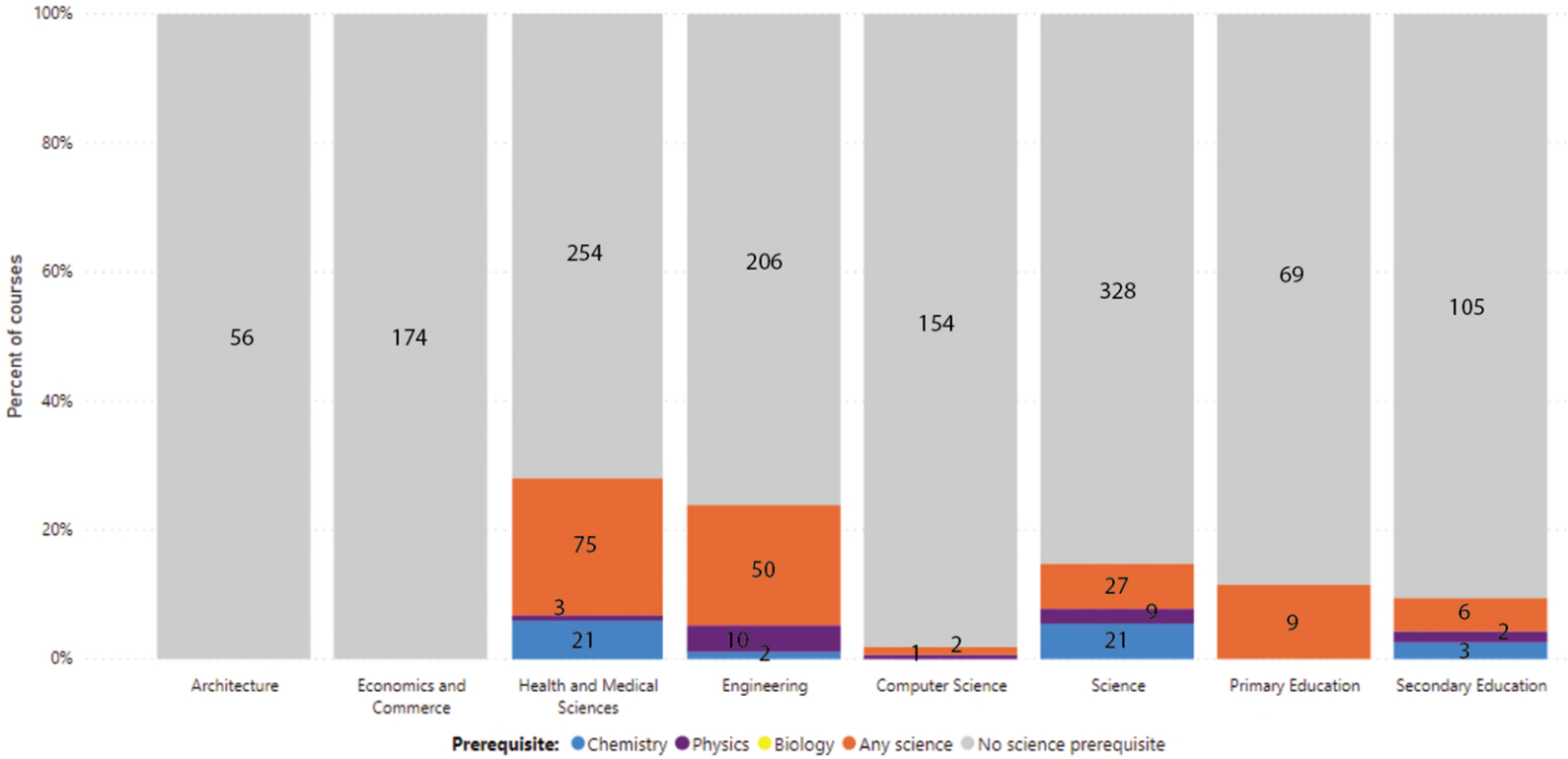


Figure 3: Percentages of undergraduate courses with science prerequisites (data labels show number of courses)



There are significant differences in prerequisite requirements across the states and territories, and between universities. On balance, universities in Victoria and Queensland are more likely to have mathematics and science prerequisites than universities in the rest of the country.

The following subsections of this chapter analyse prerequisite requirements by discipline to account for these state-based differences. For the purposes of analysis, universities in Tasmania, the Northern Territory, the Australian Capital Territory, and multi-jurisdictional universities are grouped into one, labelled 'Other Jurisdictions', to protect anonymity given the small numbers of universities in those states and territories. Prerequisite requirements are not analysed on a university by university basis.

Universities with prerequisites for some or all of their courses in one discipline tend to also have prerequisites in others (with the exception of disciplines that have very few courses with prerequisites, such as Architecture).

Of the 40 universities examined, there are 11 universities in Australia with no mathematics prerequisites for any of their courses in the eight disciplines measured and 14 universities with no science prerequisites.

The scale of this mapping project indicates that there is currently no clear and easy way for prospective students to understand prerequisite requirements for certain undergraduate courses.

Currently, a Year 10 student about to pick his or her Year 11 and 12 subjects would need to examine existing search engines, such as Course Seeker, and individual university websites to find information about prerequisites. Although useful tools, this would require examination on a course by course basis.

Furthermore, requirements for specialisations/majors that are different from general academic entry requirements could be opaque to students as they are not (or not clearly) included in the information supplied to school students. For example, courses may have no prerequisites or prerequisites of a lower mathematics level for general entry, but then may have higher prerequisites for certain subjects, majors or second-year coursework.

This is undoubtedly a large challenge for students and it is very unclear on university websites whether or when this occurs. To gather evidence, one would need to go far beyond the general academic entry requirements and delve deep into subject handbooks. Given this difficulty, it was beyond the scope of this mapping project to identify subjects and universities in which this occurs, but it is an issue of concern to note.

3.3. Prerequisites for Architecture Courses

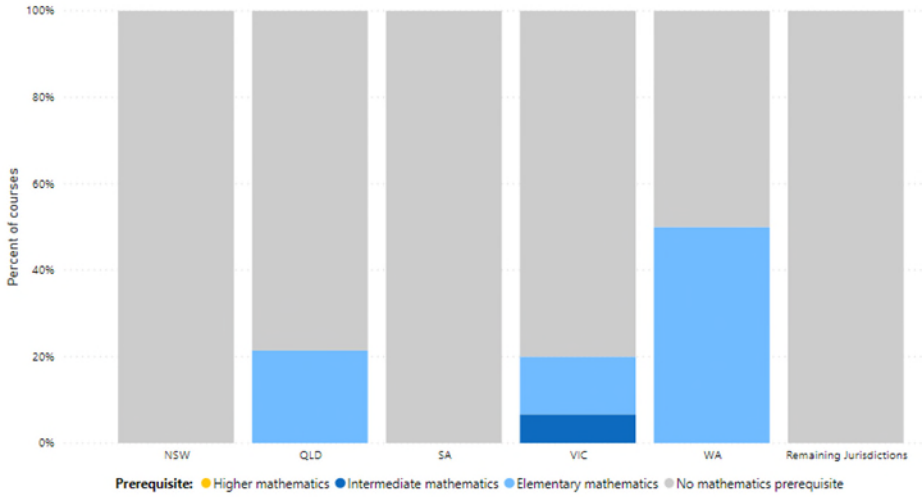
The disciplines of Architecture and Mathematics are considered to have a close relationship, predominantly because of the importance of geometry in architectural design.[48] Therefore, the courses in Architecture were selected for analysis in relation to mathematics prerequisites.

No architecture courses in Australia have science prerequisites, but the links between Architecture and Science are not as pronounced as for mathematics. Courses in the Architecture discipline include urban and regional planning/development, architectural design, building design management, construction management, and surveying.

In total, 56 courses from 26 universities were examined, the smallest number of courses from the eight disciplines.

Across Australia, only seven courses (13%) require any mathematics, of which six require elementary mathematics and one intermediate mathematics (see Figure 2). In all, 49 courses (87% of courses) and 20 universities do not require a student to study mathematics, even at the most elementary level, for entry into Architecture courses. There are few states or territories which stand out much above this national average (see Figure 4).

Figure 4: Mathematics prerequisites for Architecture courses, by level



3.4. Prerequisites for Economics and Commerce Courses

> "Having mathematics prerequisites for science, commerce and engineering degrees is not just a good idea, it is fundamentally important. Why? Because almost every aspect of these broad subject areas is becoming increasingly quantitative, more computational, reliant on larger and larger volumes of data, and we need people who understand what is being done."
>
> **Professor Terry Speed, Walter & Eliza Hall Institute of Medical Research**[49]

The types of courses examined as part of the Economics and Commerce discipline included accounting, finance, commerce, financial planning, financial mathematics, and actuarial studies.

In total, 174 courses from 40 universities were examined.

A solid foundation in mathematics is required for successful completion of a university course in the Economics and Commerce discipline.

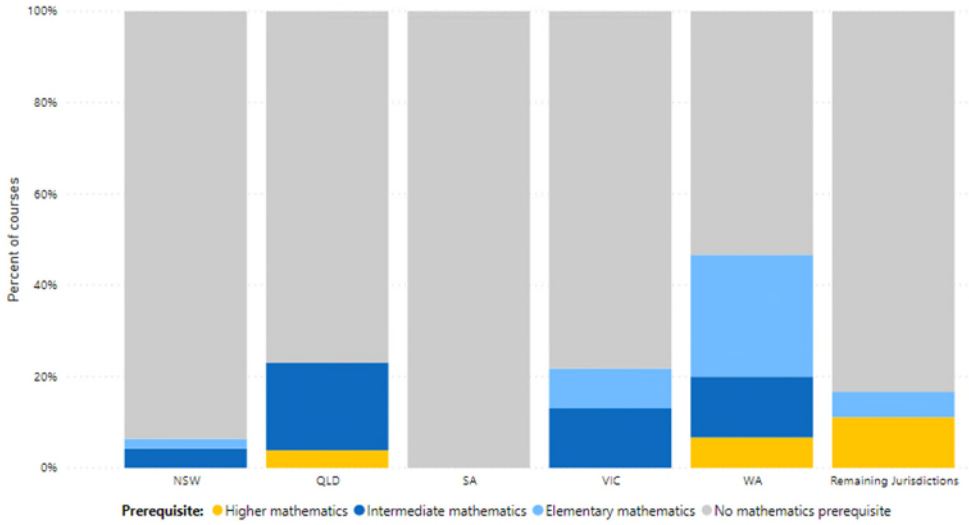
Economics and Commerce courses had the second lowest proportion of courses with mathematics prerequisites across the eight disciplines examined (17% or 29 courses) (see Figure 2). 83% (145 courses) of Economics and Commerce courses had no mathematics prerequisites.

There are 28 universities which do not require a student to study mathematics, even at the most elementary level, for entry into Economics and Commerce courses.

Only 12 universities had any prerequisite requirements for Economics and Commerce courses, split relatively evenly across the country (see Figure 5). Of those 12, eight required mathematics for 50% or more of their courses. No universities in South Australia had any mathematics prerequisites for Economics and Commerce courses, while 53% of 15 examined courses in Western Australia required at least elementary mathematics.

Undergraduate courses in actuarial studies were more likely to require intermediate or higher mathematics than other Economics and Commerce courses, with 66% requiring intermediate or higher mathematics.

Figure 5: Mathematics prerequisites for Economics and Commerce courses, by level



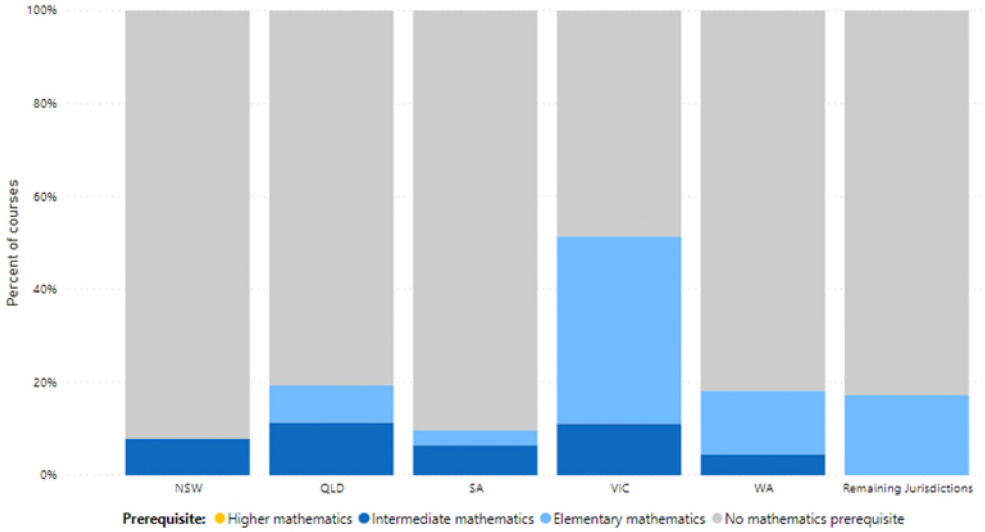
3.5. Prerequisites for Health and Medical Sciences Courses

Mathematics and science provide a solid foundation for study in Health and Medical Sciences at university, and many university courses in this discipline will require this knowledge for success in first year studies. It is, however, worth noting that many courses in Medicine are only offered as a postgraduate degree, and for many programs students have to complete the UCAT examination and an interview. These specialist components may likely direct students towards engagement in mathematics and science, even if there are few prerequisite requirements.

Courses in the Health and Medical Science discipline analysed included biomedical science, applied science, dentistry, medical science, physiotherapy, medical imaging, sports science, nutrition, and medical laboratory sciences. Nursing and midwifery courses were excluded from the study. In total, 353 courses from 40 universities were examined.

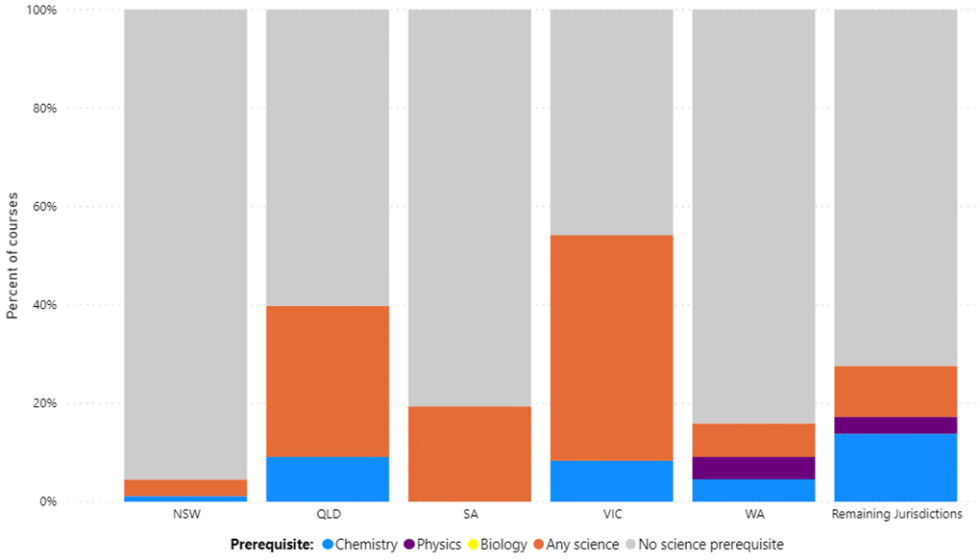
Across Australia, 78% of Health and Medical Sciences courses do not require any mathematics. 22 universities do not require a student to study mathematics, even at the most elementary level, for entry into any Health and Medical Science course offered, and a further seven universities require mathematics for fewer than 40% of their courses. 29 courses (8%) require intermediate mathematics (see Figure 6). These courses are relatively evenly spread across the country although Victorian universities are more likely to require mathematics than other states and territories. Only one university requires mathematics for 100% of its Health and Medical Science courses.

Figure 6: Mathematics prerequisites for Health and Medical Science courses, by level



The Health and Medical Sciences discipline has the highest proportion of courses with science prerequisites of the eight disciplines examined, with 28% of courses requiring at least one science subject to be studied in Years 11 and 12 (see Figure 3). Nevertheless, 254 Health and Medical Science courses do not require any science subject for entry. There are 20 universities that do not require students to have studied any science subjects for entry into Health and Medical science courses, and a further five require science for fewer than 25% of their courses. Victorian and Queensland universities more frequently have courses with science prerequisites than the other states and territories (see Figure 7).

Figure 7: Science prerequisites for Health and Medical Science courses

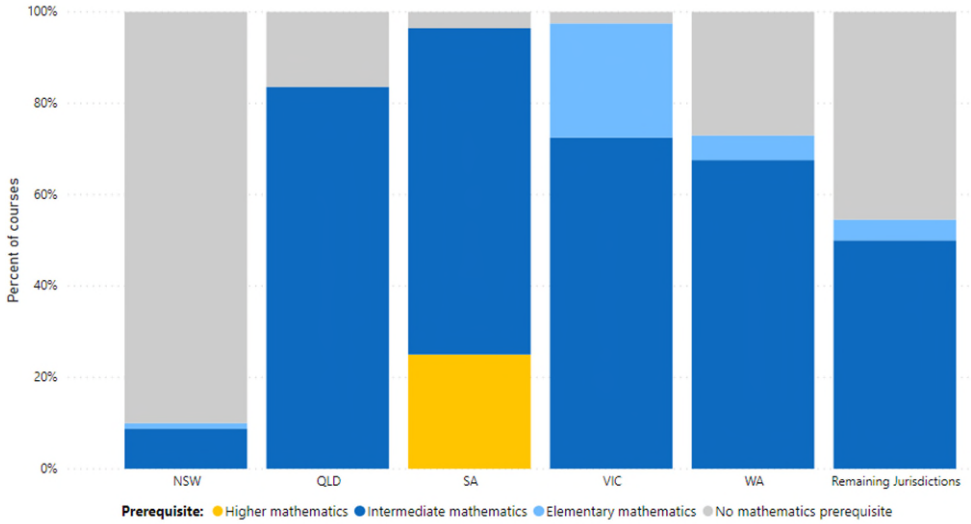


3.6. Prerequisites for Engineering Courses

Engineering discipline courses were selected for analysis because evidence shows mathematics to be a fundamental knowledge area underpinning engineering practice.[50] According to the Australian Council of Engineering Deans, "good understanding of mathematical concepts and quantitative reasoning is essential to both engineering education and engineering practice. All tertiary engineering programs include mathematics subjects".[51] Courses analysed from the Engineering discipline included engineering technology, spatial sciences and engineering. In total, 268 undergraduate Engineering courses from 34 universities were examined.

Across Australia, 104 of 268 courses, or 38%, do not require any mathematics. Just over half (53%) of all undergraduate Engineering courses require at least intermediate mathematics (see Figure 2). However, Queensland, South Australia, Victoria and Western Australia are well above this national average (see Figure 8). In South Australia, for example, 27 of 28 Engineering courses require at least intermediate mathematics.

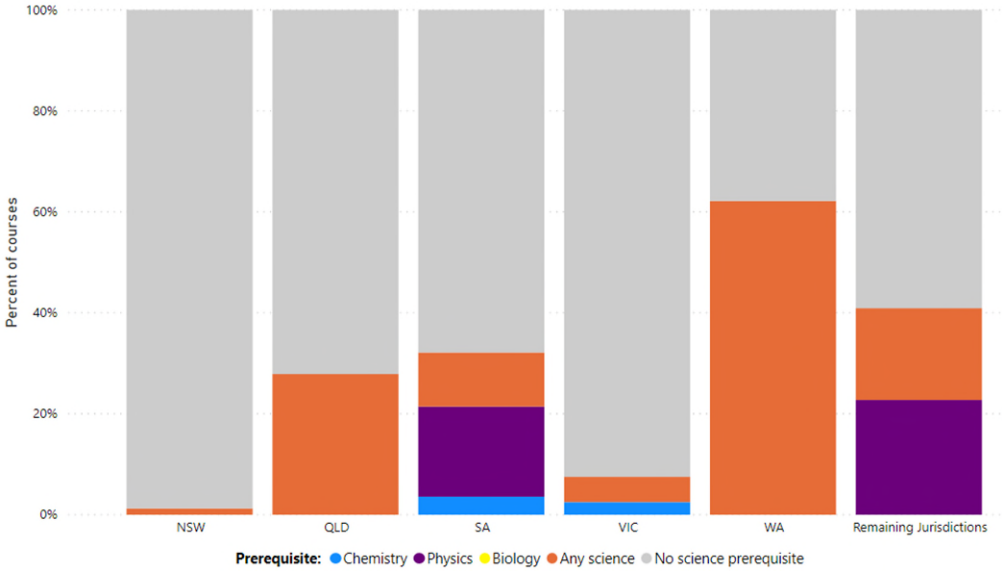
Figure 8: Mathematics prerequisites for Engineering courses, by level



Although the overall prerequisite rates in New South Wales are low, one university has intermediate mathematics requirements for 100% of its Engineering courses, while the remaining universities bar one in that state have no prerequisite requirements.

76% of Engineering courses do not require any science. 24% of the 268 Engineering courses in Australia require at least one science subject, most commonly physics or 'any science' (see Figure 3). This overall percentage is slightly higher than the percentage of Science courses with science prerequisites, but equates to only eight universities in the country. Of these, seven universities have more than 50% of their Engineering courses requiring science. The majority of these universities are located in Western Australia which, as a state, is well above the national average, with 65% of Engineering courses requiring 'any science' (see Figure 9).

Figure 9: Science prerequisites for Engineering courses



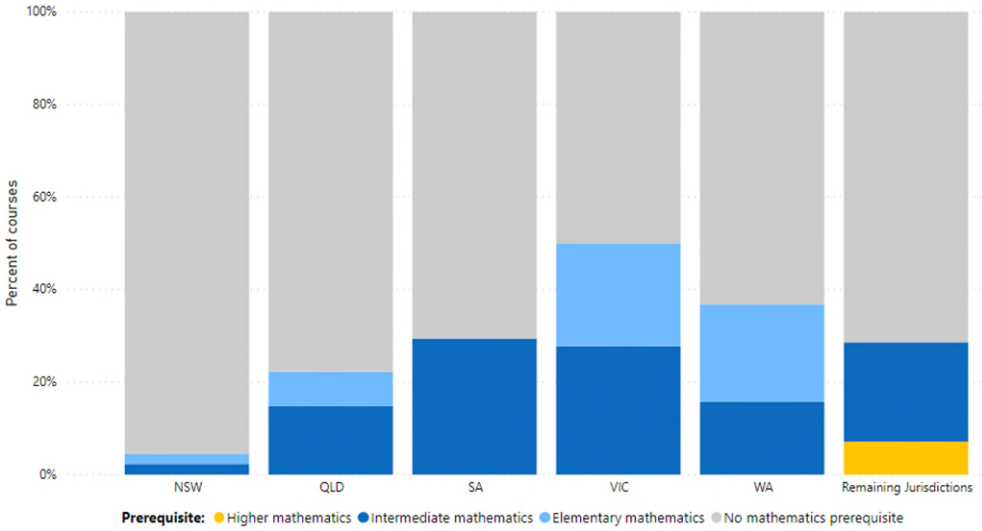
3.7. Prerequisites for Computer Science Courses

Courses in the Computer Science discipline were selected for analysis as "mathematics provides the theoretical basis for many subfields of computer science, and important analytic tools for others".[52] Therefore, Computer Science undergraduate courses often require a large amount of mathematical knowledge, deeply embedded within their courses. Only three Computer Science courses have any science prerequisites.

Courses in the Computer Science discipline include information technology, software engineering, computer science, business analytics and information systems, and data science, among others.

In total, 157 undergraduate courses from 36 universities were examined.

Figure 10: Mathematics prerequisites for Computer Science courses, by level



Across Australia, 73% of Computer Science courses do not require any mathematics (see Figure 2). 19 universities do not require a student to study mathematics, even at the most elementary level, for entry into Computer Science courses.

Of the 27% of courses that do require mathematics, 82% require intermediate mathematics. Universities in Victoria and Western Australia are more likely to require mathematics for Computer Science courses than other states, with all universities bar two in those two states having mathematics requirements for at least some of their courses (see Figure 10).

Across Australia five of the 36 universities offering Computer Science courses require mathematics for 100% of their courses with most of these courses requiring intermediate or higher mathematics. Universities with smaller proportions of their courses requiring mathematics are more likely to require elementary mathematics.

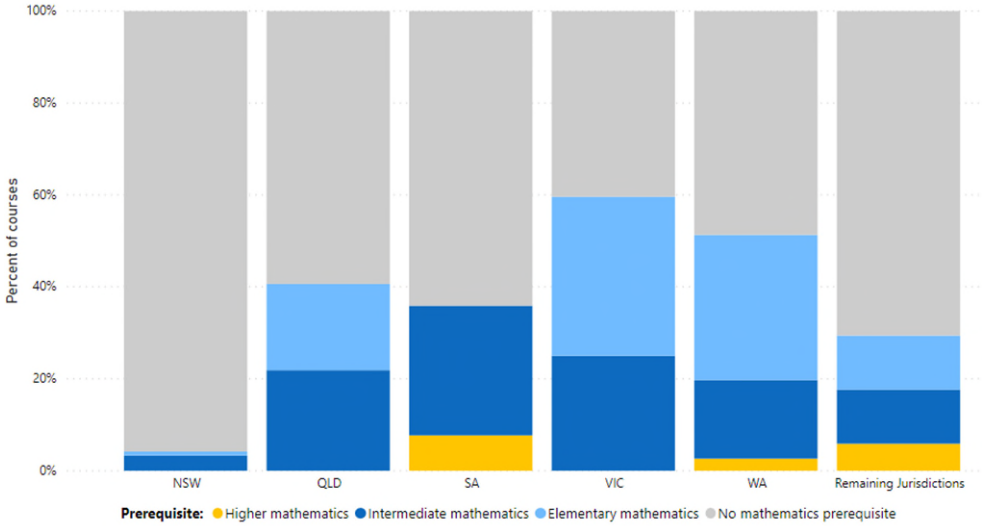
3.8. Prerequisites for Science Courses

Science discipline courses were selected for analysis because evidence shows that science and mathematics knowledge from secondary school improves performance in first-year undergraduate Science courses.[53]

The undergraduate Science courses examined included courses such as biological sciences, physics, biotechnology, aviation, environmental science, exercise and sports science, agriculture, veterinary sciences, mathematical sciences, genetics, geology and psychological sciences, among others. In total, 385 Science undergraduate courses from 39 universities were examined, the largest discipline of the eight in the study.

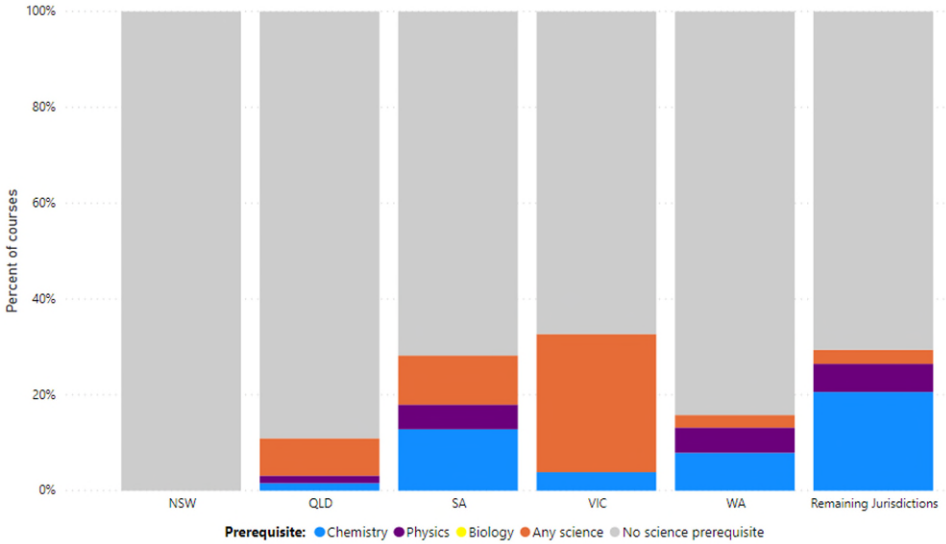
Across Australia, 68% of Science courses have no mathematics prerequisites, 15% require at least elementary mathematics, 15% require at least intermediate mathematics, and only 2% or seven courses require higher mathematics (Figure 3). 18 universities do not require a student to study mathematics, even at the most elementary level, for entry into Science courses, and a further five universities require mathematics for fewer than 30% of their courses.

Figure 11: Mathematics prerequisites for Science courses, by level



As Figure 11 demonstrates, however, these statistics are not evenly spread across the states and territories. While Victoria and Western Australia have more mathematics prerequisites than the national average, New South Wales has significantly fewer, with only one university in that state having any mathematics prerequisites for any of its science courses. Six out of the eight Victorian universities have mathematics prerequisites for more than half of their Science courses.

Figure 12: Science prerequisites for Science courses



That only 15% of Science courses across Australia have science prerequisites is striking (see Figure 3). It stands to reason that a student wishing to study physics, for example, would be better prepared for that course having studied physics in secondary school. There is no comprehensive data available for the total number of students entering Science courses without having studied science subjects in secondary school.

However, the lack of prerequisites from universities does send a message to students that they might not require science in secondary school and reinforces the notion that students can pick up Year 11 and 12 science knowledge through short 'bridging' type courses, which evidence shows to be less successful on average than the comprehensive secondary school curriculum.[54] This is because "their short nature does not allow students to catch up on the work they would have done in the same subject at secondary school. In addition, students who just pass the bridging course generally struggle in subsequent courses".[55]

Where science is required, the most commonly required secondary science subject is chemistry followed by physics, and Victorian universities are slightly more likely to require science for Science courses than universities in other states and territories (see Figure 12). Of the 17 universities with a science prerequisite, 10 have fewer than half of their Science courses with science prerequisites.

Box 3: Curtin University Case Study

In 2017, Curtin University announced the introduction of advanced science degrees in several disciplines, including physics, as a complement to regular science degrees, to commence in 2018. The minimum ATAR was set to 95, with individual discipline areas able to set explicit prerequisites. To enter the Advanced Physics degree, aspiring students need to have completed highest level mathematics in Year 12. In addition, to enter the 1st-year core Advanced Mathematics Units they need to have completed the Year 12 mathematics with a minimum score of 70 (out of 100).

According to Igor Bray, Head of Physics and Astronomy at Curtin University, "wanting our students to succeed as physics graduates on the international stage meant that highest level mathematics at school as a prerequisite (with strong performance) was an obvious starting point." Compared to the regular physics degree, students in advanced physics receive preferential access to research projects and summer scholarships. Furthermore, the advanced physics degree contains the highest levels of university study in mathematics and computing.

Despite the stringent entry prerequisites, the Advanced Physics degree has been well received, and interest in studying physics at Curtin University is higher than ever. Aided by an extensive outreach program, first preferences for physics have doubled in two years. The advanced students are now the dominant cohort of the physics-related degrees, and the current second and third year student cohorts being the largest to date.

There are 23 universities in Australia which do not require a student to study science in secondary school for entry into Science courses at university. There are more science prerequisites for courses with honours than for three-year undergraduate courses.

3.9. Prerequisites for Education Courses

Regardless of whether or not teachers are instructing in mathematics or science, proficiency in these fundamental areas is vital for professionals in the field.[56] In total, 78 Primary Education courses from 34 universities and 116 Secondary Education courses from 35 universities were examined. Early childhood courses were excluded from the study.

> "The early years are the most formative and important in a child's educational journey. No one teaching our kids the basis of maths should be unable to complete high school maths themselves."
>
> **Sarah Mitchell, Minister for Education and Early Childhood Learning in NSW, 2019**[57]

3.9.1. Prerequisites for Primary Education Courses

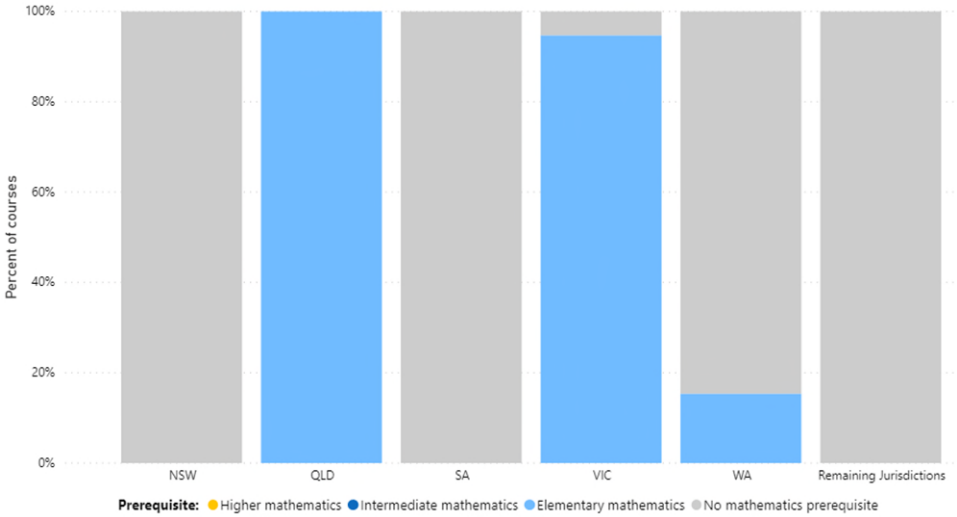
Figure 2 shows that 63% of primary education courses do not require a student to have studied mathematics in Years 11 and 12. Only 37% of all primary education courses in Australia have a mathematics prerequisite.

However, as Figure 13 shows, the balance of courses with prerequisites is heavily weighted towards universities in Queensland and Victoria. It is a requirement in Queensland for students to have studied English, mathematics and science for entry into a teaching course at university.[58]

Therefore, it is no surprise that all eight universities that offer Primary Education in Queensland require elementary mathematics for all Primary Education courses. In Victoria, six of the seven universities offering primary education have some courses with mathematics prerequisites.

Only one university in any of the other states has any mathematics prerequisites for Primary Education courses. No universities across Australia have mathematics requirements for Primary Education above elementary mathematics. Queensland is the only state in which universities require any science prerequisites for Primary Education.

Figure 13: Mathematics prerequisites for Primary Education courses, by level



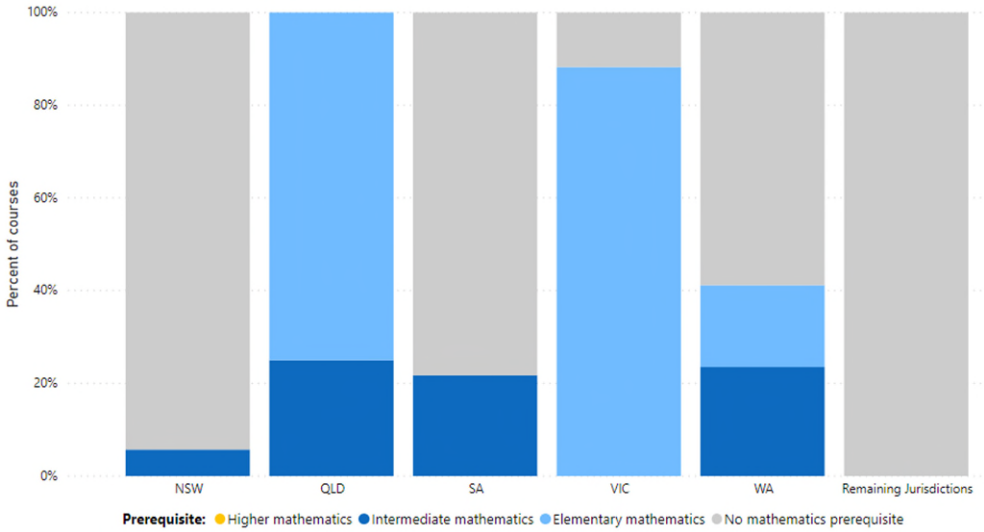
Although no universities in New South Wales currently require students to study mathematics, the Berejiklian Government announced in October 2019 that aspiring teachers will have to achieve at least band four in HSC mathematics (intermediate mathematics) to work at a NSW primary school from 2021, or pass a maths-based course at university.[59] Prerequisite requirements for primary school teachers is a controversial topic, with many arguing that introducing prerequisites could exacerbate primary school teacher shortages.

3.9.2. Prerequisites for Secondary Education Courses

Across Australia, 42% of courses require mathematics for entry into Secondary Education undergraduate university courses (see Figure 2). Although proportionally this places Secondary Education as the second most likely discipline to require mathematics, it also means that students can enter 67 secondary education courses across the country without having studied mathematics in Years 11 and 12. Where intermediate mathematics prerequisites apply they are for entry into science or mathematics secondary teaching.

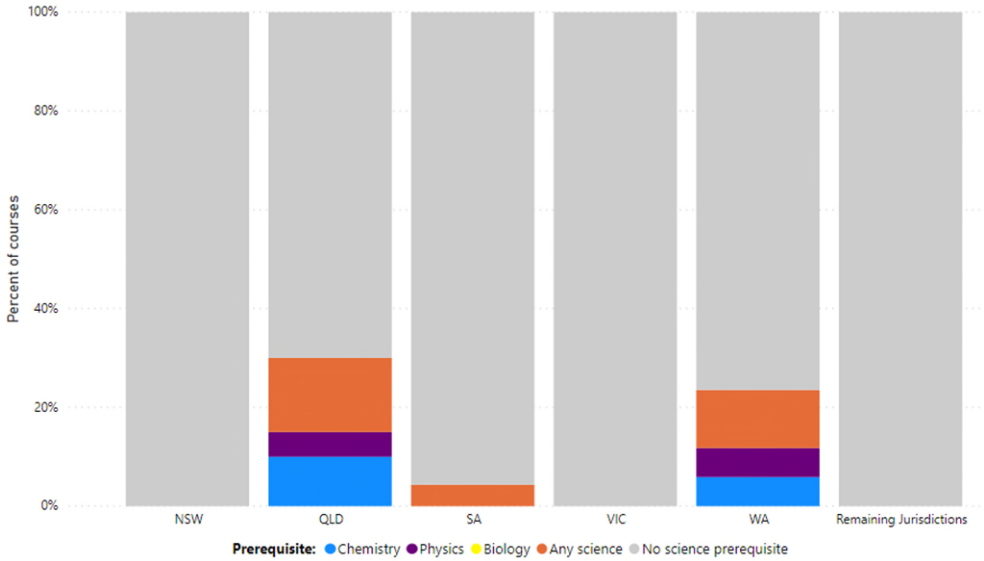
Universities in Queensland and Victoria are more likely to require mathematics than universities in the rest of the country, 100% and 88% of universities respectively (see Figure 14). However, where universities in other states require mathematics, they are more likely to require intermediate mathematics than elementary mathematics as is required in Queensland and Victoria.

Figure 14: Mathematics prerequisites for Secondary Education courses, by level



Few universities in Australia require a science subject for entry into secondary teaching courses. Across the country, only 11 courses (7%) require any science subjects to have been studied in Years 11 and 12 (see Figure 15).

Figure 15: Science prerequisites for Secondary Education courses



Chapter 4
The Way Forward

> "In the last 20 years, many Australian universities offering undergraduate degrees in the science, engineering, technology, business, education and health disciplines have had to adapt their curriculum, teaching practices and management of students to meet the needs of the growing number of students who enter their course without the required mathematical background."
>
> **Associate Professor Deborah King & Joann Cattlin, The University of Melbourne** [60]

University prerequisites allow universities to select students who have shown interest in and aptitude for certain subjects, and set the baseline for first-year university teaching. They also provide an incentive for secondary school students to choose subjects that provide the best preparation for university study.

In the past, prerequisites were more common and through these requirements, universities made it clear which subjects secondary school students should be studying in order to be prepared for the range of undergraduate courses into which they might want to enrol. Today, a large number of Australian universities have removed or softened prerequisite requirements (see Chapter 3). This trend can be traced back to the 1990s, but it appears to have accelerated with the massification of higher education and the uncapping of university places. Many courses do not have mathematics or science prerequisites in disciplines that require skills in mathematics or science.

Today, many universities instead advise that applicants should have 'assumed knowledge' of Year 11 and 12 subjects. Assumed knowledge recommendations differ from prerequisites in that students without the assumed knowledge are not prevented from enrolling. Instead, there has been an increase in the number of 'bridging courses' or 'foundation studies' offered to prospective students. Such types of remedial courses (Box 1) have mixed levels of success, mainly due to the length of study time and the support given by the university to students.

The decline in prerequisite requirements from universities has a range of consequences impacting both the universities and students.
For universities, these impacts include:

- universities cannot rely on students being adequately prepared to take first-year university courses – some students "may enter university with a level of mathematics two years below the expected level";[61]
- first-year university courses have students with a wide range of skills and differing background knowledge;
- universities are required to use resources to bridge the knowledge gaps of their students through a range of measures (including voluntary, not-for-credit support services, preliminary subjects for credit, remedial coursework and bridging courses), all with varying levels of success.[62]

> "We need to change our messaging as a matter of urgency. By clearly stating the mathematics requirements of courses like science and engineering we will make a good start. But if we also explain how students should understand mathematics and why it is needed, we will exhibit the academic leadership that is expected of us."
>
> **Associate Professor Deborah King, The University of Melbourne[63]**

As shown in Chapter 2, students are influenced by the removal of prerequisites in secondary school which in turn impacts their preparedness for universities. Although universities may offer 'catch-up' courses or programs, the challenge for students is to complete these courses while also balancing heavy workloads in other university coursework and managing the cultural and social shocks associated with the transition from secondary school to university. Furthermore, completing coursework that could have been studied at secondary school might extend the time a student must spend at university, which is associated with a heavier financial burden.

Some remedial measures might prevent subject failure to a certain extent, however, to date, no program or solution has been able to close the gap completely.[64] Therefore, although the notion of returning to prerequisites is not compatible with Australia's current landscape (see Section 2.5), students still need authoritative advice on which subjects to select to study in Years 11 and 12 so they can be as prepared as possible for university study without relying on catch-up or bridging courses. Given this advice is no longer coming from university prerequisite requirements, an alternative solution is required.

The evidence provided in this paper, combined with consultation with the sector, influenced the Australia's Chief Scientist's 'Informed Choices' proposal which aims to guide and nurture change through creating a coalition of thought-leading universities, and producing common advice on Year 11 and 12 subject selection principles coupled with individual university-based incentive packages. Further information on Informed Choices is available in the *Informed Choices Position Paper* available at www.chiefscientist.gov.au.

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- → Associate Lecturer, Mr Michael Jennings (The University of Queensland)
- → Director of the Bachelor of Science, Associate Professor Deborah King (The University of Melbourne)
- → Director of First Year Mathematics, Dr Adrian Koerber (The University of Adelaide)

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List of Figures, Tables, and Boxes

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